EVALUATING NEST PROTECTORS FOR TURTLE CONSERVATION

A Final Report of the Tibor T. Polar Fellowship Program

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ABSTRACT:

Nest predation is a major conservation problem for turtles all over the world. Many researchers and conservation agencies depend heavily on nest protectors/nest predator excluders to protect nests; however, there are potentially negative impacts of nest protectors. Standard nest protectors may affect the incubation temperature of turtle eggs, which is potentially important because embryological development can be profoundly influenced by incubation temperature. A subtle change in incubation temperature caused by nest protectors can affect the sex ratio, growth, development, behavior and survival of turtle hatchlings. This study investigates the impact of standard nest protectors on incubation temperature of turtle nests and body size of hatchlings using diamondback terrapins (*Malaclemys terrapin)* as a model. During the summer of 2009, 48 terrapin nests were located at Jamaica Bay wildlife refuge and transplanted in experimental plots with temperature loggers. Temperature loggers were retrieved and emerging hatchlings were measured from the nest in the fall. Many of the nests were disturbed by raccoons during the season resulting reduction of sample size. However, data collected from the remaining nests indicate, a significant difference in incubation temperature between the nests with metal box protectors and nests without protectors, but the nest protectors didn’t affect the size of the hatchlings.

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INTRODUCTION

Turtles and tortoises have existed for nearly 300 million years; however, due to anthropogenic impacts and global climate change, turtles are now one of the most highly endangered vertebrate orders (Klemens 2000). Nest predation is a common conservation issue for turtles worldwide. Urbanization and suburbanization have reduced natural habitats, and have created good environments for predators. In North America, the most common turtle predator is the raccoon *(Procyon lotor).* Raccoons are known to eat turtle eggs and adults. Raccoon populations in urban areas have flourished due to the fact that they are highly adaptive and opportunistic, and regularly exploit human-modified habitats. Urban habitats provide raccoons with resources such as shelters and easy access to food in the form of discarded wastes and artificial feeding. The elimination of predators has aided increasing raccoon abundance as well (Mitchell and Buhlmann 2003). Thus, nest protectors/nest predator excluders have become an important means of preventing nest predation.

Diamondback terrapins and nest protectors

This study was conducted on the diamondback terrapins (*Malaclemys terrapin)* of Jamaica Bay, New York. Terrapins are the only estuarine turtles in North America. These medium-sized turtles can be found in coastal environments from Cape Cod to the Gulf of Mexico. The diamondback terrapin is listed as endangered in Rhode Island and considered a threatened species in Massachusetts. It is considered a "species of concern" in Georgia, Delaware, Louisiana, North Carolina, Virginia and New York (Burke 2000).

Although little is known about the aquatic ecology of *M. terrapin*, its nesting behavior has been well documented (Giambianco 2002). On Long Island and New Jersey, the nesting season begins in early June and extends to the end of July (Feinberg 2000). Diamondback terrapins nest primarily on sandy beaches and vegetated dunes. Females come ashore primarily along with high tides to seek out appropriate nest sites. The peak of the nesting season in New York begins in late May and ends in late July (Feinberg and Burke 2003). Terrapin hatchlings emerge from the nests in 50-90 days.

As with many other turtle species (Burke et al. 2000), nest predation is one of the major conservation issues for terrapins throughout much of their range (Butler et al. 2006). Nest predation can be as high as 100% in some locations (Feinberg 2000). In recent years, nest predation has increased due to the increase of subsidized predators (e.g. raccoon*s*) aided by rapid urbanization (Ner and Burke 2008). Most nest predation occurs within 48 hours of oviposition (Feinberg and Burke 2003) with raccoons being the predominant predators of terrapin eggs throughout their range (Ernst et al. 1994). Previous research has shown that raccoons heavily depend on olfactory cues to locate terrapin nests. Increased soil moisture, subsurface soil disturbance, ocean-water scent and terrapin scent probably indicate the locations of terrapin nests to raccoons (Burke et al. 2005). Feinberg and Burke (2003) reported that nest predation rates drop off rapidly after 24 hours as terrapin scent fades away. Nest predator excluders (nest protectors) are probably the most common and widely used tools for turtle conservation, and are used far more often than they are reported. A partial list of researchers and conservation programs in the Northeast that utilize nest protectors include: Jamaica Bay terrapin research, Hofstra University, NY; The Wetland Institute, Stone Harbor, NJ; Barnegat Bay terrapin research; Drexel University; Barnstable Bay Wildlife Refuge, Cape Cod, MA; Turtle conservation, Hudsonia Ltd,; Teatown Lake Reservation spotted turtle research, Ossining, NY; Boston College Terrapin Research, MA and; Turtle Conservation Project, MA. These organizations and many others have depended heavily on nest protectors; however, they have not published any reports about their use of nest protectors.

