DIAMONDBACK TERRAPIN (MALACLEMYS TERRAPIN) NEST DEPTH COMPARISONS AT ANTHROPOGENICALLY IMPACTED AND NON-IMPACTED NESTING AREAS IN THE BARNEGAT BAY ESTUARY, NEW JERSEY

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Location: N. Sedge Island, NJ

Duration: June 1- July 31, 2010

Report submitted in partial fulfillment to the Barnegat Bay Student Grant Committee

August 13, 2010

Introduction

The Northern Diamondback Terrapin (*Malaclemys terrapin*) inhabits estuaries along the Atlantic and Gulf coasts of the United States. Terrapins live and feed in marshes and they nest on bay beaches and islands. The terrapin lives year-round in the estuary and it utilizes aquatic and terrestrial habitats. It feeds and breeds in the aquatic environment and females lay their eggs on land. The diamondback terrapin is therefore a good model organism to study the dynamics of estuarine ecosystems.

In New Jersey the loss of barrier island beach habitat is a very important conservation and management issue. Significant losses of estuarine habitats are also projected in the near future due to sea level rise. In the past, society's reaction to help prevent sea level rise has been to protect the shoreline by erecting bulkheading, riprap, filling in sand on the beaches, and other methods that are barriers to wildlife. These efforts to stop erosion drastically affect coastal habitats and potential nest sites for terrapins and other wildlife. It is predicted that sea level rise and coastal erosion will cause an increase in coastal habitat destruction due to efforts to protect the shoreline (Lathrop 2007). As sea levels rise barrier islands and marshes will disappear and turn into open water, which will reduce habitat for terrapins and other organisms in Barnegat Bay and other North American estuaries.

Because terrapins are unable to relocate long distances to other areas, loss of coastal habitat poses a great challenge to their future survival. As their natural habitat becomes more altered terrapins may resort to human impacted nesting areas which can increase their risk of mortality and will reduce their nesting success. It is likely that the soil composition of terrapin nesting sites will be drastically changed resulting in nest depth and temperature changes. Alterations in nest temperature can affect the incubation period, development, and sex of the embryos. Changes in soil composition may also alter the amount of moisture and gases in the nests which impact the incubation success of eggs (Wnek et al., in review).

Nest temperatures may vary depending on many environmental factors including sediment composition, nest depth, and nest location, among other factors (Widrig 2006). Studies done by Burger (1976) in New Jersey have shown that temperature affects the duration of the incubation period. Terrapin nests that have higher temperatures have a shorter incubation period. Studies have also shown that the nest depth affects incubation of the eggs. Nests that are too shallow are exposed to higher temperatures and the embryos may show reduced survivorship if the nests get too warm. Nests that are too deep have low temperatures at the bottom depths and these eggs also do not develop (Burger 1976).

Terrapins, like most turtle species, have temperature-dependent sex determination (TSD); sex is determined by the nest temperature during the incubation period. Warmer nest temperatures generate female development (higher than 29 ^{0}C) and cooler temperatures result in predominantly male development (lower than 28 ^{0}C; Roosenburg and Kelley 1996). Nest site selection of female terrapins varies but some research suggests that females choose nest sites to vary the sex ratio of their clutches (Roosenburg 1996). Terrapins tend to nest in areas of open sun or partial sun. Most terrapins do not nest in areas of high vegetation and shade (Roosenburg 1996).

The composition of substrate is also very important to terrapin nest success because it affects the temperature, gas exchange, and moisture of nests (Kolbe 2002). Nest soil composition may also affect how shallow or deep a terrapin is able to dig. Soil may be more compacted in one location than in another which may also affect how much a female is able to dig. On Sedge Island, New Jersey (Figure 1) there are areas of different types of soil particle sizes, which may result in differences in nest depth and other factors including nest temperature and moisture.

Many other organisms use sand shoreline to nest just as the terrapin does. For example, terns nest along shoreline beaches. Organisms will have to put more energy and effort into finding suitable nesting sites as more anthropogenic changes occur that reduce the number and condition of nest areas. These changes will not only affect the terrapins, but they will have an effect on other organisms living within Barnegat Bay. Organisms will have to relocate and find suitable habitats to live in or they will have to adapt to the alterations being made along the shoreline. Studying the terrapin lifecycle and focusing on nesting, soil compaction, and moisture of the sediment in nests will give an insight into nesting areas of other coastal organisms that nest throughout the Barnegat Bay. My research will facilitate a better understanding of how diamondback terrapins use their nesting sites along changing shorelines in Barnegat Bay. My research will also provide a model of how terrapins will be impacted by anthropogenic changes to habitat alteration due to global warming and other factors. These findings will have implications for other North American estuaries as well as Barnegat Bay.

Methods

The handling of terrapins for this project was only done by trained research staff and others listed on Dr. Avery's research permits. At North Sedge Island (Figure 1) female terrapin nest sites were randomly chosen for research. The nest locations were recorded using the Universal Tranverse Mercator Coordinate System by using a hand-held Garmin GPS-12. Each nest was protected using a wire cover for the duration of the research to protect them from predation (Figure 2). My research on North Sedge Island complemented the ongoing long-term study of nesting terrapins on the Island. Due to human activity on the island some nests were excavated and moved to the hatchery. Nesting female terrapins were captured and scanned with a Bio-mark portable PIT tag reader and any external notches were also recorded. Nesting females that were not captured before were notched and a PIT tag was inserted. Measurements of the nesting females were taken. Using a 400 millimeter tree caliper measurements of straight carapace length, carapace width, carapace height and plastron length were taken. The terrapins were also weighed in grams using an Ohaus ® Digital Scale 4100 (+/- 1.0 g) and measurements of the females' fully extended hind limbs were taken using a 150 millimeter caliper. The compaction of the soil near the nests was measured with a soil penetrometer (psi).

