2003 Sea Turtle Monitoring Project Report
Bogue Banks, North Carolina
INTERIM REPORT

Loggerhead sea turtle nest crawl in Pine Knoll Shores, NC

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Summary:

The Bogue Banks Beach Restoration Plan is a three-part nourishment project being carried out on large portions of Bogue Banks in Carteret County, North Carolina. Phase II (November 2003–April 2003) involved distributing dredged beach fill material on about 6 miles of beach in the eastern half of Emerald Isle. Monitoring and data collection on loggerhead sea turtle reproductive activities resumed on 1 May 2003. Data on nest success, hatchling production, sand/nest temperatures and sand compaction from the 2003 sea turtle nesting season are presented in this report. These data will contribute to a long-term study assessing the potential impact of nourishment activities on sea turtle reproductive success on the island of Bogue Banks.

Introduction

Bogue Banks is a developed barrier island in Carteret County, North Carolina. With roughly 25 miles of south-facing beach, it lies between Shackleford Banks and Bear Island in the Southern Outer Banks. The entire oceanside stretch of Bogue Banks constitutes suitable nesting habitat for loggerhead (*Caretta caretta*) and green (*Chelonia mydas*) sea turtles.

As a response to beach movement, the towns of Pine Knoll Shores, Indian Beach and Emerald Isle in cooperation with Carteret County established a short-term beach nourishment project. The first phase of this project was completed between November 2001 and April 2002, and consisted of placing dredge material on nearly 7 miles of beach in Pine Knoll Shores and Indian Beach. Phase II was completed between January and April 2003 and nourished the eastern half of Emerald Isle. Phase III was originally planned for late 2003/early 2004 to complete the western half of Emerald Isle, but was postponed due to logistics.

One of the requirements for the nourishment project 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. Emerald Isle and Pine Knoll Shores boast well-established volunteer programs within the North Carolina Sea Turtle Protection Program of 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 guaranteed 100% coverage of the nesting areas that fell within the project area.

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 temperatures 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 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. If tall and wide enough, these vertical faces 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 beach monitoring.

The sea turtle monitoring area was expanded in 2003 by roughly 4 miles to include the town of Atlantic Beach in addition to Pine Knoll Shores, Indian Beach/Salter Path, and Emerald Isle. Though not included in the Bogue Banks beach restoration plan, Atlantic Beach does receive beach fill material on an eight-year cycle as part of a US Army Corps of Engineers dredge disposal plan linked to the maintenance of the Morehead City port. In Bogue Sound, Brandt Island is a dredge spoil storage site for material frequently dredged from Beaufort Channel (which serves Morehead City port). As part of regular maintenance, sand is periodically removed from Brandt Island and placed on the adjacent beaches at Fort Macon State Park and Atlantic beach. The most recent nourishment from this process took place in 1994 and was to be repeated during the winter of 2003-2004, however pending litigation between subcontractors involved with dredging delayed the process for at least one year.

Previously, Atlantic Beach did not have a formal sea turtle monitoring program of organized volunteers. The Public Works Department of Atlantic Beach and interested local citizens assisted by occasionally reporting strandings and nest crawls. However, the lack of regular monitoring in this area made it impossible to fully assess the occurrence of sea turtle nests, as records of sea turtle activity in this area was limited to recollection of casual observation and "word of mouth" accounts of turtle occurrences. With financial support from the US Fish & Wildlife Service, daily surveys of sea turtle reproductive activities in Atlantic Beach were conducted in 2003. The beach in Fort Macon is patrolled daily by Park Rangers. Thus, in 2003, for the first time ever, the entire length of Bogue Banks was surveyed daily for sea turtle reproductive activities.

Herein we present the data collected during the 2003 nesting season. Although we provide some analyses, final assessment of the results cannot be completed before the end of this multi-season assessment project.

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 31 August 2003. Unless they were postponed due to lightning, the patrols began at dawn and were completed no later than 12 pm. The monitoring area extends roughly 23 miles westward from the Ft. Macon/Atlantic Beach town boundary to Bogue Inlet. Each morning, volunteers in Emerald Isle and Pine Knoll Shores patrolled designated zones on foot. In collaboration with the Bogue Banks Sea Turtle Coordinator, they recorded specific details of each new turtle track, 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.

Since 2002, there has been a moratorium on relocation 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 laid in 2003 were left in their original locations for the duration of incubation and emergence periods (except for one nest, discussed below). As day 55 of incubation approached, volunteers fashioned out of sand 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. In doing so, they provided estimates of the hatching time and/or number of turtles that emerged and also ensured that the presence of passersby on the beach did not pose a threat to the hatchlings scrambling to the ocean. 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

If uncovered during excavation, remaining hatchlings were placed on the sand surface and observed until they safely entered the ocean. The remaining nest material was 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 some nests as soon as possible after laying, with care taken to avoid rotating the eggs temporarily removed from the nest. To measure sand temperatures, 6 transects were established along Bogue Banks, on both nourished and non-nourished areas. 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.

A cone penetrometer (Field Scout SC-900) 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. Six replicate measurements were taken at each location to increase 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."

Data were analyzed using t-tests 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, α= 0.5.

Results and Discussion

A. Nesting events.

From 13 May through 2 September 2003, a total of 118 separate emergences made exclusively by loggerhead turtles were observed in Atlantic Beach, Pine Knoll Shores, Indian Beach, and Emerald Isle (see Figure 9 in Appendix I). Eighty of these emergences did not result in nests. It is not uncommon for loggerheads to make many false crawls on different nesting beaches worldwide (Miller et al. 2003), although commonly this species exhibits a ratio of 1:1 nesting events to false crawls (Dodd, 1988). Excluding Atlantic Beach, whose prior beach nourishment schedule is different from the other towns on Bogue Banks, the overall ratio of nests to false crawls was 36:59 (Table 1). This is not significantly different from a 1:1 ratio (p=0.14, χ^2=2.1 with Yates correction). However, when the crawl data from 2003 were grouped by zones that had been nourished in 2002 or 2003 vs. the non-nourished area of Emerald Isle, there was a significantly greater ratio of false crawls to nests in the nourished areas (p=0.005, χ^2=6.7 with Yates correction; Figure 1). Moreover, in nourished areas there were several false crawls that consisted of multiple primary body pits (as many as 13), and one of those false crawls had more than one abandoned unfinished egg chamber. This suggests that turtles were having difficulty in successfully excavating an egg chamber in the nourished sand.

2002 Location	Nests	False Crawls
Phase I (PKS/IB)	6	8
Pre-Phase II (EI)	8	7
non-nourished (EI)	5	4

2003 Location	Nests	False Crawls
Phase I (PKS/IB)	14	36
Phase II (EI)	8	15
non-nourished (EI)	14	8
Atlantic Beach (AB)	*2*	*21*

Table 1. Number of nests and false crawls observed on Bogue Banks during the nesting season. Rows in grey indicate zones of beach that were nourished in 2002 or 2003. Data from Atlantic Beach were collected in 2003 only, and are not included in analyses.

