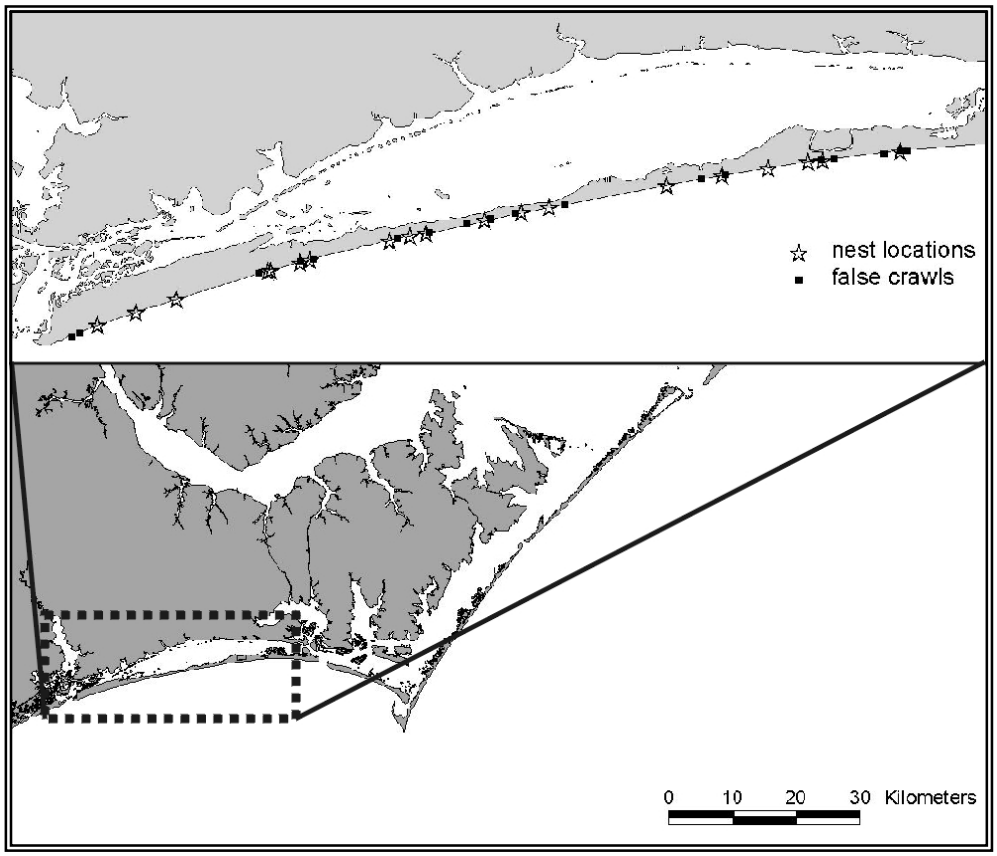
2002 Sea Turtle Monitoring Project Report
Bogue Banks, North Carolina
PROVISIONAL REPORT



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Summary

This report is a preliminary examination of the potential impacts of sand nourishment activities on sea turtle reproduction. It also addresses objectives and accomplishments of the sea turtle monitoring program in 2002, including aspects of public education and awareness, nest protection, and the scientific gathering of data. Sand and nest temperatures, sand compaction and loggerhead sea turtle (Caretta caretta) activity were monitored during the 2002 nesting season on nourished and non-nourished beaches of Bogue Banks in Carteret County, North Carolina. Preliminary statistical analyses of the data collected are provided in an effort to establish a baseline. Comprehensive analysis to determine the effects of beach nourishment on sea turtle activity will require extensive, long-term data collection in additional seasons to come.

Introduction

Running East-West between Bear Island and Shackleford Banks, Bogue Banks is a developed barrier island in Carteret County, North Carolina with roughly 24 miles of beach. The beaches of Bogue Banks are the reproductive grounds of loggerhead (*Caretta caretta*) and occasionally green (*Chelonia mydas*) sea turtles.

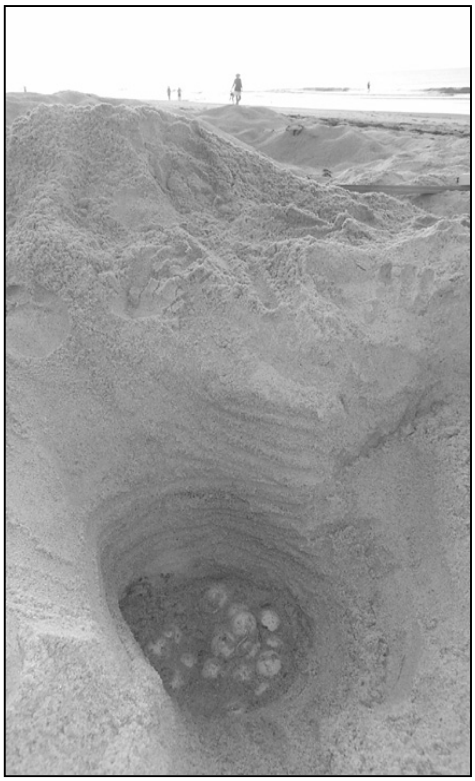
As part of an extensive beach preservation plan of Carteret County, the US Army Corps of Engineers has designed a 50-year Shore Protection Project which calls for periodic sand nourishment (i.e. the placement of beach fill as an engineering solution to beach erosion) for the entire island of Bogue Banks. In anticipation of the deferred commencement of that plan (early 2008 at best), interim nourishment projects are being pursued on the local level by the towns of Pine Knoll Shores, Indian Beach and Emerald Isle in cooperation with Carteret County. Comprised of three phases, the current Bogue Banks Restoration Plan is intended to place dredge material on approximately 17 miles of beach west of the boundary between Atlantic Beach and Pine Knoll Shores. Phase I (November 2001 - April 2002) nourished about 7 miles of beach in Pine Knoll Shores and Indian Beach. Phase II (January-April 2003) will replenish the eastern half of Emerald Isle, and Phase III (late 2003/early2004) will complete the western half of Emerald Isle.