Soil samples of each nest were taken in air tight containers and weighed. They were then placed in the oven at 140°. After 24 hours the samples were weighed again and moisture percentages were calculated using an Ohaus ® analytical balance. Other soil samples were also dried in the oven and then were put through a sieve. Next the samples were used to find the soil texture fractions. 15ml samples were placed in test tubes and 1ml of dispersing liquid was added. The tubes were then filled to 45 ml with tap water and then shaken until all of the soil was wet. After 30 seconds, the soil that settled was recorded as sand. Then the liquid was poured into another tube and after 30 minutes the soil that settled is silt. Fractions were calculated and the soil texture was classified using the Soil Texture Classification Triangle (US Geological Survey). I-Buttons were placed in nests of areas of different soil compositions to record the temperature every half an hour for approximately one month. I-buttons were excavated after one month, and all temperature data were downloaded to a computer.

Eggs in some of the nests on North Sedge Island were excavated and relocated to the hatchery. Clutch sizes and egg depths were recorded and measurements of the eggs were be made. All eggs in the excavated nests were measured in millimeters for length and width and mass in grams. When eggs were taken from the nests they were transported in plastic containers that contained the original substrate from the oviposited nest taken at the same depth of the cavity. Relocated eggs were placed in the hatchery at the same depth and orientation that they were dug in the original nest.

Throughout the nesting season (June and July) terrapin nests were located and monitored. Depth (cm), temperature (°C), sediment compaction (psi), and moisture were measured and recorded. Terrapins were captured and carapace length (mm), carapace width (mm), carapace height (mm) and plastron length (mm) were measured. Terrapins were weighed (g) and their fully extended hind limbs (mm) were also measured. Soil compaction was measured in pounds per square inch (psi) using a penetrometer at the 3” and 6” depths.

Results

Extended hind limb measurements were taken and compared with plastron lengths (Figure 3). This comparison showed that there is a significant correlation ($r^2 = 0.573$ $P=0.0486$) between the hind limb length and the plastron length of terrapins. Mean nest depth was compared to plastron length (Figure 4) but there was no significant correlation ($r^2 = 0.3006$ $P=0.1008$). This is probably due to other nesting factors like sediment compaction. Sediment composition tests were done to classify the texture of the sediment using the Soil Texture Triangle (US Geological Survey; Figure 5). Sediments were composed of mostly sand with small amounts of silt (Figure 6). This resulted in the areas to be considered sand and loamy sand textures. Site 1 had the lowest moisture content of 2.74%, Site S had a lower moisture content of 2.97% and Site A had the highest of 5.45%. Site 2 had 3.36% moisture and Site 3 had 5.45% moisture (Figure 7). Each of the nesting areas had different compaction readings, the human impacted areas had higher compaction readings then those that were non-impacted (Figure 8). Site 1 had the least compacted sediment and the East Lawn had the most compacted sediment (Figure 9). Nest temperatures were warmer closer to the top of the nest and cooler deeper down. The temperatures varied throughout the month and by depths (Figures 11 & 12).

Discussion

Within the study timeframe from June through July 2010, female terrapins that were captured had a significant correlation between their hind limb lengths and plastron lengths (Figure 3). This correlation between plastron length and hind limb length enabled me to use just the plastron length to make comparisons. When comparing the plastron length to the mean nest depth no significant correlation was found (Figure 4). This is probably due to other nesting factors including soil compaction, nest site availability and access, and human disturbance. In terrapin nests changes in sediment particles, temperature and moisture effect hatching success (Roosenburg 1996; Packard 1997). Different types of soils hold varying amounts of moisture and in terrapin nests soil moisture of around 4% seems to be best (Packard et al. 1987). My soil moisture data shows that the moisture content varies depending on the soil composition (See Figure 7). Areas of higher sand content hold less moisture whereas areas of more loamy sand hold more moisture creating a better environment for developing terrapin eggs. Soil compaction tests showed that areas that were exposed to more human impact had higher compaction readings (Figure 8). The East Lawn on the island had the highest soil compaction readings (Figure 9). This area is by a walkway and porch which is an area of high human traffic on the island (people walking and riding a lawn mower). Nesting areas (Sites 1, 2, 3, A, and S) are on the northwest side of the island where there is not much human traffic and Sites 1-3 are fenced off so people aren't walking in the area and compacting the soil. In 2007 temperature data shows that upper areas of the nest reached the pivotal temperature (29°C) a few times over three months (Figure 10). In my study, within 24 hours four of the nests reached the pivotal temperature (Figure 11). Over a month of time a nest reached the pivotal temperature many times (Figure 12). Compared to 2007, the nest will probably hatch more female terrapins as a result of it exceeding the pivotal temperature more times.