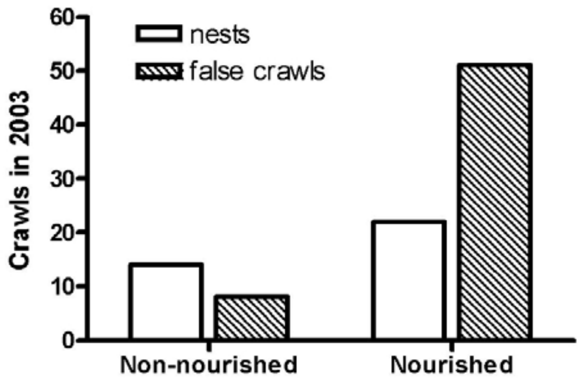


Figure 1. Relative numbers of nests and false crawls made by sea turtles in 2003 in the nourishment project area (between Pine Knoll Shores and Bogue Inlet)

B. Hatching success.

Hurricane Isabel made landfall on 18 September 2003, on Core Banks, north of Cape Lookout, NC. The associated storm surge before and after landfall caused higher than normal overwash along Bogue Banks, often leaving parts of upper beach inundated for several hours. As a result, 9 nests did not successfully complete incubation, and 2 nests produced only a single live hatchling. Four of these affected nests were laid in the non-nourished area; the other 7 were laid in the zones that were nourished during Phase I and Phase II of the project.

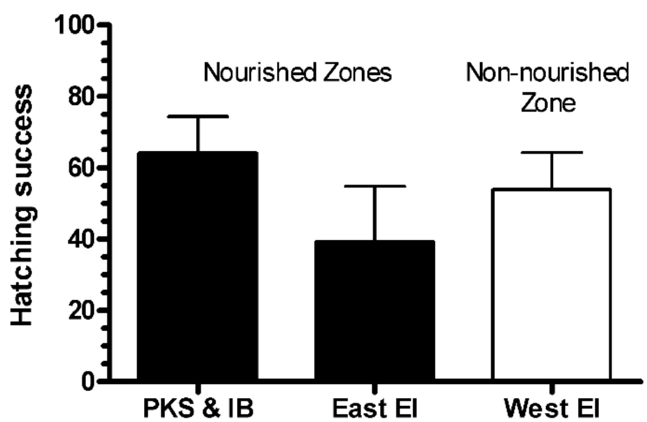


Figure 2. Mean hatching success ±SEM of nests that were grouped by beach zone: PKS&IB zone was nourished in Phase I, East EI zone was nourished in Phase II, West EI was not nourished. There is no significant difference among groups (p=0.41, one way ANOVA).

The overall success was 64.09% ± 8.39 SEM (n=38) for all nests laid on Bogue Banks, excluding Ft. Macon (Appendix I). If nests that produced zero hatchlings due to the hurricane are excluded from the analysis, then overall success was 79.05% ± 6.18 SEM (n=29). However, excluding these data is not straightforward, as some nests did successfully produce hatchlings despite being overwashed for many days due to the hurricane (e.g. Nest EI 21). When comparing nests laid in zones that had been nourished during Phase I and Phase II with those laid in non-nourished zones, there were no significant differences in hatching success across the groups (p=0.41, one way ANOVA, Figure 2). The negative impact of Hurricane Isabel on several nests in each zone effectively "swamped" the overall hatching success values, thereby making it difficult to evaluate the relationship between nourishment and hatching success (if any).

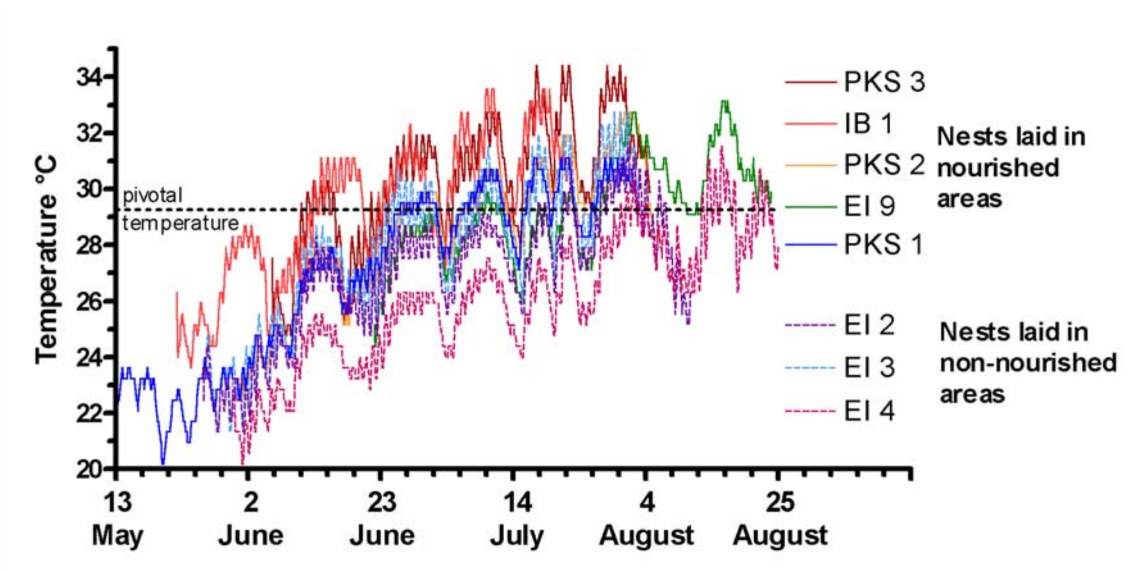


Figure 3. Temperatures of loggerhead nests laid in the first half of the nesting season. Dotted line is the pivotal temperature for loggerheads in the southeastern United States (Mrosovsky 1988).

C. <u>Nest and sand temperatures</u>

Dataloggers were placed in 9 nests during the 2003 season. There were not enough dataloggers available for placement in every nest laid. The last datalogger was buried in a nest laid on 22 June. Therefore the nest data presented here reflect temperature trends of nests laid only during the first half of the season. As the first half of the nesting season progressed, there was a gradual increase in nest temperatures (Figure 3), concurrent with an increase in sand temperatures (see below). Note that in general, temperatures of nests laid in non-nourished areas were cooler than those nests laid in nourished areas, although because nests were laid at different times, it is difficult to directly compare nest temperatures. Two nests were laid on 31 May: nest PKS 3 was laid in a nourished zone and nest EI 4 was laid in a non-nourished zone. When mean temperatures during the thermosensitive period (TSP) for sexual differentiation (roughly the middle three weeks of incubation) were compared between these two nests, the mean temperature during the TSP was significantly warmer for the nest laid in renourished area as compared to the nest laid in the non-nourished zone ($p<0.001$, unpaired t-test, $t=38.88$, $df=614$, Table 2).

