THE EFFECTS OF ENVIRONMENTAL VARIABLES AND HUMAN ACTIVITY ON THE NESTING FREQUENCY OF DIAMONDBACK TERRAPINS IN COASTAL NEW JERSEY

by

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ABSTRACT

Wildlife is constantly at risk due to many anthropogenic and environmental factors. The diamondback terrapin *(Malaclemys terrapin)*, a small estuarine species of emydid turtle is no exception as they are currently rated as a species of concern in many states on the East Coast including Delaware and New Jersey and have been declining throughout their range. There is concern that increased anthropogenic disturbances could be influencing terrapin population declines especially during their nesting season in late May-July. In addition, water temperature drops, possibly due to upwelling events have been observed to decrease foraging and possibly terrapin nesting activity. Using a backwards stepwise linear regression, I tested the effects of environmental factors such as average air temperature, landing location, date, tides, average water temperature, moon phases and rain presence, on terrapin landings on North Sedge Island in Barnegat Bay, New Jersey 8 June 2012- 17 July 2012. The best fit model indicated date, time, and location were most correlated to nesting frequency. While human activity was not a significant predictor in my final model, anecdotal observations indicated a possible relationship may occur and biologists are encouraged to further investigate this variable due to the high management implication in the very developed coastal New Jersey.

Chapter 1

INTRODUCTION

The diamondback terrapin (*Malaclemys terrapin)* is an endemic emydid turtle to coastal wetlands (Ernst et al. 1994) and brackish waters along the east coast (Daiber 1982). Female terrapins nest above the tidal line on bay beaches and areas that are high in sand composition (Burger and Montevecchi 1975). The average diamondback terrapin clutch size is 10 eggs with the range of 4–18 eggs per clutch (Daiber 1982). In New Jersey, terrapins nest from May through July (Burger and Montevecchi 1975), with some females returning multiple times in one nesting season (Feinberg and Burke 2003, Wnek 2010). Although the age of terrapins is hard to determine, it is predicted that terrapins have a lifespan of 50 years with sexual maturity in females between ages 8–13 (Roosenburg 1990). Females have a high proximity to return to the same dune area to nest year after year (Burger 1977).

Declines in diamondback terrapin populations have been noted throughout their range (Seigel and Gibbons 1995) and may be due to human-induced habitat loss, road mortality and commercial harvest for food (Seigel and Gibbons 1995, Wood and Herlands 1997). Human activity has also caused turtles to become more concentrated on the beach when basking, with some turtles going as far to stack themselves on top of others (Moore 2006). However, it is unknown how human activity may affect terrapin nesting initiation and success.

In addition to anthropogenic disturbances, environmental variables such as water temperature may play a role to either increase or decrease terrapin nesting. Coastal upwelling events bring nutrient-rich, cooler water to near-shore areas and estuarine waters depending on proximity to an inlet (Glenn et.al. 1996). Additionally, Nor'easter storms bring cold rain water that causes an event that may be similar to an upwelling. In aquatic turtles, a water temperature of 16^{0}C or greater increases foraging activity (Ackerman 2008). Diamondback terrapins are more sensitive, exhibiting a sharp decrease in foraging activity below 20°C due to their depressed metabolic state at cooler temperatures (Davenport and Ward 1993). If this colder, nutrient-rich water is brought to terrapin nesting sites, it is unknown whether terrapins will spend less of their time nesting due to the lowered metabolic state.

Because little is known about the effects of natural and anthropogenic disturbances and stochasticity on terrapin nest initiation and success, my objective was to assess the effects of a series of environmental variables and human activity on nesting frequency on North Sedge Island in Barnegat Bay, New Jersey, during the summer of 2012. This research will potentially benefit management of diamondback terrapins in the face of increased human impact on New Jersey coastal habitats.

