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Turtle Nesting on Adjacent Nourished Beaches with Different Construction Styles: Pinellas County, Florida

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ABSTRACT

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Successful nesting of loggerhead turtles is an important aspect of beach management along the Gulf Coast of Florida. A detailed time series of beach monitoring has provided a wealth of data on turtle nesting and resistance to penetration in order to assess the effect of beach nourishment on turtle nesting. Three adjacent, nourished beaches, and nearby unnourished beaches provided the locations for systematic measurement of conditions. Two years of data are provided, 1994 and 1995, with the latter including tilling of the nourished beach on one of the projects.

Nesting density increased from 1994 to 1995. Although cone penetrometer measurements routinely exceeded guidelines for turtle nesting, the turtles paid no attention to compaction. The nature of the sediment with large quantities of bivalve fragments is such that although vertical penetration is very difficult, the style of digging by turtles experiences little resistance. Data provided in this study indicate that the current guidelines based on cone penetrometer data for nesting in highly compacted beaches are incorrect. Nourished beaches on the Gulf Coast of Florida do not inhibit turtle nesting, they encourage it by providing a wide, dry beach.

ADDITIONAL INDEX WORDS: *Beach nourishment, turtle nesting, compaction, cone penetrometer.*

INTRODUCTION

The loggerhead turtle (*Caretta caretta*) is listed as a threatened species by the U.S. Fish and Wildlife Service. Its nesting area in the continental United States ranges from Texas to New Jersey (NELSON, 1988) but more than 99% of the nests are in Florida, Georgia, South Carolina and North Carolina. In 1983, nearly 85% of all nests were in Florida (GORDON, 1983). The number of nests on the Gulf of Mexico Coast of Florida pales in comparison with that on the Atlantic Coast, however, at least several hundred are present on Gulf beaches in any given year. Four other turtle species have been identified on the Florida coast, but all are rare.

Turtle-nesting habits are categorized into four types: (1) a false crawl where the turtle emerges from the water and crosses the beach without digging; (2) a false dig where the turtle emerges and digs without laying eggs; (3) a successful nest with hatchlings; and (4) an unsuccessful nest with eggs that do not hatch. This discussion will concern only the nesting.

Many factors influence the beach environment for successful turtle nesting. These include moisture of the beach, sediment characteristics, compaction, temperature range, and human activity of various types. Several investigations into the effect of each of these factors have been conducted on Florida beaches (e.g. RAYMOND, 1984; NELSON, 1988; NELSON and DICKERSON, 1988). The general conclusions reached by these and other investigations are that successful turtle nesting requires a dry beach with a narrow temperature range. In addition, the sediment should be loosely compacted in order to facilitate efficient excavation by the turtles (NELSON, 1988). All of these important characteristics of the beach can be modified by human activities.

Florida beaches are one of the most valuable natural resources of the State and as such, they are monitored, controlled, and rebuilt on a regular basis. Beach nourishment in Florida has become the standard method of beach management over the past two decades or so. This type of construction has obvious implications for turtle nesting and as a result, its effects have been examined on multiple nourishment projects (*e.g.* NELSON and MAYES, 1986; NELSON *et al.*, 1987; NELSON and DICKERSON, 1989; PARKINSON and RYDER, 1992; HODGIN *et al.*, 1993). Most of these studies have concluded that nourished beaches generally have a detrimental effect on turtle nesting, caused primarily by producing compacted beach sediment.

Because beach nourishment is widely used and because it is viewed by most people as the only viable answer to most beach erosion problems, it is necessary to reconcile this problem. The most commonly invoked method of doing this is by tilling the compacted beach to loosen the sediment and thus facilitate excavation by loggerhead turtles. The depth of till-

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Figure 1. Map of Sand Key, Pinellas County, Florida showing location of the study area.

ing is critical because this turtle species has a rather distinct depth range for their nests; typically from 45–90 cm (1.5–3.0 ft) (NELSON, 1988). Tilling must therefore extend to at least that depth range in order to be effective. Studies on the east coast of Florida (*e.g.* NELSON, 1986, 1987) have found that tilling results in considerable reduction in compaction but that there is a significant increase in compaction after several months. It has been recommended that tilling be conducted on nourished beaches annually before the initiation of the nesting season in late spring (NELSON, 1987).

STATEMENT OF PROBLEM AND OBJECTIVES

Most of the previously cited studies and generalizations are based on work conducted along the southeast coast of Florida where turtle nesting density is the highest in the United States; up to 100/mile (100/1.6 km). The Florida Gulf Coast also hosts a modest number of turtle nestings each year; generally several hundred, up to about 10/mile (10/1.6 km). This coast has also experienced numerous beach nourishment projects over the past 15 years. It is these nourishment projects that provide excellent conditions for conducting a time-series investigation of the relationships between beach conditions and tilling on turtle nesting.

The Pinellas County coast extends for about 60 km along the central peninsular Gulf Coast of Florida. Most of this coast has been nourished at least once over the past decade. The best opportunity to investigate how nourishment might influence turtle nesting is along the beaches of Sand Key in the central part of the county (Figure 1). This barrier is continuous for 30 km and has experienced three major nourishment projects over the past decade with another in the planning stages. These projects, known as Sand Key Phases I–III, were constructed at Redington Beach (1988), Indian Rocks Beach (1990) and Indian Shores (1992) (Figure 1). They represent three distinct combinations of borrow area and construction techniques thus providing an excellent data base for analyzing their respective effects, if any, on turtle nesting. The first phase, Redington Beach, was constructed with borrow material from the ebb-tidal delta of Johns Pass (Figure 1) using traditional suction dredging and piping in a slurry to the site. The second phase was constructed with material taken from the Egmont ebb-tidal delta at the mouth of Tampa Bay (Figure 1) using a suction dredge but the borrow material was then barged and off-loaded by pumping in a slurry to the site. The borrow material for the last phase at Indian Sores was also taken from the Egmont ebb-tidal delta but a dragline was utilized. The sediment was barged