An index of nest temperature is the overall incubation period (days between date of laying and date of emergence), as cooler temperatures are associated with decreased metabolism and therefore slower rates of development. Although there are difficulties in comparing incubation periods of nests laid at different times of the thermally variable season, we nevertheless compared mean incubation periods of nests laid in nourished areas to those laid in non-nourished areas. When we compared clutches laid only in June, nests laid in nourished areas had a significantly shorter incubation period (p=0.02, Mann-Whitney test, Figure 4). When we compared all nests that successfully emerged, those laid in nourished areas had significantly shorter incubation periods than those laid in non-nourished areas (p=0.002, Mann-Whitney test, Figure 4). The "pivotal incubation duration" for loggerheads of the Southeastern United States is estimated to be 62 days (Godfrey and Mrosovsky 1997; Godley et al. 2001). Incubation durations shorter than this generally produce more females, and nests with longer durations produce more males. The mean incubation period of nests laid in nourished areas of Bogue Banks was shorter than the pivotal duration, while nests laid in non-nourished areas had a mean duration much longer than the pivotal duration (Figure 4). This suggests that, in 2003, the sex ratios of hatchlings produced from nests in nourished sand differed from those produced in non-nourished sand.

	Non-nourished Sand				***Nourished Sand***				
nest #	**EI 1**	**EI 2**	**EI 3**	**EI 4**	**EI 9**	**IB 1**	**PKS 1**	**PKS 2**	**PKS 3**
mean (°C)	**26.44**	**27.40**	**28.46**	**26.03**	**29.08**	**29.88**	**27.73**	**29.12**	**30.78**
SEM	0.05	0.06	0.09	0.05	0.11	0.07	0.07	0.06	0.08
n	342	309	276	344	252	255	327	272	239
TSP(days)	27	25	22	28	20	20	26	22	19
Hatching success	58.16	96.36	61.90	80.46	97.18	88.49	59.38	88.46	93.10
Date of laying	5/22	5/26	5/26	5/31	6/22	6/03	5/13	5/31	6/06

Table 2. Mean nest temperatures during the thermosensitive period (TSP) of sexual differentiation of nests in non-nourished and nourished zones of Bogue Banks in 2003. Volunteers tampered with nest EI 1 in Emerald Isle during the final stages of incubation. The data recovered from EI 1 are presented for general information, but have been excluded from all statistical analysis. n=number of temperature readings available for each nest during TSP.

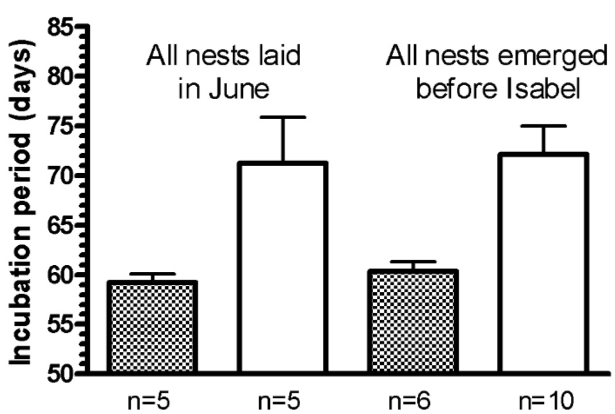


Figure 4. Mean incubation periods ±SEM of nests laid in nourished (grey) or non-nourished (white) beach areas. Estimated pivotal incubation period is 62 days (Godfrey and Mrosovsky 1997, Godley et al. 2001). Sample sizes of each group are given below the bars.

In terms of sand temperatures, there was a gradual warming trend across the nesting season, until early September, when temperatures began to decrease around the time of Hurricane Isabel (Figure 5). The dataloggers were removed from the beach prior to landfall of the hurricane and reburied one week later. However, several dataloggers failed or were lost to erosion following this period, and we could not recover those data. Therefore, we present temperature data only until early September. Note that, with a single exception, all nests still incubating after Hurricane Isabel made landfall failed to result in a successful emergence of hatchlings.

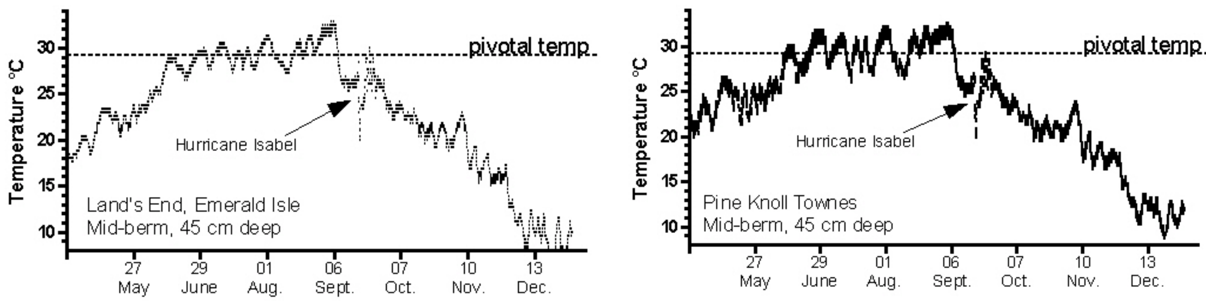


Figure 5. Typical sand temperatures at nest depth (45cm) buried at mid-berm in Land's End in Emerald Isle (non-nourished zone) and Pine Knoll Townes in Pine Knoll Shores (nourished zone). The dotted line is the pivotal temperature for loggerheads in the SE USA (Mrosovsky 1988).

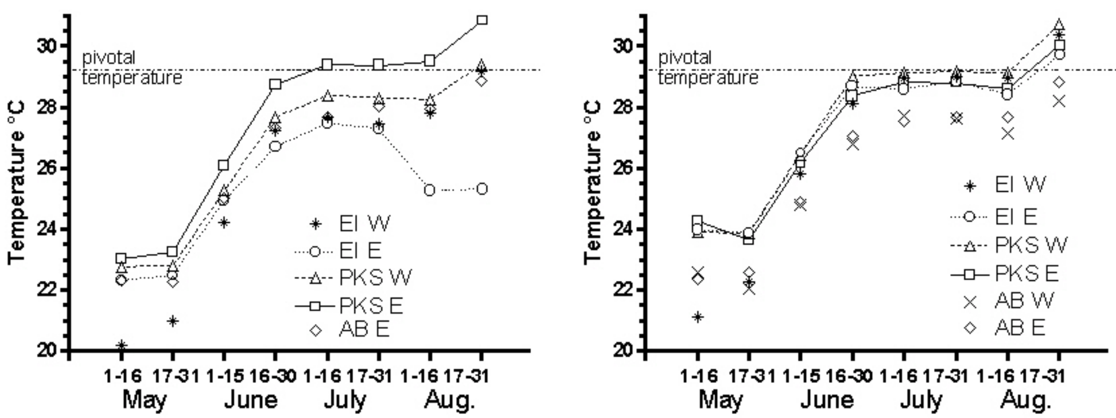


Figure 6. Mean sand temperatures per half-month period at nest depth on Bogue Banks. Left side is mid-beach, right side is at the base of the sand dune. Abbreviations: EI = Emerald Isle, PKS = Pine Knoll Shores, AB = Atlantic Beach (not included in statistical analyses). Note that all points were derived from transects located in nourished areas except for EI W, a transect located in a non-nourished area.