One of the requirements for the Restoration Plan was the establishment of a formal sea turtle monitoring program separate from voluntary efforts, principally by the hiring of a full time sea turtle contractor. Concurrently, Emerald Isle and Pine Knoll Shores boast well-established volunteer programs within the North Carolina Sea Turtle Protection Program, which is coordinated by the North Carolina Wildlife Resources Commission. Local volunteers not only invest many hours in monitoring and guarding nests, but also play a crucial role in raising public awareness. The teaming of volunteers with the permanent contractor created a solid monitoring system that included excellent communication among everyone concerned, thereby guaranteeing 100% coverage of the nesting areas. Crawls along the beach were given immediate attention and nests received maximum protection. Volunteers were a valuable resource because each had a detailed understanding of the zone for which each was responsible, which could in turn be conveyed to the contractor as necessary. The presence of a local permanent contractor also facilitated a wider range of contacts and audiences for raising awareness of sea turtle conservation, either through school visits, impromptu education on the beach, or communication with various local, state and federal entities. Consistent monitoring throughout each phase of nourishment and beyond allows a unique opportunity to compare affected versus unaffected areas in a “before and after” paradigm.

The primary objective of the establishment of a formal monitoring program in Bogue Banks is to assess the potential impact of nourishment activities on sea turtle reproduction. Certain qualities of the beach are essential to successful sea turtle nesting, and can be influenced by nourishment efforts. If the sand placed on the beach is physically different from the naturally occurring sand, this could result in altered

reproductive characteristics of sea turtles. For instance, because the direction of sexual differentiation in sea turtles is temperature dependent (higher temperatures resulting in females and lower resulting in males), there is the possibility that sand deposited for beach nourishment can influence nest temperature, if it is of a different color than the natural beach sand. If incubation temperatures are significantly altered by thermal characteristics of nourishment material, it is possible that altered sex ratios could result. Additionally, the material could influence the shape of the egg chamber, or gas diffusion within the clutch during incubation. The "new" sand, often being tilled and containing a different percentage of shell content may also differ in its compaction, while increased sediment amounts could be responsible for higher moisture retention. These types of potential alterations can adversely impact nest site selection or digging behavior of sea turtles (Rumbold 2001). Some researchers argue that nourished beaches provide a larger nesting habitat while others say that it is the quality of the nourished sand, rather than amount, that will encourage or discourage nesting. Nevertheless, since females are known to return to nest on or near beaches where they hatched, nourishment could alter the ability of females to find a particular beach (Crain 1995). Until a balance is reached between the surf and the newly shaped beach, long, steep escarpments can form. Tall and wide escarpments can hamper access of female turtles to nesting habitat thereby possibly increasing the number of non-nesting emergences. Therefore, as a means to assess the potential positive or negative impacts of nourishment on sea turtle reproduction on Bogue Banks, the monitoring program entailed gathering data on reproductive success, sand compaction, and nest temperatures, in addition to providing general nest protection and monitoring beach escarpments.

Methods



Morning patrols for sea turtle activity were conducted daily along the beach by the contracted sea turtle monitor using an ATV from 1 May through 15 September 2002. Unless they were postponed due to lightening, the patrols began at dawn and were completed no later than 10:30 am. The monitoring area extends roughly 18 miles westward from the Atlantic Beach/Pine Knoll Shores town boundary to Bogue Inlet. Along the entire beach in Emerald Isle and parts of Pine Knoll Shores volunteers were assigned designated zones that they patrolled each morning to record crawl and nesting information. Specific details of each new turtle track were recorded, including whether it was a false crawl or nest, GPS coordinates, street location, date, etc. A crawl was defined as a nest only after carefully moving sand and confirming the presence of eggs. Nests were covered again, cordoned off and protected using

four wooden stakes, construction tape and a sign. Nests were observed daily during incubation for evidence of overwash, predation, or human manipulation.

In the 2002 nesting season there was a moratorium on all relocations of nests, regardless of location or perceived threats. This helped to minimize the influence of extraneous variables in the assessment of effects of beach nourishment on sea turtle nests. Therefore, all nests were left in their original locations for the duration of incubation and emergence periods. As day 55 of incubation approached, volunteers fashioned out of sand smoothed and cleared of debris a protective runway with high edges to discourage hatchlings from crawling laterally along the shore, and to facilitate their quick entry into the sea. Staking off the runway created added protection for the hatchlings by keeping spectators at a distance. Many volunteers "sat" with the nests at night to be able to witness the hatching event. In doing so, they were able to provide estimates of the hatching time and/or number of turtles which emerged and also to ensure that passersby on the beach did not interfere with the process. At least three days after the main emergence event, each nest was excavated in order to determine the hatching success rate, record any noticeable characteristics of the nest, and enable and expedite the emergence of any live hatchlings remaining in the nest. Nest contents were segregated into the following groups: whole unhatched eggs (UE), empty eggshells (ES), broken or pipped eggs that contained a dead hatchling (PE), dead hatchlings free from any shell (DH) and live hatchlings (LH). The following equations were used to characterize the reproductive success of the nest.

Total clutch size (CS) = UE + ES + PE
Hatching success = (ES – DH)÷CS

Following nest excavation, any remaining live hatchlings were released to enter the ocean. The remaining nest material was then reburied into the original nest chamber. Early evening excavations provided valuable opportunities for public education, as people walking along the beach saw the action and quickly became a crowd of curious observers.