Nest protectors can be made of plastic, metal, wood, and/or PVC cloth and have various designs. Designs and choice of materials to be used vary depending on experience and what materials are available. There is no standardized or published literature on predator excluder designs. In the northeastern United States, the most commonly used nest protectors are circular or square cages made of ½-inch hardware cloth tucked into the ground (Burke, pers. obs.). Protectors made of PVC cloth and wooden framed wire nets are also used (Burke, pers.obs.). These nest protectors are very successful against raccoons and other predators (Brenessel 2006; Burke, pers. obs.).

There are some potential risks associated with nest protectors. Nest protectors make the nest very conspicuous. As a result, the eggs or hatchlings could be easily located by predators, collectors and poachers. Also, nest protectors placed near trails or road sides are a potential safety hazard for the public. In Jamaica Bay Wildlife Refuge, NPS personnel have expressed concern that the nest protectors placed on public trails may be a tripping hazard for the public. The most important risk of nest protectors is the potential of affecting the incubation temperature of eggs, and therefore reducing the fitness of the resulting hatchlings. For this study, some common nest protector designs were tested for possible effects on hatchlings in order to suggest design improvements, if appropriate, to improve their conservation value.

The role of incubation temperature

Turtles are ectothermic, and adult turtles may mitigate some of the effects of environmental temperature via behavioral and physiological responses, i.e., moving to favorable microhabitats, basking, and changes in membrane and protein physiology. However, egg development is profoundly influenced by incubation temperature because turtles rarely provide parental care. The effects of temperature on developing embryos are more pronounced than on adults because the temperature during development can permanently affect individual phenotypes (Booth 2004). Incubation temperature can influence hatchling sex ratios (Valenzuela 2004), morphology, behavior (Deeming 2004), mass, and energy reserves for freshwater turtles (Rhen and Lang 1999; Willingham 2005), embryonic growth (Du et al. 2007), post-hatching growth (Roosenburg and Kelly 1996; Booth et al 2004*;* Rhen and Lang 1995*)* and locomotor performance for freshwater turtles (Booth et al. 2004), sea turtles (Burgess et al. 2006), and tortoises (Ligon et al. 2009). It has also been shown that temperature extremes produced slow-growing turtles, relative to turtles from intermediate temperatures, and that incubation temperature can influence freshwater turtle swimming performance, post-hatch survival, and metabolic rate (Rhen and Lang 1999; Booth et al. 2004).

The best studied example of the effect of incubation temperature in turtles is on sex determination. In human and other mammals, the sex of the offspring is determined strictly by genotype. Offspring receiving an X chromosome from the father develop into female embryos, and offspring receiving a Y chromosome from the father develop into male embryos. In contrast, most turtle species lack heteromorphic sex chromosomes and their sexes are determined by incubation temperatures. These are known as temperature dependent sex determinant (TSD) species. In animals with TSD, sex is determined by incubation temperature during a critical period of embryonic development (thermosensitive period, TSP) (Mrosovsky and Pieau 1991). Therefore, even a small change in incubation temperature during the TSP could skew the sex ratio of hatchlings (Deeming 2004).

Research Objectives

Given that nest protection is commonly used to enhance hatchling recruitment in turtle populations, it is important to determine whether nest protectors negatively impact the hatchlings in the nests they protect. Three hypotheses were tested:

1) Nest protectors either cool down or heat up terrapin nests. Both possibilities were considered because protectors may simply shade nests and cool them, or may reflect heat energy from the soil back towards the surface, acting as small greenhouses. Nevertheless, dry leaves and debris often get stuck in the nest protectors (pers. obs.) and these may alter the microhabitat of the nest.