Chapter 2

STUDY AREA

I conducted my research on North Sedge Island in Barnegat Bay, New Jersey, U.S.A. (057545/ 4427903 UTMs). North Sedge Island is approximately 1 km west of Island Beach State Park (IBSP) and is managed by the New Jersey Division of Fish and Wildlife (NJDFW) within the Marine Conservation Zone established in 2003. It is also approximately 1 km from the Barnegat Inlet. Diamondback terrapins have been studied at Sedge Island for over 11 breeding seasons with over 350 terrapins being processed and caught during that time (J. P. Wnek, personal communication). Female terrapins nest on this island from late May to mid July (Burger and Montevecchi 1975) and have an average clutch size of 12.5 eggs (J. P. Wnek, personal communication). The island is part of a salt marsh with nestings recorded on the south side of the island (Figure 1). Nesting sites are man-made, characterized by grassless patches of loamy sand.

The only means of transportation to and from the island is via privately owned boats and special permission needs to be granted to visitors to the island. There are two buildings on North Sedge Island, the Sedge Island Natural Resource Education Center and the Raniero’s boat house. The Sedge Island Natural Resource Education

Center houses educational and recreational groups that visit through programming with the NJDFW throughout the year although most groups are scheduled to stay during the summer months (June-September). Groups can vary in size from 6–30 people, and can range in ages from 11–70 years old. Groups may also stay on the island for a day trip or overnight for <5 days. The Raniero’s boat house is the residence of Jackie and Tony Raniero, the caretakers of the island. Jackie and Tony maintain the island in tasks such as lawn mowing, building extensions, maintenance of the Education Center and terrapin capture. They spend most of the summer months on the island, returning to the mainland only for groceries and supplies.

Chapter 3

METHODS

I monitored the East and West Lawns on the south side of the Island from the North Deck of the Sedge Island Education Center. Additionally, I would survey the island on walks around its south side. I did this from 8 June - 17 July 2012, 4–5 times a week between the hours of 8:00AM–12:00PM to process terrapins. I considered terrapin landings interchangeably with terrapin nestings because terrapins that land during nesting season (late May to mid July) are landing to nest. Once a nesting terrapin was located, I would keep my distance and observe her until she had finished digging her nest. Not all digging involved the laying of the nest. Female terrapins would sometimes partake in false digs, without actually laying a clutch (Feinburg and Burke 2003). I would then catch the terrapin if she tried to return to the water or as soon as she finished laying her clutch. Some terrapins were captured from residents on the island while I was absent and I would process them the following day.

To process the terrapin, we would record her designated notch code and Passive Integrated Transponder (PIT) tag number (Figure 2). If a notch code and PIT tag was not present, we would install them (J. P. Wnek, personal communication). I also took physical measurements including carapace and plastron width and length, estimated aging of the terrapin based on shell growth lines and recorded the date and time that she landed. This temporal data as well as a count of terrapin landings were applied to my research.

For all terrapin landings, I recorded 1) Julian date (between 8 June - 17 July 2012), 2) time (in 3 hour blocks over 24 hours starting at 5:30AM), 3) average water temperature during the 3 hour blocks, 4) average air temperature during the 3 hour blocks, 5) average number of humans crossing electronic sensors in the 3 hour blocks, 6) location of landings (western versus eastern lawn), 7) presence of rain, 8) average tide (low, flow, ebb, or high), 9) moonlight (new, wax/wane, full), and 10) neap/spring tide.

To measure water and air temperature, I set two HOBO® pendants to monitor water temperature and one TidbiT® to monitor air temperature. All devices recorded temperatures at 10 minute intervals with error of +/-0.5°C in HOBO® pendants with and +/-0.2°C in the TidbiT®. One HOBO® pendant was installed with zip ties in the clam bed on the West side of the island. The second HOBO® pendant was placed in a mesh bag and tied to a string that hung in the water channel off of the Raniero Dock on the Southeast side of the island. I placed both HOBO® pendants in the water column. I installed the TidbiT® below the North deck of the Sedge House. All devices were cleaned of algae and other organisms and maintained 4–5 times a week along with relative temperature recorded using a Wafer scale integration (WSI) device. These temperatures were compared at the end of the study to ensure precision.

