

ABUNDANCE AND MOVEMENT OF THE TEXAS DIAMONDBACK TERRAPIN
IN THE DEER ISLAND COMPLEX, GALVESTON, TEXAS

by

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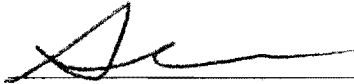
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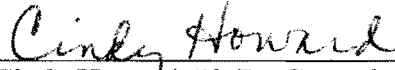
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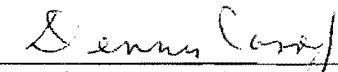
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ABSTRACT

ABUNDANCE AND MOVEMENT OF THE TEXAS DIAMONDBACK TERRAPIN IN THE DEER ISLAND COMPLEX, GALVESTON, TEXAS

Kelli Haskett, M.S.
The University of Houston Clear Lake, 2011

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A total of 151 diamondback terrapins were captured on North and South Deer Islands between March 2008 and February 2009, including 12 recaptures. Nearly 60% of terrapin captures occurred within the channels that span the length of South Deer Island. The average terrapin catch per hour of effort was 1.2. The average recapture period was 92 days with travel distances ranging from 44 to 414 meters and averaging 169 meters. Greater population readings were found throughout April and May, while populations dramatically dropped from September 2008 through February 2009. Biological data collected on terrapins indicated a male to female sex ratio of 1.1 to 1. An average of 6 growth rings were counted on male terrapins and an average of 8 growth rings were counted on female terrapins. Females were significantly larger than males in all measurements. The average carapace lengths for male and female terrapins were 131.7

cm (SD=7.6) and 186 cm (SD=27.3) respectively. Mean plastron lengths for male and female terrapins were 111.1 (SD=6.4) and 164.2 (SD=21.4), respectively. The average male weight (.38 kg, SD=.07) was significantly smaller than the mean female weight (1.2 kg, SD=.36). Six terrapins were fitted with radio transmitters. One female on South Deer Island was tracked 30.9 meters away from her original capture location, 7 days later. *Spartina alterniflora* and *Salicornia depressa* were the two dominant vegetation types recorded near collected terrapins. No nesting behavior or nesting sites were discovered during this study.

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INTRODUCTION

Diamondback terrapins are a unique species of North American turtle that ranges along the Atlantic and Gulf Coasts from Cape Cod, MA to Corpus Christi, TX. They are the only species of turtle within the United States to live solely in brackish water. There are seven recognized subspecies of this reptile, differing mostly in coloring and markings (Carr 1946). The Texas Diamondback Terrapin (*M. terrapin littoralis*) has a range that extends from western Louisiana to Corpus Christi, TX (Brennessel 2006). Based on the terrapin subspecies that have been studied, data suggests that throughout the terrapins' range, the species as a whole is experiencing a population decline (Siegel 1993, Seigel and Gibbons 1995, Gibbons et. al 2001, Mitro 2003).

As suggested by their names, diamondback terrapins have diamond-shaped markings on their shell and various black shapes that mark their light skin. In contrast to true marine turtles, diamondback terrapins are relatively small. The males' carapace length extends up to 12.7 centimeters while the females' carapace length can be as large as 22.9 centimeters (Bossaro and Draud 2004).

Turtles, tortoises, and terrapins are classified within the order Chelonia. Terrapins in turn are members of the family Emydidae, which contains mostly aquatic turtle species including their closest relative, the freshwater map turtle. Two unique features of terrapins is their ability to live in the brackish water found in estuaries, and that they spend a significant portion of their lives on land. Research has shown that terrapin hatchlings and juveniles stay on land hidden within the wetland plants for up to three years (Brennessel 2006). Once they grow to an adequate size to avoid predators, they move into adjacent coastal wetland waters. Terrapins share a combination of features present in both freshwater and sea turtles. Specifically, they lack the flippers found on sea turtles, and instead have the webbed feet, similar to freshwater turtles. However, they are similar to sea turtles in that they also have a salt gland, which freshwater turtles and tortoises lack. Due to their ability to live in an environment too harsh for other freshwater turtle species, diamondback terrapins may avoid direct competition with other turtles for space, food, and nesting sites.

Brennessel (2006) stated that though diamondback terrapins can spend several weeks in full strength seawater, they can become osmotically dehydrated by the high salt

concentration. This is because the terrapin salt gland is less effective than that of sea turtles. However, terrapin appear to thrive in brackish water. For example, a common problem with captive terrapins raised in freshwater environments is the development of fungus on the terrapins' skin, which disappears when salt is added. It appears that coastal brackish waters are the ecological niche of the diamondback terrapin. This environment results in an area free of competition from many other animals including all other species of turtles.

Terrapins have also adapted to temperature fluctuations found in estuarine wetlands. All aquatic turtles, including the diamondback terrapin, brumate during the cooler times of the year. This is a type of reptile hibernation where the turtles burrow in the mud at the bottom and sides of creeks, and remain submerged under the water for months at a time. Although these turtles have a unique ability to go extended periods without oxygen, it is thought that there may be enough dissolved oxygen in the water to sustain them during this time (Brennessel 2006). During this period, much of their metabolic activity ceases, and they remain dormant until water temperatures increase. Diamondback terrapins can compensate for freezing temperatures by supercooling. This condition allows the body fluids to remain liquid at temperatures below their freezing point. Certain turtle species can undergo supercooling based on their body size and ability to purge ingested material from their stomachs (Baker et. al 2006). The material in their gut would otherwise promote freezing of bodily fluids. Additionally, avoiding contact with ice or ice nucleating agents is an important factor in the success of supercooling. Diamondback terrapins can also tolerate the freezing of their body fluids. In this case ice actually forms around the tissues. Although the mechanisms of this physiological ability are not fully understood, it is thought that the build up of lactate in the body functions to prevent death when the animals are exposed to such conditions. Diamondback terrapins can use either of these approaches when the cold weather becomes too harsh (Baker et al. 2006).

The lifespan of a diamondback terrapin is thought to be 40 years (Brennessel 2006). Determination of age is beneficial in correlating habitat and diet preferences at different life stages. Current literature suggests that juvenile terrapins remain in the marsh areas hidden by the tall grasses and vegetation mats for the first several years of

their life. The vegetation is thought to provide protection, temperature stability, and plentiful prey species for the terrapins until reaching a size where they are less vulnerable to environmental fluctuations and predators (Lovich, et.al 1991). Terrapins are also thought to sexually mature based on size and not age as many other animals do. Therefore, simultaneously recording size and age of a terrapin is helpful in determining the starting point for a particular animal's potential production of offspring.

Unless a turtle is notched or tagged, or has been in captivity throughout its life, determining an accurate age of that animal is nearly impossible. A method that is frequently used by scientists to estimate the age of turtles is counting scute rings (Legler 1960). Similar to the annual rings that appear within a tree trunk, turtles form rings on the inside of each scute. These rings are visible on both the carapace and the plastron. Most turtles are surrounded in a protective shell made up of epidermal scutes with an underlying dermal bone (Wilson 2003). The epidermal layers consist of dead keratin that sheds as the turtle matures. In many species, including the diamondback terrapin, when the old layer of keratin is shed during growth, a new layer is formed below it leaving an impression on the shell (Legler 1960). These impressions are called growth rings.

For many turtle species it is unknown if scute rings are formed annually or are caused by changing environmental conditions. In desert tortoises, a single new growth ring establishes annually only 20 percent of the time (Nichols 1939). Other studies have found that red-eared sliders show annual growth rings up to the age of 3. This is followed by a variable number of rings per year during the later stages of life (Cagle 1946).

