THE EFFECTS OF WATER TEMPERATURE AND HUMAN ACTIVITY ON THE NESTING FREQUENCY OF DIAMONDBACK TERRAPINS

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ABSTRACT:

With diamondback terrapins *(Malaclemys terrapin)* decreasing in numbers in the past, much research has been done finding habitat needs and conservation methods. Their coastal nesting habitat is particularly at risk as coastal areas are commonly treaded with human activity during their nesting season, late May- July. In addition, water temperature drops, possibly due to upwelling events have been observed to decrease terrapin nesting activity but has not been studied thoroughly. In using trail cameras to quantify human activity there has been no significant correlation with human activity and nesting frequency. However, major decreases in nesting activity have occurred with higher human activity. When using HOBO® pendants and TidbiT® data loggers, there was a significant inverse correlation with water temperature and nesting frequency.

INTRODUCTION:

Diamondback terrapins *(Malaclemys terrapin)* are endemic to coastal areas (Ernst et al. 1994) and require salt marsh habitat. Female terrapins nest above the tidal line on bay beaches and areas that are high in sand composition (Burger and Montevecchi 1975). In New Jersey, terrapins nest from May through July (Burger and Montevecchi 1975), with some females returning multiple times in one nesting season (Wnek 2010). Because 38% of the US population lives within 100km (70 miles) of the coast or estuaries (Stewart 2009), there is concern that increased anthropogenic disturbances could be influencing population declines. Some anthropogenic threats that terrapin populations face include habitat loss, mortality caused by drowning in commercial-style crab pots, and nesting female terrapins being hit on roadways (Wood and Herlands, 1997). With this decline of habitat and loss of nesting females, terrapins are a species of concern in New Jersey. Human activity has also caused turtles to become more concentrated on the beach when basking with some turtles going as far to stacking themselves on top of others (Moore 2006). However, it is unknown how human activity may affect nesting initiation and success.

In addition to anthropogenic disturbances, natural processes that influence water temperature may play a role in the metabolism of turtles (Ackerman 1977). However, little is known about the effects of water temperature during female nesting activity and how water temperature, being linked to upwelling, can effect females' decisions to nest. Along the east coast, upwelling events occur due to prevailing summer wind patterns. Coastal upwelling events bring nutrient-rich, cooler water to near-shore areas as well as bring cooler water to estuarine water depending on proximity to inlet. In addition, Nor'easter storms bring cold rain water that causes an event similar to upwelling. In aquatic turtles, a water temperature of 16^{0}C or greater increases foraging activity. If this colder water is brought to terrapin nesting sites, will this have a negative impact on terrapin nesting?

Because little is known about the effects of natural and anthropogenic disturbances and/or stochasticity on terrapin nest initiation and success, I plan to quantify and study the effects of water temperature and human activity on nesting frequency.

METHODS:

Study Area

My research occurred on North Sedge Island in Barnegat Bay, New Jersey, U.S.A. Latitude 39^{o}47'48" N Latitude, 074^{o}07'07" W Longitude (Fig. 1). 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 within the Marine Conservation Zone established in 2003. It is also approximately 1km from the Barnegat Inlet. Female terrapins nest on this island from late May to mid July. The island is part of a salt marsh with nestings recorded on the south side of the Island (Fig. 2).

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 NJ Division of Fish and Wildlife. Groups can range from six to twenty people ranging in ages from eleven to seventy years old. Groups may also stay on the island for a day trip or overnight for a five day trip. The Raniero's boat house houses 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.