To measure human activity, I placed 2 trail monitors (TM1550) that I distinguished as 1004 and 1001 (Figure 1) on the West Lawn of North Sedge Island from 8 June - 17 July 2012. I placed them on the West Lawn of the island since it has historically experienced the most terrapin landings. Human activity was quantified with the number of human crossings through each camera beam. The 1004 camera was located at 0575454/4405345 UTMs, with its receiver located at 0575441/4405345 UTMs. The 1001 camera was located at 057545/4405361 UTMs, with its receiver at 0575441/4405345 UTMs (Figure 1). I recorded each camera's data 4–5 times a week. Cameras were sometimes faulty, yielding crossings as high as 600 although it was recorded that the island was absent of all human groups or had human tampering error. This occurred on 30 June 2012 (loose camera) and 8 July 2012 (children observed playing with camera). The data from these dates were removed from the overall data. I conducted a backward stepwise linear regression ($\alpha \leq 0.05$) to determine what external variables might influence the number of terrapin landings.

Chapter 4

RESULTS & DISCUSSION

During the summer of 2012, 70 terrapins were processed with an average clutch size of 13.4 eggs, a bit more than the overall average (mean from 2006–2009 was 12.5, Wnek 2010). The top model ($F_{3,30}$ = 4.357, *P* = 0.01, R^2 = 0.30) included date, time, and location with no environmental or anthropogenic variables impacting terrapin landings. Julian date had a negative relationship (*B* = -0.041, SE = 0.013, *P* = 0.004) with the most landings occurring during the early weeks of the study (e.g. 62% of the landings occurring in the first 13 days of the 38 day study) (Figure 3). This may be the result of warmer temperatures earlier in the nesting season during 2012 (Weather underground 2012). However, nesting season may have started earlier as a result of a warmer spring, thus shifting the start of nesting season prior to the start of this study.

Time showed a non-significant negative relationship in the top model (*B* = -0.191, SE = 0.101, *P* = 0.069) with 83% of the landings occurring between 5:30AM-2:29PM and the majority of those occurred between 8:00AM-10:00AM (Figure 4). This is unusual compared to nesting times observed on the island in 2007, 2008, and 2009 which had their most active time between 9:00AM-12:00PM (Wnek 2010). Our nesting time is also earlier than the average diamondback terrapin nesting time in Massachusets, 11:00-1:00PM (Rosenburg 1994).

Last, landings occurred more frequently on the west lawn (65%) than on the east lawn (B = -0.757, SE = 0.324, P = 0.026). This may be due to the larger size of nesting sites on the west lawn as compared to the east lawn. Also, terrapins are more likely to return to the same nesting site time after time (Burger 1977), therefore multiple generations may be returning to the west portion of the island.

Supporting Bowen's and Jenzen's (2008) work with painted turtles, human activity was not a significant predictor in my model, most likely due to the fact that most human crossing occurred between 11:00AM-6:00PM when nesting frequency was usually already lower (Figure 4). The most common landing times (8:00AM-10:00AM) occurred with ≤12 human crossings. In a few circumstances, human crossings spiked in late afternoon, which may have caused a sudden decrease in terrapin landings (Figure 4). However, the frequency of nesting females in the afternoon was greater in past years (Wnek 2010) when fewer groups were admitted to the area.