A new growth ring is believed to form when growth halts. This can be a result of a dormant period in the winter months or an extended period of drought or flooding conditions when prey is scarce (Berry 2002). During these periods of slow growth, a depression may form in the scute, which can appear as an incomplete growth ring. These "false" rings are often misidentified as a growth ring, adding to the difficulty of aging terrapins (Wilson 2003).

In addition to environmental factors playing a role in growth ring formation, ring development may also be influenced by life stage. In one study conducted by Moll and Legler (1971), adult red-eared sliders had reduced growth after they reached sexual

maturity, a time when energy is more focused on reproduction. Additionally, body size has been suggested to be a potential factor affecting the number of rings added to the scutes of a turtle. The growth rings may form to provide structural support of the shell as it becomes larger (Wilson 2003). Finally, growth ring deposition has been found to vary based on the specific species of turtle being studied.

The meat from diamondback terrapins was considered a delicacy by Native Americans, European settlers, and other ethnic groups (Garber 1990). Even today consumption of terrapin meat is considered a rare delicacy in part of Louisiana (Guillen per. comm. – interview with coastal resident). For this reason, the harvesting of terrapins was common starting in the late 1800's (Bossero and Draud 2004). It was not until the economic collapse of the Great Depression that the demand for terrapin meat declined. Prohibition most likely reduced the desire for terrapin meat indirectly, due to the fact that sherry was a fundamental ingredient in many terrapin stew recipes.

Although terrapin numbers slowly began to recover, new factors now threaten their existence. Coastal development continues to reduce terrapin habitat and nesting areas (Roosenburg 1994). Female diamondback terrapins return to the same areas to nest annually. Unnatural structures such as bulkheads or fencing can prevent them from reaching their desired location. These man-made barriers can also affect water levels leading to inundation and drowning of the embryos (Hogan 2002). Many female terrapins are also killed while trying to cross coastal roads to lay their eggs (Bossero & Draud 2004). Additionally, many estuaries in which diamondback terrapins are found have become polluted by wastes, runoff, and pesticides (Garber 1990). These water bodies normally support the production of phytoplankton that feed invertebrates, worms, snails, mollusks and crustaceans (Brennessel 2006). These organisms are the primary food source of the diamondback terrapin. Likewise, predation is another factor that can reduce terrapin population levels. Hatchlings and juveniles are preyed upon by many bird and mammal species, which can substantially diminish their population size. A study conducted at a New York wildlife refuge island revealed that raccoons depredated 92.2% of terrapin nests (Feinberg and Burke 2003). In a similar study, with the creation of artificial nests, an investigator documented a 48% depredation rate (Burke et al. 2005). Most (71%) of the nests were depredated on the first night. Recent data suggest that

collisions with watercraft may be a significant source of terrapin mortality and limb loss (Cecala et al.2008).

Commercial crab traps can also account for many terrapin deaths. After the terrapins enter the traps to eat the bait, they cannot exit and soon drown (Garber 1990). Two states have concluded that terrapin crab trap bycatch mortality is high enough to negatively impact terrapin populations. New Jersey law requires that all commercial crab traps deployed in a water body less than 150 feet wide at low tide or in a man-made lagoon include terrapin excluder devices (NJ Fish and Game 1998). Maryland requires crab traps set for recreational purposes contain turtle reduction devices (Maryland DNR 1999). Although Texas recently passed a law that prohibits the “take” of native turtle species without a permit, there is no requirement for terrapin bycatch reduction devices on crab traps within waters of the state.

The depletion of the diamondback terrapin may have detrimental consequences to the entire coastal ecosystem. These small reptiles function as top-level predators in wetlands, and may serve as keystone species, which control the structure of estuarine food webs (Tucker et al. 1995). Their diet mainly consists of bivalves, snails, and crabs (Davenport et al. 1992; Tucker et al. 1995). Consequently, reductions in terrapin populations could lead to an increase in the amount of primary consumers, which could lead to increased herbivory of native emergent vegetation. Additionally, terrapin and terrapin hatchlings serve as food sources for many birds and native animals along the coast (Burger 1977, Butler et.al. 2004, Clark 1982). In addition to population losses caused by habitat degradation and predation, terrapins exhibit low birth rates, which further reduce their ability to recover from low population levels. A female terrapin breeds every four years and does not reach sexual maturity until the age of six (Texas Parks & Wildlife Department 2007).

Due to a combination of demographic factors, including low birth rates and potentially high mortality rates from both natural and anthropogenic sources, the population viability of diamondback terrapin throughout their range has become an increasing concern to natural resource managers. Most research on terrapin demographics began after terrapin populations had been reduced by many years of harvest for the food industry. Therefore, little to no information is available about natural

terrapin population levels throughout the United States (Tucker et al. 2001). However, limited data suggests that population numbers have declined (Seigel and Gibbons 1995). This has led several states to provide protection status for the diamondback terrapins. Terrapin collection has been prohibited by the states of Rhode Island, Massachusetts, and Alabama (Watters 2004). Additionally, Mississippi and North Carolina do not allow commercial collection of diamondback terrapins. Many other states within the range of diamondback terrapins provide at least some protection through permits, seasons, bag limits, or collection method restrictions. They were recently afforded protection in Texas and can no longer be collected for personal or commercial use (Texas Administrative Code 2011).

Collection restrictions in many of these states have been set in place due to a lack of population data regarding diamondback terrapin populations. For example, little information has been gathered on the demographics and population viability of local Texas populations. One study conducted in 1984 by Texas Parks and Wildlife Department, surveyed fishermen, commercial crab trappers, biologists, and game wardens to determine sightings of the Texas diamondback terrapin along the Texas coast (D.W. Mabie 1988 written communication cited in Hogan 2002). This survey reported terrapin observations at various locations from Nueces Bay to Galveston Bay from 1973 to 1984. In 1997, 109 Texas diamondback terrapins were captured near Nueces Bay and the mouth of the Nueces River near Corpus Christi, Texas (K.A. Holdboork and L.F. Elliot, written communication 2000, cited in Hogan 2002). Huffman (1997) compiled data on sightings of diamondback terrapins in several bays near Galveston. Additionally, he surveyed the North Deer Island complex in West Bay, Galveston, TX, where one terrapin was captured. One hundred and thirty five Texas diamondback terrapins were captured at South Deer Island, Galveston, Texas during another study conducted from April 2001 to May 2002 (Hogan 2002). Due to the small number of terrapins caught in these studies, population and range estimates have not been conducted.

The goal of this study was to estimate population densities and describe the demographics and habitat use of Texas diamondback terrapins in the Deer Island complex of West Bay. The study was primarily descriptive in nature with the goal of producing statistical estimates of primary population parameters. The objectives of this

study are to gather baseline population data on Texas diamondback terrapins in the Deer Island Complex in order to monitor population trends over time. The data collected will help future researchers observe the health of this local population and identify trends that threaten its stability. The two study islands were chosen since historical data collected by Hogan (2002) documented the presence of terrapins on South Deer Island. In addition, the isolated, minimally disturbed nature of these islands provided an opportunity to estimate population demographics and habitat use in the absence of major human disturbance. Data collected on these islands will provide an important preliminary assessment of the potential densities of terrapin that may exist in similar estuarine habitats in West Bay and other adjacent water bodies. Additionally, data gathered in this study will provide information on where other terrapin populations may be located throughout Texas. A secondary goal of the project was to develop a standard protocol for future more extensive surveys to be conducted in order to identify if terrapins in Texas should become a state listed species. This research represents the first serious attempt to gather information on the Texas diamondback terrapin population numbers and home ranges in West Bay, Galveston. This study, unlike Hogan's (2002) included North Deer Island.