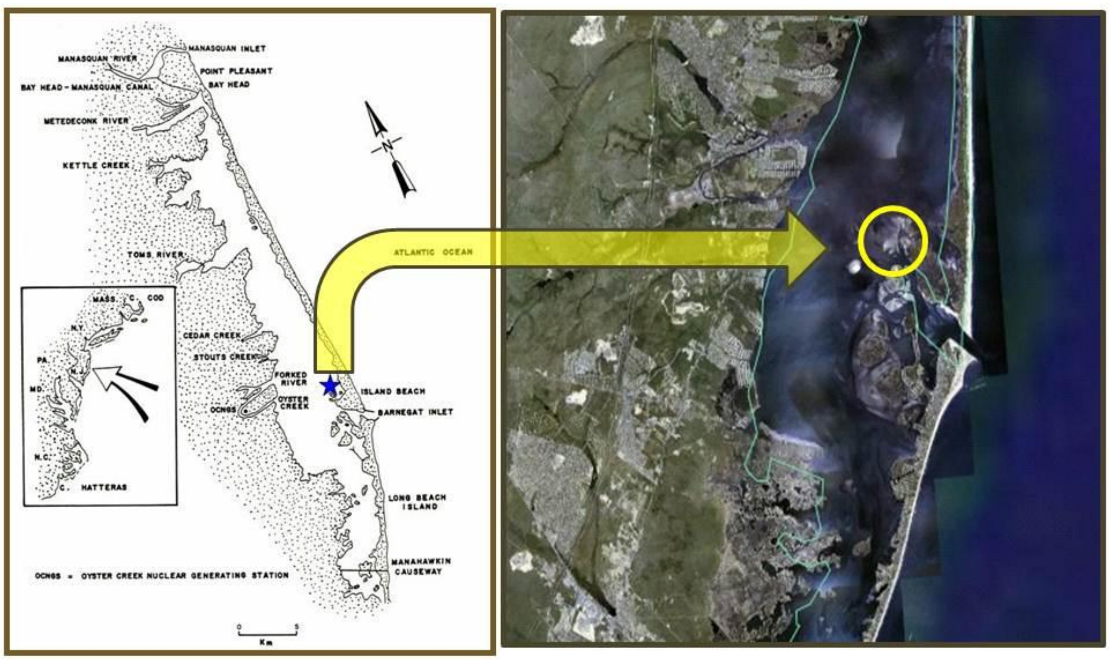

Figure 1. Barnegat Bay, NJ with North Sedge Island (yellow circle/ blue star). Map courtesy of Dr. John Wnek.

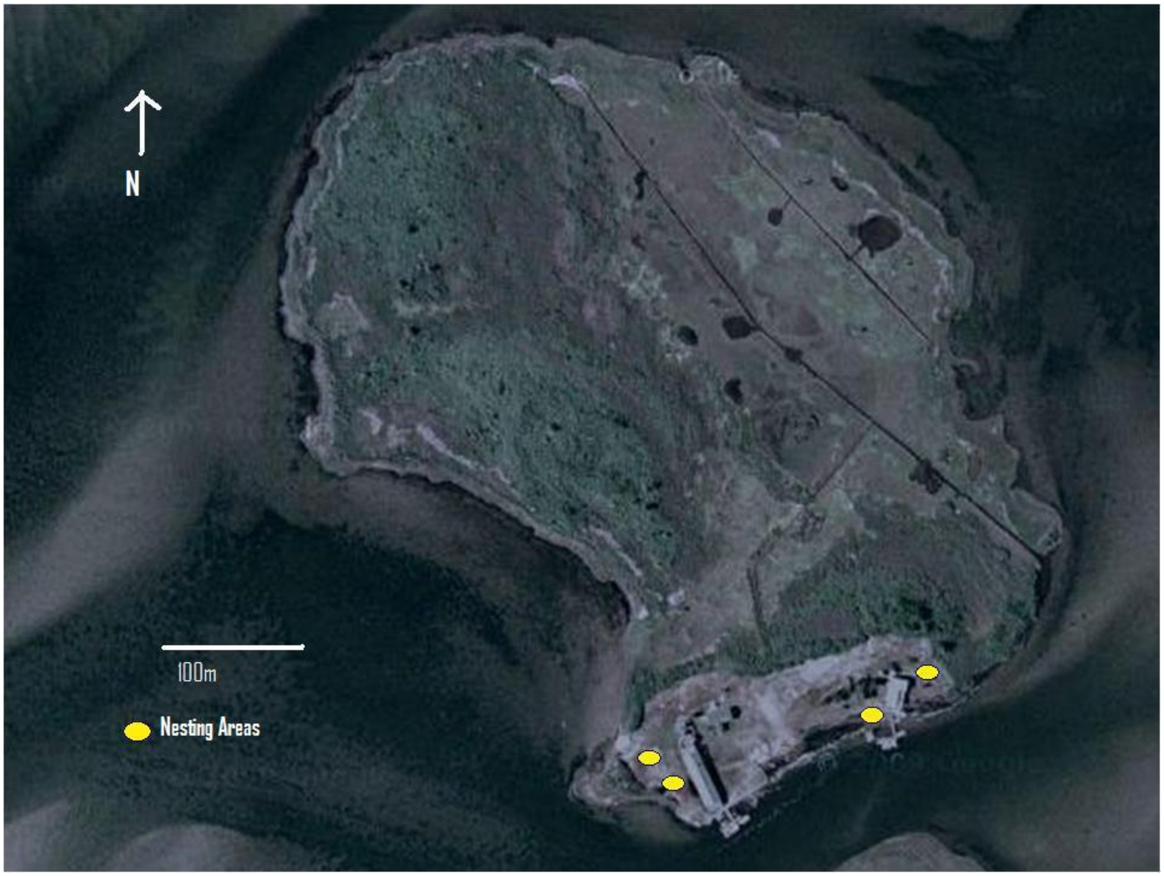

Figure 2. A closer image of North Sedge Island. Google maps. Yellow circles highlight nesting areas.