While previous research found that water temperature may play a role in the metabolism of turtles (Ackerman 1977), foraging behavior of terrapins (Davenport and Ward 1993) and possibly nesting frequency, my regression analysis suggested no significant correlations between water temperature and nesting frequency. Water temperature was ~2.0°C warmer in the clam bed compared to the Southeast end of North Sedge Island. This may be a result of shallower water depth of water at the clam bed site as opposed to the Rainero Dock. Since Barnegat Bay is a shallow, lagoon-type estuary, the majority of the Bay is shallow and is well correlated with air temperatures (BBEP Characterization Report 2001). Additionally, cold water events consisted of a Nor'easter storm (3–8 July 2012) and two upwelling events (25–28 July and 13–16 July, 2012) that brought colder, and theoretically nutrient rich water to the area. When comparing these dates to the terrapin landing dates (Figure 3), terrapin landings were less frequent with most dates consisting of no or few landings. According to Davenport and Ward (1993), there is decreased foraging at cooler temperatures which brings me to believe that terrapins may be using their energy towards increased thermoregulation of basal metabolic rate, rather than nesting and foraging. In painted turtles, the amount of overall energy that a 350g female directly invests into nesting activity is averaged at one percent for a single clutch of eggs (Congdon and Gatten 1989). Perhaps terrapins invest a similar amount but may need to allocate that one percent to thermoregulation. Although my data was non-significant, further studies should be made regarding temperature since water temperature is rising due to climate change and is expected to change the natural composition of estuaries as well as shifts the phenology of its inhabitants (Scavia et. al 2002).

Despite the insignificance in anthropogenic activity affecting landing, I anecdotally noted some trends in my observations. First, on days when groups would clam in the clam bed outside the west lawn, terrapins would not land. Second, I noticed that some people would not keep their distance from nesting terrapins, with some not noticing that a terrapin was there. The terrapin would halt her nesting and make a hissing sound as humans passed closely (Figure 5). Third, there were sudden decreases of terrapin activities following days of high human activity (Figure 3). For example, on 11 June 2012, there were two terrapin landings observed with 99 human crossings; however, once human crossings increase to 109 on 12 June 2012, there were no terrapin landings. Additionally, on 15 June 2012 there were 76 human crossings and 10 terrapin landings; however, on 16 June 2012, human crossings spiked to 244 and there were no terrapin landings. There continued to be no landing terrapins until July 15, 2012 when human activity decreased to 4 human crossings. Therefore certain thresholds may exist where human activity affects nesting frequency (possibly >100 human crossings) and a time lag is required for turtles to return to the nesting site. Unfortunately, my data set could not definitively determine this relationship. Bowen and Jenzen (2008) concur with such a finding, in that they emphasized that although human activity may not significantly affect nesting, individual actions should still be taken into account and observed. Additionally, Roosenburg's (1994) observations support mine stating that terrapins can spend anywhere from 15 minutes to 2 hours selecting a nesting site and are "easily disturbed". Other species undergo a similar nesting time lag after being disturbed including some estuarine species such as osprey (Levenson and Koplin 1984), bald eagles (Mathisen 1968) and shore nesting species such as coastal birds (J. Burger 1981) and sea turtles (Jacobson and Lopez 1994).

Although the relationships of nesting with human activity was not significant, given the multiple anecdotal pieces of information, I recommend biologists still consider limiting human visitors to the island during the mornings of key nesting dates. With terrapin populations dropping (Seigel and Gibbons 1995), it is increasingly vital to monitor populations and take into consider potential risks to their success.

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FIGURES

Figure 1 Study area, south side of Sedge Island in the Barnegat Bay, NJ. Locations of nesting areas as well as HOBO®, TidBit® and trail monitors 1004 and 1001.