MATERIALS AND METHODS

The study sites South and North Deer Islands are located in West Bay and are part of the Galveston Bay complex, immediately north of Galveston Island, Texas (figures 1 and 2). South Deer Island is a privately owned island and served as the primary study area. It has an approximate perimeter of 2.71 kilometers and an area of 24.36 hectares. The elevation ranged between sea level and approximately 1.2 meters, although most of the island is less than 0.3 meters above sea level. The island possesses numerous tidal creeks, small ponds, shell beaches, mud banks, and vegetated areas dominated by *Spartina alterniflora* and *Salicornia*.

North Deer Island, located 1.1 kilometers away from South Deer has much of the same type of habitat and conditions that are present on South Deer Island. However North Deer Island is larger with an approximate perimeter of 5.23 kilometers and an area of 50.62 hectares. It also exhibited a wider range of elevations (sea level to approximately 1.5 to 2.1 meters); however most of the island was below 0.3 to 0.6 meters above sea level.

Monitoring of North Deer Island was limited to water surveys only, as this island is an established bird sanctuary and trespassing on land is prohibited by the owners, the Audubon Society, in order to protect nesting colonial waterbirds. Therefore, only about one tenth of the total effort was expended on North Deer Island.

In order to support the goals of this study we adopted an objective of monitoring terrapin populations on South Deer Island on a weekly to bi-weekly basis during most months of the year, extending from March 2008 to February 2009 (Appendix A). However, bi-monthly to monthly sampling was generally conducted during the winter months (December to February) due to the lower activity exhibited by this species in cooler temperatures. In addition, less frequent sampling was conducted at North Deer Island.

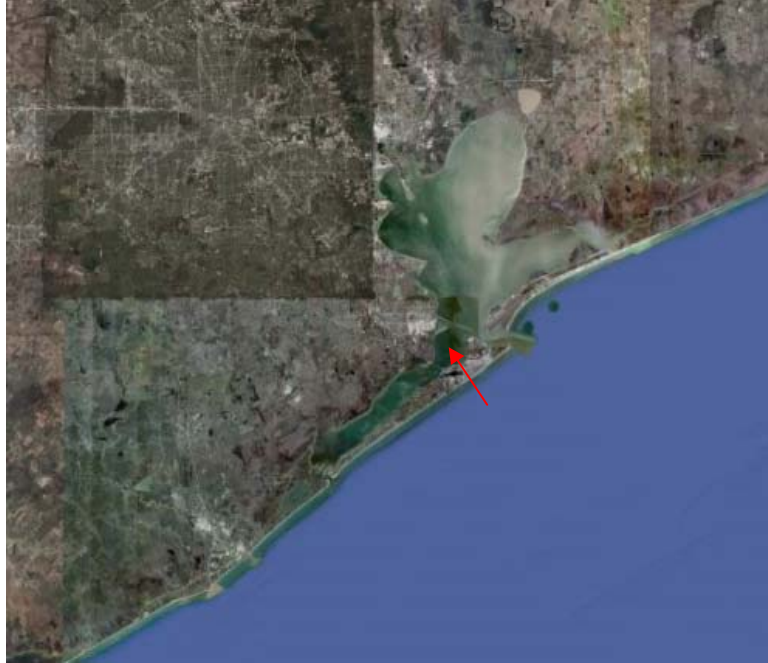


Figure 1. Location of North and South Deer Island in Galveston Bay, Texas.



Figure 2. North and South Deer Islands.

In order to estimate the population size of terrapins on South Deer Island, a Jolly-Seber mark-recapture study design was used (Krebs 1999). Crab traps were originally used as the primary method of capturing terrapins. However, the unsuccessful capture of terrapins with this method led to a change of capture techniques in March 2008 after the first sightings of terrapins on South Deer Island. In the months that followed, terrapins were collected by a combination of methods including shallow-water crab traps, crab traps with modified chimneys, and hand capture of terrapins by researchers. However, the majority of terrapins were captured by hand throughout the study period.

Hand captures of terrapins included both land and shallow water searches. Most of the channels that cut through the islands are less than three feet deep and less than ten feet wide. This allowed researchers to walk through them and grab the terrapins as they swam by. This was particularly successful during low tide stages when shallow water and low turbidity aided researchers in spotting the animals. Land areas were also searched on South Deer Island, including vegetated areas and muddy locations outlining the channels.

Searches were done in a random fashion starting at one of two main channel entrances on South Deer and one main entrance at North Deer Island. If sufficient in number, researchers spread out from the starting position to cover all areas of the island. During times when minimal staff was present, only one or two researchers would follow the channels across the island and search land areas on the way back or vice versa. Time of collection was recorded during all surveys. Each researcher also recorded starting and ending search times, which was necessary to calculate the terrapin search effort time and catch per unit effort.

Due to the low capture rates of terrapins with traps both inside the islands and around the perimeter of Deer Islands; we decided to deploy the modified crab traps only at the mouth of the lagoon at North Deer Island. These crab traps were unlike commercial crab traps in that they were made of a soft mesh material and the entrance openings were larger than those of standard crab traps. This was thought to reduce the bias in capture of the smaller male terrapins over female terrapins, which as adults are unlikely to fit inside a standard crab trap opening. In order to reduce the risk of terrapin mortality, these traps were also placed in a much shallower environment than standard

commercial crab traps. The traps in this study were fitted with modified chimneys so that the terrapins could surface for air. However, even with the chimneys attached the traps could not be deployed in water over 4.5 feet deep (Figure 3).



Figure 3. Modified crab trap used to catch terrapins.

In order to utilize the Jolly Seber population method, individual terrapin need to be recognized (Krebs 1999). This was done by first capturing and marking individual terrapins, releasing them, and recapturing them at a later date. Each terrapin was individually marked externally and internally tagged to distinguish it from the others.

External marking consisted of marginal carapace scutes that were notched with a metal file following a system that marks each terrapin with a unique number (Figures 4 and 5) (Cagle 1939). These external notches also provide a means for quick visual identification of previously captured animals.

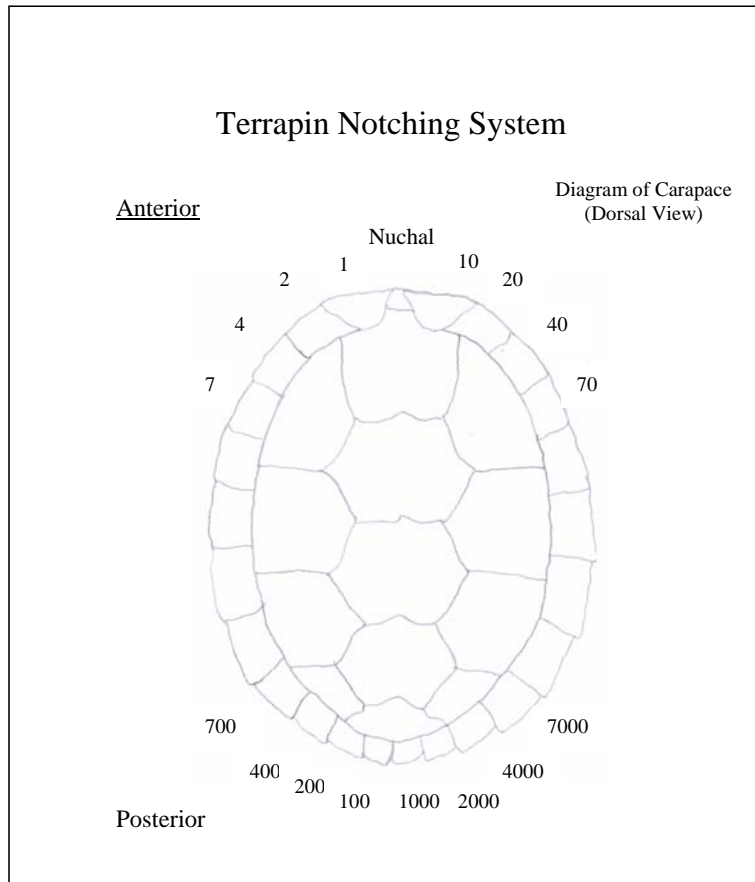


Figure 4. Modified Cagle marking system used to notch terrapin (Cagle 1939).