2) If nest protectors do in fact have an effect on the overall temperature of the nest, they may affect the body size of newly emergent hatchlings.

3) Nests can be successfully protected from predation even if protectors are removed after three weeks. This would also reduce the potential safety hazard for the public and significantly reduce the chance of the nests being located by collectors and poachers.

METHODS

While this project could be carried out using nearly any turtle species, therefore having wide application, this project was carried out using diamondback terrapins (*Malaclemys terrapin*) in Jamaica Bay Wildlife Refuge (JBWR). JBWR is a 3662 ha estuarine park, part of Gateway National Recreation Area (GNRA), a large, federally-operated park managed by the National Park Service. GNRA is geographically located in the Hudson-Raritan Estuary, otherwise known as the New York-New Jersey Harbor Estuary. This study took place at Ruler's Bar Hassock (RBH), the largest island in JBWR. Feinberg (2000) determined that the highest concentration of nesting terrapins at JBWR was on RBH.

Locating terrapin nests

Daily surveys were conducted from 1 June to 25 July in 2009 with the goal of locating 48 nests. On an average day, one to three volunteers assisted with surveys. At RBH, terrapins nested primarily on the Terrapin Trail, the Gravel Trail, the mixed grasslands and on the dunes. Each day, these nesting habitats were patrolled frequently for nesting terrapins. Once a terrapin was located on land it was allowed to complete nesting to the point that the eggs were covered, so that the nest chamber could be located easily. After the terrapins were captured they were carried to the field station for measurement and the nest was marked with flags for excavation. Date and time of nesting were recorded.

Nest transplantation and protection

Nests were excavated and transplanted 3-29 hours after nesting. Nests were excavated carefully by hand and eggs were handled with great care. The upper surface of each egg was first marked with a pencil to maintain the original orientation, and then each egg was placed in a plastic container and carried to the transplantation site. Nests were transplanted into two different habitat types: 1) Mixed grasslands adjacent to the gravel trail which had 20-50% of vegetation dominated by knapweed (*Centauerea maculosa),* 2) Slope of dunes facing the beach with 0-20% vegetation cover (Figure 1). These areas were chosen because these are the major nesting habitat types utilized at RBH (50%) (Feinberg and Burke 2003). One grassland site and two dune sites were used (Figure 1).

Nests were transplanted two at a time in pairs approximately one meter apart. The numbers of eggs in larger clutches were reduced to match the clutch size of the smaller clutches which were collected for the pairs. Flask shape nest cavities were dug to approximately 16 cm down from the surface to mimic natural nests. Eggs were gently placed into the cavity one at a time, and one temperature logger was placed in the middle of the clutch. After temperature loggers and all of the eggs were arranged in the cavity, sand was lightly packed into the hole until filled. Both nests in each pair were then covered with nest protectors. Three different types of nest protectors were tested for this experiment: 1) 30 cm x 30 cm x 20 cm square cages made of 1.3 cm mesh hardware clothing (= box metal); 2) 60 cm x 60 cm flat screens made of 1.3 cm hardware clothing (=flat metal) and; 3) 25 cm x 30 x 20 cm circular PVC 1.3 cm mesh black cloth (=PVC).