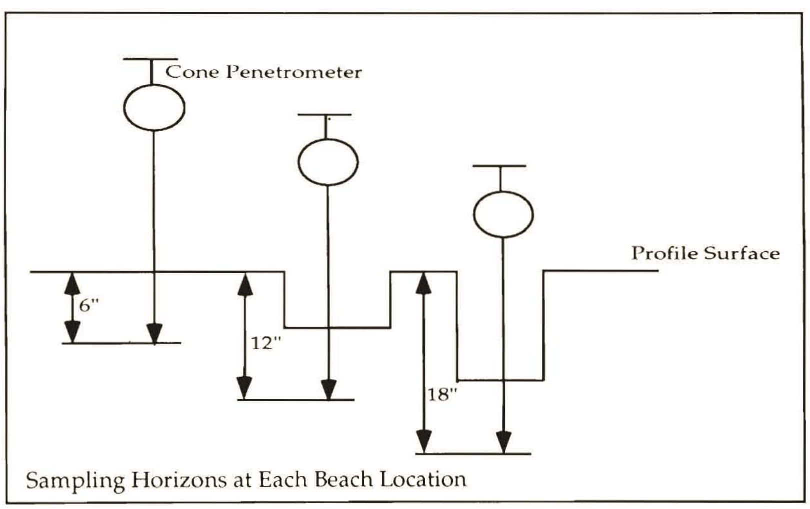

Figure 2. Diagram of portable cone penetrometer used to collect data on resistance to penetration of beach sediment.

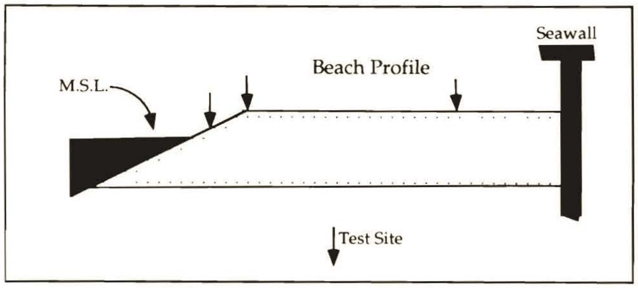

Figure 3. Schematic diagram of a beach profile showing locations of sampling sites along each profile.

to the site where it was placed on the beach using a conveyor. As a consequence, the sediment was never pumped during the construction process and the initial compaction was quite low.

The primary objectives of this study are;

(1) to determine the influence, if any, of beach nourishment on turtle nesting,

(2) to determine if there is any difference in compactness of the beach between the three adjacent nourishment projects that utilized different construction procedures, and

(3) to determine if tilling of the nourished beach has a substantial effect on turtle nesting and compactness.

DATA COLLECTION

Beach monitoring has been a continual process at each of the three nourishment projects. Shear resistance has also been measured as part of this ongoing monitoring. This parameter is measured by a hand-held cone penetrometer (Figure 2) and is commonly used as a proxy for compaction (NELSON, 1987; NELSON and DICKERSON, 1988). The penetrometer has a 0.2 in^2 (1.25 cm^2), 30-degree, circular cone and a dial ranging from 0–1000 cone index units (pounds per square inch–psi). The penetrometer is held in the vertical position and manually pushed into the beach sediment. The commonly accepted technique is to take measurements at 6, 12 and 18 inches (approx. 15, 30 and 45 cm respectively) (e.g. NELSON and DICKERSON, 1988).

Each of 40 beach profiles was visited 4 times per year for two years (1994–95). Penetrometer measurements were taken at each of three sites along all profiles; in the swash zone, at the berm crest, and in the back beach, Gulfward of the foredunes, seawall or other structure (Figure 3). The 6 inch (15 cm) reading was taken as the penetrometer was inserted from the surface to a depth of 6 in (15 cm). A hole was excavated to 6 inches (15 cm) and the penetrometer was inserted an additional 6 inches (15 cm); a total depth of 12 in (30 cm). The same procedure was conducted for the 18-inch (45 cm) measurement. All measurements that exceeded the values on the dial of the penetrometer are considered to be 1000.

Of the 40 profiles measured, 4 are beyond the actual nourished beach; two at the north end and two at the south end. These sites are at each end of the total project, and are not included in the data presented throughout the discussion because they do not represent truly nourished locations.

Tilling was conducted only in the Indian Shores nourishment project as part of the permit requirements. This is the only one of the three nourishment projects for which borrow material was not placed on the beach by the pumping-slurry method. Tilling was carried out by a commercial firm with the depth of reworking being 36 inches (92 cm). The entire unvegetated dry beach was tilled in a pattern of regular traverses. Numerous tests were conducted throughout the tilled

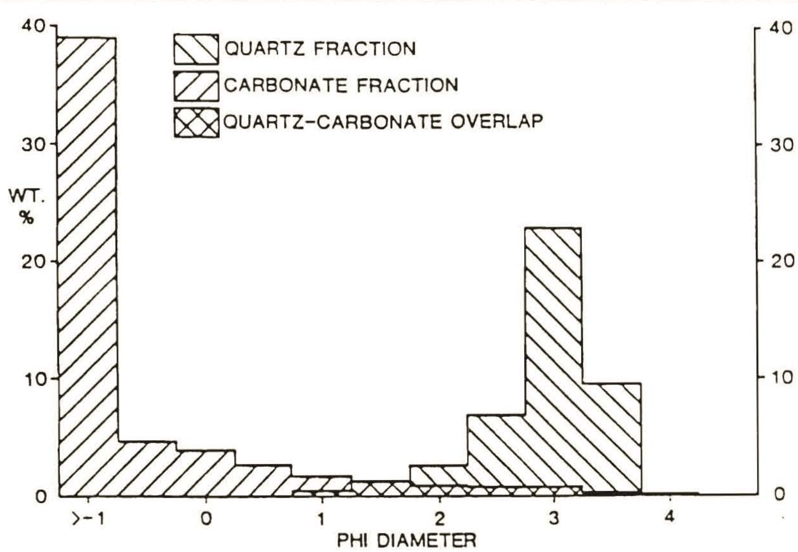

Figure 4. Histogram showing tpical bimodal sediment that occurs along this part of the Florida coast with one mode being fine quartz sand and the other comprised of coarser shell debris.