Processing Terrapins:

Since my research focuses on two separate factors affecting nesting frequency, I divided my project into two specific aims representing each factor. I looked at each factor independently of the other. While the methods of quantifying the factors are different, the methods of processing terrapins remain the same for both aims.

First, I would wait along with my team of Project Terrapin interns for a nesting terrapin (Fig. 3). We would then catch the terrapin if she returned to the water or finished laying her clutch. Some terrapins were captured from residents on the island while we were absent and we would process them the following day. Processing the terrapin entailed us recording her designated notch code and PIT tag number as well as taking physical measurements and recording the date and time that she landed (Fig. 3). This temporal data as well as a count of terrapin landings were applied to my research. I visited the island 4-5 times a week between the hours of 8:00a.m.-12:00p.m. to process terrapins.

Figure 3. Nesting terrapin (left). Notching a captured terrapin with a dremel tool (right).

Specific Aim 1: Human Activity vs. Nesting Frequency

Two sets of trail cameras (TM1550) were placed on the West Lawn of North Sedge Island from June 8, 2012- July 17, 2012 since the West Lawn of the island experiences the most terrapin landings (Fig. 4). Human activity was quantified with the number of human crossings through each camera. I named the cameras according their passwords: Camera 1004 and Camera 1001. Camera 1001's lens was located at 0575454/ 4405345 UTMs, with its receiver was located at 0575441/4405345 UTMs. Camera 1004's lens was located at 057545/4405361 UTMs, with its receiver at 0575441/4405345 UTMs. Figure 5 shows the location of the cameras relative to the study site. We recorded each camera's data 4-5 times a week.

Figure 5. Trail cameras 1004 (orange) and 1001(blue) on South side of North Sedge Island.

Specific Aim 2: Water Temperature vs. Nesting Frequency

Two HOBO® Pendants to monitor water temperature and one TidbiT® to monitor air temperature were set on North Sedge Island from May 27, 2012- July 17, 2012. All devices recorded temperatures at 10 minute intervals with +/-0.2°C error. HOBO® pendant 1(Fig. 6) was installed with zip ties in the clam bed on the West side of the island. HOBO® pendant 2 (Fig. 6) was placed in a mesh bag and tied to a string that hung in the water channel off the Raniero Dock on the Southeast side of the island. Both HOBO® pendants were placed in the water column.

The TidbiT® was installed below the North deck of the Sedge House (Fig. 6). All devices were cleaned and maintained 4-5times a week along with relative temperature recorded and compared using a WSI device. The data on the devices were collected on July 17, 2012 (Figure 6). The location of the devices can be seen in Figure 7.

Figure 6. HOBO® pendant 1 fastened to clam bed pole (Top-left). HOBO® pendant 2 tied in black zip bag (Top-middle). TidbiT® being installed into north deck of the Sedge House (Top-right). Uploading data from HOBO® device (Bottom).

Figure 7. Location of HOBO® pendants (green circle) and TidbiT® (purple circle) on South side of North Sedge Island.

RESULTS:

Terrapin landing counts taken from processing terrapins were compared with the data taken using the TM1550 trail cameras and the HOBO® / TidbiT® pendants. Terrapin landings are used interchangeably with terrapin nestings because terrapins that land during nesting season (late May to mid July), are landing to nest. Terrapin landings compared to date can be seen in

Figure 8B. There were most landings on June 15, 2012 with most landings occurring between 8:00a.m. and 10p.m. (Figure 8).

Specific Aim 1: Human Activity vs. Nesting Activity

A regression analysis suggested there were no significant correlations when comparing human crossings to terrapin landings. However human crossings ≥50 was closer to being significant, with many days with no terrapin landings (Table 1).

When comparing human activity to date, there were sudden decreases of terrapin activities following days of human activity ≥100 human crossings (Figure 9). There were the most human crossings (321) on July 12, 2012. 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 June 30, 2012 (loose camera) and July 8, 2012 (children observed playing with camera). The data from these dates were removed from the overall data. When comparing human activity to time, there were many crossings at 11:00a.m. and 6:00p.m. (Fig. 10).

Throughout this study, I found some trends in my observations. On days when groups would clam in the clam bed outside the West Lawn, terrapins would not land. Also, I noticed that some people would not keep their distance from nesting terrapins, with some not noticing that the terrapin is there. The terrapin would halt her nesting and hiss as humans passed closely (Fig.11).

Figure 11. Clammers pass closely to nesting terrapin. July 5, 2012.

Specific Aim 2: Water Temperature vs. Nesting Frequency

A regression analysis suggested that no significant correlations were found between water temperature and nesting frequency. Water temperature was ~2.0°C warmer in clam bed compared to the Southeast end of North Sedge Island but still had similar tidal patterns to the temperatures from the Raniero Dock(Fig. 12). Relatively colder tidal patterns were highlighted as cold water events. Cold water events consisted of Nor'easter storms and upwelling events that would bring colder, nutrient rich water to the area.