Temperatures were monitored during the nesting season using Hobo H8 temperature dataloggers (Onset Computer Corporation, USA). These small dataloggers (1.5 cm x 3cm x 1cm) were programmed to record temperatures every two hours (± 1.0°C accuracy, with 0.4 °C resolution). To measure nest temperatures, a datalogger was placed into the middle of each nest as soon as possible after laying, with care taken to avoid rotating the eggs temporarily removed from the nest. To measure sand temperatures, 4 transects were established along Bogue Banks: 2 in nourished zones, and 2 in non-nourished zones. Each transect consisted of 2 dataloggers that were buried at mid-nest depth (45cm), one at the toe of the dune, the second about halfway across the berm. The majority of loggerhead sea turtle nests are laid within the zone encompassed by these two sites.

Finally, a cone penetrometer was used to assess shear resistance of sand in nourished and non-nourished sand. When a turtle crawl was encountered, sand compaction measurements in pounds per square inch (PSI) were immediately taken at depths of 6, 12, and 18 inches due North, East, South, and West within 2 feet of the nest or final apparent nesting attempt in the case of false crawls. Initially, only 3 replicate readings at each depth were taken, but starting mid-season 6 replicate measurements were taken to increase statistical accuracy. At sites where the sand was too compacted to get readings at all depths or in all directions, the compaction was recorded as "na." In such cases, the minimal value of compaction was assumed to be the same as the readings recorded at preceding depths.

Data were analyzed using unpaired two tailed t-tests with Welch's correction or one-way ANOVAs with Bonferroni *post-hoc* tests, where appropriate, unless otherwise stated. Data on hatching success were subjected to the arcsine transformation (Zar, 1999) prior to statistical manipulation. In all cases, $\alpha = 0.5$.

Results and Discussion

A. Nesting events and hatching success

From 17 May through 2 August, a total of 38 separate emergences by loggerhead turtles were observed in Pine Knoll Shores, Indian Beach and Emerald Isle (Figure 1). Nineteen of these emergences did not result in nests. Potential reasons for non-nesting emergences include external interference such as artificial lighting or human presence, but as few females were observed nesting, exact causes remain unknown. It is not uncommon for loggerheads to make many false crawls on different nesting beaches worldwide (Dodd, 1988).

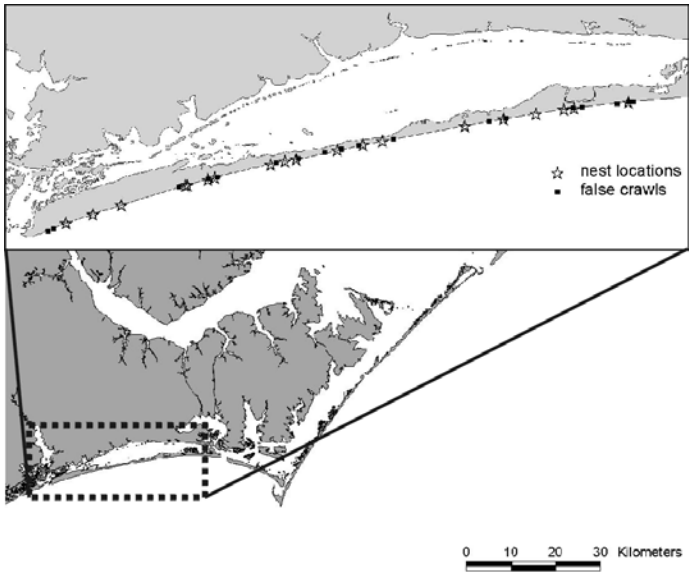


Figure 1. Site locations of all sea turtle crawls on Bogue Banks in 2002.

Nineteen of 38 emergences did result in nests: 5 in Pine Knoll Shores and 1 in Indian Beach (nourished zone), and 13 in Emerald Isle (non-nourished zone). Nests were laid in a myriad of locations: one turtle was observed nesting at 8th Street in Emerald Isle

against the side of a house relatively high into the dune, another crawled up the dune on the western end of the island and nested in between properly installed sand fencing. Some turtles laid nests only several feet above the wrack line, and several of the nests in Pine Knoll Shores were located at the toe of the dune where "old" and "nourished" sand met while others were laid only half way up the berm. Several nests were overwashed, some heavily due to tropical storm Gustav (particularly a nest in Emerald Isle from which the tide washed away the protective stakes). However, no nests were lost to erosion.

Hatching success for all nests was 89.83% ± 0.04 SEM. There was no significant difference in mean hatching success between nests laid in the nourished zone of Pine Knoll Shores/Indian Beach (88.46% ± 0.09) and those laid in the non-nourished zone of Emerald Isle (90.44 ± 0.05 %). Nest 3 in Pine Knoll Shores had the lowest success rate of all nests laid in 2002 (70.2%), which was probably related to the following three factors: first, there was a week of consistent and considerable rain at the time the hatchlings were pipping from their eggs and emerging; second, there were higher than normal tides that washed over the nest after the first major hatchling emergence, but before some of the later hatching turtles were able to leave the nest; and third, the excavation of the nest was postponed due to the inclement weather, thereby reducing the chance of survival of any hatchlings left in the nest after the major emergence. Excessive moisture in sea turtle nests can reduce hatching success (e.g. Kraemer and Bell 1980).

The 2002 nesting season resulted in promising hatching success numbers. However, because female loggerhead sea turtles produce multiple clutches of eggs over the course of a single nesting season, but generally do not return to nest again for several years, trends in annual nesting numbers should be evaluated only on the scale of decades or more. It is important to note that previously, there was no volunteer monitoring program in Indian Beach (Emerald Isle volunteers tended to the single known nest that was laid in Indian Beach in 2001), and consistent daily patrols cannot be confirmed for past years in some parts of Pine Knoll Shores (some local volunteers have pointed out the difficulty in establishing manageable monitoring zones along that beach due to the lack of adequate access points). Therefore, it is impossible to assess comparison results of 2002 with those of past seasons.