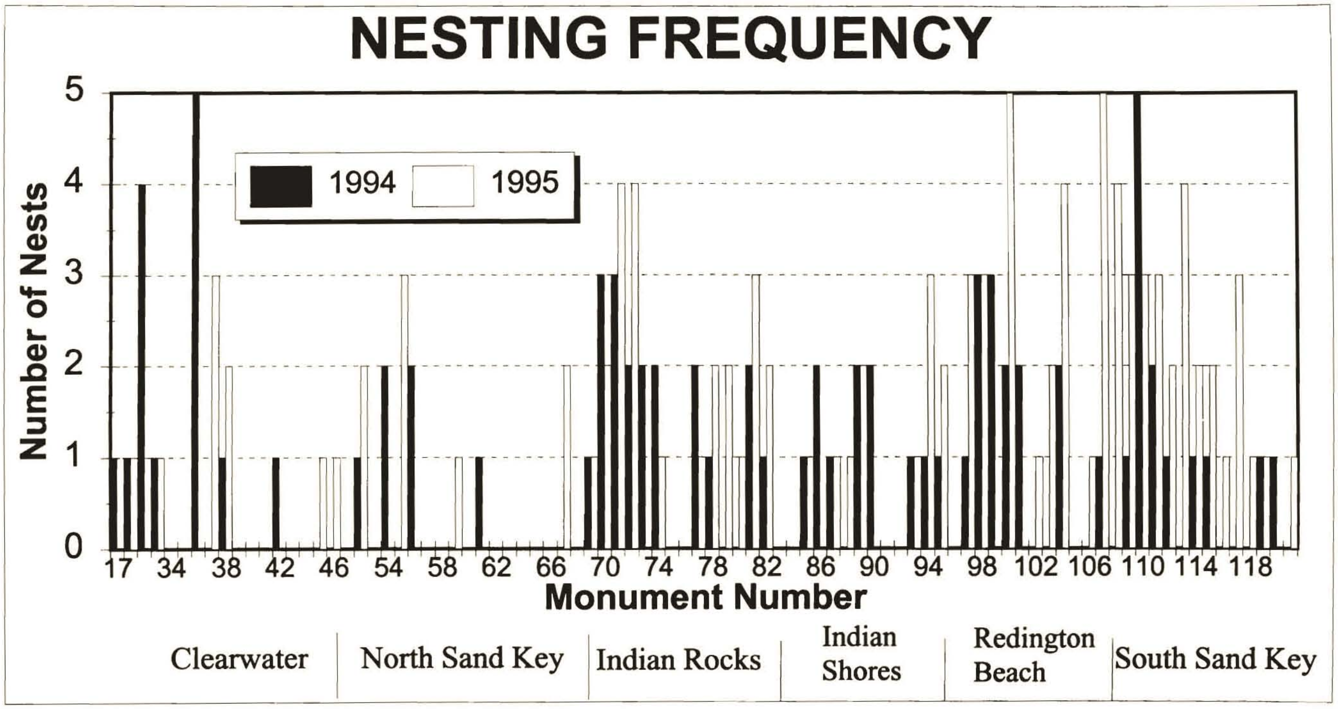

Figure 5. Nesting frequency by R-location on Sand Key, Florida. Each numbered beach segment is 1000 feet (306 m) apart. Each nest was placed on this diagram at the closest of these DEP monuments. (Data from Harman, 1994; 1995).

area to be certain that the resistance to penetration was less than 500 psi from the surface to the base of the tilled material.

BEACH SEDIMENTS

Sediments along the peninsular Florida Gulf Coast are distinctly bimodal in both grain size and composition. They are comprised of a fine sand quartz fraction and a medium sand to gravel biogenic shell fraction. The quartz fraction is dominant at most locations and the shelly fraction is typically the variable. This fraction tends to be granule to fine cobble in size and varies in both location and time. A typical percentage of shell gravel is 10–15% for natural beaches but is generally higher for borrow material used on nourished beaches. There is commonly a sand fraction of carbonate shell also. The distribution of both grain size and composition is shown by an example from Pinellas County (Figure 4).

As a consequence of this bimodal texture, it is inappropriate to characterize the sediments of this coast by their mean grain size. In actual fact, there is a very small percentage of sediment grains that represents the mean value. This textural characteristic of Florida Gulf Coast is in contrast to the east coast where sediments tend to be more unimodal (see Nelson and Mayes, 1986; Nelson *et al.*, 1987). This is an important difference insofar as sediment compaction is concerned. The shell component of the sediments is almost entirely composed of bivalves; both fragments and complete shells. The platy shape of these grains results in a preferential orientation that produces a distinct layering. This layering is facilitated by the slurry-pumping mode of construction. The dragline and conveyor approach to construction does not provide a means for preferentially organizing the platy shell particles.