There was a significant inverse correlation when categorized at 1.9°C intervals (Table 2) with temperatures <20°C and >30°C removed since terrapins are not as active during those temperatures (Fig. 13).

Air temperature did not show a significant correlation or any trends in data as compared with nesting frequency and was removed from our data.

Discussion:

Specific Aim 1: Human Activity vs. Nesting Frequency

Human crossings of six can be estimated at one person walking past both cameras multiple times. Although no significant correlation could be found, some vital observations can be made. When observing terrapin landings vs. time, terrapins had the most landings between 8:00a.m.-10:00a.m. (Fig. 8B). This is unusual compared to nesting times observed in 2007, 2008 and 2009 which had their most active time between 9:00a.m.-12:00p.m. (Fig. 14). The most common landing times (8:00a.m.-10:00a.m.) occurred with ≤12 human crossings, as highlighted with red in Figure 10. However, at 10:17a.m., human crossings spiked to 18, which may have caused a sudden decrease in terrapin landings (Fig. 10).

When observing terrapin landings vs. date, days with sudden decreases in terrapin landings were observed following days with ≥100 human crossings (green boxes, Fig. 9). One example that demonstrates this was observed on June 15 and June 16. On June 15, 2012, there were 76 human crossings and 10 terrapin landings. On June 16, 2012, human crossings spiked to 244 and there were no terrapin landings. Another event that portrayed a human crossing inverse effect on terrapin landing can be observed on June 11 and June 12. On June 11, 2012, there were 2 terrapin landings observed with 99 human crossings. Once human crossings increase to 109 on June 12, 2012, there were no terrapin landings. This causes me to believe that there may be a 100 human crossing threshold that may severely decrease diamondback terrapin landings.

A lingering effect of human activity can also be observed in Figure 9, as represented with the asterisk. After having a day of 327 crossings on July 12, 2012 there were no landing terrapins on June 13, 2012(Fig. 9). There continued to be no landing terrapins until July 15, 2012. This continuation of no landings may be explained by a lingering effect of human activity. It is not until the human activity is decreased to 4 human crossings that terrapins return to land (blue box, Fig. 9). This may show that terrapins will not return after a highly active day until the activity is dramatically decreased.

Similarly, Bowen and Jenzen (2008) observed the effects of human activity on the nesting of painted turtles and also did not observe a significant correlation. However, they emphasize that while in general terms, human activity may not significantly affect nesting, individual actions should still be taking into account and observed.

Specific Aim 2: Water Temperature vs. Nesting Frequency

Water temperatures in the clam bed and Raniero Dock both suggested similar tidal patterns, although the clam bed may have been slightly warmer as a result of heating of the shallower water. The cold water events are characterized by relatively cooler tidal patterns. Cold water events that occurred during my research include a Nor'easter storm, July 3-8, 2012 (purple boxes; Fig. 12) and 2 upwelling events, June 25-28,2012 and July 13-16, 2012(green boxes; Fig. 12). When comparing these dates to the terrapin landing dates (Fig. 8A), terrapin landings were less frequent with most dates consisting of no or few landings.

There was an inverse significant correlation when comparing categorized temperatures to terrapin landings (Fig. 12). This may infer that warmer temperatures due to climate change can shift nesting season to be earlier in the year. This may explain the observation of an early start to the nesting season this year and it may be possible that the warmer water temperature is the cause of this.

Conservation Practices:

I suggest the reduction of human activity on the West Lawn of North Sedge Island from late May- mid July between 8:00a.m-11:00a.m. for optimal diamondback terrapin nesting. Also, during and a few days after an influx of nesting activity, human activity should be reduced to 50 crossings (~10 people) or less.

In addition, I cannot stress enough the importance of reducing emissions to slow climate change. Further studies can embellish and may even find significant correlations between the factors we have studied.

My research fulfills two points of the Governor's 10-Point Plan for Barnegat Bay: 1) educating the public and 2) filling gaps in research. While on the island, I educated visiting groups about nesting ecology. I also presented my work at the Save Barnegat Bay Student Grant Presentations and plan to present my findings at upcoming conferences. In addition, I have filled gaps in terrapin nesting and behavioral ecology based on environmental factors.

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Table 1. Human crossings ≥50 vs. landings. No significant correlation. r^2=0.138

Date	Human crossings	Terrapins
13-Jul	50	0
21-Jun	52	2
19-Jun	62	4
5-Jul	71	3
15-Jun	76	10
27-Jun	82	2
6-Jul	84	1
9-Jun	85	7
11-Jun	99	2
12-Jun	109	0
11-Jul	111	0
14-Jul	131	0
16-Jun	244	0
12-Jul	327	0

Table 2. Categories of temperatures compared to terrapin landings.