Conclusion

My study showed that the size of the terrapin plastron correlates well with the length of the hind limb. However, the size of the plastron doesn't directly relate to the depth of the nest probably because of other factors including soil compaction. Changes in soil composition may affect the amount of available nest moisture and temperature, which will ultimately affect incubation duration and hatching success. My research also showed that female terrapins are able to nest in highly impacted areas with very compacted soil but the nest depth, temperature and hatching success may vary in the areas. My research gives insight to the future of terrapins and other estuarine species, especially those that nest on land. Areas of compacted soil that are impacted by humans may pose potential problems for females that are digging nests. Due to human impacts including efforts to prevent erosion and development, female terrapins may have to resort to digging in compacted areas and this may result in shallower nest depths which may lead to higher temperatures which will ultimately lead to female bias sex ratios. As for the future of terrapins and other estuarine species, Global Climate Change will make survival harder. As air temperatures increase nest temperatures will also increase resulting in a large amount of female bias. Also as the sea level rises suitable nesting areas will decrease and terrapins and other estuarine organisms will be forced to nest in new locations or adapt to new conditions.

Acknowledgements

The Barnegat Bay Partnership

Dr. Hal Avery

Dr. John Wnek

The Marine Academy of Technology and Environmental Science

Earthwatch Staff

Jackie and Tony Raniero

New Jersey Division of Fish and Wildlife

Jules Winters

Lori Lester

Dave Kaminsky

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List of Figures

Figure 1- The red circle shows the location of North Sedge Island. It is located in Barnegat Bay, west of Island Beach State Park, New Jersey.

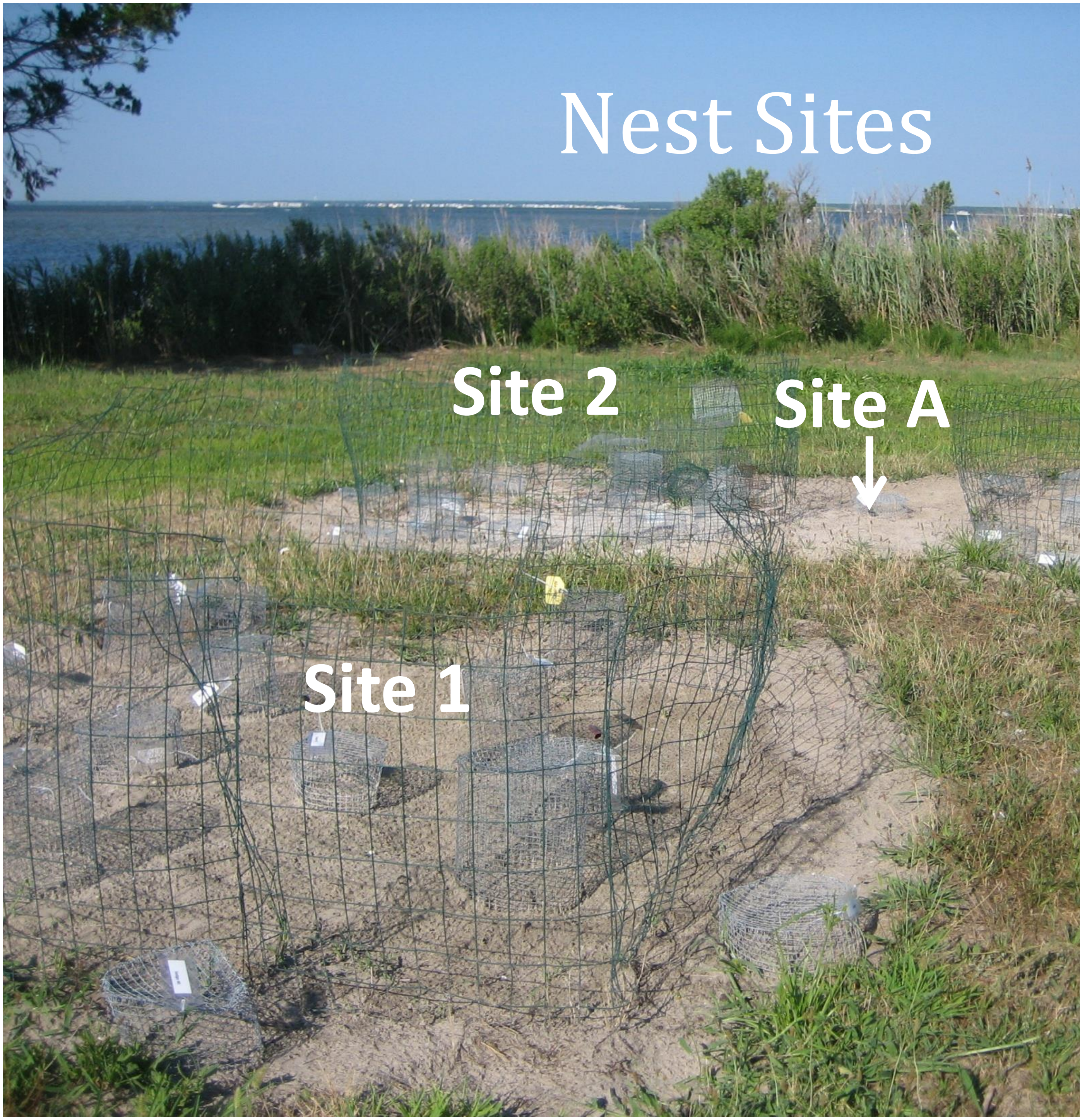


Figure 2- Nests were covered with wire baskets to protect from predation.