Borrow Material

The Gulf Coast of Florida suffers from a general dearth of sediment for nourishment purposes. The shoreface commonly has less than a meter of sediment resting on Miocene limestone bedrock thereby providing insufficient volume for a major borrow source along much of this coast. The alternative borrow area and most widely used sedimentary environment along this coast is the ebb-tidal deltas associated with tidal inlets. These sediment bodies are numerous, large, have a very low content of fines, and are typically coarser than adjacent beaches. The reason for the coarse grain size is that the ebb deltas tend to have high concentrations of shell material; up to 50% (Davis *et al.,* 1991). Grain size distribution of these borrow sites still maintain a bimodal character (Figure 4). Examples of ebb deltas that have been used as primary nourishment sources on this coast include Johns Pass, Pass-a-Grille, Egmont Channel, Longboat Pass and Redfish Pass.

RESULTS

The data base used for analysis in this investigation includes the aforementioned cone penetrometer readings plus turtle nesting data provided from annual reports to Pinellas

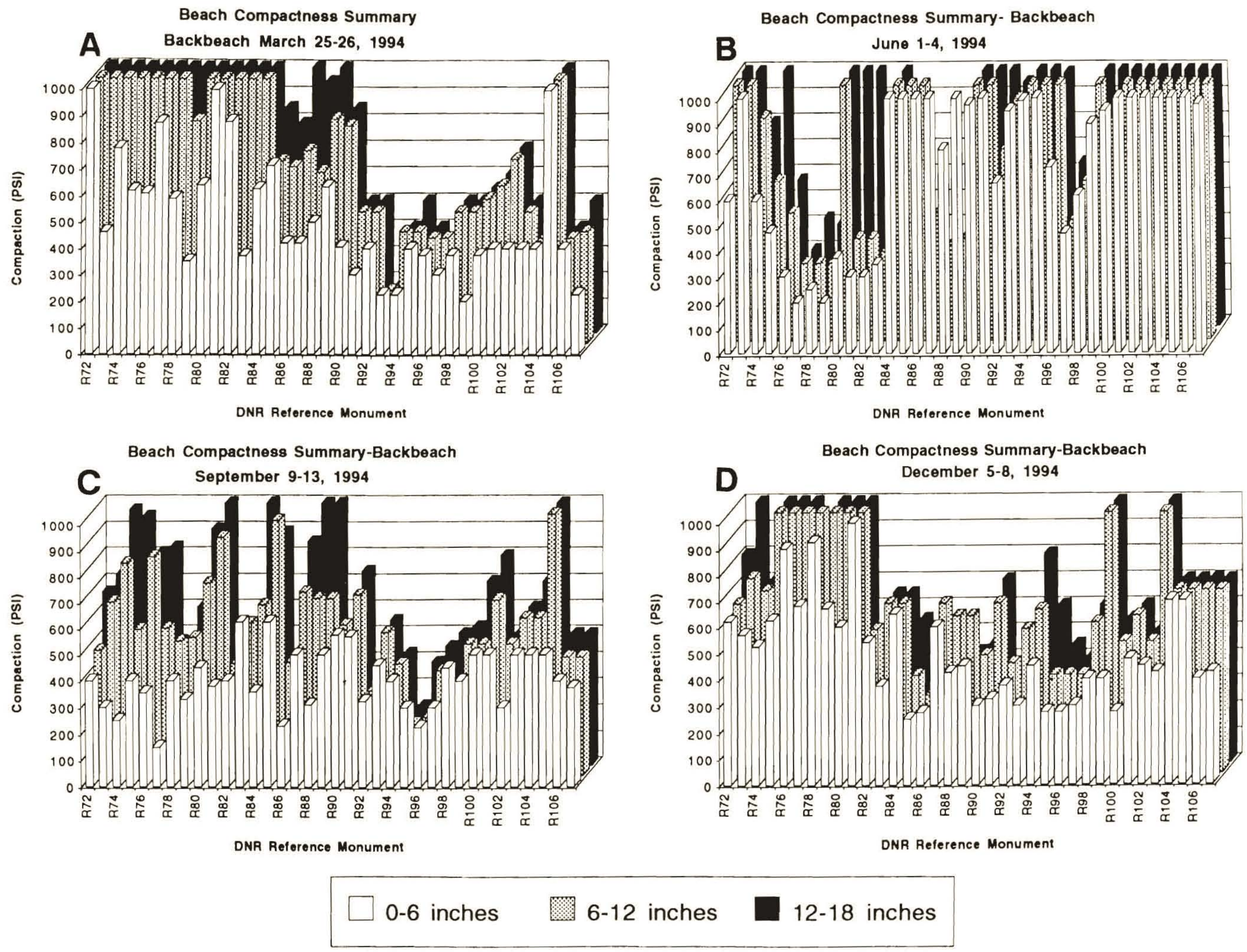

Figure 6. Resistance to penetration at each location by depth for 1994. Each bar on the histogram represents one measurement and this diagram shows all data collected.

County from the Clearwater Marine Aquarium (HARMAN, 1994; 1995).

Turtle Nests

Pinellas County contracted with the Clearwater Marine Aquarium to monitor turtle nesting along the entire shoreline of its jurisdiction (HARMAN, 1994; 1995). The data are quite complete and include false crawls, nests and the success of the nests. This report will address only the nests and their relationships to shear resistance.

The total number of nests located and monitored along the entire Pinellas coast during 1994 was 91 and during 1995 it was 137. Each was located by street address and by the State of Florida permanent monuments. For purposes of this study, all nests between monuments R-60 and R-119 are included. Each nest is assigned to a R-monument based on the closest position. These two years of data provide for a comparison of a year during which tilling was conducted (1994) and one when it was not (1995). The northernmost nourishment project and the second phase chronologically, Indian Rocks Beach (1990), includes monuments R-72 to R-85. The middle project and the third phase, Indian Shores (1992), includes monuments R-86 to R-98. The southern project was the first completed, Redington Beach (1988), which includes monuments R-99 to R-107 (Figure 1).