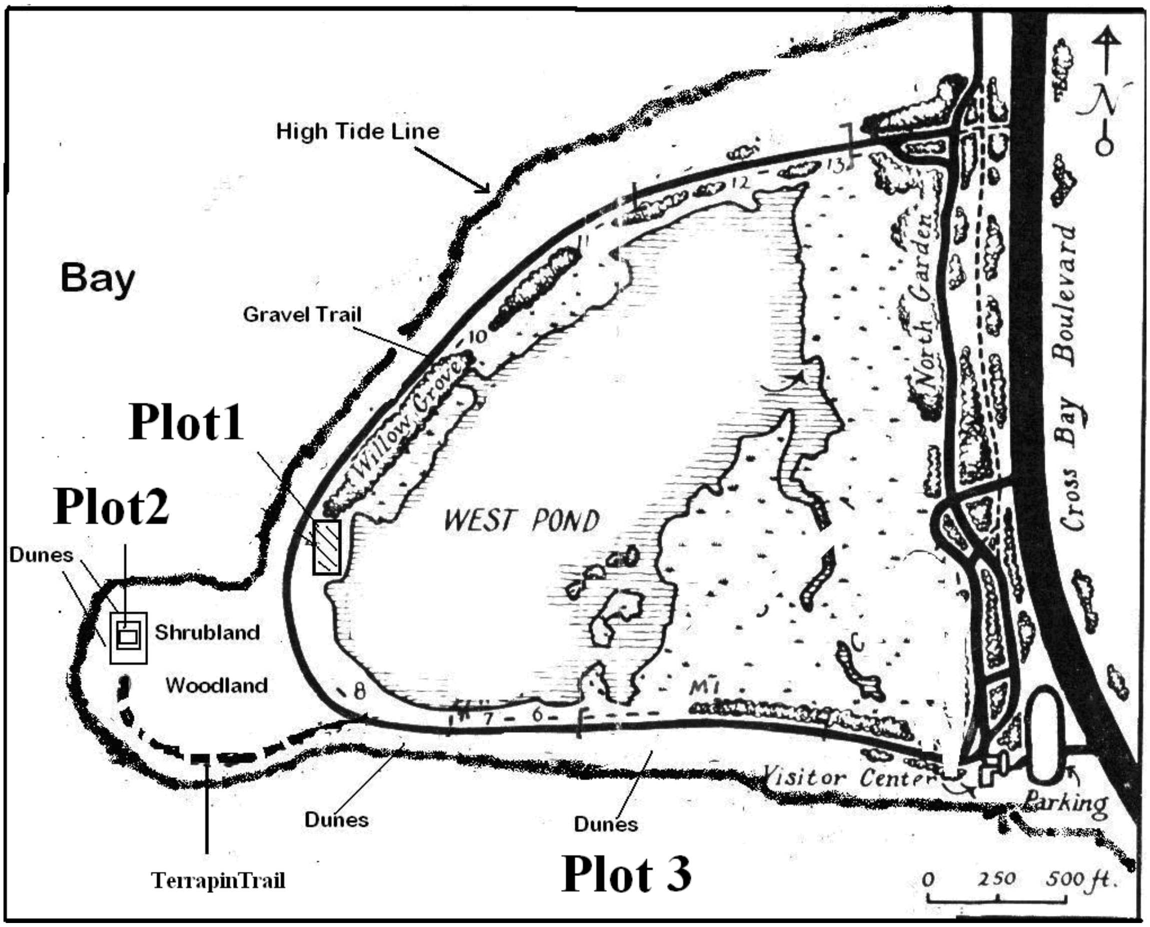

Figure 1. Map of the West Pond trail in Jamaica Bay Wildlife Refuge, Jamaica Bay, New York. Plot 1 represents mixed grassland); Plots 2 and 3 represent dunes.

Nest protectors were anchored into the ground with four to eight 42 cm metal stakes. One protector from one of the nests (chosen randomly) was removed after 21-25 days to test for successful protection from predation if protectors were removed after a shorttime. After protectors were removed, sand was kicked over the area of the nest in order to obliterate traces of activity and possibly mask any traces of egg or human scent. The unprotected nests were marked with orange vinyl flags placed 45 cm away from the center of the cavity in opposite directions (Figure 2). It was hypothesized that after three weeks, leftover olfactory cues would dissipate and soil disturbance would not be visible; therefore, the raccoons would not be able to find these nests.

Experimental nests, nest cavities but with no eggs, were also made one meter apart from each real nest. One of these had a nest protector and one did not. The purpose of these experimental nests was to determine the amount of metabolic heat produced by the eggs for comparison with the translocated nests. The cavity of these simulated nests was similar to the transplanted nests. One temperature logger was also placed in the middle of the cavity, then the cavity was lightly packed with sand and covered like a natural nest.