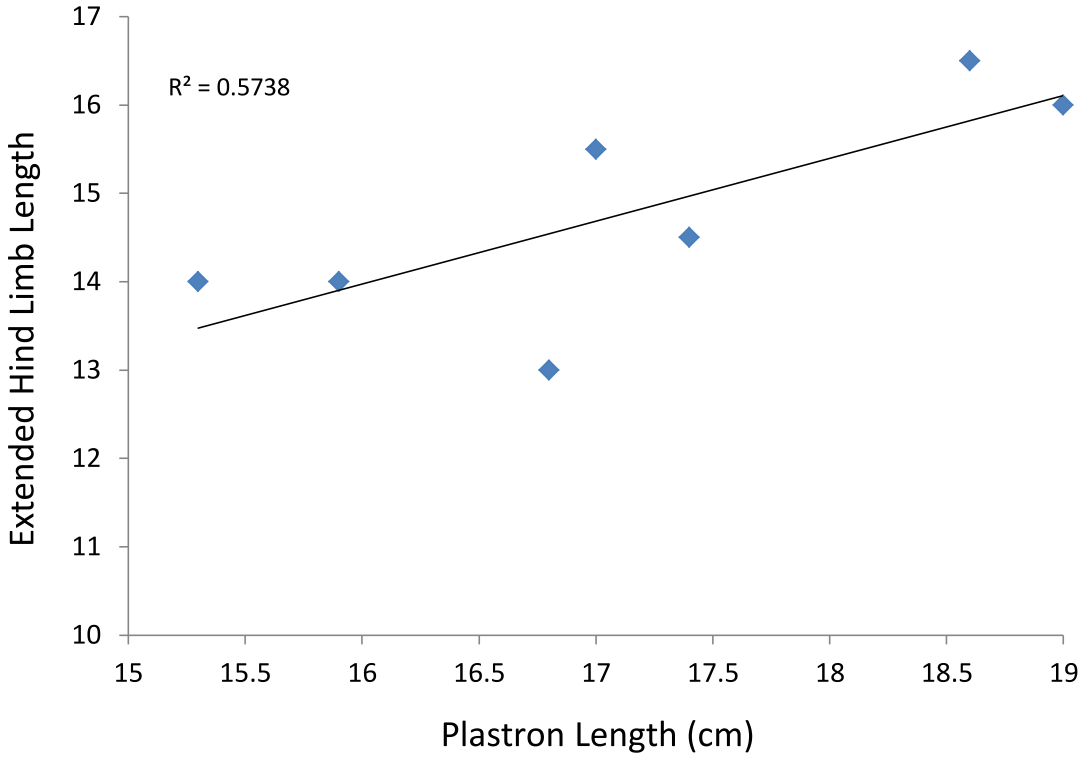


Figure 3- Extended Hind Limb Length vs. Plastron Length. There is a significant correlation between the extended hind limb length and the plastron length.

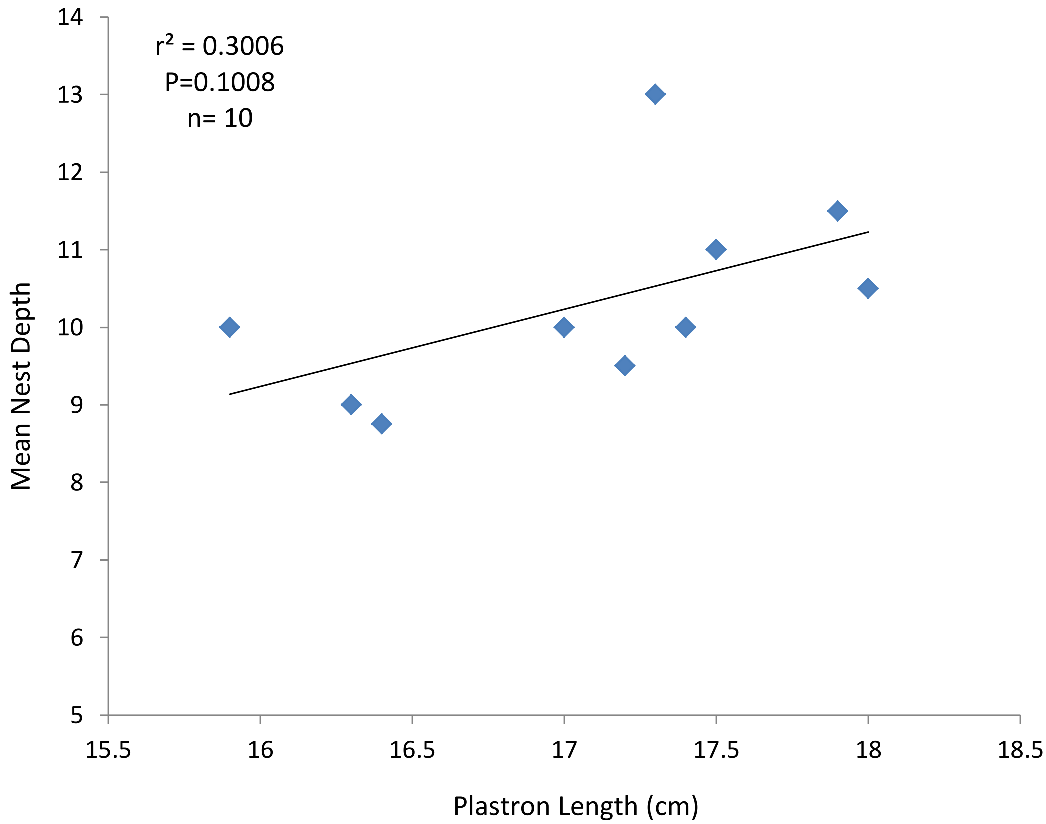


Figure 4- Mean Nest Depth vs. Plastron Length. This figure reveals that there is no significant correlation between the mean nest depth and the plastron length of female terrapins.