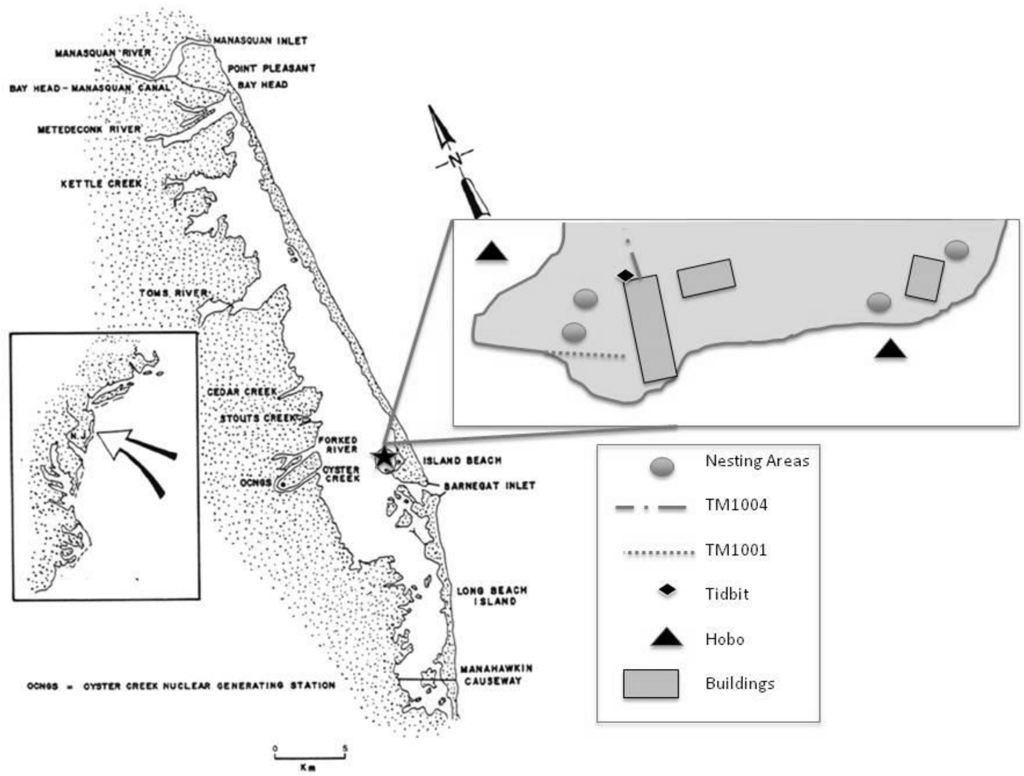

Figure 2 A nesting terrapin (left) on North Sedge Island, NJ. Installation of notches in terrapin's marginal scutes with dremel tool(right).

Figure 3 Terrapin landing frequency vs. human crossing frequency and date on North Sedge Island, NJ from 8 June 2012- 17 July 2012.