As a result of these manipulations, nests were assembled in sets of four, all in the same habitat type within a few meters of each other. Each set had the first nest consisting of a translocated clutch of eggs covered with a nest protector throughout incubation, the second nest consisting of a translocated clutch of eggs covered with a nest protector that was removed after 3 weeks, the third simulated nest without eggs and covered with a nest protector, and the fourth simulated nest without eggs not covered with a nest protector. One third of the sets used box metal protectors, one third used flat metal protectors, and one third used PVC protectors. These were randomly assigned in each case.

An additional 28 nests were used to calculate current nest predation rates. For these nests, nesting terrapins were allowed to finish nesting completely, and nests were marked with two vinyl flags 45 cm away from the cavity in opposite directions. Nests were monitored regularly until hatchlings successfully emerged or until they were predated.

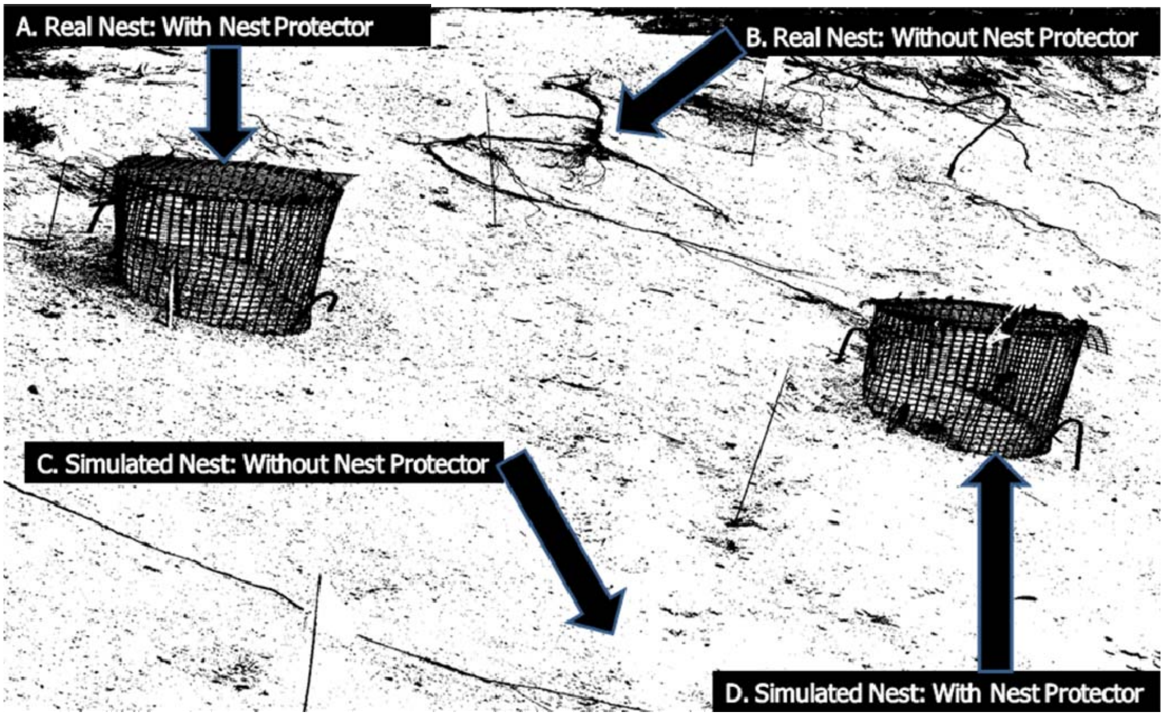

Figure 2. Photograph describing the organization of one set of paired nest protectors in the field; illustrated above are two real nests (one covered, the other uncovered) and two simulated nests (covered and uncovered), cage material used was black PVC mesh. Jamaica Bay, New York.

Hatchlings

At the beginning of hatching season, all unprotected nests were covered to prevent hatchlings from escaping. Both covered and uncovered nests were monitored at least once daily until all of the hatchlings emerged from the nest. When all hatchlings had emerged, nests were carefully excavated to evaluate the status of the nest. All hatchlings that were recovered from successfully protected nests were measured (to the nearest mm) for straight-line carapace and plastron length, width and height with a caliper.