B. Nest and sand temperatures

Due to a delay in equipment acquisition, dataloggers were placed only in the last 7 nests that were laid. Of those, one datalogger failed; hence only data from 6 nests could be analyzed. Nest temperatures showed that the temperature of the individual clutches changed across the season, largely due to environmental influences such as overall sand temperature, rainfall, and tidal overwash (Fig. 2). The thermosensitive period for sexual differentiation occurs during the middle third of incubation (Mrosovsky and Pieau 1991). The mean temperature during the thermosensitive period of incubation for each nest was significantly different from all other nests ($p<0.001$ in all cases except EI 11 vs. PKS 4, where $p<0.05$, one way ANOVA with Bonferroni tests *post hoc*), regardless of whether they were laid in nourished or non-nourished zones (Table 1). This

variation was not unexpected, as seasonal variation in sand temperatures will translate into variable sex ratios of nests laid at different times (Mrosovsky 1994).

Table 1. Mean nest temperatures during the thermosensitive period (TSP) of sexual differentiation of nests in non-nourished (EI) and nourished (PKS) zones.

	EI 11	**EI 12**	**EI 13**	**PKS 3**	**PKS 4**	**PKS 5**
Mean (°C)	30.3	28.7	27.6	31.6	30.6	29.5
SEM	0.08	0.08	0.09	0.07	0.10	0.07
n	228	240	253	228	216	252
TSP (days)	19	20	21	19	18	21

When nests were grouped by zone in which they were laid (non-nourished zone = Emerald Isle vs. nourished zone = Pine Knoll Shores), the mean temperature during the thermosensitive period of incubation for nests was higher in the nourished zone than for nests laid in non-nourished areas. Small samples sizes (n=3 for each group) preclude statistical analyses, but more data collected in the future will facilitate further analyses. Note that the mean incubation duration (59.17 ± 3.15 days) of nests laid in nourished zones was shorter than the mean incubation duration (61.77 ± 1.23 days) of nests in the non-nourished zones (again, sample sizes were too small for statistical tests). The duration of egg incubation is directly related to ambient temperatures experienced by the eggs (Godfrey and Mrosovsky 1997). Because it was not possible to monitor temperatures in all nests, sand temperatures measured across the season may be a better indication of the relative micro-thermal environments of sea turtle clutches laid in nourished and non-nourished sections of the study area.

The sand temperature transects were established on 22 and 23 June--approximately 2 weeks prior to the first set of nest temperature readings. Mean sand temperatures were calculated from data that were grouped by month (July through October) and site (for each transect the site located at the toe of the dune is referred to as "site A," and the site at mid-berm, "site B"). Data from site B at Royal Pavillion (nourished zone) were excluded because the datalogger failed. Over the season, sand temperatures varied at nest depth (Figure 3). At each site, mean monthly sand temperatures were significantly different from other months, except for the months of July and August in the case of both sites in Land's End (non-nourished zone) and the dune site at 6900 Ocean Drive (non-nourished zone). This variation in sand temperature across the season is typical for sea turtle nesting beaches (Mrosovsky 1994).

At each transect, monthly mean sand temperatures were not significantly different between sites A and B, except in the following cases: for Land's End (non-nourished zone), the sites were different in September and October; in the 6900 block of Ocean Drive (non-nourished zone), the sites were different in July; and in Pine Knoll Townes (nourished zone), the sites were significantly different in August and September. Note that in these cases, the mean significant differences between upper and lower sites were small (<0.8 °C).

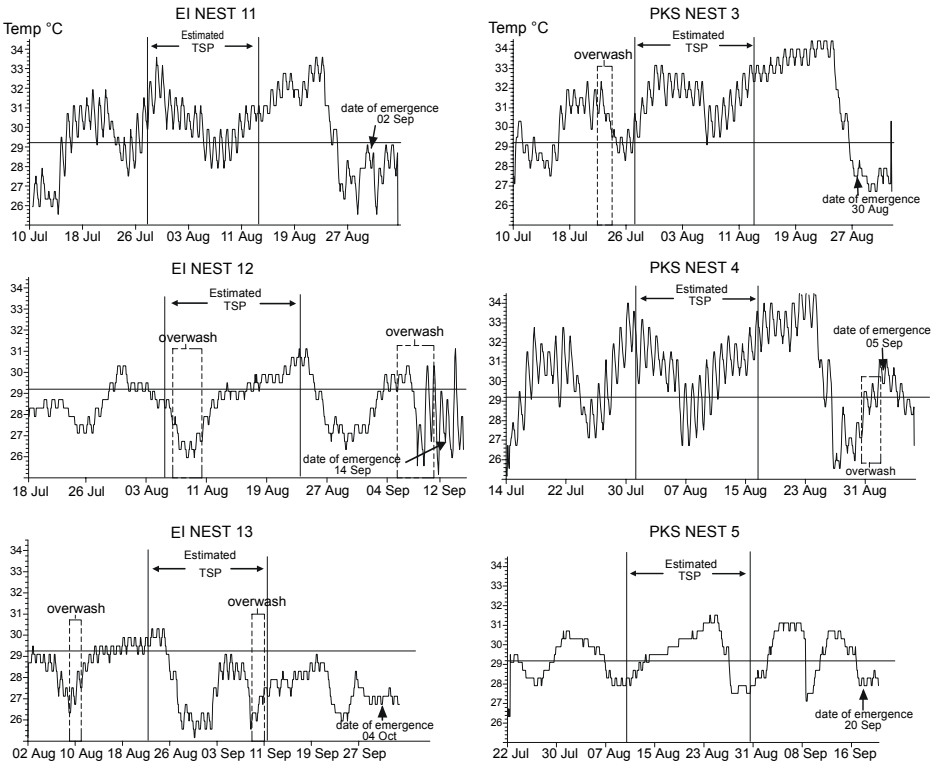


Figure 2. Nest temperatures in unnourished (EI) and nourished (PKS) sections of Bogue Banks. Lines at 29.2 °C indicate the pivotal temperature which produces 50% of each sex; warmer temperatures produce more females, cooler temperatures produce more males. The estimated thermosensitive period (TSP) for sexual differentiation occurs the middle third of incubation. The rapid drop in temperature several days prior to date of emergence is related to hatching of the eggs.