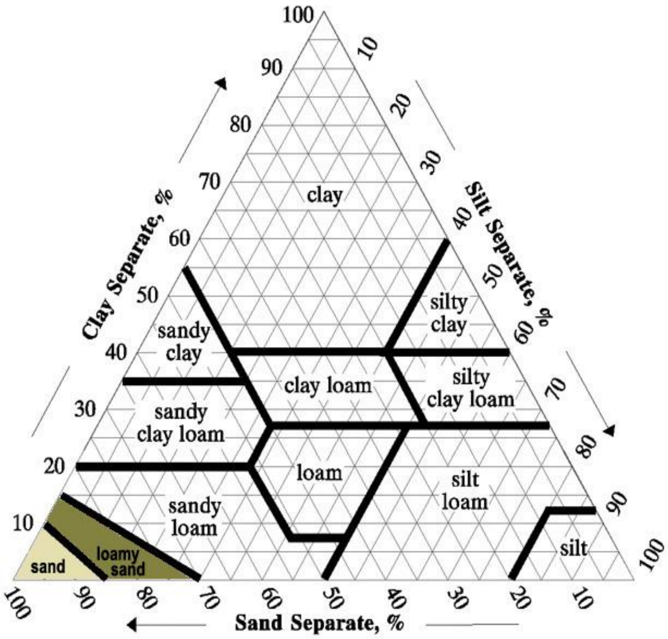


Figure 5- The Soil Texture Triangle (US Geological Survey) was used to classify the sediment on Sedge Island using the composition fractions found.

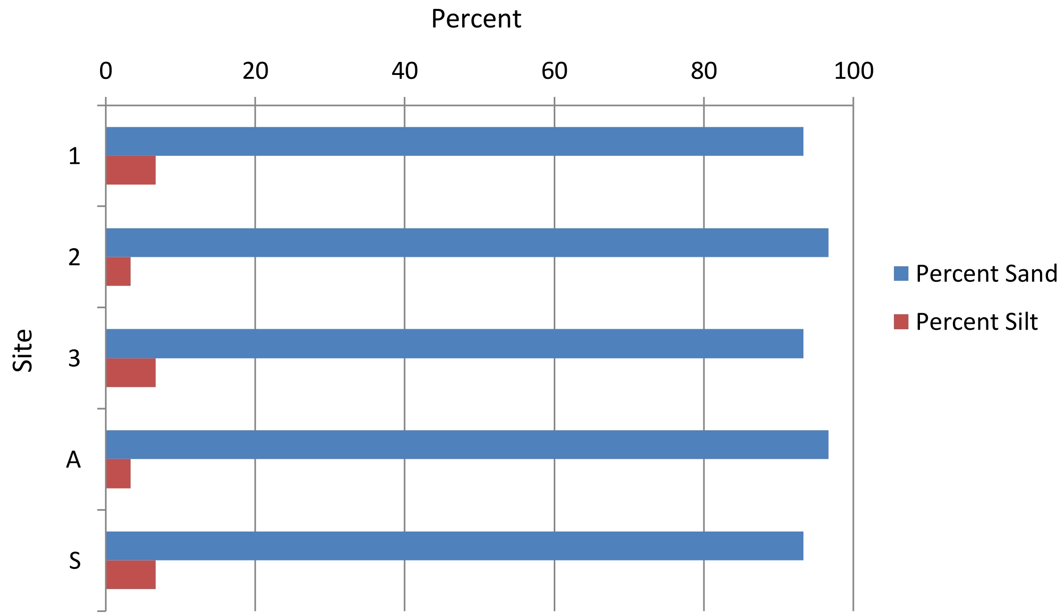


Figure 6- Sediment Percent Composition. The figure above shows the sediment percent composition for each different nesting site.