RESULTS

Nesting season began on June 6th, 2009 and ended on July 28th, 2009. During this time, 105 nests were located. The average clutch size was 13 eggs/clutch. The first recorded hatchlings emerged on August 22, 2009. Twenty-four experimental sets of four nests, consisting of twenty-four pairs of real nests and twenty-four pairs of simulated nests were used. Eight sets used the box metal protectors, eight used the flat metal protectors, and eight used the PVC protectors. Twelve experimental sets were transplanted into mixed grassland habitat (Plot 1), six into dune habitat in Plot 2, and six into dune habitat in Plot 3. Two sets on the dunes in Plot 3 were accidentally damaged by NPS personnel performing fence construction work. Data from these nests were not usable. All of the other nests were monitored throughout the season. Out of forty-eight real nests, thirteen were predated by raccoons, and two were accidentally damaged. Out of forty-eight simulated nests, eleven were disturbed by raccoons, where temperature loggers were regularly displaced out of the nest cavity and therefore were not usable for the project. Also, five of the temperature loggers malfunctioned due to unknown causes and seven of the loggers were lost due to sand shift or dune erosion. Without complete data within any given set, within site comparisons could not be performed. Only four sets of nests had complete data available for analysis for the 2009 field season.

Hypothesis 1: Temperature logger data

Paired t-tests were performed comparing temperature variation between nests with eggs which had nest protectors through the entire season and those where nest protectors were removed after three weeks. For this comparison, for both types, temperature data points were used starting from the point when the covers for the nests which were only to be covered for three weeks were removed. There were significant differences between nests with Metal Box protectors and the neighboring nests without protectors.

Set 1	**Real Nest With Cover**	**Real Nest Without Cover**	***p*-value**
Mean Temperature	27.65	27.99	
Variance	6.76	7.99	6.97E-66
Set 2			
Mean Temperature	28.1	28.64	
Variance	8.45	10.52	2.80E-59
Set 3			
Mean Temperature	27.31	26.79	
Variance	8.81	8.73	2.00E-242
Set 4	**Simulated Nest With Cover**	**Simulated Nest without cover**	***p*-value**
Mean Temperature	28.86	28.54	
Variance	7.23	10.88	2.80E-02

Table 1. Mean temperature and the p-value for three pairs of real nests and a pair of simulated nest.

Hypothesis 2: Hatchling size

Paired t-tests were performed comparing the straight carapace (SCL) and straight plastron measurements (SPL) of hatchlings which emerged from protected (flat screen wire mesh, PVC, or square box wire mesh cages) with their neighboring nests with eggs which were protected for only three weeks and then left uncovered. This summer 616 terrapin eggs were protected in 48 nests. However, data on only 144 hatchlings could be collected. Many of the nests were predated by raccoons, and at least 1 hatchling escaped from 5 different cages. A total of 20 hatchlings were found dead due to predation by fly maggots in five different nests within the Plot 1 habitat. There were no hatchlings that died from maggot infestations within Plot 2 and 3.

Flat metal protectors

Hatchlings (n= 86) that emerged from flat metal protectors were significantly larger SCL ($p<0.000847$) than those from nests without protectors (Covered Mean = 29.4 mm, Variance = 0.46; Uncovered Mean = 28.7 mm, Variance = 0.63). There was no significant difference ($p<0.100513$) in SPL of emergent hatchlings (n= 43) (Covered Mean = 25.0, Variance = 0.65; Uncovered Mean = 24.7, Variance = 1.09).

Box metal protectors

There was no significant difference ($p<0.09502$) in SCL or SPL ($p<0.053974$) for hatchlings (n = 46) which emerged from box metal protectors and nests without protectors (SCL: Covered Mean = 29.3, Variance = 2.66; Uncovered Mean = 28.2, Variance. = 4.70, SPL: n = 23, Covered Mean = 25.8, Variance = 2.99; Uncovered Mean = 24.9, Variance = 1.14).