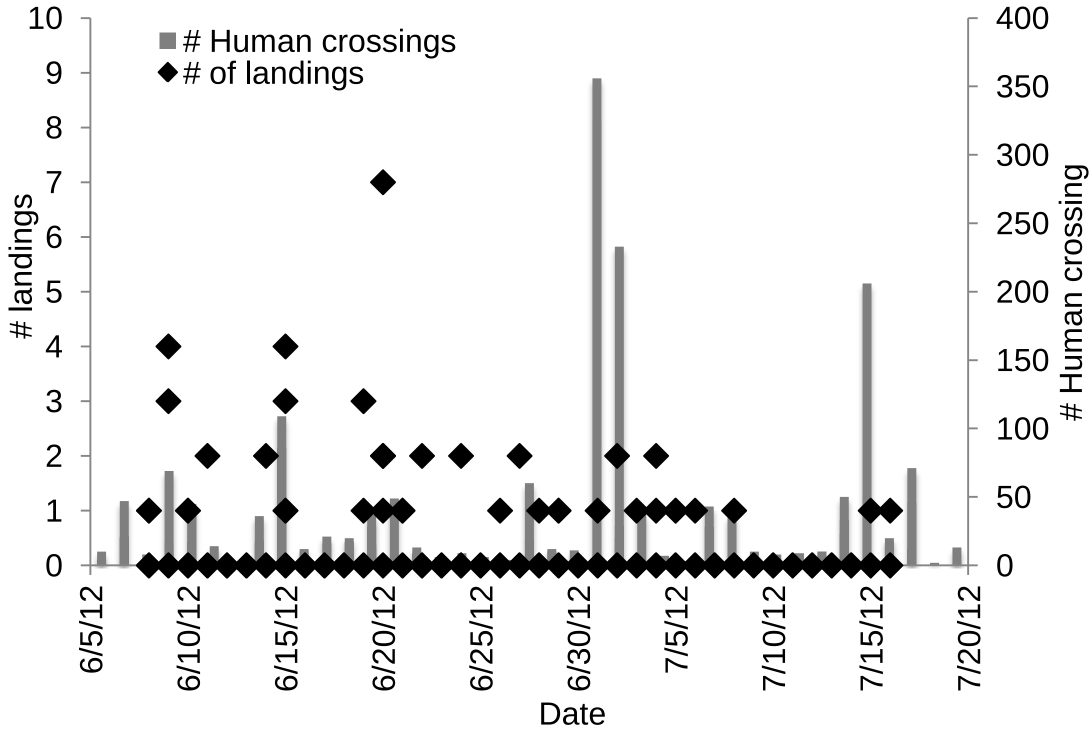

Figure 4 Landing frequency vs. human crossing frequency and time on North Sedge Island, NJ from 8 June 2012- 17 July 2012. Time groupings (24-hour scale) are 1) 5:30–8:29, 2) 8:30–11:29, 3) 11:30–14:29, 4) 14:30–17:29, 5) 17:30–20:29, 6) 20:30–23:29, 7) 23:30–2:29, and 8) 2:30–5:29.

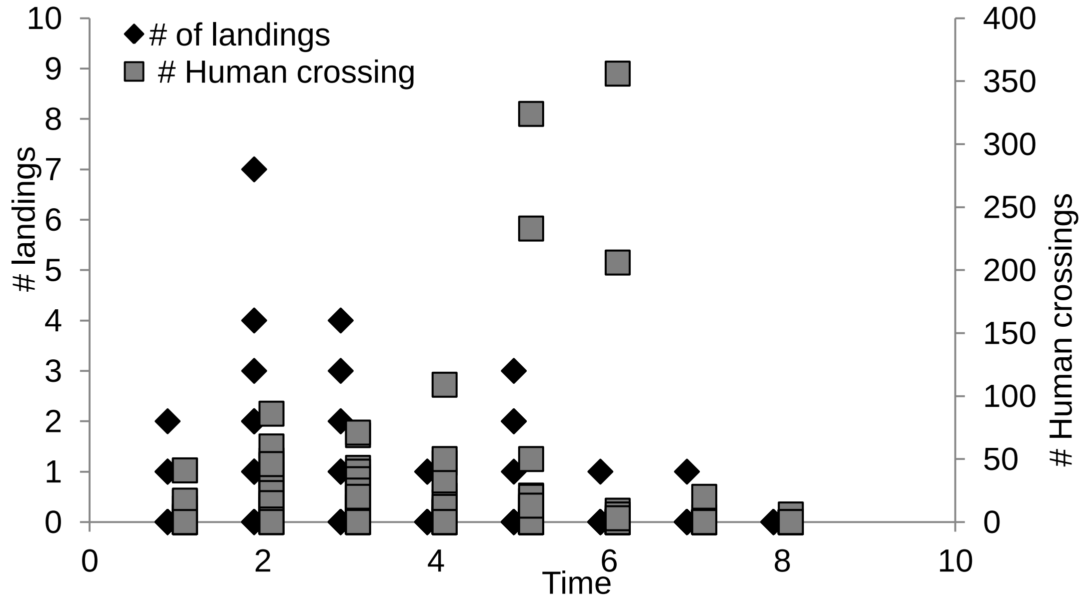

Figure 5 Humans passed closely to nesting terrapin (black circle) on July 5, 2012 during study taken place on North Sedge Island, NJ from 8 June 2012- 17 July 2012. The terrapin halted her nesting when in close proximity to a person.