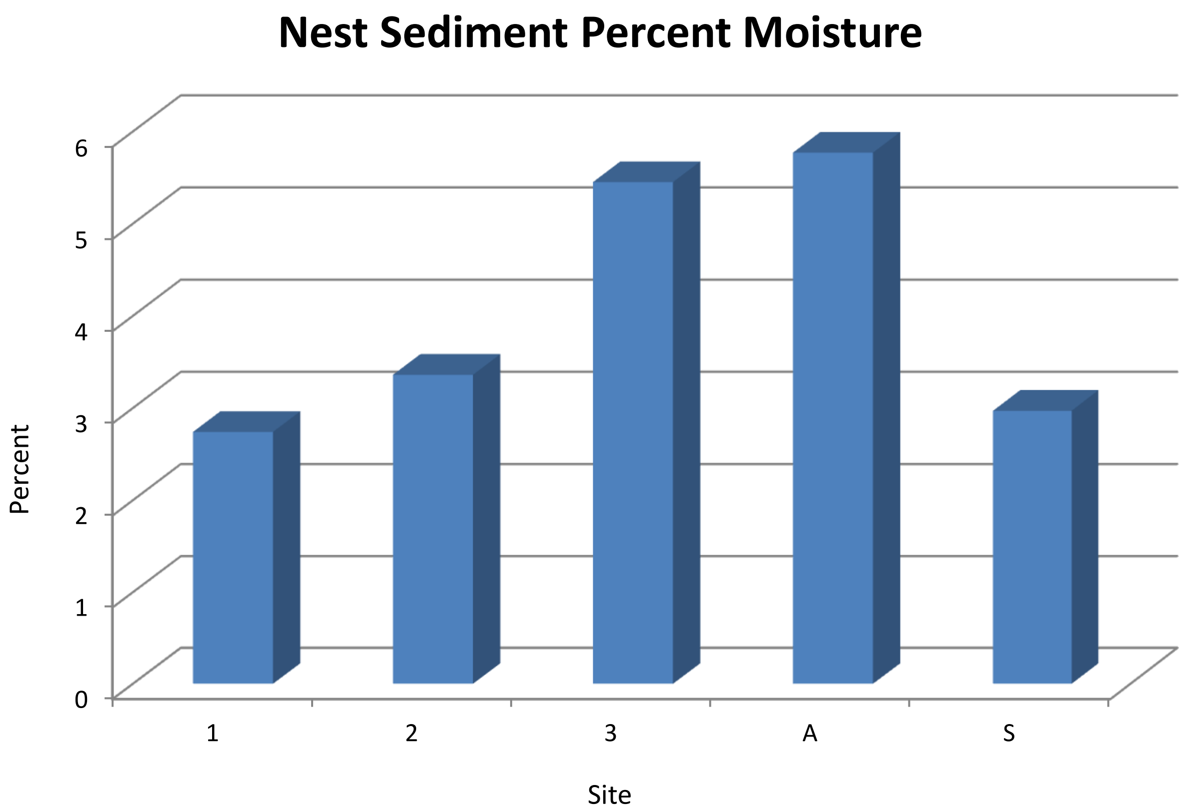


Figure 7- Nest Sediment Percent Moisture. The more sand particles the sediment had, the less percent moisture the sediment contained.

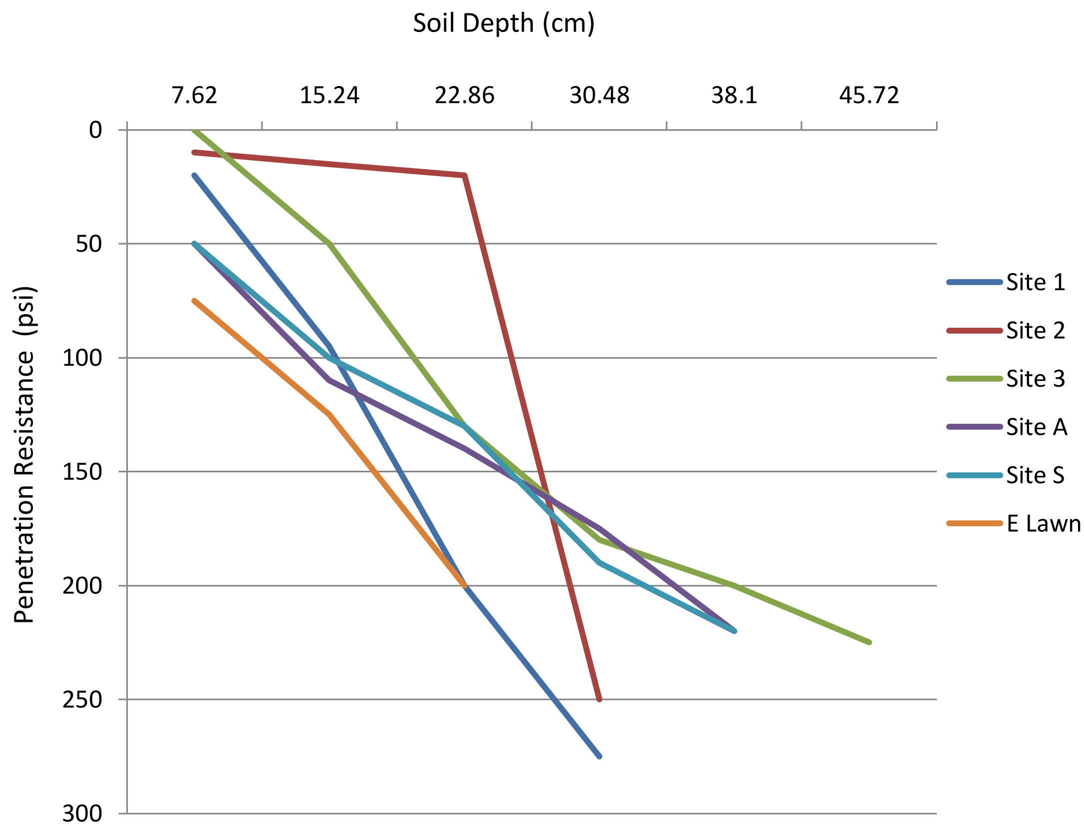


Figure 8- Soil Depth vs. Penetration Resistance. Impacted Sites like the East Lawn were more compacted then non-impacted sites including nesting Sites 1-3.