Temperature Categories	Terrapin Landings
less than 20	2
20-21.9	21
22-23.9	18
24-25.9	15
26-27.9	10
over 28	2

LIST OF FIGURES

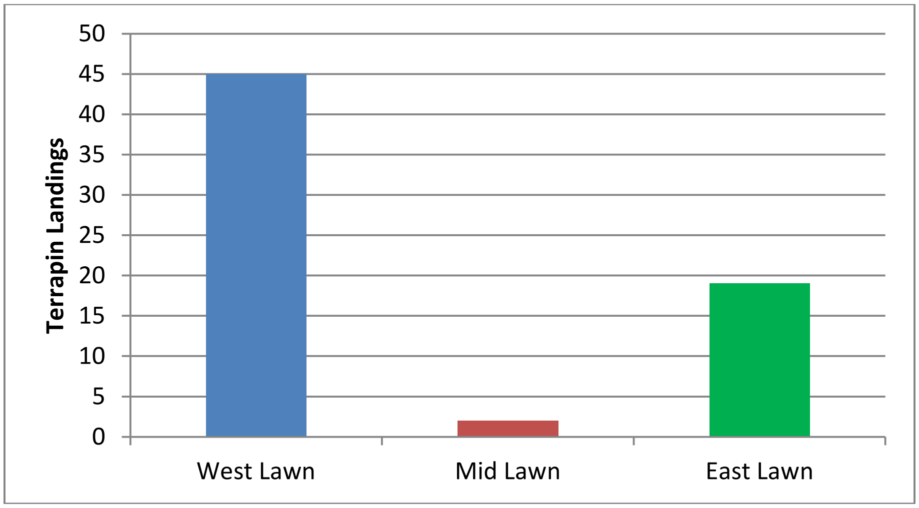
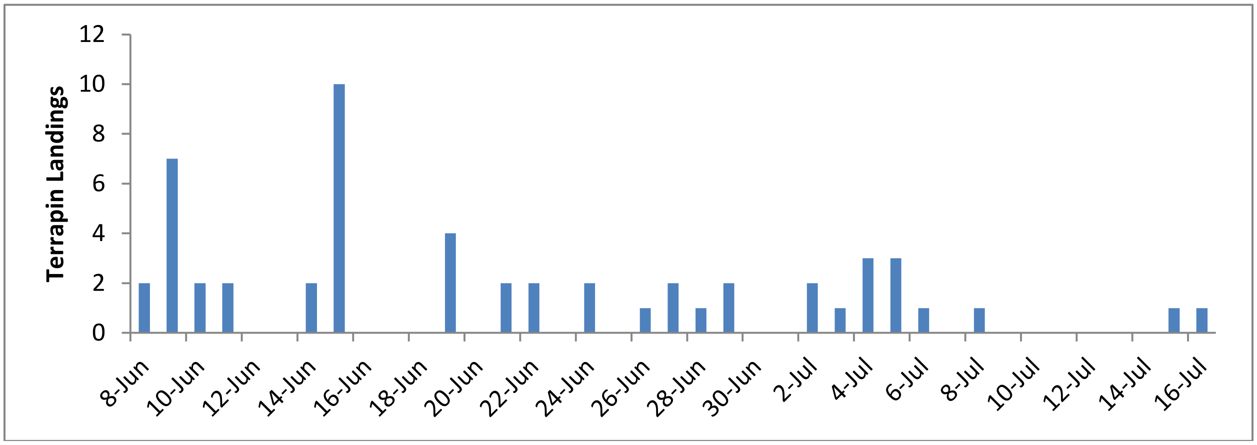


Figure 4. Number of terrapin landings on North Sedge Island by location from May 27,2012-July 17, 2012. The West Lawn had the most terrapin landings.

A.