The overall pattern of sand temperatures during May through August 2003 was reflected in all areas monitored: a gradual increase through the season until Hurricane Isabel. In general, sand temperatures were cooler in 2003 as compared to 2002, with temperatures at nest depth generally falling below pivotal temperature for the majority of the season. This suggests that there was less likely to be a female biased sex ratio of hatchlings, although care must be taken when interpreting sand temperatures, as developing sea turtle nests are generally warmer than the surrounding sand (Godfrey et al. 1997; Broderick et al. 2001). Statistical comparison revealed that for each half-month period, nearly all sites were significantly different from each other, even if the differences were on the order of 0.4 °C, which is the same as the resolution of the dataloggers ($p<0.001$ for all half month periods, Kruskal-Wallace test). It is likely that these small significant temperature differences are not biologically relevant. Nevertheless, there was a general trend for sand temperatures at nest depth in nourished areas to be warmer than in non-nourished areas (Figure 6).

C. <u>Sand compaction</u>

In 2003, a new cone penetrometer was obtained with the help of the town of Emerald Isle. However, there can be substantial differences in datasets produced by different penetrometers even when measuring the same substrate (unpublished observation). This makes it impossible to definitively compare datasets from 2002 and 2003, when different equipment was used. The penetrometer used in 2003 has improved measuring accuracy, but appears unreliable at shallow depths (<4cm). We obtained the penetrometer several days after the first few turtle crawls were registered, so no compaction data are available for the first 3 false crawls in Emerald Isle and for the first false crawl in Pine Knoll Shores. Nor were readings recorded at a false crawl site on 19^{th} Street in Emerald Isle because the sand was so compact that the cone could not penetrate beyond one inch. Compaction was not measured at the following false crawls because the turtle turned around before ever going past the high tide swashline: Atlantic Beach #10, 11, 14, 16, 17; Indian Beach #6, 9, 10; and Emerald Isle 21. Compaction data are missing from the following false crawls due to human error: Pine Knoll Shores #1, and Indian Beach #7.

In general, the mean compaction at various depths around nests and false crawls were variable both within and across beaches on Bogue Banks (Figure 7). There were significant differences in mean compaction at different depths across the different beaches and zones of Bogue Banks ($p<0.001$, Kruskal Wallace test). However, there was no apparent pattern of compaction values of sand at different depths when grouped by nest, false crawl, or beach (Figures 7, 8).

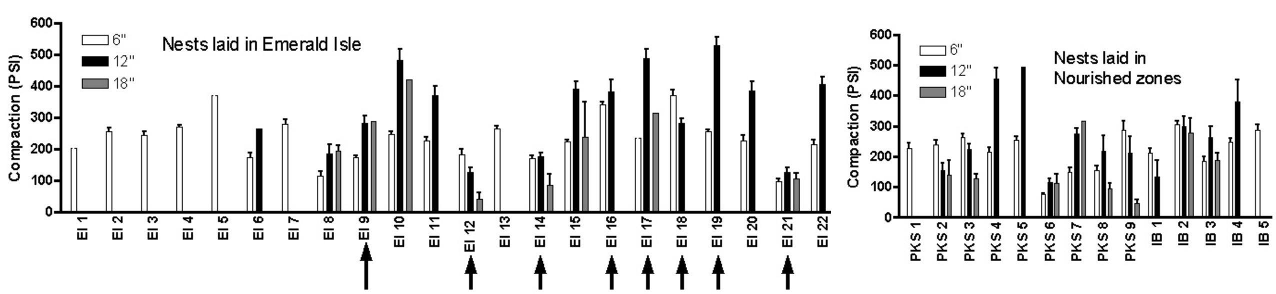


Figure 7. Mean compaction ±SEM at 6", 12" and 18" depths at nest locations in non-nourished locations in Emerald Isle (nests without arrows on left histogram), nourished areas of Emerald Isle (nests with arrows in left histogram), Pine Knoll Shores and Indian Beach (right histogram). EI = Emerald Isle, PKS = Pine Knoll Shores, IB = Indian Beach.

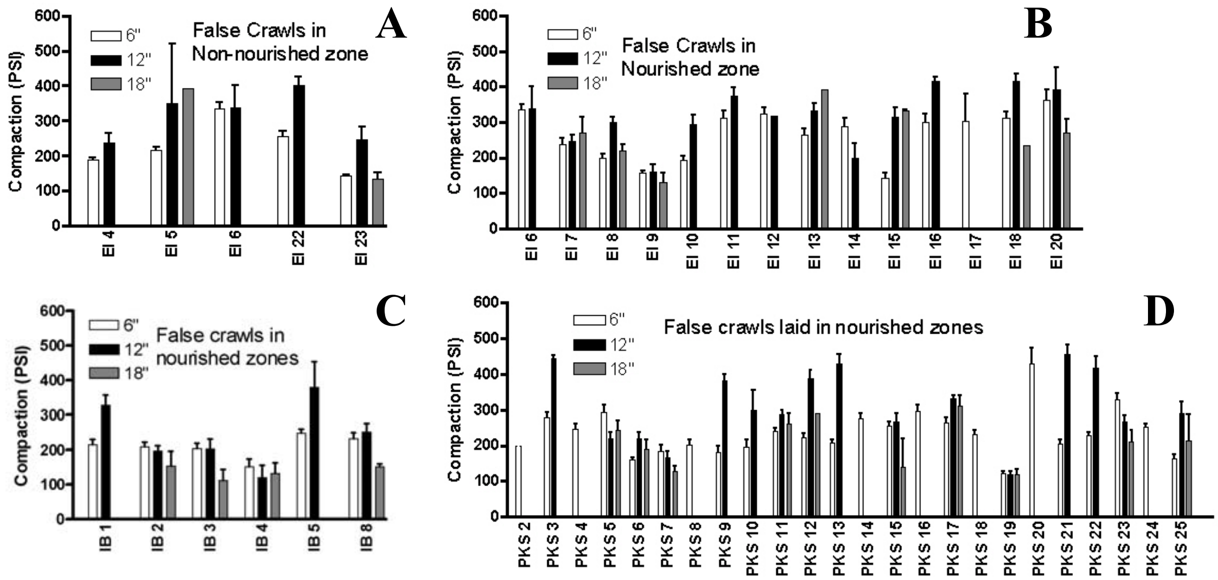


Figure 8. Mean compaction ±SEM at 6", 12" and 18" depths at false crawl locations in non-nourished locations in Emerald Isle (histogram A), nourished areas of Emerald Isle (histogram B), Indian Beach (histogram C) and Pine Knoll Shores (histogram D). EI = Emerald Isle, PKS = Pine Knoll Shores, IB = Indian Beach.