Figure 5. Notching method used to externally mark individual terrapin using Cagle system.

A more permanent and reliable marking method was also used in the form of Passive Integrated Transponder (PIT) tags (Figure 6). These tags, initially provided by Texas Parks and Wildlife Department, also provide a source of individual identification for the terrapins. These tiny devices have been used since the mid-1980's to successfully provide long-term identification of reptiles in scientific studies (Ferner 2007). They ranged between 10 and 14 mm in length and 2 mm in diameter. The tag consists of an electronic microchip surrounded by biocompatible glass that prevents tissue irritation.



Figure 6. Avid PIT tag, injector, and reader used to identify terrapins.

PIT tags were injected by a 12-gauge needle under the terrapin's skin near the back leg and above the plastron to provide permanent identification for each individual (Figure 7) (Gibbons & Andrews 2004). After allowing the terrapins to join back in with the overall population for several days, subsequent samples were collected from the general population. All sequential terrapin catches were scanned with a PIT tag scanner and if tagged, identified by their personal alphanumeric code. This process was repeated over the course of the study period.



Figure 7. Injection of PIT tags into rear leg of terrapin.

Each diamondback terrapin was also weighed and measured to determine weight, size and relative age distribution and growth rates within populations (Appendix B). Calipers were used to measure carapace length from the nuchal scute down the midline of the carapace, ending between the posterior marginal scutes (Figure 8). Carapace width was measured from the widest point on either side of the carapace. Plastron length was measured from between the gular scutes down the midline of the plastron and ending between the anal scutes. Plastron width was measured posterior to the bridges and perpendicular to the midline. Depth was measured from the highest vertebral scute on the carapace down to the plastron. Head width was measured from the widest point of the terrapin head. Body weight was measured by placing each animal in a mesh bag and hanging the bag from a digital scale (Figure 9). The weight of the bag was then subtracted to obtain a weight measurement for each terrapin.



Figure 8. Measurement of terrapin morphometrics with calipers.

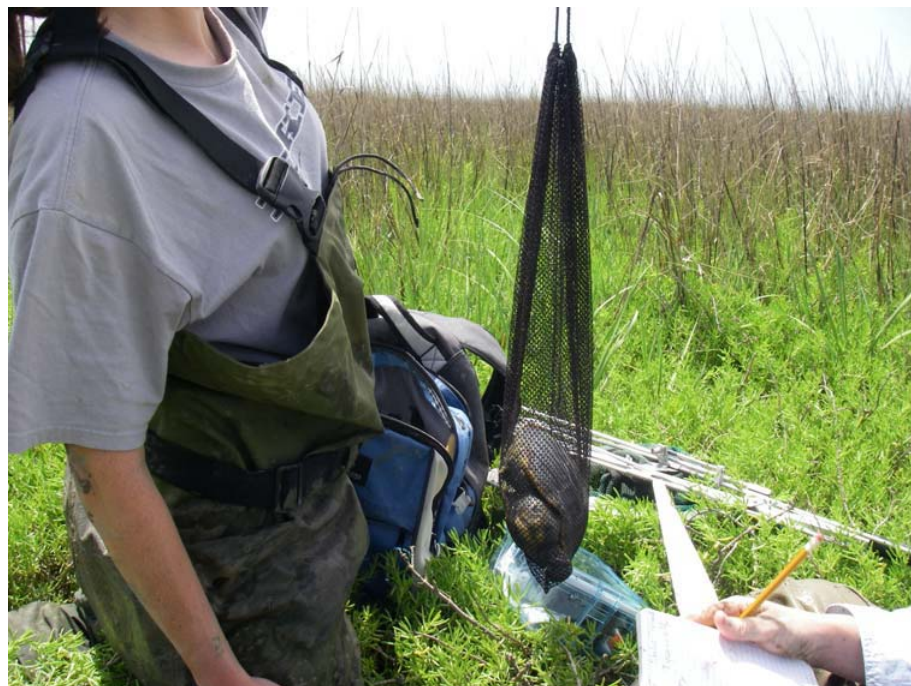


Figure 9. Measurement of terrapin weight with hanging bag and scale.

Growth rings were counted on each terrapin that was captured. The specific scute used to count the rings varied based on the visibility of the rings within the scutes. Without past studies of growth rings on diamondback terrapins along the Texas Coast, it is difficult to determine how many growth rings are added to scutes annually. Despite this lack of past research, terrapin growth rings in this study were counted to give a rough estimation of age. Together with size, the use of growth rings will aid in estimation of relative age.

Male to female sex ratios were determined based on certain secondary sex characteristics such as body and head size, tail size and shape, cloacal opening placement, and carapace shape. Certain turtle species, including diamondback terrapins, exhibit sexual dimorphism (Stephens and Wiens 2009). Females have larger heads, greater body mass, and longer and wider plastron and carapace lengths than do males upon reaching sexual maturity (Hay 1892, Hildebrand 1932). Male terrapins have a longer, thicker tail than females, with a cloacal opening located well past the posterior edge of the carapace.

Terrapin movement was also calculated for recaptured terrapins. This was calculated by measuring the shortest straight-line distance between the location of original capture and the location of recapture. This provides the minimum distance the terrapins traveled between capture times.

Additionally, habitat utilization by Texas diamondback terrapins was quantified during field surveys. Observations made at the time of capture include the GPS location where the animals were captured. Information was also gathered on whether the terrapin were captured on land, in the water, or buried in the mud. Land sightings include information on vegetation and substrate type as well as the distance from the closest channel. Observations made during water collections almost always took place inside the small channels that run the length of the islands. The depth of the water and turbidity during high tide events were the greatest factors prohibiting researchers from capturing terrapin within channels. Depth of water and unlimited escape routes were the greatest factors preventing researchers from capturing terrapin in water surrounding the islands. Observed potential terrapin prey types present on the islands were also noted during field studies. Air and water temperature and salinity were measured at the beginning of each terrapin survey day.