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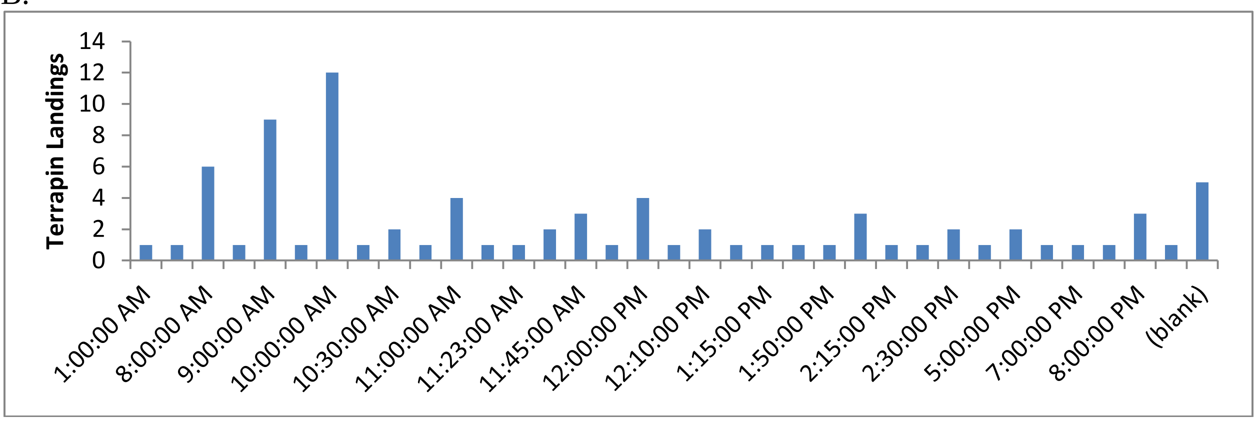


Figure 8. (A)Terrapin Landings vs. Date and (B) Terrapin Landings vs. Time. Most terrapins landed on June 15 and between 8:00a.m. – 10:00a.m.

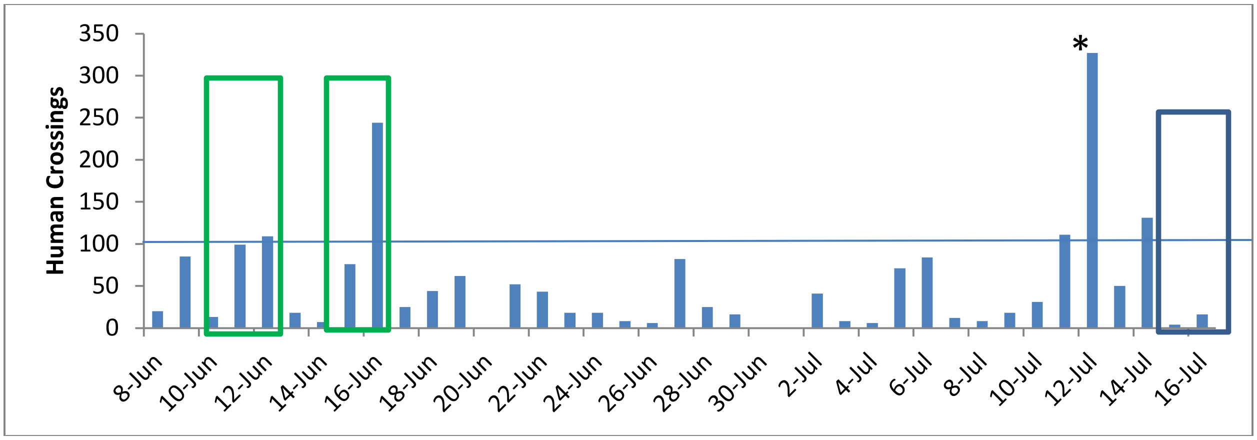


Figure 9. Human Crossings vs. Date. Crossings ≥100 (green boxes). Sudden decrease in human activity (Blue box). Lingering effect (asterisk). There was no correlation between human crossings and nesting frequency (P=0.19, r^2=0.14)

