2004 Sea Turtle Monitoring Project Report
Bogue Banks, North Carolina

INTERIM REPORT

Turtle hatchling release following nest excavation in Pine Knoll Shores, NC – 2004

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Introduction

Bogue Banks, in Carteret County, is a barrier island that runs east to west between Shackleford Banks and Bear Island in southeast North Carolina. A 50-year Shore Protection Project designed by the US Army Corps of Engineers includes periodic sand renourishment. Phase I of the Bogue Banks Beach Restoration Project took place from November 2001 to April 2002. Dredge material was pumped onto the beaches of Pine Knoll Shores and Indian Beach, covering an area of approximately seven miles. Phase II, from January to April 2003, nourished the eastern half of Emerald Isle. Phase III, scheduled to begin in January 2005 will complete the renourishment of the western end of Emerald Isle. Additionally, dredge material was placed on Indian Beach and Salter Path, together with the extreme western end of Pine Knoll Shores, from February to March 2004. This activity was Phase I of "Project 933," a component of the Morehead City Harbor Federal Navigation Project that includes regular dredging of the harbor channel. Phase II of Project 933 was linked to the scheduled maintenance pump-out of Brandt Island that involves placing material on Fort Macon and Atlantic Beach every 8 years or so. Phase II was intended to spread the material from Ft. Macon through Pine Knoll Shores in December 2004 – April 2005. However, for logistic reasons associated with the reduced quality of the material, at the time of this writing Phase II is not expected to be successfully completed, such that Pine Knoll Shores will not receive any material at this time.

Bogue Banks is also regularly used as a nesting site for loggerhead sea turtles (*Caretta caretta*). The Bogue Banks Sea Turtle Monitoring Project was implemented to assess the impact of the recent renourishment efforts on sea turtle nesting success on the island. There is concern that the material placed on the beach during nourishment may be different from what was there before. These differences may have negative impacts on sea turtle reproduction. For instance, characteristics such as sand compaction and sand temperature directly affect sea turtle nests. Sex determination in hatchlings is dependent upon the temperature at which nests incubate: higher temperatures yield greater numbers of females while cooler temperatures result in more male hatchlings (Wibbels 2004). Given that darker colors absorb more solar radiation, sediment used as beach fill could result in warmer nests if turtles lay their eggs in darker nourished sand (Hays et al. 2001). North Carolina is roughly the northern boundary of sea turtle nesting in the SE USA. North Carolina sand temperatures are cooler than those of more southerly states, thereby producing relatively more male hatchlings than more southerly states (Mrosovsky et al. 1984; Mrosovsky and Provancha 1992). Other potential impacts include the possibility that dark sediment could create nest temperatures that are too hot for successful incubation or that the nourished material is too compact for successful nest construction.

The goal of the study in the 2004 nesting season was to continue to collect information on sea turtle reproductive success on Bogue Banks, comparing nests laid in zones that were recently nourished to those laid in zones that have not been recently nourished.

Methods

Daily patrols began 7 May 2004 and ended on 31 August 2004. Using an ATV, the Bogue Banks Coordinator patrolled nearly the length of the island's oceanside beach (approximately 23 miles), from the Atlantic Beach/ Fort Macon town line to the western point of Emerald Isle. Local volunteers patrolled on foot, covering sections of beach within their town's jurisdiction. Patrols were conducted in the early morning, around sunrise, to ensure that turtle tracks had not been effaced by human footprints.

Each sea turtle nesting activity was recorded both by the Bogue Banks Sea Turtle Coordinator and the volunteers. Information collected included date, identification as a nest or false crawl, location description, GPS coordinates, and species identification when possible. Nests were identified only after careful digging to confirm the presence of eggs in a body pit. Confirmed nests were recovered and marked by four wooden stakes, flagging tape and a Sea Turtle Protection Program sign. During incubation, each nest was monitored during the daily morning patrol for signs of disturbance and ocean wash-over. The Bogue Banks Coordinator collected sand compaction readings at every nest and false crawl using a cone penetrometer (Field Scout SC-900). Three readings at depths of 6, 12, and 18 inches were taken at each south, east, north and west point surrounding a nest or at the turn in a false crawl.