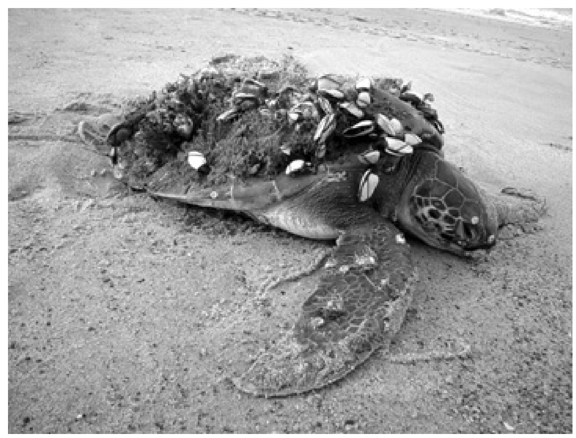
D. <u>Escarpments</u>

Having had a year to equilibrate, the beaches nourished during Phase I in Pine Knoll Shores and Indian Beach showed improved profile consistency this summer in contrast to the 2002 season. Escarpments that did develop dissipated with varying tides and rarely reached a height greater than roughly 15 inches.

Escarpments were consistently present along most of the Phase II nourishment area—from beyond the small number streets through the 5000 block in Emerald Isle. Over the course of the entire monitoring period, it was not uncommon to encounter "scarps" at least 100 feet long or 18 inches high and occasionally higher. A sea turtle's ability to scale scarp heights greater than 18 inches is limited. However, bulldozing, the recommended remedy for persistent scarping that occurs beyond established limits, would not have been recommended unless a false crawl was observed in the area of concern. This threshold was adopted in order to minimize additional manipulation of the beach. There were also times when particularly strong tides graded sections of the beach and greatly reduced the severity of the drop-off. Although, several turtles that managed to climb over escarpments measuring almost 18” high, they nevertheless turned around at the halfway point of the berm and returned to the sea without successfully nesting.

In contrast, there were two false crawls that occurred in Atlantic Beach in which the turtles crawled from the ocean until they reached an escarpment, whence they turned around to go back to the water without attempting to nest. This beach had not been nourished in the preceding 8 years and the escarpments observed were not thought to be disruptive for nesting turtles (less than 18 inches). The width of these crawls appeared to be smaller than other crawls observed elsewhere, suggesting that the turtles who made them were younger and less experienced.

E. Strandings



During 2003 there were 16 sea turtle strandings on Bogue Banks: 8 dead loggerheads, 3 green turtles (one still alive), 2 Kemp’s ridleys (one still alive), 1 dead leatherback, and 1 live unidentified turtle that was caught on a fishing line and released before the species could be confirmed. The live stranded green turtle (pictured here) was found on 5 June in Pine Knoll Shores. It was lethargic, covered by algae, barnacles and other epibionts, and was transported to the Karen Beasley Sea Turtle Hospital for rehabilitation. After a successful recovery, “Pine” was released to the ocean at the end of September.

Other dead wildlife observed on the beach during the monitoring period included sharks (lemon, tiger and one unidentified species), more than 2 dozen pelicans and gannets, and a mass stranding of fish assumed to the result of bycatch from fisheries activities that were taking place offshore Emerald Isle at the time.

F. Seabeach amaranth

The successive recruitment and establishment of other more hearty and competitive plant species limits the proliferation of this endangered plant, which is intolerant to competition. In addition to the inability to withstand excessive tidal inundation, amaranth populations are also vulnerable to motorized traffic that sometimes breach the toe of a dune when avoiding pedestrians on the beach or the surf at higher tides.

In 2003, seabeach amaranth was observed along much of the Phase II area of nourished beach. The onset of this population was somewhat later in the season compared to the initial establishment of the Phase I population in 2002, perhaps related to cooler sand temperature in 2003. Although plant sizes in 2003 were not as large as those observed after Phase I in 2002, there appeared to be a greater overall number of individual plants in 2003 relative to 2002.

G. Human activity

The monitoring project included several components that targeted raising public awareness and increasing public participation in sea turtle conservation efforts on Bogue Banks. In addition to their regular monitoring activities, the volunteer projects in Emerald Isle and Pine Knoll Shores also developed awareness campaigns specifically aimed at reducing the amount of nighttime lighting that reaches the beach during the nesting and hatching season. In addition, new volunteers were recruited in Atlantic Beach to help oversee nest incubation and emergence, and we anticipate their active participation in future years. A new volunteer group in Indian Beach is to be formed in time for the 2004 nesting season. The increased participation and collaboration will benefit the overall sea turtle conservation efforts on Bogue Banks.

There were some instances of miscommunication and inappropriate actions on the part of the volunteers. In particular, the volunteers relocated a nest several weeks into the normal incubation, in disregard of the moratorium on this activity on Bogue Banks. There were also instances when volunteers dug into nests, prior to any hatchling emergence. Although the motivation was concern for the developing eggs, this activity is expressly prohibited in the guidelines for sea turtle volunteers, and also resulted in some temperature data being invalid for analyses.

The purpose of the Bogue Banks Sea Turtle Monitoring Program is to gather scientifically sound data to be used in making informed decisions to guarantee that conservation efforts will meet their full potential with respect to sea turtles in North Carolina. What may be a short-term sacrifice in leaving a threatened nest alone is equal to a long-term gain for the sea turtle population as a whole. To fairly determine the impacts of beach nourishment on sea turtle reproduction we must observe and collect data on the turtles' natural responses and apply standardized analyses of that information for proper interpretation. Understandably, when so much time and emotion are involved, it is sometimes difficult to step back and let nature take its course.

H. Priorities for future monitoring

The relatively large number of nests laid in 2003 meant that only a small portion could be monitored with temperature dataloggers. It would be useful to have more dataloggers in order to increase sample size of nest temperatures in future seasons so we may better understand incubation trends. In addition to temperature and compaction data collected on Bogue Banks, the presence of body pits and attempted egg chambers observed at false crawl sites should be recorded in a standardized manner. We also suggest developing a way to indicate crawl location relative to the width of the possible nesting area, perhaps by delineating specific zones of the beach, parallel to the waterline (e.g. above high tide, mid beach, upper beach, dune). And we further recommend that sand samples be gathered at crawl sites. Analyses of these variables may provide insight into the relationship crawl behavior relative to nourished and non-nourished beaches. Nonetheless, measuring sand compaction and sand temperature is still critical to the establishment of baseline data.

The Bogue Banks Monitoring Program is expected to carry on for at least 6 seasons. However, it is highly unlikely that the ATV purchased for the program will withstand so many seasons on the beach. We recommend that funds be secured to acquire a replacement ATV in time for the 2005 season.

As always, we strongly encourage additional outreach and education for all generations within the community. There is considerable interest in sea turtle biology among students in Carteret County public schools, as well as at Carteret Community College. Perhaps these students could team up with volunteer "mentors" from the Sea Turtle Protection Program to develop a community service agenda with a sea turtle conservation theme. In the same vein, there is great potential for expanding the monitoring activity on the beach if a program were established to meet the participatory interests of tourists.