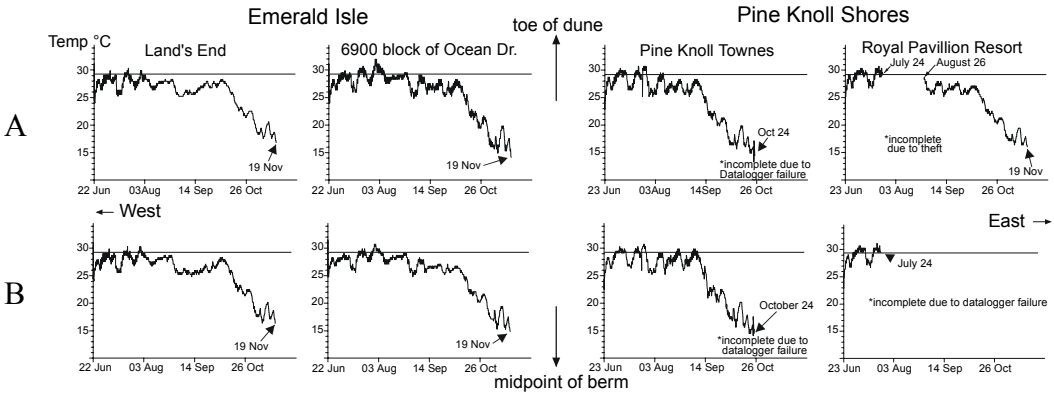


Figure 3. Sand temperatures (45cm depth) in control transects established in zones that were non-nourished (Emerald Isle) and nourished (Pine Knoll Shores). The horizontal lines at 29.2 °C indicate pivotal temperature.

Because of the relative lack of significant differences between site A and B at each transect in each month, values from both sites were combined for analyses across transects (Table 2). For each month from July through October, the mean sand temperature per transect was significantly different from all other transects, except for 3 cases: in July, the 6900 Ocean Drive (non-nourished zone) transect was not significantly different from Pine Knoll Townes (nourished zone); and in September and October, the 6900 Ocean Drive transect was not significantly different from the Royal Pavillion (nourished zone) transect. Note that the mean absolute differences between transects in July and August were all <1.0 °C (mean of all differences for these months = 0.6 °C). Because the sand temperatures were close to pivotal temperature in these months, nests incubating close to each transect around this time may have had different sex ratios. In September the maximum difference between two transects was 2.5 °C, and in October, the maximum difference in mean temperature was 7.4 °C. However, in these months, sand temperatures were well below pivotal temperature, hence even differences as great as 10 °C across transects probably would not have affected sex ratios of clutches incubating in this period.

In general, there was wide variation in sand temperature across transects, and even the sand temperatures recorded in the two transects in Emerald Isle (non-nourished zone) were significantly different from each other. This makes it difficult to tease out any direct impacts that nourishment may have had on sex ratios. Future monitoring (and the resultant increased sample size) is needed for a greater understanding between the effects of nourishment on sex ratios of sea turtle clutches.

Table 2. Average monthly sand temperatures (°C) in transects located in non-nourished (Emerald Isle) and nourished (Pine Knoll Shores) zones. NA indicates no data due to datalogger failure.

	Emerald Isle		Pine Knoll Shores	
Month	Lands End	Ocean Drive	Pine Knoll Townes	Royal Pavillion
Jun/Jul	27.86	28.11	28.37	28.89
Jul/Aug	28.02	28.82	27.44	NA
Aug/Sep	26.02	26.69	24.92	26.68
Sep/Oct	25.18	24.03	17.78	24.18
Oct/Nov	18.99	17.54	NA	18.14

C. Sand compaction

A cone penetrometer is not an exact reflection of the same resistance that turtles encounter because of the manner in which a female turtle digs her nest cavity; moreover, the readings generated by a cone penetrometer are influenced by the mass and technique of the person collecting the measurements. (Ferrell et al., in press). However, at this time, it is one of the few options available for measuring compaction and data collected should at least provide a general idea of local sand characteristics. Due to budgetary constraints, sand compaction readings did not begin until 18 June, which was day 33 of incubation for PKS nest 1, day 2 for PKS nest 2, day 18 for IB nest 1, day 27 for EI nest 1, 22 for EI nest 2, 20 for nest 3, 19 for nest 4, 15 for nest 5, 13 for nest 6, 10 for nest 7,

and day 6 for nests 8 and 9. For these nests as well as for two false crawls, three replicate compaction readings were taken at each nest before the protocol was modified to a 6 replicate reading requirement.

Several incomplete readings of "na" occurred in Pine Knoll Shores. When the penetrometer hit shells or large shell pieces within the sand, readings often exceeded 850 PSI, but were not recorded because the sample depth had not yet been reached. Another cause for incomplete readings was nest location. Some nests were laid in a sensitive dune area. Measurements were not attempted if it appeared that the dune habitat would be disturbed, or if it appeared that sand would heavily shift and accrete on the nest. In one instance, the "na" readings for a false crawl occurred on a part of the beach in Emerald Isle that had been substantially inundated by the tide. One other possible cause for such compaction could be the amount of previous sand manipulation such as emergency bulldozing. However, the lack of accurate historical data on this activity makes it impossible to adequately evaluate this possibility.