To monitor nest temperatures during incubation, temperature dataloggers (Hobo H8, Onset Computer Corporation, USA) were buried in the center of select nests on the morning that the nests were discovered. For datalogger placement, some eggs were removed and later replaced so as to create a pocket in the nest where the datalogger could sit. Rotating eggs was kept to a minimum to avoid early embryonic mortality.

Volunteers began to prepare for nest emergence starting on day 55 of nest incubation. A hatchling runway was constructed, consisting of built up sand edges lining a smooth track toward the ocean and marked with flagging tape to provide protection from curious beach walkers. Volunteers sat with nests after dark. Nest sitting provides protection for the hatchlings, especially in areas of bright ambient lighting, as well as providing the opportunity for sharing environmental education with beach visitors.

A minimum of 72 hours after the first emergence of hatchlings, each nest was excavated for evaluation of hatching success and to free any trapped live hatchlings at the bottom of the nest. Dataloggers were also recovered at this time and their data downloaded to a computer. During the nest excavation, the clutch total was calculated by adding the number of empty shells (ES) to the number of unhatched eggs (UH) and pipped eggs (PE). The number of dead hatchlings found in the nests was recorded as (DH). Live hatchlings found in the nests were released and allowed to crawl along the runway to the ocean. The emergence success rate of each nest was calculated using the following formula.

$$(ES - DH) \div (ES + UH + PE) * 100 = \text{emergence success rate (\%)}$$

In addition to nest temperatures, we also collected sand temperatures from dataloggers buried at 6 transects along the island in different sections of beach: Atlantic Beach, Pine Knoll Shores and Emerald Isle. At each transect, the dataloggers recorded sand temperature at high and low locations along the beach, at 45cm depth (corresponding to mid turtle nest depth), from May to October 2004. The majority of sea turtle nests were laid in the zone encompassed by the high and low sites. In a few cases, dataloggers were lost due to excessive high tides due to hurricanes and/or tropical storms.

2004 Season Results

Nest activity and nesting success

For the 2004 season, on the island of Bogue Banks there were 41 loggerhead sea turtle emergences. Of these, 21 were nests and 20 were false crawls. The first crawl (and nest) on Bogue Banks was discovered 25 May 2004. The ratio of false crawl to nest on Bogue Banks in 2004 was 20:21 (Table 1), consistent with data reported from other loggerhead nesting beaches around the world (Dodd 1988).

Table 1. Occurrence of false crawls to nests on Bogue Banks in 2004

Nourished Beach		***Non-Nourished Beach***	
False crawls	Nests	False crawls	Nests
13	13	7	8

The total number of eggs laid on Bogue Banks during the 2004 season was 1888. The hatch success rate was 56.3% (Table 1). Two nests in Pine Knoll Shores that were completely lost due to high tides associated with tropical storms or hurricanes. Three nests in Emerald Isle were also washed out by high tides, however some eggs from each of these were recovered and reburied further up the beach. Some of the these eggs eventually produced hatchlings. However, because the original clutch size of these nests were unknown, it is certain that the emergence success rates for Emerald Isle are overestimated, as the values in Table 1 do not take into account the lost eggs.