External radiotelemetry tags and manual receivers manufactured by Advanced Telemetry Systems (ATS) were used in this study for the purpose of estimating home ranges, short-term migration patterns, dispersal, and habitat use of diamondback terrapins in West Bay (Garton et al. 2001). Each radio tag had its own unique frequency in order to discern an individual terrapin from the others. The small receivers were attached with epoxy glue to the back of the carapace on the second vertebral scute (Figure 10). This location reduces the probability that the tags will endanger the terrapin or interfere with its daily activities. The tag is also placed to minimize behavioral, physiological, and reproductive effects. Radio transmitters placed on a single front costal scute have been shown not to interfere with a turtle's normal activity (Boarman, et al. 1998). The proportion of tag to animal weight was maintained at less than 5% to reduce impacts on animal movement. Studies have shown the 5% rule to be effective without impairing activity even on flying animals such as the big brown bat (Neubaum et al. 2005). In consideration of this rule, larger terrapins were usually the only animals tagged in order to reach this target weight percentage. Tracking was conducted from both boat and on foot using a Yagi antenna attached to an ATS manual receiver. This apparatus was used to track the short-term movements of each terrapin from North and South Deer Islands in West Bay. Radio tracking was conducted several times each month throughout the study period.



Figure 10. Female terrapin with ATS radio-tag attached.

The Jolly-Seber mark-recapture population estimation method was used to estimate population size (Krebs 1999). This method is designed for estimation of a population size in open systems. This technique takes into account the continuously changing size of the terrapin population as a result of birth, death, immigration, and emigration. An important component of this method is classifying the date that the terrapins are captured. With this information, as each individual is marked, data can be gathered simultaneously on population size and terrapin movements (Krebs 1999). The size of the terrapin population was determined by the ratio of the size of the marked population to the proportion of animals marked. With the Jolly-Seber method, the proportion of animals marked was estimated by the following formula:

$$a_t = \frac{m_t + 1}{n_t + 1}$$

where “+ 1” is the correction for bias in small samples.

The size of the marked population can be measured by using:

$$M_t = \frac{(s_t + 1)Z_t}{R_t + 1} + m_t$$

Finally, the population size can be estimated by using this formula:

$$N_t = \frac{M_t}{a_t}$$

Where N_t = the population size of diamondback terrapin just before sample time t

M_t = the estimated size of the marked population just before sample time t

a_t = proportion of marked diamondback terrapin

m_t = Number of marked diamondback terrapin caught in sample t

u_t = Number of unmarked diamondback terrapin caught in sample t

n_t = Total number of animals caught in sample t

$$= m_t + u_t$$

s_t = Total number of animals released after sample t

$$= (n_t - \text{accidental deaths or removals})$$

Z_t = Number of individuals marked before sample t, not caught in sample t, but caught in some sample after sample t

R_t = Number of the s_t diamondback terrapin released at sample t and caught again in some later sample

This method has been successful in the past in determining population levels and developing management plans for other species of turtles (Mitro 2003).

Statistical data analysis on terrapin morphometrics was conducted using independent group t-tests. Data was summarized using means and measures of variability were reported with standard error and standard deviation. Regression analysis was also conducted to analyze the effect of environmental conditions and search time on terrapin catch per unit effort. Important regression results including p values for the hypothesis test for the slope=0 and r^2 were computed and presented. A 95% confidence interval was used on all significance tests.

RESULTS

Density and Population Estimates

A total of 139 diamondback terrapins were captured on North and South Deer Islands between March 2008 and February 2009 (Figure 11). Additionally, 12 terrapins were recaptured during this period (Figure 12). One terrapin was recaptured an additional third time during the study period. Of the 12 terrapins that were collected a second time, the average time period between captures was 77 days. This includes one individual that was collected one day after the original capture. In addition, one animal was recaptured 258 days after the original collection date.

Following the first terrapin capture, data was collected approximately once per week over a twelve-month period. Tables 1 and 2 show the mark recapture population estimate on each island at each sample time. Each sample represents one day of data collection or two days in cases where collection dates were within several days of each other. Population levels fluctuated considerably. The highest estimated population levels were recorded at South Deer Island during April and May. Although overall numbers dropped during June sampling, the highest monthly peak occurred in a sample taken mid-June. August saw another increase in population size during each sampling period. However, population levels decreased to very low numbers throughout the remaining samples collected from September 2008 through February 2009. Fluctuations in the catch rates appeared to be more of a function of seasonality instead of effort (Figure 13).



Figure 11. Diamondback terrapin capture locations on North and South Deer Island March 2008 to February 2009.



Figure 12. Original capture locations and recapture locations of diamondback terrapins on North and South Deer Island March 2008 to February 2009.

Table 1. Diamondback terrapin population size at sample time on North Deer Island March 2008 to February 2009.

	Marked Catch	Unmarked Catch	Total Catch	Population Size at Sample Time
Sample 1 (4/23/08)	0	4	4	4
Sample 2 (5/2/08)	0	3	3	3
Sample 3 (5/10/08)	0	2	2	9
Sample 4 (5/16/08)	0	6	6	49
Sample 5 (5/21/08)	0	4	4	25
Sample 6 (5/29/08)	1	0	1	1
Sample 7 (5/31/08)	0	0	0	NA
Sample 8 (6/2/08)	0	0	0	NA
Sample 9 (6/14/08)	0	0	0	NA
Sample 10 (6/15/08)	0	0	0	NA
Sample 11 (9/8/2008)	0	1	1	1
Sample 12 (11/3/08)	0	0	0	NA

NA= No catch, population estimate not possible

Table 2. Diamondback terrapin population size at sample time on South Deer Island March 2008 to February 2009.

	Marked Catch	Unmarked Catch	Total Catch	Population Size at Sample Time
Sample 1 (3/27/08, 3/28/08)	0	7	7	7
Sample 2 (4/1/08)	0	7	7	43
Sample 3 (4/7/08)	0	4	4	50
Sample 4 (4/11/08)	0	6	6	123
Sample 5 (4/18/08, 4/19/08)	1	8	9	255
Sample 6 (4/25/08)	0	1	1	20
Sample 7 (4/29/08)	1	8	9	105
Sample 8 (5/8/08, 5/9/08)	0	6	6	123
Sample 9 (5/10/08)	1	4	5	93
Sample 10 (5/16/08)	0	8	8	203
Sample 11 (5/21/08)	0	2	2	27
Sample 12 (5/29/08)	0	2	2	63
Sample 13 (5/31/08)	0	0	0	NA
Sample 14 (6/2/08)	0	0	0	NA
Sample 15 (6/14/08-6/16/08)	0	9	9	700
Sample 16 (6/30/08)	0	0	0	NA
Sample 17 (7/13/08)	0	2	2	32
Sample 18 (7/20/08)	0	1	1	32
Sample 19 (7/27/08)	0	1	1	32
Sample 20 (8/4/08)	0	2	2	72
Sample 21 (8/11/08)	3	5	8	108

	Marked Catch	Unmarked Catch	Total Catch	Population Size at Sample Time
Sample 22 (8/18/08)	3	15	18	195
Sample 23 (8/25/08)	1	9	10	66
Sample 24 (9/8/08)	0	0	0	NA
Sample 25 (10/6/08)	0	2	2	9
Sample 26 (10/21/08)	0	2	2	9
Sample 27 (11/3/2008)	0	0	0	NA
Sample 28 (12/5/2008)	0	0	0	NA
Sample 29 (12/23/2008)	0	0	0	NA
Sample 30 (1/19/09)	0	1	1	4
Sample 31 (2/3/09)	1	0	1	1
Sample 32 (2/17/09)	0	7	7	7