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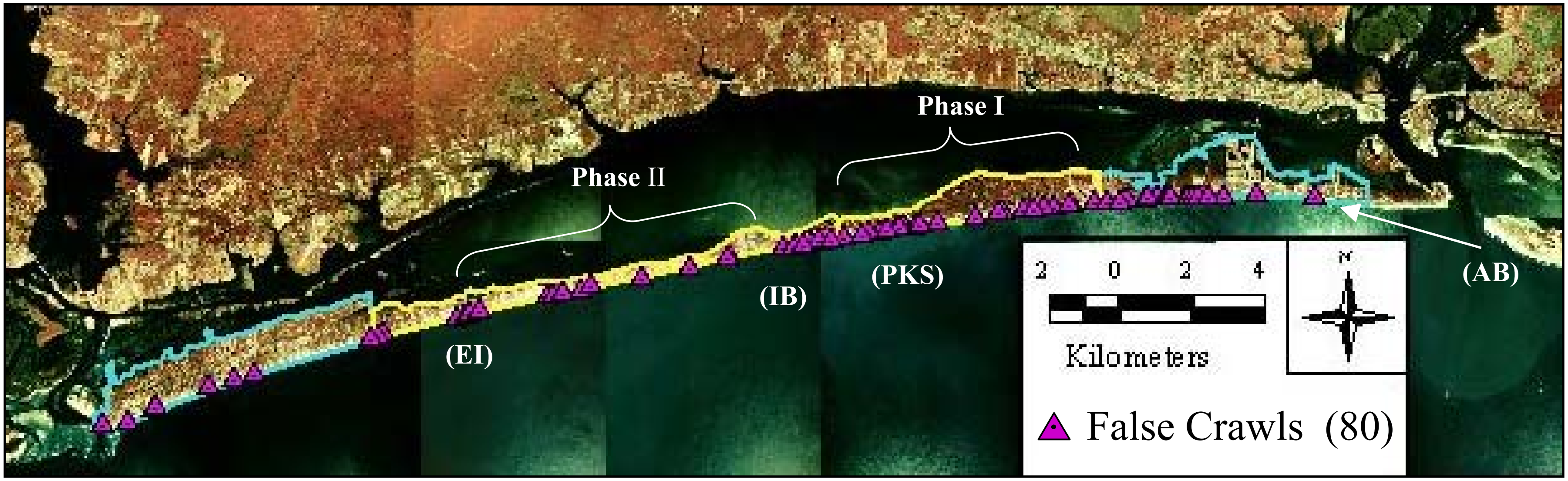
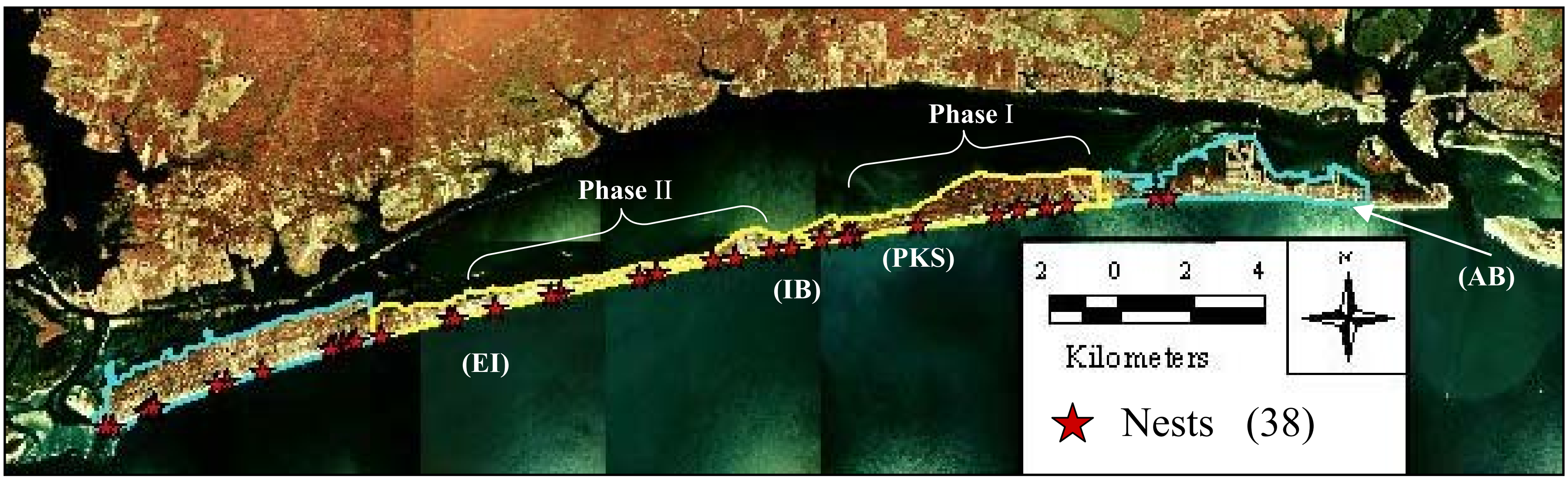
Appendix I

Figure 9. Loggerhead Sea Turtle Crawls on Bogue Banks, NC 2003





Appendix II

Table 1: 2003 Nest Inventories and Hatchling Emergence Success for Emerald Isle, Indian Beach,Pine Knoll Shores, and Atlantic Beach. Emerald Isle nests laid in nourished sand are indicated in bold. Where tidal inundation (largely due to Hurricane Isabel) resulted in arrested egg development, incubation duration is listed as "incomplete."

nest number	nest location	date laid	date of excavation	incubation duration (days)	days washed over	empty shells	live hatchlings	pipped eggs	dead hatchlings	unhatched eggs	total live hatched	total clutch size	hatching success
E.I. 1	Queen's Court	22-May	15-Aug	80	0	59	20	0	2	39	57	98	58.16
E.I. 2	10000Spinnaker's Reach	26-May	10-Aug	74	0	160	24	0	1	5	159	165	96.36
E.I. 3	10100Spinnaker's Reach	26-May	2-Aug	65	0	118	33	0	1	71	117	189	61.90
E.I. 4	East of Teak Street	31-May	24-Aug	83	0	121	0	0	1	28	120	149	80.54
E.I. 5	11100 Spinnaker's Reach	7-Jun	21-Aug	73	0	122	7	0	0	30	122	152	80.26
E.I. 6	Tracy Street	7-Jun	7-Sep	88	3	46	0	0	6	40	40	86	46.51
E.I. 7	Land's End Access	12-Jun	18-Aug	64	0	136	2	0	0	15	136	151	90.07
E.I. 8	James Street	19-Jun	20-Aug	61	0	104	0	0	0	8	104	112	92.86
E.I. 9	**Howe Street**	**22-Jun**	**23-Aug**	**61**	**0**	**138**	**6**	**0**	**0**	**4**	**138**	**142**	97.18
E.I. 10	Shell Street	26-Jun	7-Sep	70	8	109	0	0	49	14	60	123	48.78
E.I. 11	Lee Street	6-Jul	8-Sep	63	0	168	0	0	0	3	168	171	98.25
E.I. 12	**24th Street**	**15-Jul**	**12-Oct**	**?**	**13+**	**59**	**0**	**0**	**1**	**56**	**58**	**114**	50.88
E.I. 13	Black Skimmer Rd.	18-Jul	15-Oct	incomplete	9+	0	0	0	0	86	0	86	0.00
E.I. 14	**5400 block**	**19-Jul**	**16-Oct**	**incomplete**	**12+**	**0**	**0**	**0**	**0**	**145**	**0**	**145**	0.00
E.I. 15	the point	23-Jul	20-Oct	incomplete	20+	8	1	0	7	122	1	130	0.77
E.I. 16	**2600 block**	**23-Jul**	**20-Oct**	**incomplete**	**15+**	**11**	**0**	**33**	**11**	**103**	**0**	**147**	0.00
E.I. 17	**Pinta Street**	**24-Jul**	**21-Sep**	**56**	**0**	**59**	**58**	**0**	**1**	**16**	**58**	**75**	77.33
E.I. 18	**11th Street**	**26-Jul**	**23-Oct**	**incomplete**	**11+**	**1**	**0**	**0**	**0**	**76**	**1**	**76**	1.32
E.I. 19	**Cedar Tree Lane**	**1-Aug**	**29-Oct**	**incomplete**	**7**	**0**	**0**	**0**	**0**	**163**	**0**	**163**	0.00
E.I. 20	Craig Street	4-Aug	2-Nov	incomplete	12+	0	0	0	0	136	0	136	0.00
E.I. 21	**7th Street**	**9-Aug**	**21-Oct**	**72**	**11+**	**94**	**4**	**0**	**0**	**13**	**94**	**107**	87.85
E.I. 22	10000Spinnaker's Reach	2-Sep	30-Nov	incomplete	0	0	0	0	0	136	0	136	0.00
I.B. 1	East of Regional Access	3-Jun	5-Aug	59	0	123	5	1	0	15	123	139	88.49
I.B. 2	East of Vehicle Access	23-Jun	25-Aug	61	0	118	1	1	4	13	114	132	86.36
I.B. 3	Regional Access	25-Jun	28-Aug	63	0	103	2	0	0	23	103	126	81.75