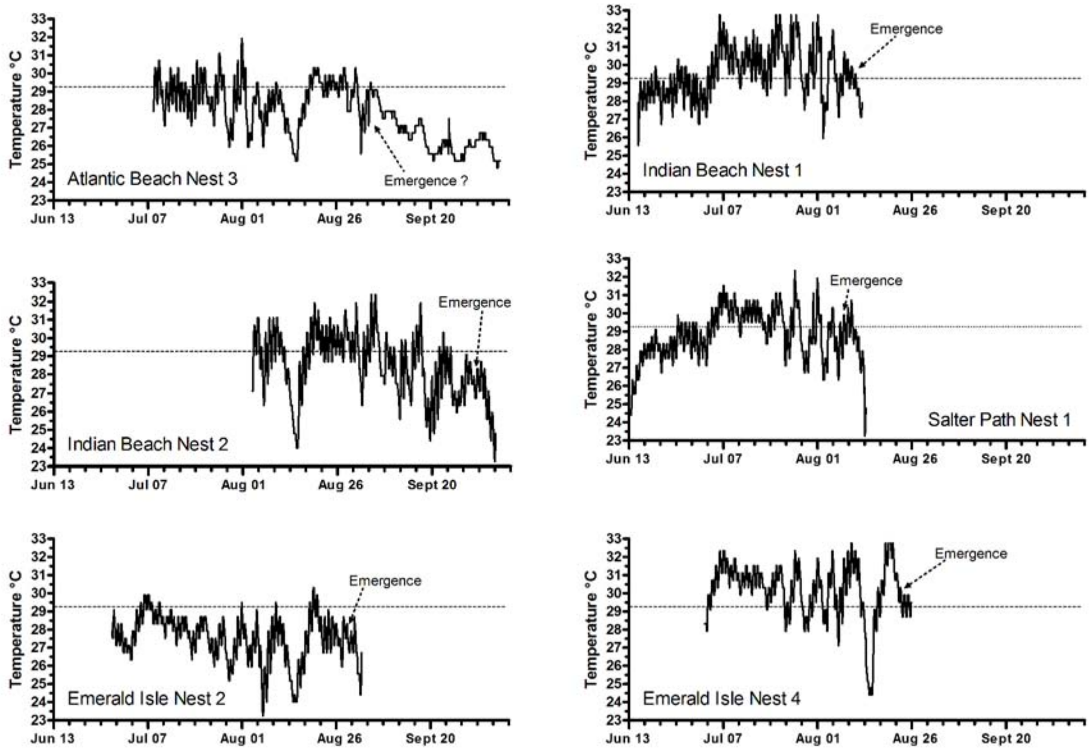
Table 2. Turtle activity on Bogue Banks in 2004. Note that Fort Macon did not report any turtle crawls for the entire season.

Beach area	**False crawls**	**Nests**	**Mean emergence success***
Fort Macon	0	0	n/a
Atlantic Beach	7	3	54.5%
Pine Knoll Shores	5	5	39.5%
Indian Beach/Salter Path	6	4	79.74%
Emerald Isle	2	9	54.87%
Bogue Banks	**20**	**21**	**56.3%**

*average values were calculated after data were arcsin transformed

Nest and sand Temperatures

Eleven nests were outfitted with dataloggers at the beginning of incubation. Two dataloggers from turtle nests in Pine Knoll Shores and one from a nest in Emerald Isle were lost when the high tides washed away the nests. A fourth datalogger failed to collect data during incubation in a nest from Emerald Isle. Therefore, temperature data were collected from seven nests in 2004; of these, five nests occurred in areas that received dredge material during nourishment activities since 2001/2002.



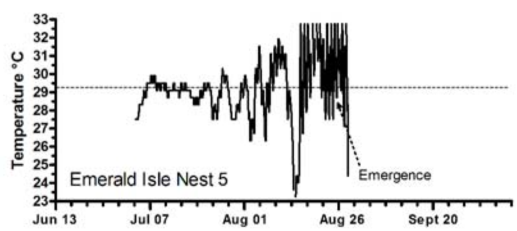


Figure 1. Temperatures for loggerhead sea turtle nests on Bogue Banks, 2004. Dotted horizontal line indicates pivotal temperature (see text). High swash that temporarily flooded nests occurred on August 2-3 (Hurricane Alex) and 14 August (Hurricane Charley). Suspected emergence date of Nest 3 from Atlantic Beach is indicated by arrow. Emerald Isle Nest 2 and Atlantic Beach Nest 3 were in non-nourished zones.