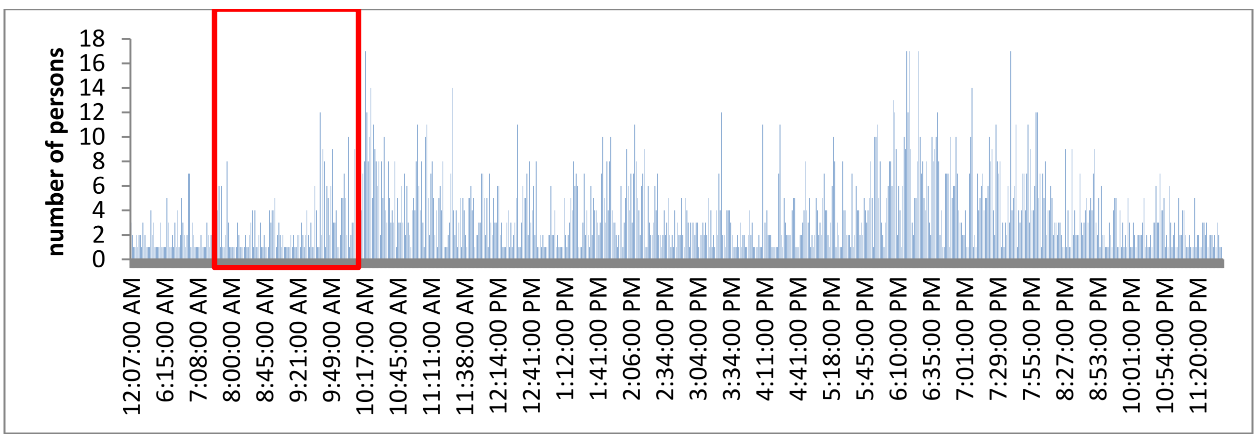
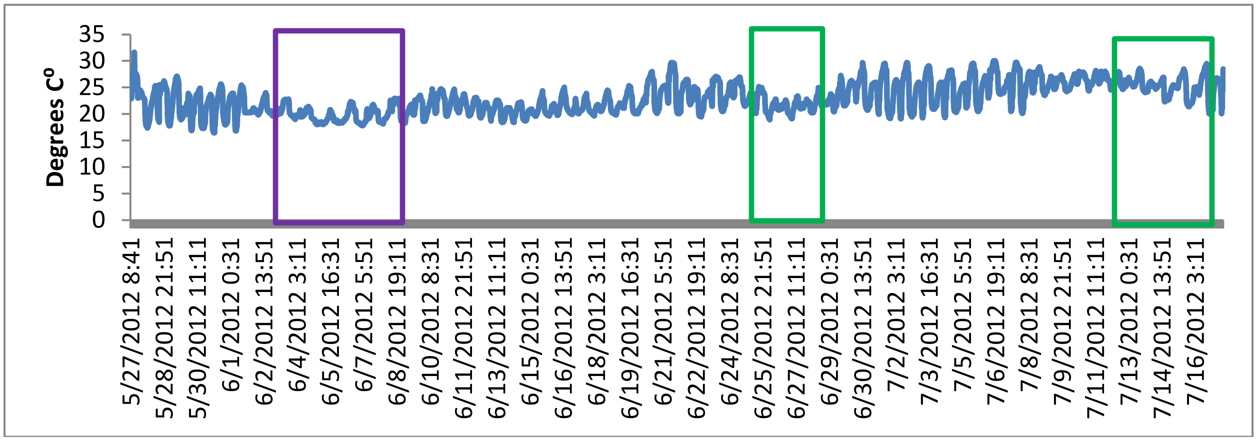


Figure 10. Human Crossings vs. Time. Most terrapin landings occurred between 8:00a.m.-10:00a.m. (red box). There was a sudden increase of human activity at a mean time of 10:17am. with a significant correlation between time and nesting frequency (P=0.003, r^2=0.24)

A.



B.

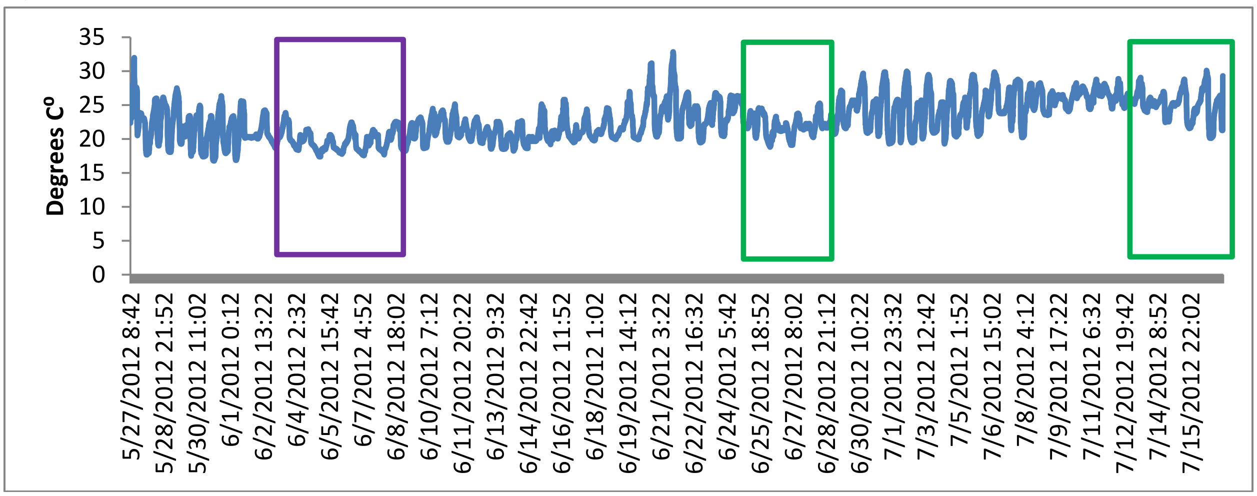


Figure 12. Raniero Dock temperatures (A) and clam bed temperatures (B). There was a reduction in mean temperatures in the highlighted areas. There was a Nor'easter event (purple box; June 3-8, 2012) and two upwelling events (green box; June 25-28, 2012 & July 13-16, 2012).