In considering nesting frequency, ten monuments are also included north of the nourished section, monuments R-60 to R-70, and ten are included to the south, R-110 to R-119. This provides two shoreline reaches that are about the same length as the nourished sites for comparison during each of the two study years.

Counts of the number of nests in each of these five beach segments over the two-year period (HARMAN, 1994; 1995) show that the relative frequency is similar in each (Figure 5). These data also show that there is some difference in nest frequency among the three nourishment projects. Within this

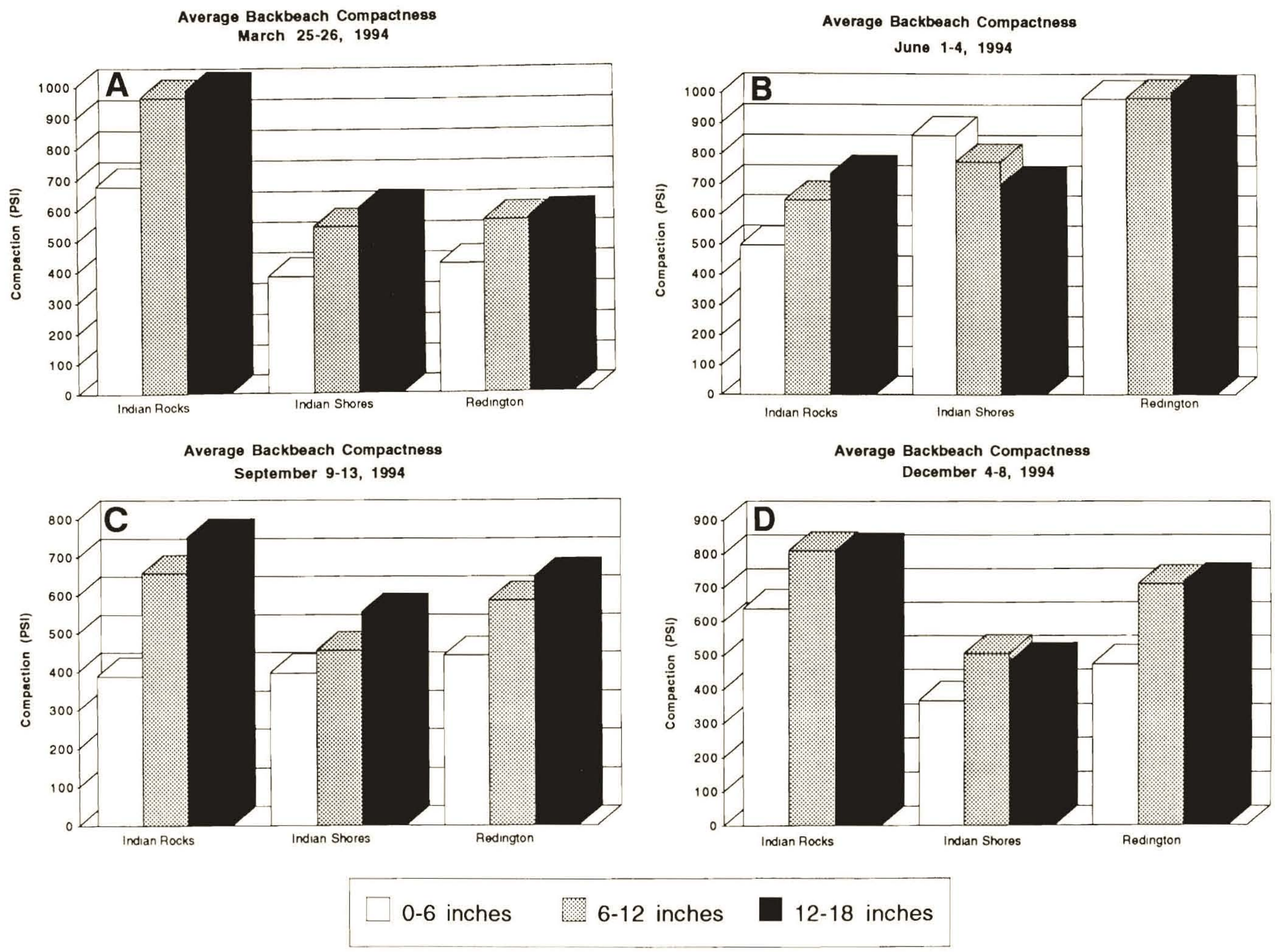

Figure 7. Resistance to penetration by nourishment segment for 1994. Each bar on the histogram represents the mean value for each depth at all locations within a given beach nourishment project (IRB n = 14, IS n = 13, RB n = 9).

shoreline investigated, there were 62 nests in 1994 and 88 in 1995. In both years there were more nests at Indian Rocks and Redington than there were at Indian Shores (Figure 5). Indian Shores was the only segment where tilling of the beach was conducted and that was done only in 1994.

Notice that the Bellair area (R55-70; Figure 5) has a much lower nest frequency than the other four with only 3 nests each year. The reason for this situation is a simple one. There is essentially no dry beach along this reach of shoreline. This area has not been nourished and it has not gained much sediment from end loss as a result of littoral drift from the Indian Rocks Beach project located immediately to the south. The opposite situation has occurred at the south end of the project at the south end of Sand Key (Figure 5) where there is a substantial dry beach with the resulting increase in turtle nest density.

Beach Compactness

Measurements of penetration resistance acquired from the cone penetrometer show a wide range; spatially, temporally, and with depth. Because of the dynamics of the foreshore zone coupled with the absence of turtle nesting in that zone and in the berm crest, these data are not considered in this discussion. Only data from the backbeach are discussed (Figure 3).