All nests displayed variation in temperature during incubation (Figure 1). There was diel variation on the order of ~1°C, except for extreme temperature fluctuations associated with high tides and swash from tropical storms and hurricanes (Hurricane Alex on 2-3 August, Hurricane Charley on 14 August). There was also seasonal variation in nest temperatures, with cooler temperatures in June (early in the season) and September (late in the season), and warmer temperatures in July and August. This corresponded with sand temperatures at nest depth that peaked in July and August (Figure 2). Note that nest temperatures were warmer than corresponding sand temperatures from the same beach zones, due to metabolic heat produced by the incubating eggs themselves (Mahoney et al. 1990; Godfrey et al. 1997).

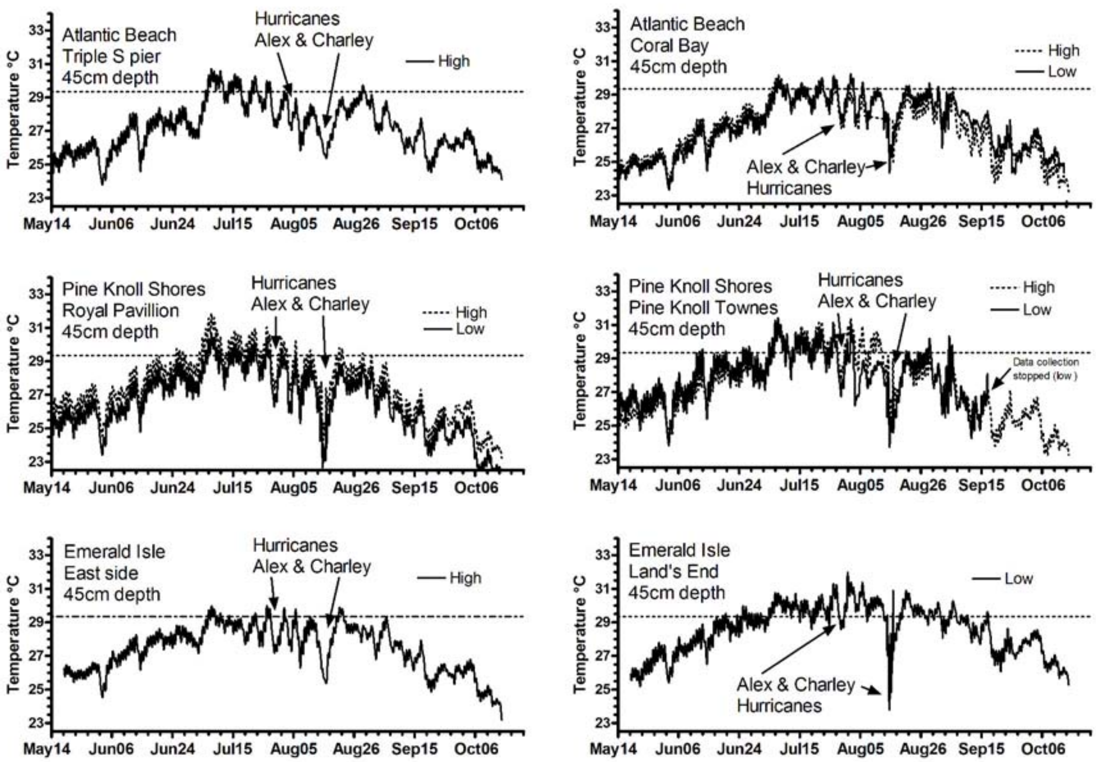


Figure 2. Sand temperatures at nest depth from different transects located along Bogue Banks. Although dataloggers were deployed at high and low locations of each transect, some data were lost from dataloggers that were washed away by high tides or failed during data collection.