Appendix II

Table 1 continued

I.B. 4	Salter Path Campground	3-Jul	4-Sep	62	0	126	10	0	13	5	113	131	86.26
I.B. 5	Big Red House	3-Aug	2-Nov	incomplete	56	0	0	0	0	118	0	118	0.00
P.K.S. 1	Pine Knoll Townes	13-May	2-Aug	78	17	95	7	0	0	65	95	160	59.38
P.K.S. 2	Trinity Center Access	31-May	6-Aug	65	0	115	9	0	0	15	115	130	88.46
P.K.S. 3	East of Ocean Park	6-Jun	4-Aug	56	0	135	0	0	0	10	135	145	93.10
P.K.S. 4	East of mile marker 6	30-Jun	29-Aug	59	0	110	2	0	0	6	110	116	94.83
P.K.S. 5	East of mile marker 5.5	21-Jul	14-Sep	54	9	83	14	28	36	22	47	133	35.34
P.K.S. 6	Trinity Center Access	22-Jul	18-Oct	55	0	122	0	0	1	8	121	130	93.08
P.K.S. 7	East of Maritime West	24-Jul	20-Sep	57	0	116	14	0	0	12	116	128	90.63
P.K.S. 8	West of Hammer Park	1-Aug	29-Oct	incomplete	10	0	0	0	0	13	0	13	0.00
P.K.S. 9	Trinity Center Access	10-Aug	9-Nov	incomplete	14	0	0	0	0	119	0	119	0.00
A.B. 1	mile marker 3.5	19-Jun	21-Aug	60	0	109	1	0	3	3	**106**	**112**	94.64
A.B. 2	mile marker 3.2	19-Jun	24-Aug	64	6	139	3	0	0	9	**139**	**148**	93.92
										Bogue Banks Total:	**2870**	**4833**	59.38

Table 2: Mean hatching success for each beach and overall Bogue Banks (note that data were transformed with arcsin transformation prior to calculating means).

	n	**mean**	± SD	**±SEM**
Emerald Isle	22	55.67	49.67	9.99
Indian Beach	5	73.47	44.72	26.45
Pine Knoll Shores	9	69.04	50.02	18.42
Atlantic Beach	2	94.29	1.53	1.53
Bogue Banks Total	38	64.09	48.92	8.39

Mean hatching success based on nourishment phases of the Bogue Banks nourishment plan which does not include Atlantic Beach.

PKS & IB *(phase I)*	14	70.65	46.69	13.43
E. half of EI *(phase II)*	8	46.14	52.67	20.81
W.half of EI *(non-nour.)*	14	60.82	48.71	14.06

Appendix II

Table 3. GPS coordinates for all nests 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 in approximately 5 meters (17 feet.)

nest	**date**	**location** (town nest number)	**latitude** (N)	**longitude** (W)	**nest**	**date**	**location** (town nest number)	**latitude** (N)	**longitude** (W)
1	13-May	Pine Knoll Townes (PKS 1)	34.69412	76.81643	20	3-Jul	Salter Path Campground (IB 4)	34.68445	76.89780
2	22-May	Queen's Court (EI 1)	34.65515	77.05699	21	6-Jul	Lee Street (EI 11)	34.66325	77.02282
3	26-May	10000Spinnaker's Reach (EI 2)	34.64904	77.07901	22	15-Jul	24th Street (EI 12)	34.67600	76.95217
4	26-May	10100Spinnaker's Reach (EI 3)	34.64770	77.08278	23	18-Jul	Black Skimmer Rd. (EI 13)	34.66265	77.02470
5	31-May	Trinity Center Access (PKS 2)	34.68920	76.86207	24	19-Jul	5400 block (EI 14)	34.67010	76.98715
6	31-May	East of Teak Street (EI 4)	34.65435	77.05997	25	21-Jul	East of mile marker 5.5 (PKS 5)	34.69581	76.79414
7	3-Jun	East of Regional Access (IB 1)	34.68673	76.88074	26	22-Jul	Trinity Center Access (PKS 6)	34.68942	76.86081
8	6-Jun	East of Ocean Park (PKS 3)	34.69493	76.80926	27	23-Jul	the point (EI 15)	34.64407	77.09524
9	7-Jun	11100 Spinnaker's Reach (EI 5)	34.64370	77.09297	28	23-Jul	2600 block (EI 16)	34.67533	76.95574
10	7-Jun	Tracy Street (EI 6)	34.66424	77.01802	29	24-Jul	Pinta Street (EI 17)	34.66619	77.00852
11	12-Jun	Land's End Access (EI 7)	34.64844	77.08087	30	24-Jul	East of Maritime West (PKS 7)	34.69187	76.84079
12	19-Jun	James Street (EI 8)	34.66388	77.02034	31	26-Jul	11th Street (EI 18)	34.67981	76.92827
13	19-Jun	mile marker 3.5 (AB 1)	34.69729	76.76612	32	1-Aug	Cedar Tree Lane (EI 19)	34.67034	76.98559
14	19-Jun	mile marker 3.2 (AB 2)	34.69731	76.76236	33	1-Aug	West of Hammer Park (PKS 8)	34.69533	76.80043
15	22-Jun	Howe Street (EI 9)	34.67274	76.97292	34	3-Aug	Big Red House (IB 5)	34.68800	76.87055
16	23-Jun	East of Vehicle Access (IB 2)	34.68342	76.90484	35	4-Aug	Craig Street (EI 20)	34.66451	77.01667
17	25-Jun	Regional Access (IB 3)	34.68602	76.88662	36	9-Aug	7th Street (EI 21)	34.68093	76.92204
18	26-Jun	Shell Street (EI 10)	34.65773	77.04605	37	10-Aug	Trinity Center Access (PKS 9)	34.68897	76.86334
19	30-Jun	East of mile marker 6 (PKS 4)	34.69526	76.80147	38	2-Sep	10000Spinnaker's Reach (EI 22)	34.64878	77.07973