PVC protectors

There was no significant difference ($p<0.39388$) in SCL for hatchlings (n=12) or SPL (n=6, $p<0.610881$) which emerged from PVC protectors and nests without nest protectors (SCL: Covered Mean = 28.3, Variance = 0.57; Uncovered Mean = 28.7, Variance = 0.47, SPL: Covered Mean = 25.3, Variance = 1.48; Uncovered Mean = 25.5, Variance = 0.30).

Hypothesis 3: Nest Predation

Nineteen out of the twenty eight natural nests, which were left undisturbed, were predated. All predation occurred within 24 hours of nesting.

The hypothesis of this study was that nests could be successfully protected from predation even if the nest protector was removed after 3 weeks. The nests that were covered for the whole season were compared to the nests that were only covered for the first 3 weeks. In Plot 2 and Plot 3, there was no significant difference in predation rate between the nests covered the entire season and the nests covered only initially (Chi test, p = 0.56). However, in plot 1, there was a significant difference in predation rate between nests covered the entire season and the nests covered initially (Chi test, p = 0.01) (Table 2). Predation for all of the predated nests in Plot 1 occurred on the first night to even as far as 11 nights after the nest was uncovered for nests where nest protectors were removed after approximately 3 weeks.

Location and Habitat type	Number of nests covered entire nesting season	Number of nests Predated	Number of nests covered only initially	Number of nests predated	Chi Test P-value
Experimental Plot 1 (mixed Grassland)	11	1	11	9	0.01
Experimental Plot 2 and Plot 3 (dunes)	10	1	10	1	0.56

Table 2. Nest predation in experimental plots

DISCUSSION

Hypothesis 1: Temperature logger data

During the analysis of temperature logger data, it was found that there were points where there was a significant gap between temperatures of paired nests in a given area. These were considered to be outliers within the data set which have been included in statistical analysis. For example, on July 25, 2009 the temperature reading of logger #82 (metal box covered) for a covered nest and logger #94 (uncovered nest pairing with #82) were 23 degrees Celsius and 43 degrees Celsius, and 31.5 degree Celsius and 53.5 degree Celsius respectively (a 17 and 22 degree Celsius difference). However, readings for the rest of the days did not even come close to such a high temperature difference between logger #82 and #94. This means that either the this logger malfunctioned at that point in time, or something occurred during that hour in the habitat which caused the abrupt temp change, such as rainfall, or the logger shifting beneath the sand.

The initial results indicate that the nests with metal box protectors cause significant difference in temperature of the nest. Since the sample size analyzed was very small, more data needs to be collected to reach definite conclusion about the relationship between temperature and the three nest protector designs used in this study.

Hypothesis 2: Hatchling size

It appears that nest protectors have no affect on body size, only one of six comparisons found significant differences in body size; however, there are other variables regarding body size which were not taken into account in this study. For example, egg size affects hatchling size (Janzen and Morjan 2002), but egg size was not measured.

The number of hatchlings measured was small, and more data must be collected for more robust tests.

Hypothesis 3: Nest Predation

Raccoons are the predominant nest predators at Jamaica Bay. Over the past nine years, nest predation at JBWR was very high; however, we observed a low nest predation rate in 2009. There were several periods of heavy rainfall this season, so rainfall potentially washed away terrapin scent and made it difficult for raccoons to locate terrapin nests (Feinberg and Burke 2003). During the 2009 field season, it seemed that raccoons concentrated their efforts in excavating nests in Plot 1 (grassland). Each day when checking the nests in this area, signs of raccoons were found attempting to either uncover real nests, or completely uncover simulated nests, leaving the temp loggers out on the surface. This behavior may have occurred because there was such a high concentration of nests at that site that raccoons learned to check this area each night for signs of nesting. Possibly, they learned to associate human scent with nests. Each time simulated nests were re-buried, they were found uncovered again the next morning. However, there was a low rate of nest predation in Plot 2 and Plot 3 (dunes) compared to Plot 1. This is due to the low concentration of nests in Plot 2 and 3 compare to Plot 1. Considering this, results indicate that it is possible to prevent nest predation, even if the nest protectors are removed after 2-3 weeks, if the nests are transplanted in plots, with small number of nests, spread out throughout the refuge.

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