All nests laid in zones that were nourished since 2001/2002 tended to be near or above the pivotal temperature (dotted horizontal line in Figure 1). The pivotal temperature is the incubation temperature that results in equal number of males and females; in loggerheads from the SE USA, the pivotal temperature is around 29.2 °C (Mrosovsky 1988). Incubation temperatures higher than pivotal produce more or all females, temperatures lower than pivotal produce more or all males. There were two nests laid in areas of Bogue Banks that have not been recently nourished: Atlantic Beach Nest 3 and Emerald Isle Nest 2. Both displayed temperatures that were cooler than the other nests (Figure 1).

The thermosensitive period (TSP) for sexual differentiation of sea turtle eggs occurs roughly during the middle third of incubation (Hewivisenthi and Parmenter 2002). The mean temperature of the TSP for nests in Bogue Banks showed significant differences (Kruskal-Wallance nonparametric test with Dunn's Multiple Comparison test, p<0.001; Figure 3). The mean temperatures during the TSP for two nests laid in zones not recently nourished were cooler than the TSPs for the other nests (Figure 3). However, given the seasonal fluctuation of sand temperatures, the strongest comparison is between nests whose TSPs overlap on calendar days. Only 3 nests (all from Emerald Isle) shared overlapping TSPs; the nest laid in the nonnourished zone was cooler than the two nests laid in the recently nourished zone (Figure 4). Although Emerald Isle Nest 2 barely reached pivotal temperature on one day during its TSP, the other two nests were at or above pivotal temperature for much of their TSPs (Figure 4). This suggests that eggs incubating in nourished zones were warmer than non-nourished areas, and the resulting sex ratios of hatchlings produced were likely feminized by the increased temperatures associated with darker material placed on the beach during recent nourishment activities.

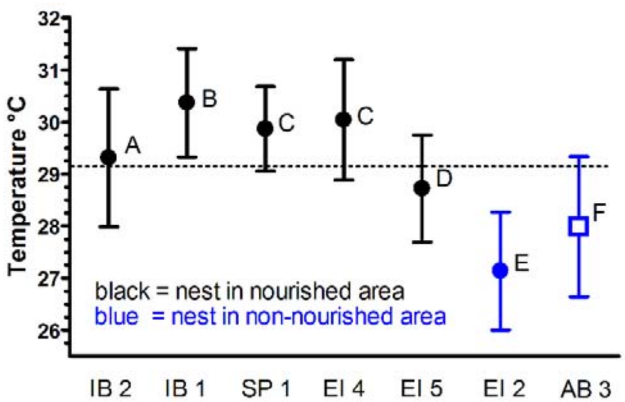


Figure 3. Mean (±SD) nest temperatures during the thermosensitive period for sexual differentiation. Mean values with different letters are significantly different (Kruskal Wallace test, p<0.001). Dotted horizontal line indicates pivotal temperature.

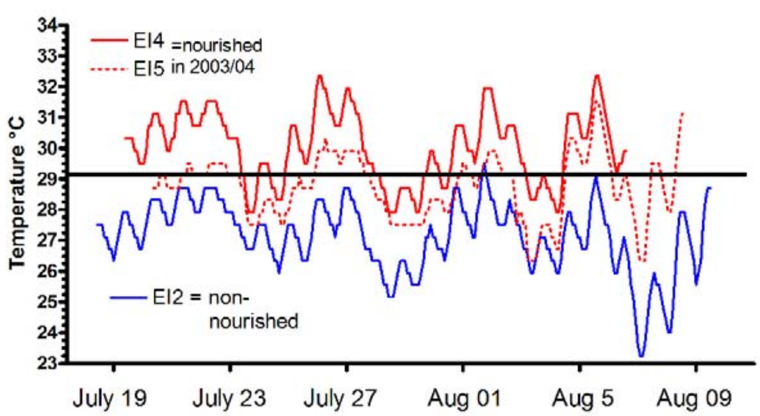


Figure 4. Overlapping thermosensitive periods (TSPs) for three nests laid in Emerald Isle in 2004. Horizontal line indicated the pivotal temperature for loggerheads in the SE USA.