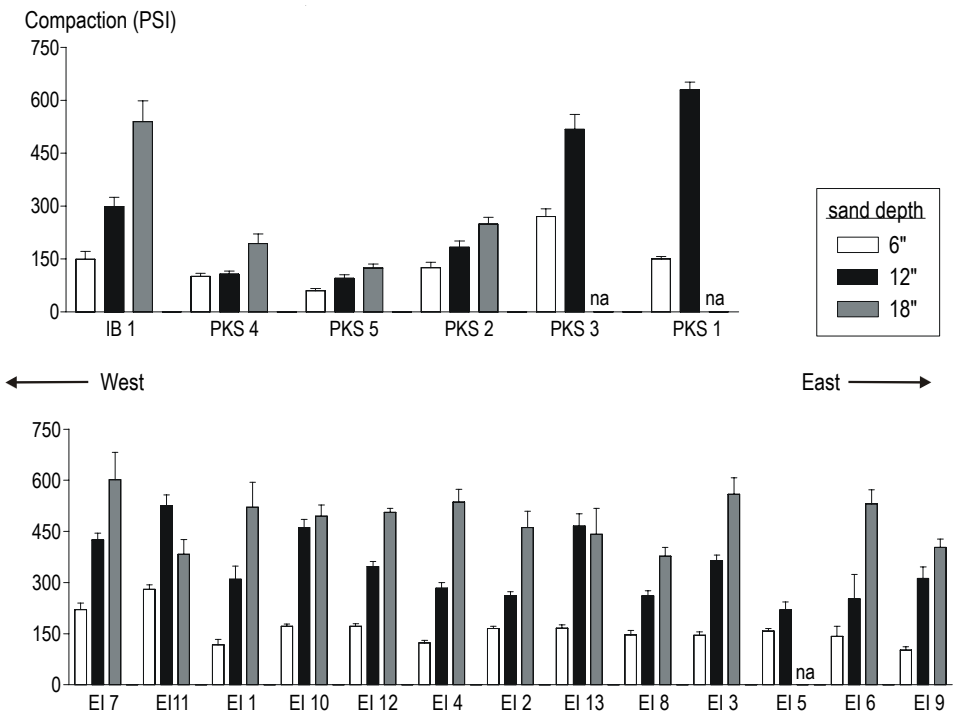


Figure 4. Average sand compaction measurements at nest sites in Indian Beach/Pine Knoll Shores (nourished) and Emerald Isle (non-nourished). "Na" refers to where it was not possible to record compaction (see text for details).

Sand compaction at nest sites varied across the beach, with some clutches being placed in areas with relatively compacted sand and other nests being laid in relatively loose sand (Figure 4). Sand compaction also varied in each direction at each nest. Although sample size is small, there is an indication of greater variability in compaction at turtle activity sites on Pine Knoll Shores (nourished zone) than those of Emerald Isle (non-nourished zone)(Figures 4 and 5). In addition to limited sample size, the uneven

number of datapoints collected at each activity also hampers comparisons. This was related to discarding any "na" reading from the analyses and is a limitation of the way the data were treated as there was no discrimination between "na" values that were caused by sand that was severely compacted, or caused by the presence of large pieces of shells in the sand column. The complications arising from how "na" values were treated (i.e. excluded) can be seen in those cases when the average compaction at 18" was calculated to be less than at 12" (for example, EI 11 in Figure 4).

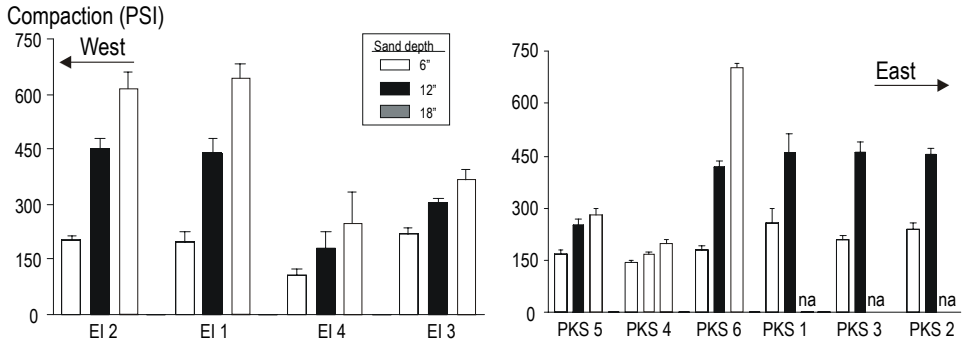


Figure 5. Average sand compaction measurements at false crawl sites in Emerald Isle (non-nourished) and Pine Knoll Shores (nourished).

An important consideration is that any deviation from normal compaction may impede the reproductive activities of sea turtles. Just as sand that is too compact may impede a female from being able to dig a nest cavity, sand that is too loose may be unable to hold the form of the nest cavity during digging (Mortimer 1995). In addition to complementing the present database, future measurements in the 2003 nesting season will include assessment and improvement of methods of measuring sand compaction.

D. Escarpments

Over the course of the 4-month monitoring period, several escarpments exceeding 18 inches in height formed on the nourished beaches. Occasionally, on the same mornings that escarpments were present there, noticeable erosion had occurred on parts of the beach in Emerald Isle—both at the eastern end, and to the west beyond Bogue Inlet Pier. Two escarpments exceeded 100 feet in length (mostly in Indian Beach near the large condominium complex and RV park) but all were graded by later tides in the following 24 to 48 hours.

E. Strandings

During 2002 there were 25 sea turtle strandings on Bogue Banks: 12 dead and 2 live loggerheads, 2 dead and 1 live green turtle, 1 dead and 1 live Kemp's ridley, 3 dead leatherbacks, and 3 unknown species (due to extent of decomposition).