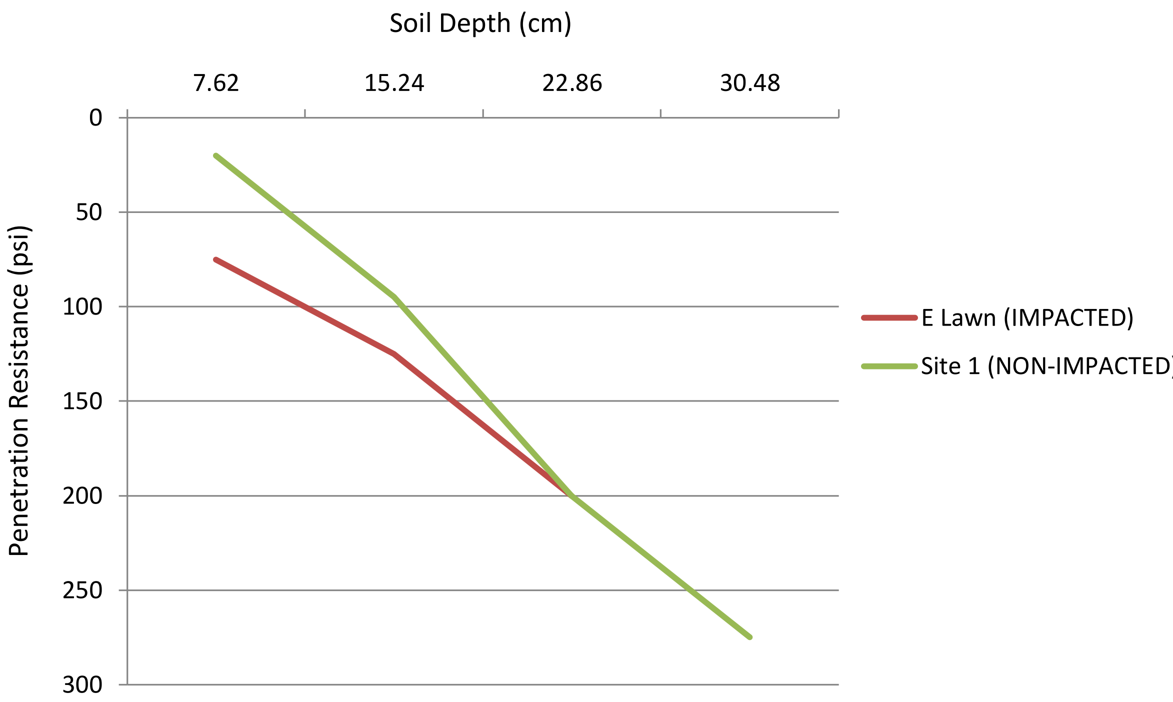


Figure 9- Soil Depth vs. Penetration Resistance. The figure above shows that the most impacted site E Lawn has higher compaction than non-impacted Site 1.

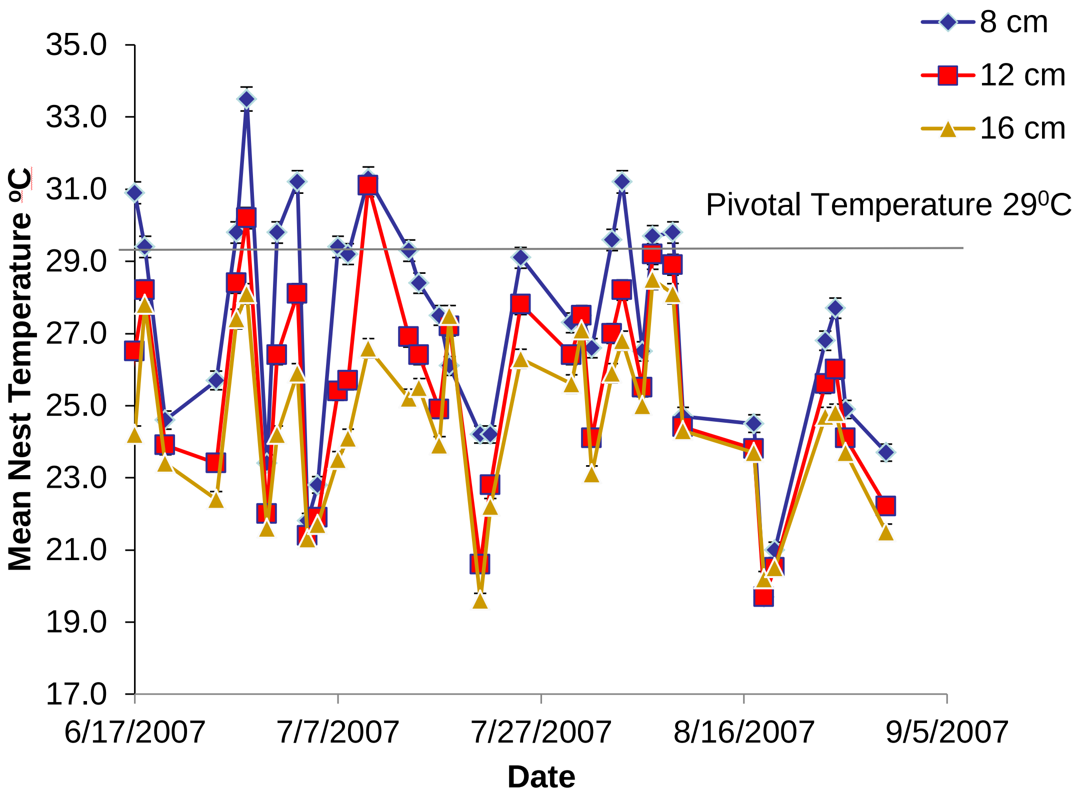


Figure 10- The graph above shows temperature data at different depths from the summer of 2007.