There are two primary ways of looking at these data. One is to consider the values at individual sites during each surveying period (*e.g.* Figure 6) and the other is to look at mean values for each of the three phases of nourishment (*e.g.* Figure 7). The former illustrates well the rather wide range of variation within the study area but the latter shows the average differences, if any, between adjacent nourishment projects. The usual statistical treatments are not applicable because of the combination of the small samples at each nourishment project (n = 9–14), and the large standard deviation among the readings.

Another problem with analyzing the data is the temporal variation in compaction values. If the mean values at each of the three projects are considered, it is apparent that there are great differences at each location between successive

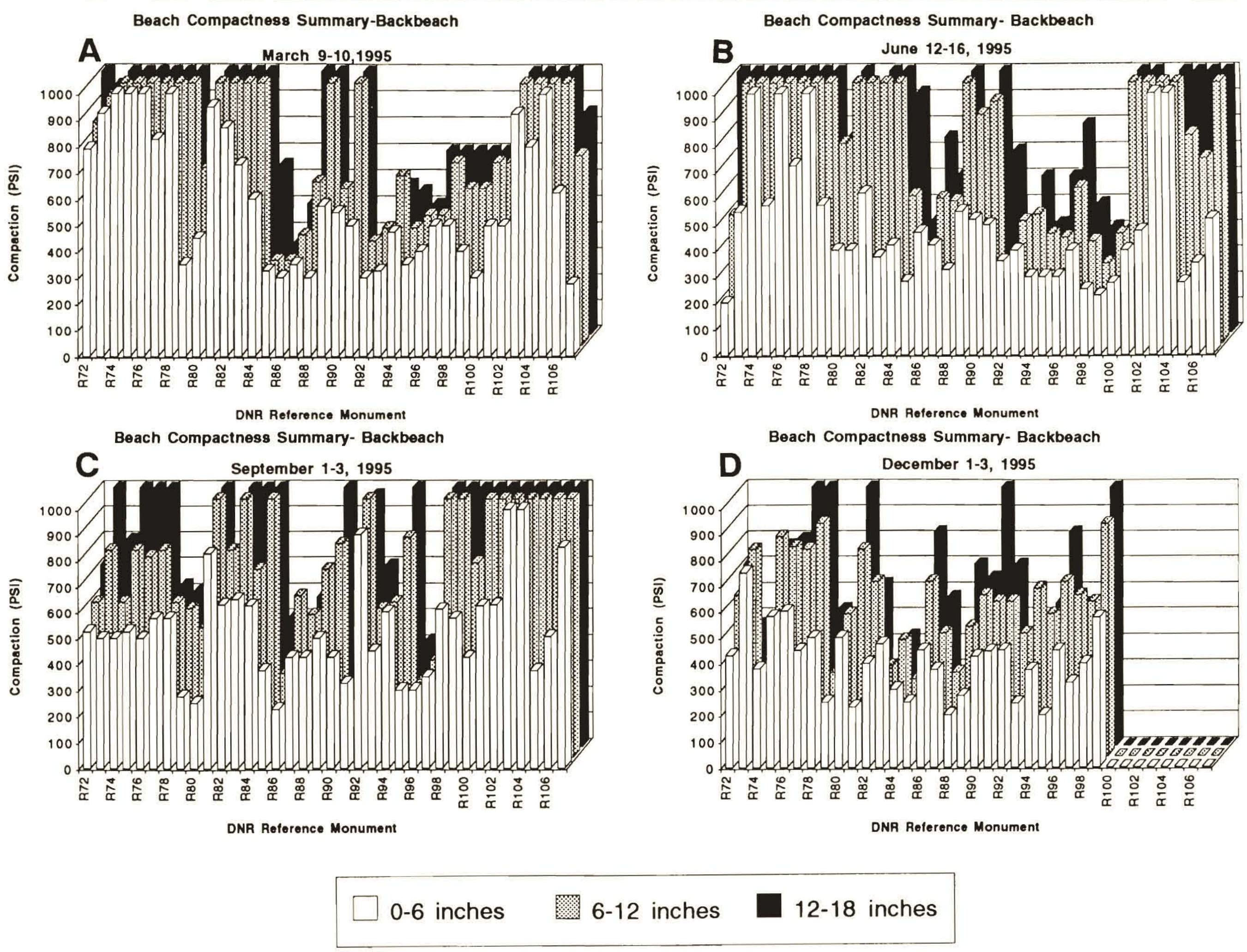

Figure 8. Resistance to penetration at each location by depth for 1995. Each bar on the histogram represents one measurement and this diagram shows all data collected.

sampling periods (Figure 8). This also holds for the relative compactness values at adjacent projects during a given sampling period.

The differences in compactness at a given site or even the differences in mean values for a segment do not show a trend of increasing compactness. One would expect that, in the absence of tilling or some similar process, the compactness of the beach should remain the same or increase over time. This does not occur; some sites and segments show a decrease in compactness values through time. The only explanations for this change are the possible influence of groundwater seeping from the landward direction and/or the influence of storm tidal flux through the sediment as the result of surges. Both of these phenomena, if flow is sufficiently strong, could reduce sediment compaction. Surface and groundwater movement over and within the sediment do show markedly lower compactness values for the foreshore locations than on either the berm crest or the backbeach sites. Another factor might be the nature of the cone penetrometer and the accuracy of its measurements. Temperature differences of the metal could cause changes in the resistance to deformation of the stainless steel ring on the penetrometer (Figure 2) although this would be expected to be quite small.

The backbeach part of the beach remains relatively undisturbed except during high-energy events like storms when it is inundated by storm surge. It is possible that this influx of water on the normally dry beach would cause a reduction of compactness. The high density and occurrence of people on nearly all Sand Key beaches may contribute to increasing the compactness of the backbeach.