Sand Compaction

Sand compaction varied greatly both among nests and among crawls (Figures 5-8). In general, it was often impossible to reach 18 inch depth using the cone penetrometer, indicating that the substrate was too compact for accurate measurement. However, when collecting compaction data from crawls found in recently nourished zone (Figures 5 and 7), it was more difficult to reach deeper depths, relative to crawls found in areas not recently nourished (Figures 6 and 8). Nevertheless, it is thought that compaction measured on a vertical axis with a penetrometer does not adequately mimic sand resistance encountered by turtles that dig at non-vertical angles with their rear flippers when constructing a nest (Davis et al. 1999).

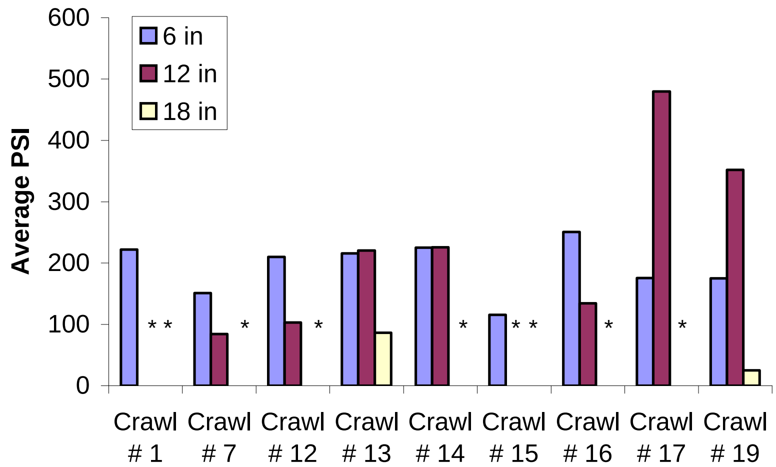


Figure 5: Mean sand compaction measured at loggerhead false crawls that occurred in zones that have been nourished since 2001/2002. It was sometimes impossible to drive the compaction meter to deeper depths, as indicated by *.

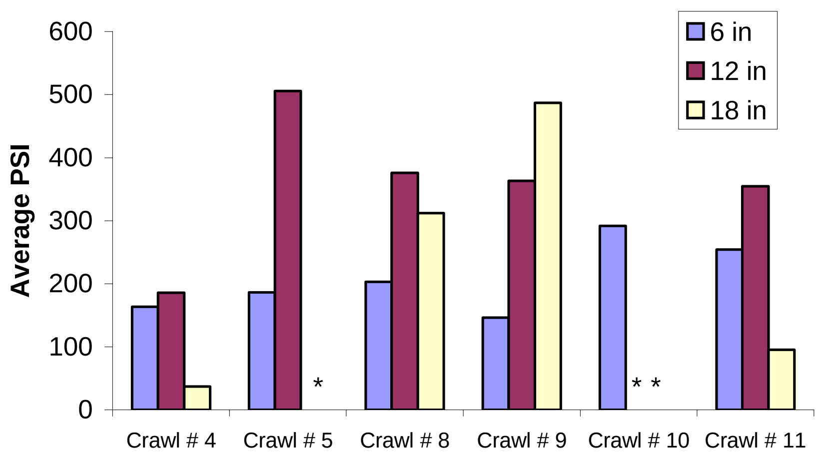


Figure 6: Mean sand compaction measured at loggerhead false crawls that occurred in zones that have not been nourished since 2001/2002. * indicates depths where no data were collected due to excessively compacted material.