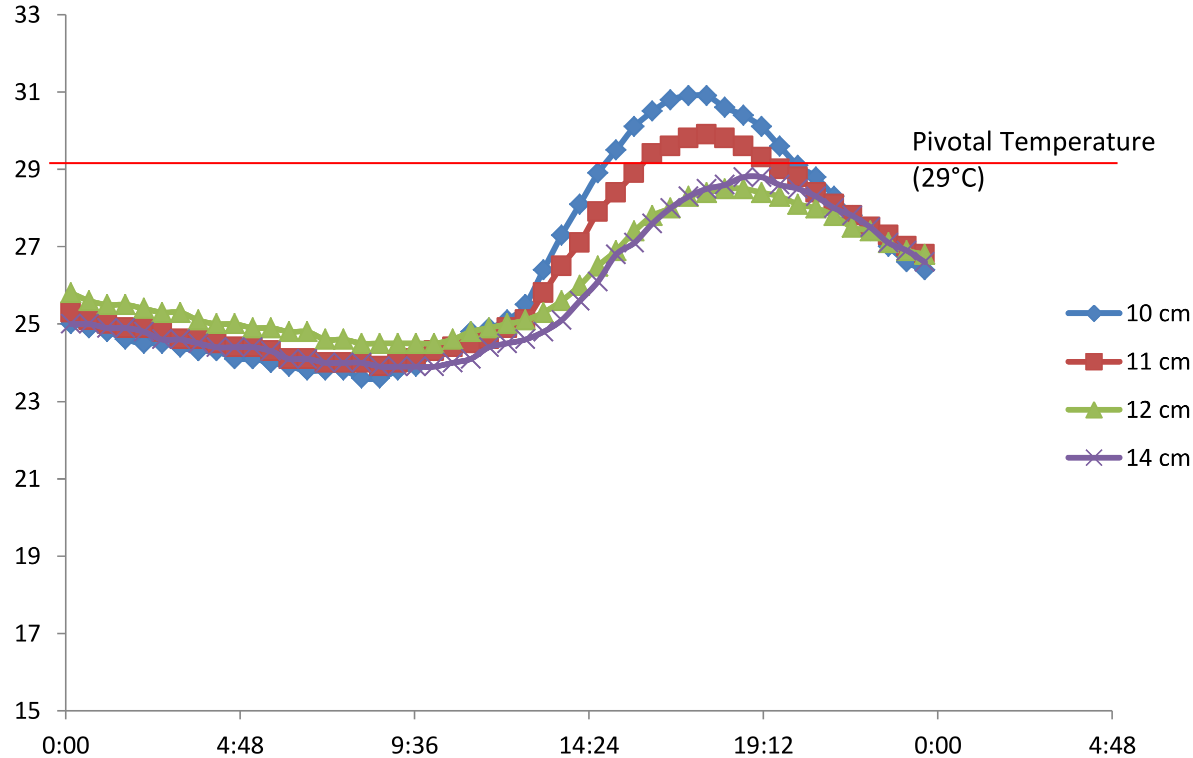
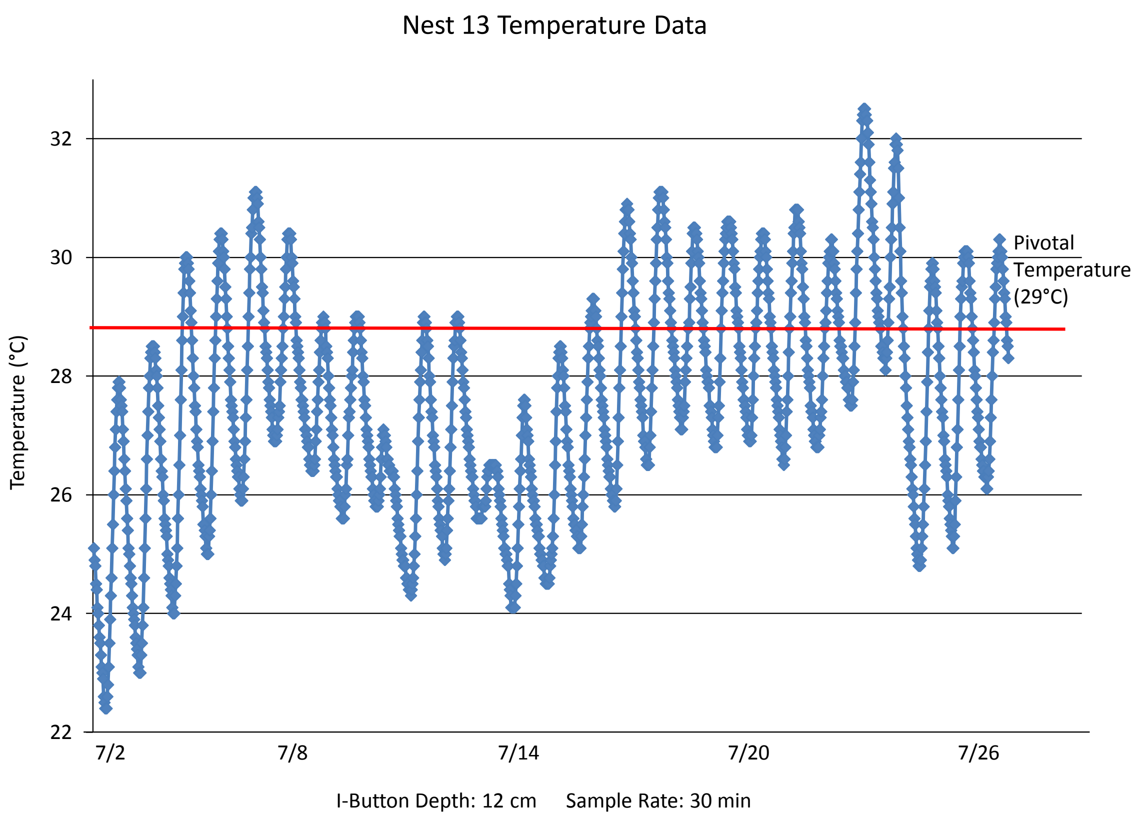


Figure 11- Temperature data at different depths for 24 hours on July 13, 2010.



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