NA= no catch, population estimate not possible

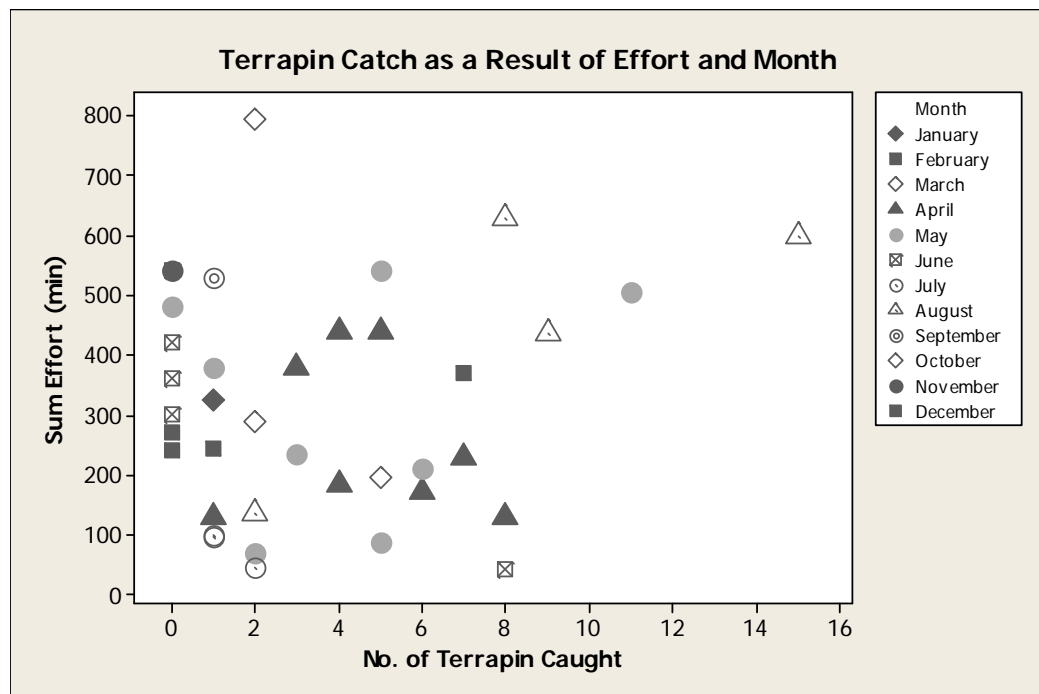


Figure 13. Monthly number of terrapins captured versus search effort March 2008 to February 2009.

The majority of terrapins were collected on South Deer Island as a result of the intensified search efforts that occurred on this island. Additionally, North Deer Island collections were limited to those animals sighted only in the water. This island is a protected bird sanctuary and researchers were forbidden to trespass on the land. Many more terrapin were sighted in and between the two islands than were actually recorded, however reaching these animals on foot was impossible due to the depth of water outside the islands and the various routes of escape available to the animals. Even within the islands capture was limited due to visibility issues created by rising tides and turbid water.

Movement

Of the 12 terrapins that were collected more than once during the course of this study, all were recaptured on the island of their original detection (Appendix C). The single recaptured terrapin from North Deer Island was located 231 meters from its original capture site, 27 days after its original capture. The longest “minimum” straight-line distance traveled by a recaptured terrapin was 414 meters (Table 3). This terrapin was recaptured 28 days after the original capture. The longest amount of time between original capture and recapture was 258 days. Unfortunately, the recapture location was not recorded. The second longest amount of time between original capture and recapture of a terrapin was 146 days. This individual traveled 243 meters within that time period. Additionally, a terrapin was recaptured one day after its original capture and had traveled 44 meters during that time. Twelve terrapins from South Deer Island were found a second time in another location on the island at distances ranging from 44 to 414 meters. The mean straight-line distance traveled by the recaptured terrapins was 169 meters with a standard error of 34.4 meters. The mean time period between original capture and recapture of terrapins was 92 days with a standard error of 22 days.

Table 3. Distance traveled and time lapsed between original capture and recapture of diamondback terrapins on North and South Deer Islands.

Notch	Distance Between Captures (Meters)	Days Between Capture
54	44	1
6	47	143
89	68	29
21	104	126
1	125	136
63	131	94
80	NA	258
13	174	7
47	231	27
333	243	146
43	280	111
12	414	28

Habitat Utilization

Vegetation found on South Deer Island was consistent with that identified by Hogan (2002). In six transect locations along the exterior of South Deer Island, Hogan (2002) reported saltwort (*Batis maritima*), slender seapurslane (*Sesuvium maritimum*), or seabeach orache (*Atriplex arenaria*) present with at least a 20 % relative frequency in each transect (2002). In our study, *Salicornia depressa* was commonly found bordering the channels within the island and even formed dense mats throughout slightly elevated regions of South Deer Island. One terrapin was located basking on a thick mat of *S. depressa*, 20 feet away from the nearest channel. One additional terrapin was found hiding in submerged *S. depressa*, and two others were found near a channel, buried in mud that was surrounded by *S. depressa*.

Spartina alterniflora was also found throughout South Deer Island in areas inundated with water. Fifteen terrapins were either located hiding within *S. alterniflora*, or retreated to it when an observer approached them. *Sesuvium maritimum* and *Batis maritima* were also commonly observed on the island, as well as many woody plant species and cacti that were present at higher elevations.

Although greater effort was focused on the stream portions of the study area, other portions of the upland areas were surveyed each sample time. However, the various habitat types were not selected at random and sampling effort was not stratified. Therefore, we cannot translate these observations into strict habitat preference estimates. The majority of terrapins were captured swimming within the intricate channels that span the length of South Deer Island. Nearly 60% of the captures occurred within these channels (Figure 14). Fifty-nine terrapins were found swimming in the narrow channels within the islands, seventeen terrapins were found on land, thirteen terrapins were found buried in the mud, and six terrapins were caught in modified crab traps. Six terrapins were caught in areas other than those listed above, including one that was found in a commercial crab trap, one that was basking on a barrel, and one that was caught in water outside of South Deer Island on an oyster reef. Additionally, one terrapin was found walking on a sandy strip along the outside of North Deer Island, and two individuals were found swimming on the outside of North Deer Island. Furthermore, of the terrapin that were captured on land (16.7%), 50% were found within less than .3 meters from a channel. Additionally, 30% were found within .3 to 1.5 meters from a channel and 15% were located between 1.6 to 3 meters from a channel (Figure 15). The mean distance from water was .92 meters with a standard error of .16 meters. Close to 13% of the total terrapins captured were found buried in the mud with all or nearly all of their shell concealed.