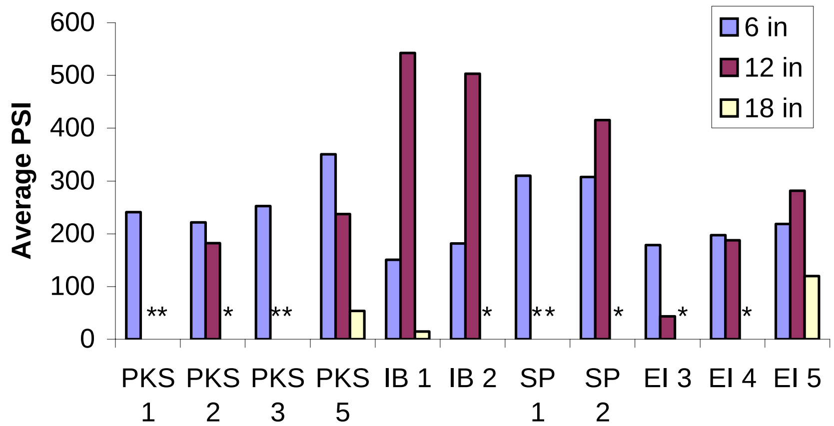


Figure 7: Mean sand compaction measured at loggerhead nests that occurred in zones that have been nourished since 2001/2002. * indicates depths where no data were collected due to excessively compacted material.

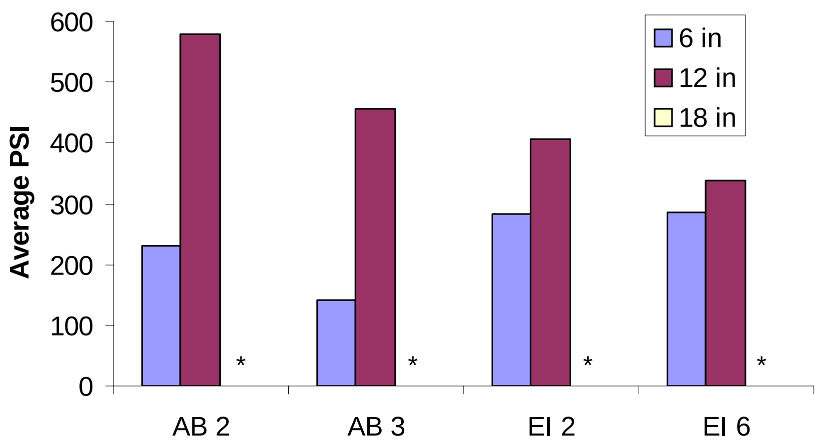


Figure 8: Mean sand compaction measured at loggerhead nests that occurred in zones that have not been nourished since 2001/2002. * indicates depths where no data were collected due to excessively compacted material.

Despite the difficulty for the penetrometer to reach 18 inches depth in nourished areas of Bogue Banks, the turtles nevertheless managed to successfully construct egg chambers in nourished zones during the 2004 nesting season.

Conclusions

The 2004 nesting season comprised the third consecutive monitoring period for this study on the impact of nourishment on sea turtles on Bogue Banks. Although fewer nests were laid in 2004 relative to 2003, the results were consistent with previous years: sea turtle nests were laid in nourished zones and successfully produced hatchlings.

However, the results were also consistent with previous years in showing that nests laid in nourished zones tend to be warmer than nests laid in non-nourished areas, thought to be a direct result of the darker color of the material being placed on the beach. This increase in nest temperature likely causes an increase in the production of female hatchlings from the beach. Future monitoring is warranted in order to confirm whether this trend continues. Also, because Phase III will be completed before the 2005 nesting season and will result in the entire study area being classified as "recently nourished," we recommend using sand and nest temperatures from Bear Island, located just west of Emerald Isle, for comparison purposes.

Acknowledgements: Thanks to the Public Works Department of Atlantic Beach for allowing us to use their facilities during the nesting season. We are grateful to the countless hours donated by the different volunteers in Emerald Isle, Salter Path/Indian Beach, Pine Knoll Shores, and Atlantic Beach. Financial support for this project came from Carteret County, US Fish and Wildlife Service, and the US Army Corps of Engineers. Thanks to Wendy Cluse for helping patrol and monitor the beach throughout the summer.