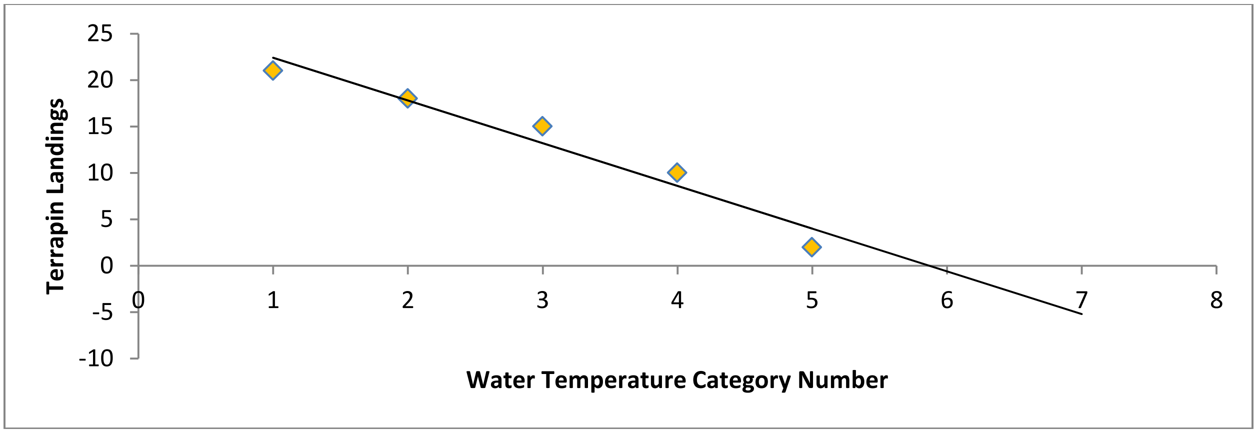


Figure 13. Categorized Temperatures vs. Terrapin Landing. Temperature Categories (°C): 20-21.9 (1), 22.0-23.9 (2), 24.0-25.9 (3), 26.0-27.9 (4), 28.0-29.9 (5). There was a strong inverse correlation with terrapin landings and water temperatures per category ($P<0.0001$ and $r^2 = 0.9497$)

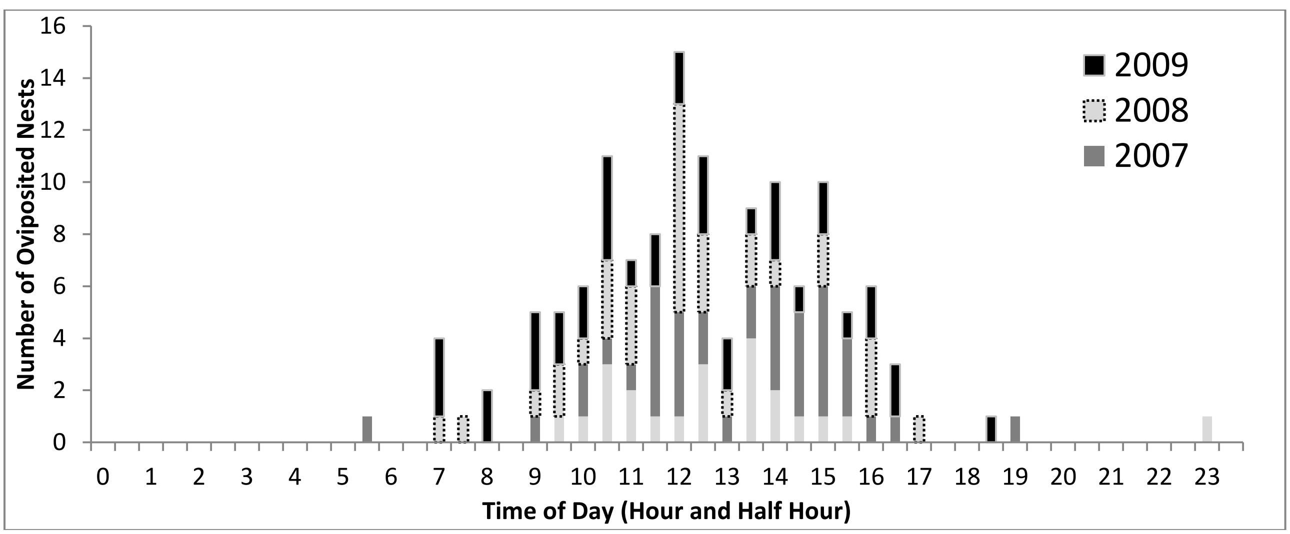


Figure 14. Distribution of nesting time at N. Sedge Island from 2006 – 2009 (Wnek 2010). Notice the peak nesting hours were between 10 a.m. and 12:30 p.m. In 2012, there was a shift in nesting to earlier in the morning (possibly a result of increased activity after 10:00 a.m.)