1994—Data from this year show that in June, just prior to tilling, the compactness was variable in the Indian Rocks segment and nearly uniformly high throughout the other two areas (Figure 6A). After tilling of the Indian Shores segment only, there was a marked reduction in the compactness of that segment as shown by the September data (Figure 6B).

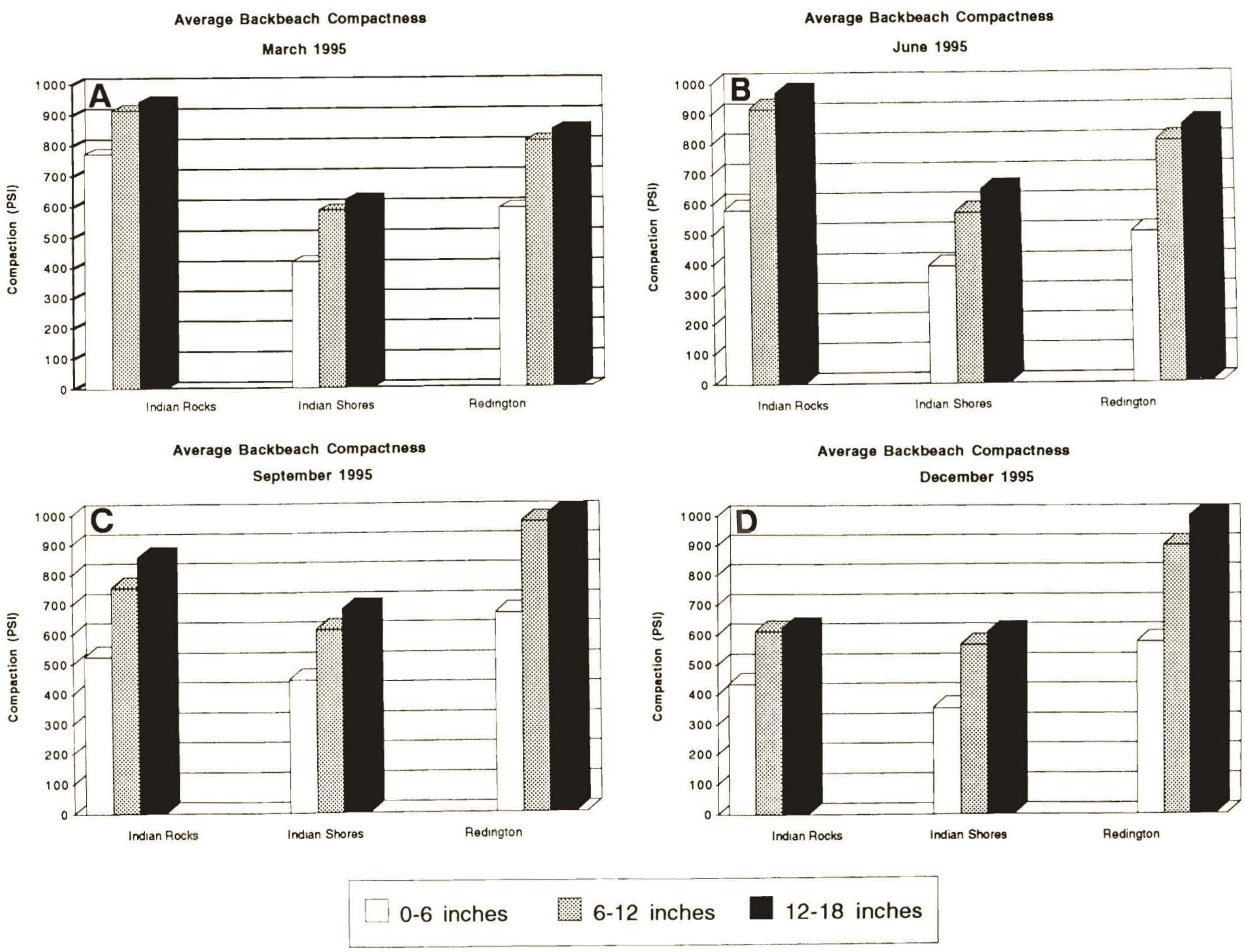

Figure 9. Resistance to penetration by nourishment segment for 1995. Each bar on the histogram represents the mean value for each depth at all locations within a given beach nourishment project (IRB n = 14, IS n = 13, RB n = 9).

Surprisingly, the Redington segment (R98-107) showed a similar reduction in compactness without benefit of tilling. A question arises as to whether the tilling is causing the decrease in compactness or some natural phenomenon. The December data show a similar pattern to the September values except in the Indian Rocks area (R72-85).

The summarized data for 1994 for each segment of the three nourishment projects (Figure 7) show that in the early part of the nesting season the Redington segment was very highly compacted, the Indian Shores less and Indian Rocks was the least compacted of the three nourished segments (Figure 7A). Tilling took place shortly after these data were collected and showed a modest reduction in the compactness of the Indian Shores segment (Figure 7B) however, the Redington segment showed a greater reduction without benefit of tilling. Indian Rocks displayed a marked increase in compaction over the same period (Figure 7B). By December, Indian Shores showed further reduction in compaction, and Indian Rocks and Redington were the same as in September (Figure 7 B and C).

1995—The 1995 data for each of the profile locations also show great spatial variability but less temporal change than the 1994 data (*cf* Figures 8 and 9). During March there was a rather uniformly highly compacted condition at Indian Rocks (R72-85) and quite a range of compactness throughout the other two segments (Figure 8A). The June data show a generally similar pattern but with more compaction at the Indian Shores (R85-98) and Reddington (R99-107) segments (Figure 8B and C). September data also show great range but with less uniform and severe compaction in the Indian Rocks segment and more at the Redington segment; the Indian Shores segment was about the same.