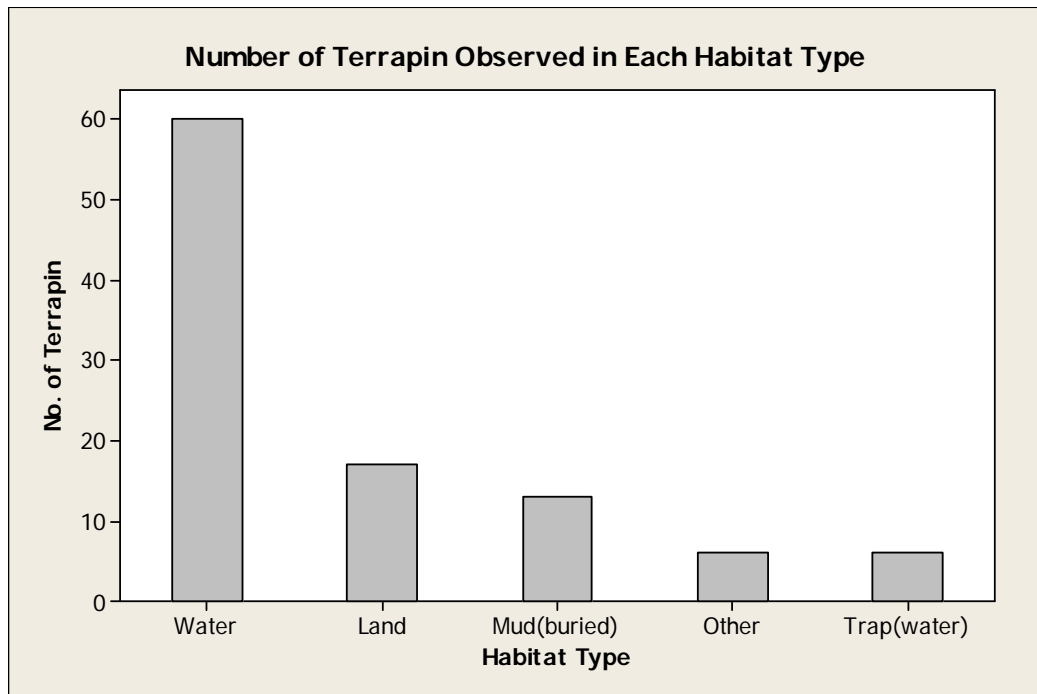


Figure 14. Terrapin catches in various habitats and by gear type.

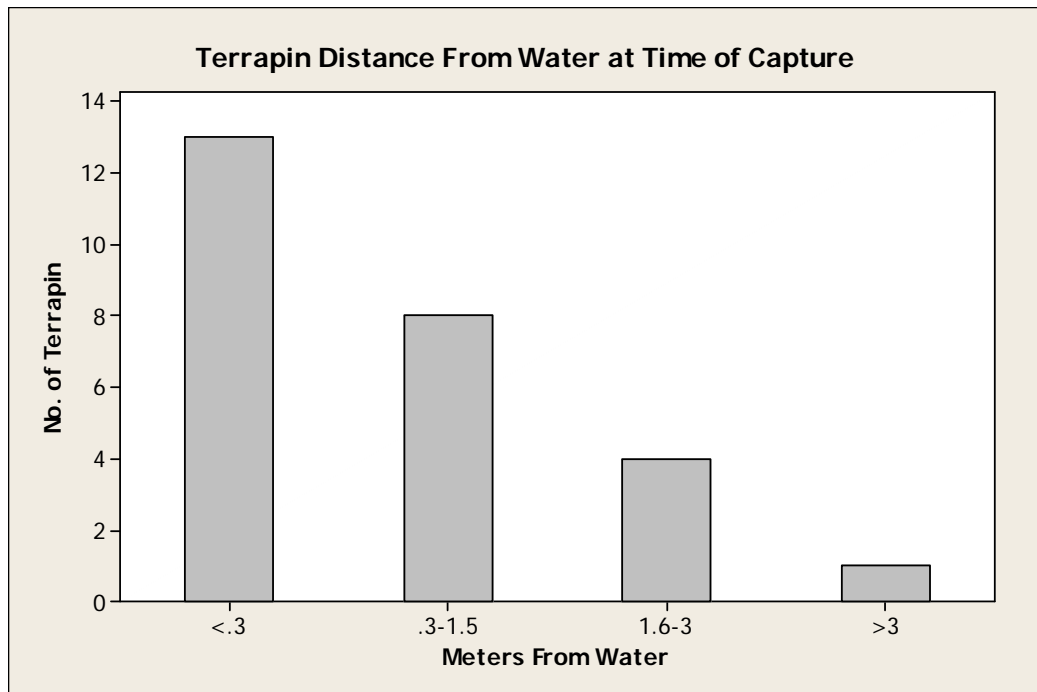


Figure 15. Distance of terrapins from standing water at time of capture.

Terrapins were found buried in the mud throughout the study period and at a range of different temperatures. The terrapin catch per unit effort value increased only slightly with increasing air and water temperatures (Figures 16 and 17). The mean air temperature during the study was 25.84 °C with a standard deviation of 4.5. The maximum air temperature recorded during a sampling period was 31.5 °C and the minimum air temperature recorded was 10 °C. Regression analysis failed to detect a significant linear relationship between air temperature and terrapin CPUE ($r^2=.018$, $p=.43$). We concluded that air temperature was not a significant factor affecting terrapin catch per unit effort. Likewise, regression analysis failed to detect a significant linear relationship between water temperature and terrapin CPUE. Therefore, we concluded that water temperature fluctuations did not significantly impact terrapin catch per unit effort ($r^2=.037$, $p=.24$). The mean water temperature during the study was 25.36 °C with a standard deviation of 5. The maximum and minimum water temperatures recorded during the study period were 34 °C and 13 °C, respectively. Changing salinity values seemed to have little, if any, affect on the terrapin catch per unit effort (Figure 18). The average salinity reading during the sampling period was 27.41 psu with a standard deviation of 3.2. The maximum salinity level recorded during the sampling period was 35 psu and the minimum salinity level was 22 psu. Terrapins were captured in the water during both of these salinity periods, in addition to salinity levels between the two extremes. Regression analysis failed to detect a significant linear relationship between salinity and terrapin CPUE ($r^2=.003$, $p=.77$). We concluded that salinity was not a significant factor in affecting terrapin catch per unit effort.

During our study we found one terrapin in an abandoned commercial crab trap that had washed onto shore. One terrapin was found walking around on a sandy area at North Deer Island. This area was created during construction of artificial reefs and breakwaters meant to prevent erosion of the island from the wakes of passing boat traffic from the intercoastal waterway (ICWW). The deep channel between the sandy area and the newly created reef was a popular area for terrapin and many heads were spotted in this location during the latter course of the study period when construction was completed. However, due to the depth of the channel, it was impossible to capture the animals by hand. Additionally, many terrapins throughout the study period were spotted

basking on a tire near the opening to the North Deer Island lagoon. One terrapin was located basking on a rusty barrel that had washed onto South Deer Island. One terrapin was captured on an oyster reef located on the perimeter of South Deer Island. Although this animal could be captured by hand due to its location on the reef, many other terrapins in the vicinity were unable to be collected in the open water environment.

In addition, five terrapins were caught in modified crab traps deployed for that purpose. This study began in November 2007 with traps being deployed around the perimeter of South Deer Island. From November 2007 through February 2008 no terrapins were caught in the traps that were deployed. Additionally, no terrapin heads were seen surfacing for air. It was not until March 2008 that the first terrapin was recorded near the south island. Although several other terrapin heads were seen surfacing that day, none of the modified traps yielded a terrapin. It was then decided that in addition to the modified crab traps, terrapins would need to be searched for by researchers on foot inside of the island's channels.