Early in July a dead stranded Beaked whale was found in the surf in Pine Knoll Shores. A necropsy performed by the National Marine Fisheries Service marine mammal stranding team revealed plastic bags in the whale's stomach, which were determined as the most likely cause of death. Later that month an Atlantic sturgeon over 5 feet long washed ashore on the western tip of the island, but the cause of death was not determined. Also in July, a Northern gannet missing a foot was retrieved from the surf in Emerald Isle and taken to the Outer Banks Wildlife Shelter (OWLS) for care. Because this species uses its feet and the water surface to take off for flight, it was beyond rehabilitation and had to be euthanized. Also taken to OWLS from Emerald Isle in August was a fresh dead grebe whose cause of death was fibrous material (most likely cigarette butts) found in its esophagus and stomach, during a necropsy.

F. Seabeach amaranth

As a result of the amount of time required on the beach to implement the monitoring program throughout the turtle reproductive season, a watchful eye was kept for other threatened species as well. Such observation has provided a program by-product of enhanced information exchange and support from other interests.

Because of its intolerance to competition, for example, Seabeach amaranth (*Amaranthus pumilus*) can establish temporary populations on nourished beaches until other vegetation populations recover. It is currently listed as a threatened species due to its sensitivity to impacts such as "herbivory by insects and feral animals, beach grooming, tidal inundation and, in certain circumstances, off-road vehicles." Seabeach amaranth growth was most apparent in Pine Knoll Shores, between the toe of the dune and the halfway point of the berm along the beach from the Sheraton to the Ramada. In some cases, individual amaranth plants measured in excess of a foot in diameter. David Nash, Coastal Management extension agent with the NC Cooperative Extension Service has made arrangements to harvest amaranth seeds on Bogue Banks to be used for future local revegetation efforts.

G. Human Activity

Many people both local and visiting were curious about and held sea turtle conservation efforts in high regard--and often wanted to participate. Some had turtle stories from past seasons and admitted that having the chance to witness any sea turtle activity was a motivating factor in their decisions to return. Turtle protection volunteers often picked up large quantities of trash during their patrols throughout the summer. On

peak holiday weekends the trashcans overflowed with garbage--particularly at the most accessible points along the beach, and often trash ending up being carried out by the surf. Most consistently encountered on the beach throughout the season were large items of trash such as toys, floats, chairs and especially canopies that were often mangled by a single night of high tide and winds. Sea turtles can be injured by, entangled in and/or deterred from nesting by such objects. Threats to turtles, beachgoers, and official vehicle drivers are the large craters that people dig in the sand and do not refill. This summer there was one confirmed incident where a turtle did crawl up to the edge of one such hole before veering away from it in order to lay her eggs. Had she fallen in, injury or suffocation likely would have occurred.

H. Priorities for future monitoring

Despite initial logistical difficulties that delayed the collection of temperature and compaction data, the experience gained during the 2002 season can serve as a benchmark for more efficient and complete data collection in the 2003 season and beyond. Ultimately, data gathered from monitoring sea turtle activities over several seasons are necessary for an adequate assessment of the potential impacts of nourishment on the reproductive success of sea turtles on Bogue Banks.

Cooperation, communication and commitment among all participants in the sea turtle related activities were crucial to the monitoring efforts in 2002. The nesting season was a success because of the devoted turtle protection volunteers, the public works employees who kept a watchful eye, vacationers who "adopted" the nest that was laid at their beach entrance, the Karen Beasley Sea Turtle Hospital which cared for the live strandings, the aquarium at Pine Knoll Shores who directed interested observers to the Bogue Banks program, members of the local media who helped to keep the public informed, and many others, especially determined nesting mother sea turtles! The integrity and scope of the data collected were strengthened by the involvement of volunteers and it is hoped that voluntary participation will continue to increase. Those intimately familiar with a stretch of the beach take on a sense of stewardship and will do more to ensure its well being, not only by encouraging others to form a similar connection, but by also realizing the greater connection between their "backyards" and the global environment.

For these reasons, a priority for the future is the creation of volunteer groups in the towns of Indian Beach/Salter Path and Atlantic Beach. The ongoing cooperation of the public works department in Atlantic Beach has greatly benefited the sea turtle stranding network, and a local volunteer group would further contribute towards better daily monitoring for sea turtle crawls in that area of Bogue Banks. It is crucial that the entire length of Bogue Banks is monitored in a consistent manner for sea turtle reproduction and other species, not only for evaluating the impacts of different

management strategies enacted on Bogue Banks, but also to increase the understanding of the dynamics unique to the island.

Funding is scarce, limiting the degree to which conservation efforts can be pursued not just locally, but throughout North Carolina. Equipment such as a cone penetrometer still must be acquired. Additional outreach is needed to explain the monitoring and enlist the support of local residents and visitors. Continued coordination among various agencies and organizations will facilitate information exchange and dissemination and greater understanding of the processes which affect the natural history of Bogue Banks.

Despite the fact that few immediate conclusions can be made based on this data collection, this season offered a chance to implement, test and analyze an effective monitoring system, which provided valuable baseline data, and can be built on in seasons to come. It is hoped that the sea turtle monitoring program will help in recognizing how human manipulations of the coastal environment immediately impact the island as well as how it recovers in the years following.