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APPENDIX I

Bogue Banks Nests 2004

Atlantic Beach

nest number		location	date laid	date of emergence	incubation duaration (days)	empty shells	unhatched eggs	pipped eggs (dead)	dead hatchlings	live hatchlings	clutch total	hatch success rate
AB 1		Dunescape	6/5/2004	8/7/2004	63	84	7	3	9	48	94	79.79%
AB 2		Dunescape	6/21/2004	8/24/2004	64	90	0	0	3	5	90	96.67%
AB 3	*	713 Ocean Ridge	7/9/2004	~~~~~~~	?	53	56	12	53	0	121	0.00%
										Mean hatch success		***54.51%***

Pine Knoll Shores

nest number		location	date laid	date of emergence	incubation duaration (days)	empty shells	unhatched eggs	pipped eggs (dead)	dead hatchlings	live hatchlings	clutch total	hatch success rate
PKS 1	*§	Ocean Park	5/25/2004	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	0.00%
PKS 2		403 Maritime East Drive	7/17/2004	9/16/2004	61	137	3	0	0	0	140	95.71%
PKS 3	*§	Pelican hs. Trinity Cntr.	7/26/2004	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	~~~~~~~	0.00%
PKS 4		E of mm 5.0	7/30/2004	10/6/2004	68	80	11	7	65	1	98	70.41%
PKS 5		Ocean Park	8/7/2004	10/13/2004	67	96	14	0	0	0	110	74.55%
										Mean hatch success		***39.53%***

Indian Beach/Salter Path

nest number		location	date laid	date of emergence	incubation duaration (days)	empty shells	unhatched eggs	pipped eggs (dead)	dead hatchlings	live hatchlings	clutch total	hatch success rate
IB 1	*	Sea Isle Drive	6/15/2004	8/10/2004	56	92	22	1	0	23	115	80.00%
IB 2	*	Sea Isle Drive	8/4/2004	10/4/2004	61	74	4	0	0	0	78	94.87%
SP 1	*	W of SP beach access	6/13/2004	8/11/2004	59	50	12	3	0	1	65	76.92%
SP 2		E of SP beach access	7/15/2004	9/10/2004	57	73	45	0	1	9	118	61.02%
										Mean hatch success		***79.74%***

Emerald Isle

nest number		location	date laid	date of emergence	incubation duaration (days)	empty shells	unhatched eggs	pipped eggs (dead)	dead hatchlings	live hatchlings	clutch total	hatch success rate
EI 1		The point - Land's End	5/19/2004	7/27/2004	69	130	13	0	1	12	143	90.21%
EI 2	*	8600 Ocean Drive	6/28/2004	8/30/2004	63	94	26	5	1	89	125	74.40%
EI 3	* §	801 Ocean Drive	7/1/2004	8/22/2004	52	71	5	4	1	1	80	87.50%
EI 4	*	5421 Ocean Drive	7/2/2004	8/24/2004	53	92	6	2	0	3	100	92.00%
EI 5	*	4601 Ocean Drive	7/3/2004	8/26/2004	54	84	16	0	0	10	100	84.00%
EI 6		6900 Ocean Drive	7/15/2004	9/17/2004	64	8	22	3	0	5	33	24.24%
EI 7		7409 Ocean Drive	7/23/2004	9/24/2004	63	75	25	0	0	75	100	75.00%
EI 8	*	7200 Ocean Drive	8/1/2004	~~~~~~~	?	0	107	0	0	0	107	0.00%
EI 9		W of East Reg. Access	8/24/2004	~~~~~~~	?	0	69	4	1	0	73	0.00%
										Mean hatch success		***54.87%***

* indicates buried datalogger

~~~~~~ indicates data not available

§ indicates nests/dataloggers lost by storms

MEAN HATCH SUCCESS OF ALL NESTS IN 2004 ***56.27%***
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