Appendix II

Table 4. GPS coordinates for all false crawls are listed in order of occurrence.

crawl #	date	location	latitude (N)	longitude (W)	crawl #	date	location	latitude (N)	longitude (W)
1	18-May	Condos at the point (EI)	34.64485	77.08920	41	10-Jul	Ocean Park (PKS)	34.69483	76.80848
2	25-May	the point (EI)	34.64446	77.09658	42	10-Jul	119 Pinewood (PKS)	34.69539	76.79923
3	31-May	E. of Lands' End Access (EI)	34.64849	77.08053	43	11-Jul	Town Line at Sheraton (PKS)	34.69654	76.78206
4	1-Jun	Ocean Grove West (PKS)	34.69019	76.85320	44	11-Jul	Condos East of Sheraton (AB)	34.69685	76.77691
5	3-Jun	Maritime West (PKS)	34.69147	76.84183	45	12-Jul	mile marker 3.6 (AB)	34.69741	76.76433
6	4-Jun	10000Spinnaker's Reach (EI)	34.64872	77.07967	46	13-Jul	mile marker 3.2 (AB)	34.69746	76.75756
7	5-Jun	The Ocean Club (IB)	34.68415	76.90035	47	14-Jul	mile marker 3.3 (AB)	34.69738	76.75298
8	5-Jun	East of Regional Access (IB)	34.68699	76.87947	48	14-Jul	mile marker 3.2 (AB)	34.69728	76.75724
9	6-Jun	Colony by the Sea (IB)	34.68742	76.87515	49	14-Jul	mile marker 4.3 (AB)	34.69703	76.77619
10	6-Jun	Big Red House (IB)	34.68794	76.87135	50	15-Jul	25th Street (EI)	34.67580	76.95257
11	7-Jun	The Breaker's Condo's (PKS)	34.69103	76.84589	51	15-Jul	Sheraton (PKS)	34.69672	76.78229
12	9-Jun	East of mile marker 5.5 (PKS)	34.69581	76.79427	52	16-Jul	E. of PineKnollTownes (PKS)	34.69445	76.81431
13	10-Jun	Islander Beach Bccess (EI)	34.65554	77.05515	53	16-Jul	110 Knollwood St. (PKS)	34.69613	76.79366
14	11-Jun	Fairfax Street (EI)	34.67070	76.98336	54	17-Jul	E. of Ocean Park (PKS)	34.69508	76.80832
15	12-Jun	W. of Iron Steamer Pier (PKS)	34.69218	76.83507	55	17-Jul	E. of milemarker 5.5 (PKS)	34.69576	76.79388
16	14-Jun	mile marker 2.6 (AB)	34.69741	76.74599	56	18-Jul	W. of milemarker 3.3 (AB)	34.69733	76.76358
17	15-Jun	The Shutters Condos (PKS)	34.69647	76.78589	57	18-Jul	W. of milemarker 3.3 (AB)	34.69727	76.76289
18	16-Jun	Coral Bay Club (AB)	34.69726	76.76677	58	19-Jul	mile marker 3.1 (AB)	34.69739	76.75572
19	16-Jun	mile marker 3.5 (AB)	34.69736	76.76239	59	19-Jul	mile marker 3.0 (AB)	34.69743	76.75372
20	16-Jun	mile marker 3.2 (AB)	34.69746	76.75724	60	20-Jul	mile marker 6.0 (PKS)	34.69536	76.80192
21	17-Jun	mile marker 3.9 (AB)	34.69718	76.77031	61	21-Jul	E. of maritime west (PKS)	34.69170	76.84046
22	18-Jun	11th street (EI)	34.67966	76.92790	62	22-Jul	E. of trinity center (PKS)	34.68944	76.85888
23	18-Jun	2nd street (EI)	34.68188	76.91264	63	23-Jul	mile marker 6 (PKS)	34.69512	76.80482
24	19-Jun	Pinta Street (EI)	34.66629	77.00885	64	23-Jul	mile marker 4.4 (AB)	34.69671	76.77825
25	19-Jun	Cedar Tree Lane (EI)	34.67028	76.98594	65	24-Jul	preserve (IB)	34.68628	76.88330
26	19-Jun	Elizabeth Street (EI)	34.67104	76.98180	66	24-Jul	mile marker 2.0 (AB)	34.69728	76.73603
27	20-Jun	Elizabeth Street (EI)	34.67085	76.98242	67	25-Jul	mile marker 8.5 (PKS)	34.69096	76.84739
28	20-Jun	Matt Street (EI)	34.67132	76.98162	68	25-Jul	E. of PineKnollTownes (PKS)	34.69418	76.81590
29	21-Jun	Nina Street (EI)	34.66585	77.01056	69	25-Jul	mile marker 3.0 (AB)	34.69737	76.75355
30	21-Jun	Edna Street (EI)	34.67190	76.97874	70	25-Jul	mile marker 2.8 (AB)	34.69735	76.75036

Appendix II

Table 4 continued.

31	22-Jun Pier Point (EI)	34.67528	76.95755		71	27-Jul West of PKS border (IB)	34.68815	76.86853
32	22-Jun 21st Street (EI)	34.67677	76.94666		72	28-Jul East of Whaler Inn (PKS)	34.69343	76.82349
33	23-Jun West of Trinity Center (PKS)	34.68878	76.86467		73	29-Jul mile marker 3.9 (AB)	34.69728	76.76940
34	23-Jun Maritime West (PKS)	34.69129	76.84220		74	1-Aug Ocean Crest (EI)	34.65682	77.04922
35	24-Jun mile marker 1.0 (AB)	34.69643	76.71776		75	1-Aug Ocean Club (IB)	34.68401	76.90092
36	7-Jul West of Big Red House (IB)	34.68803	76.87216		76	3-Aug Sand Castle (EI)	34.65350	77.06310
37	7-Jul Coral Shores Condos (PKS)	34.69095	76.84788		77	4-Aug Bluewater Street (EI)	34.66530	77.01300
38	8-Jul 26 th street (EI)	34.67561	76.95573		78	4-Aug E. of Regional Access (IB)	34.68680	76.88015
39	8-Jul 19th street (EI)	34.67760	76.94363		79	4-Aug E. of Colony by the Sea (IB)	34.68712	76.87758
40	8-Jul mile marker 9.0 (PKS)	34.68999	76.85625		80	5-Aug Ocean Grove East (PKS)	34.69027	76.85134