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APPENDIX

TABLE 1: 2002 Nest Inventories and Hatchling Emergence Success for Emerald Isle, Indian Beach, and Pine Knoll Shores

nest number	nest location	date laid	date of emergence	incubation duration (days)	days washed over	empty shells	live hatchlings	dead hatchlings in broken eggs	dead hatchlings	unhatched eggs		number hatched	number eggs	emergence success
E.I. 1	Ocean Crest	23-May	27-Jul	64	0	129	38	3	1	2		128	134	0.9552
E.I. 2	White Water	28-May	31-Jul	64	0	125	22	2	0	8		125	135	0.9259
E.I. 3	Pier Point	30-May	28-Jul	59	0	60	11	5	0	20		60	85	0.7059
E.I. 4	Ebbtide	31-May	31-Jul	61	0	105	0	0	0	4		105	109	0.9633
E.I. 5	15th Street	04-Jun	02-Aug	59	13	101	46	5	2	8		99	109	0.9083
E.I. 6	8th Street	06-Jun	17-Aug	72	0	147	34	2	0	11		147	160	0.9188
E.I. 7	Deerhorn Dr	09-Jun	14-Aug	66	0	133	0	8	1	16		133	158	0.8418
E.I. 8	3300 Ocean Dr	13-Jun	13-Aug	61	6	123	3	0	0	7		123	130	0.9462
E.I. 9	2nd Street	13-Jun	15-Aug	63	5	85	3	4	1	17		85	107	0.7944
E.I. 10	Arthur Street	23-Jun	21-Aug	59	0	118	0	7	1	6		117	131	0.8931
E.I. 11	Spinnaker's Reach	10-Jul	02-Sep	54	0	115	2	0	0	5		115	120	0.9583
E.I. 12	Indigo Dr	18-Jul	14-Sep	58	11	122	8	2	0	4		122	128	0.9531
E.I. 13	4000 Ocean Dr	02-Aug	04-Oct	63	4	51	0	0	1	7		50	58	0.8621
											EI Total:	**1409**	**1564**	
I.B. 1	E. of EI/IB boundary	01-Jun	30-Aug	59	0	120	1	0	0	26		120	146	0.8219
											IB Total:	**120**	**146**	
P.K.S. 1	Royal Pavillion Hotel	17-May	29-Jul	73	3	100	0	0	1	15		99	115	0.8609
P.K.S. 2	Ocean Terrace	17-Jun	15-Aug	59	0	105	10	0	0	9		105	114	0.9211
P.K.S. 3	E. of Ocean Terrace	10-Jul	30-Aug	51	2	102	2	20	15	2		87	124	0.7016
P.K.S. 4	Ocean Grove East	14-Jul	05-Sep	53	0	116	1	0	0	4		116	120	0.9667
P.K.S. 5	Maritime Place	22-Jul	20-Sep	60	3	94	1	1	0	4		94	99	0.9495
											PKS Total:	**501**	**572**	
											Bogue Banks Total:	**2030**	**2282**	

Mean hatching success for each beach and overall Bogue Banks (data transformed with arcsin transformation prior to calculations).

	n	**mean**	± SD	**±SEM**
Emerald Isle	13	**0.9044**	0.16	**0.05**
Indian Beach	1	**0.8219**	**-**	**-**
Pine Knoll Shores	5	**0.8956**	0.21	**0.16**
Indian Beach&PKS	6	**0.8846**	0.20	**0.09**
Bogue Banks Total	19	**0.8983**	0.17	**0.04**

APPENDIX CONT'D

Table 2. GPS coordinates for all crawls are listed in order of occurrence. Names of streets, housing complexes, or hotels within the closest proximity to the site were assigned to each crawl for easy reference. Readings were taken using a Garmin GPS 12XL personal navigator accurate within approximately 5 meters (17 feet.)

nest	location	latitude (N)	longitude (W)
1	Best Western (PKS)	34° 41.789	76° 47.125
2	Ocean Crest (EI)	34° 39.432	77° 02.914
3	White Water (EI)	34° 40.079	76° 59.992
4	Pier Point (EI)	34° 40.515	76° 57.475
5	Ebbtide (EI)	34° 40.039	77° 00.210
6	east of EI/IB boundary (IB)	34° 41.279	76° 52.223
7	15th (EI)	34° 40 725	76° 56.183
8	8th (EI)	34° 40.847	76° 55.391
9	Deerhorn (EI)	34° 39.206	77° 03.799
10	Connie (EI)	34° 40.464	76° 57.812
11	2nd (EI)	34° 40.934	76° 54.769
12	Ocean Terrace (PKS)	34° 41.643	76° 49.137
13	Arthur (EI)	34° 39.892	77° 00.908
14	Pine Knoll Townes (PKS)	34° 41.666	76° 48.810
15	Spinnaker's Reach (EI)	34° 38.987	77° 04.636
16	Ocean Grove East (PKS)	34° 41.440	76° 51.025
17	Indigo (EI)	34° 39.901	77° 00.840
18	Maritime Place (PKS)	34° 41.551	76° 49.995
19	Rhett (EI)	34° 40.393	76° 58.256

false crawl	location	latitude (N)	longitude (W)
1	Blue Water (EI)	34° 39.930	77° 77.736
2	E. Reg. Access (EI)	34° 40.526	76° 57.395
3	10th (EI)	34° 40.827	76° 55.521
4	Land's End (EI)	34° 38.842	77° 05.028
5	Dogwood (PKS)	34° 41.683	76° 48.560
6	W. Land's End (EI)	34° 38.780	77° 05.205
7	East Ramp (EI)	34° 40.093	76° 59.913
8	14th (EI)	34° 40.744	76° 56.071
9	Tammy (EI)	34° 40.425	76° 58.087
10	Royal Pavillion (PKS)	34° 41.756	76° 47.479
11	Best Western (PKS)	34° 41.788	76° 46.963
12	Atlantis Motel (PKS)	34° 41.800	76° 47.131
13	Dunes Condos (PKS)	34° 41.436	76° 50.962
14	Periwinkle (EI)	34° 40.040	77° 00.184
15	Tracy (EI)	34° 39.845	77° 01.103
16	Ocean Grove (PKS)	34° 41.376	76° 51.452
17	Pine Knoll Townes	34° 41.660	76° 48.841
18	EI/IB boundary (EI)	34° 40.979	76° 54.434
19	19th (EI)	34° 40.661	76° 56.576