The summary data by segment for 1995 show distinct patterns and some expected relationships. The March compaction readings (Figure 9A) clearly show that the Redington segment has the highest mean values and the Indian Shores

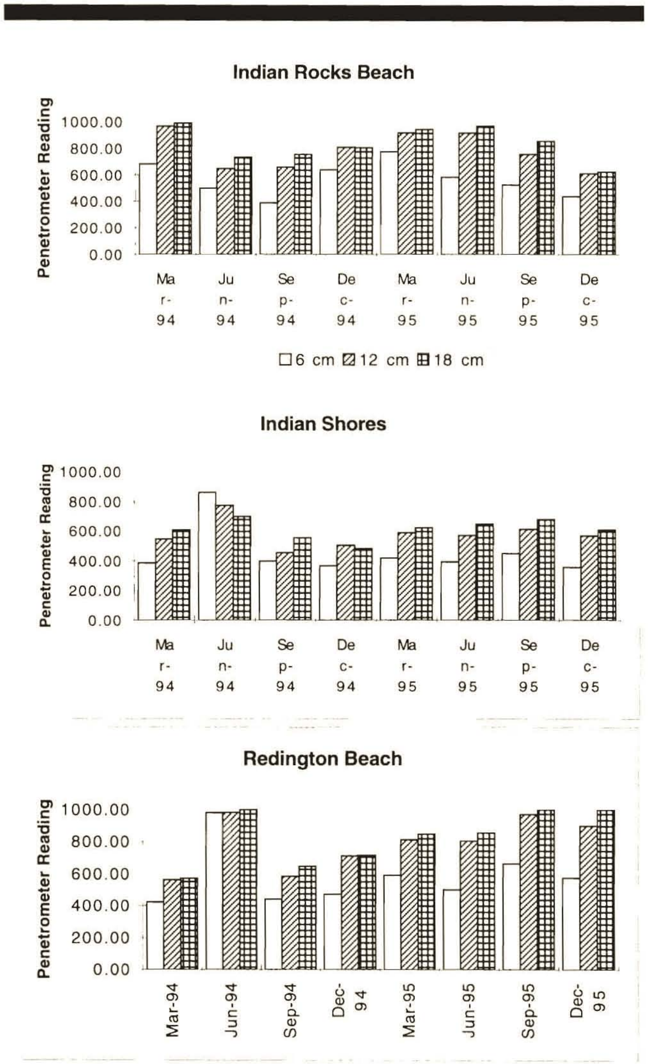

Figure 10. Plots of mean penetrometer readings in the backshore of the beach at each nourishment project over the two-year study period. Each value represents the following individual sites: Indian Rocks Beach, n = 14, Indian Shores, n = 13, Redington Beach, n = 9. The horizontal line represents 500 psi.

segment has the lowest. The June data (Figure 9B) show the same pattern. The September data display a modest departure from this pattern in that the Redington segment had the highest compaction; Indian Shores was the lowest (Figure 9C). Throughout the period of monitoring the Indian Shores segment has shown the greatest rate of erosion (DAVIS *et al.*, 1993). It is also the most recently completed nourishment project of the three investigated.

DISCUSSION

The most compacted segments are at Indian Rocks and Redington (Figures 6–9). Both of these segments were constructed by suction dredge and pumping in a slurry onto the beach. In addition, both of these segments have sediments that have relatively high percentages of shell gravel compared to Indian Shores. This shell gravel is comprised dominantly of partial and whole bivalve shells. Because the nourishment material is pumped onto the beach in a slurry, these bivalve pieces are oriented parallel to the sediment surface. These platy shapes oriented in such a fashion present considerable resistance to penetration by the cone penetrometer. The result is elevated compaction values.

The higher nesting frequency occurs in the beach nourishment segments that have the highest shell concentration and the highest compaction (Figure 5), *i.e.* Indian Rocks Beach and Redington Beach. We do not believe that the turtles are preferentially selecting the more compact beach for nesting but that the values are artificially elevated due to the orientation of the shells, and the method of nourishing the beaches. The absence of any slurry pumping at Indian Shores produced a constructed beach that was less compacted from its initual construction. This is demonstrated by the summary histograms that cover all three depths of measurements at all three nourished beach reaches for both of the study years (Figure 10). This clearly shows that Indian Shores penetration values are lower throughout the study with the possible exception of the June, 1994 surveys which were after tilling. This figure also shows that the vast majority of locations throughout all three projects have values above the 500 psi level most of the time.

Turtles do not dig vertically in the same fashion as the cone penetrometer moves through the sediment layers. It is our opinion that the cone penetrometer is providing data that are not appropriate for assessing turtle nesting limitations. The 500 psi limitation on nourished beaches or any other beaches, is unwarranted. The summary data (Figure 10) show that all readings at 12 and 18 inches (30 and 45) at Indian Rocks Beach and Redington Beach exceed 500 psi. Nesting frequencies show that turtles do not perceive any differences in compactness on these beaches and appear to be able to nest anywhere there is a dry beach. Other factors such as lighting, temperature and vegetation are potentially important and were not addressed in this study.

CONCLUSIONS

There have been numerous reports on conflicts between turtle nesting and beach nourishment. These studies have been largely responsible for setting limitations on compactness of nourished beaches and for requiring tilling of nourished beaches prior to the nesting season.

This study shows that on a significant reach of the peninsular Gulf Coast of Florida:

(a) there is no relationship between turtle nesting and beach sediment compactness,

(b) Nesting frequency is primarily related to the presence of a wide dry beach provided directly or indirectly by beach nourishment,

(c) the compactness of the beach ranges and varies widely in both space and time with little rationale,

(d) tilling has a quite temporary influence on compactness and no demonstrable influence on nesting frequency, and

(e) upper values of compactness tolerance currently utilized (500 psi) are artificial.

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