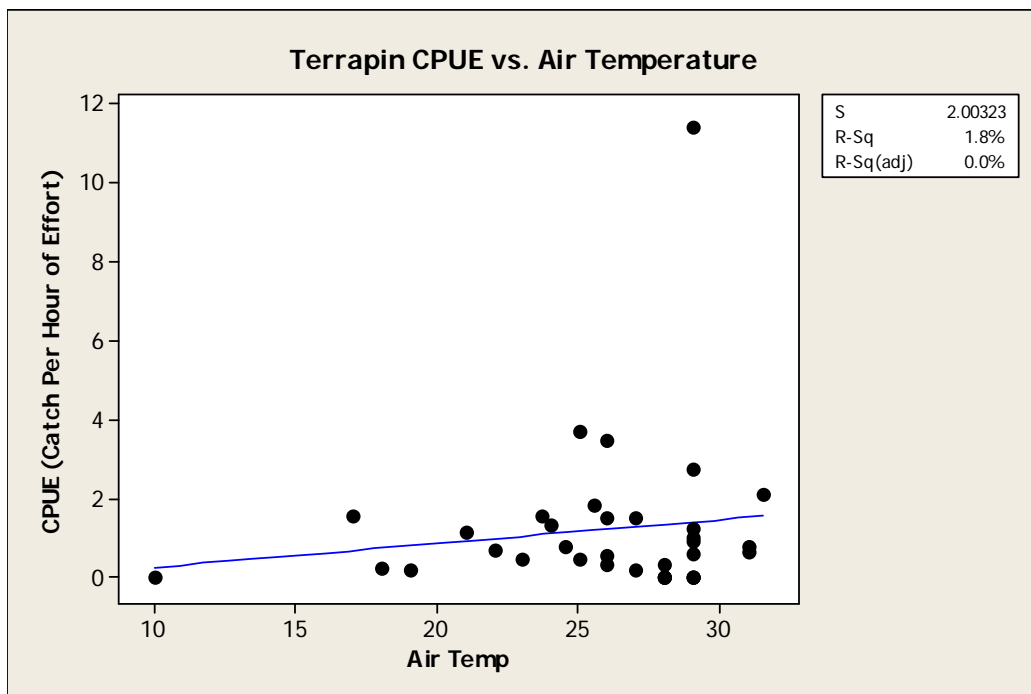


Figure 16. Air temperature versus terrapin catch per hour effort.

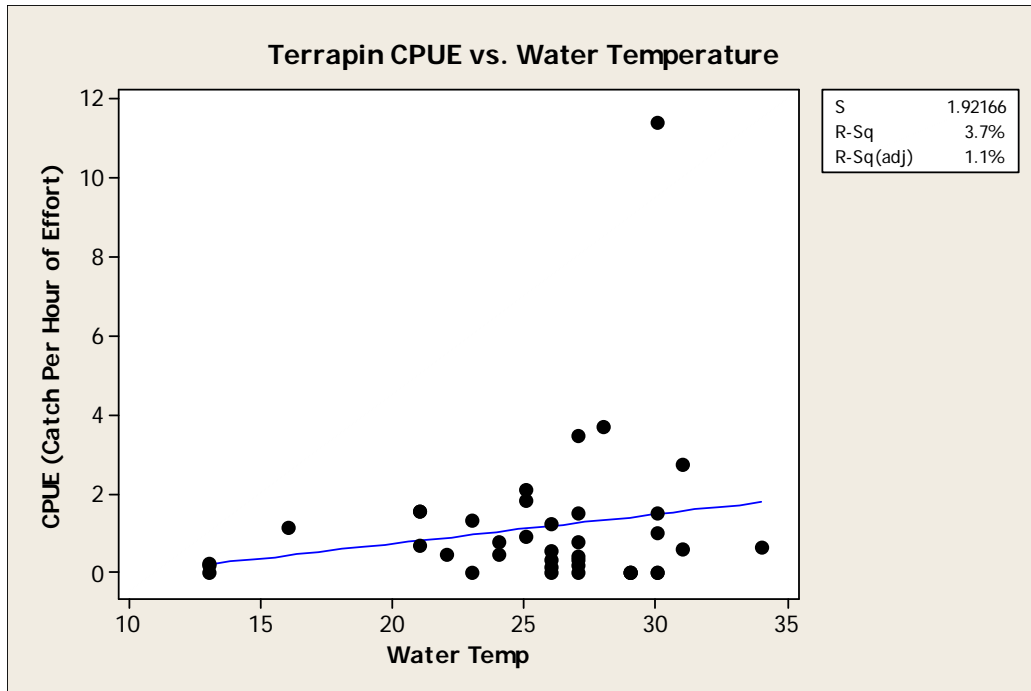


Figure 17. Water temperature versus terrapin catch per hour effort.

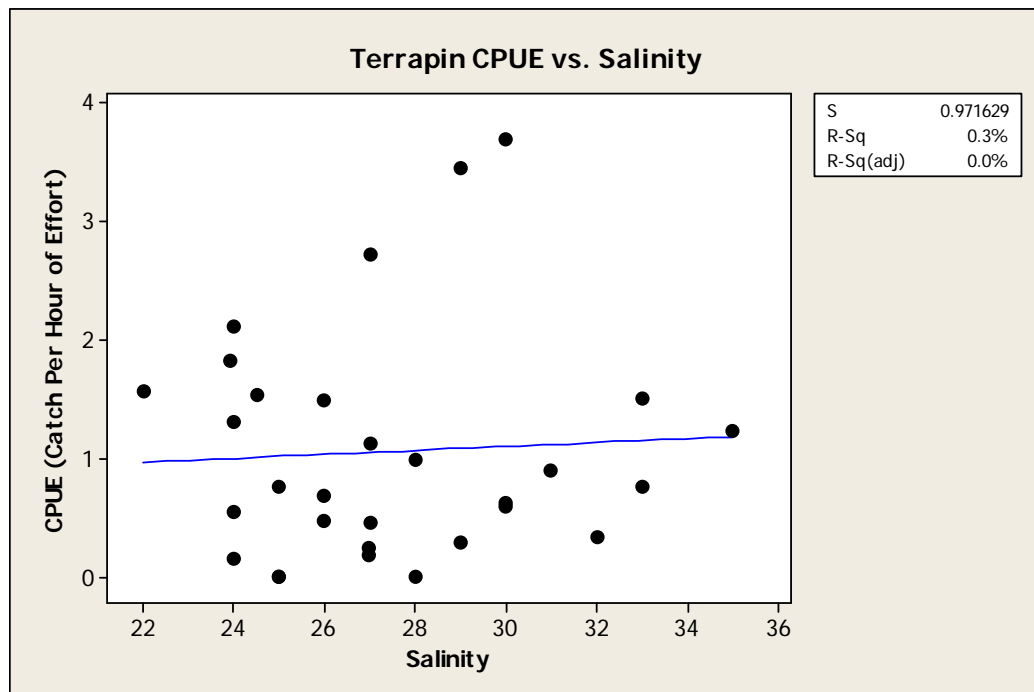


Figure 18. Salinity versus terrapin catch per hour effort.

Starting with the first terrapin capture on March 27, 2008 through June 14, 2008, traps were periodically deployed on North and South Deer Island's channel entrance openings and select perimeter locations. During this period the total amount of time that traps were deployed on both islands equaled 578 hours. The average terrapin catch per unit effort in the modified crab traps equaled 0.0001 terrapin/hour. Due to this low catch rate, it was decided in June 2008 to no longer deploy traps and instead focus all of the effort on the search and grab method of collection.

Terrapin observers throughout the year of study employed a total of 202 hours of search time throughout the islands. Using the search and grab method, the average terrapin catch per hour of effort was 1.2 terrapin/hour (Figure 19). Regression analysis failed to detect a significant linear relationship between search time and the amount of terrapin collected ($r^2=.087$, $p=.04$). We concluded that search time was not a significant factor affecting the amount of terrapins collected. Table 4 shows the effort and CPUE at each sample time. This approach differed from the one employed by Hogan (2002) in the same location. The majority of her captures resulted from the use of modified commercial crab traps set around the perimeter of South Deer Island.

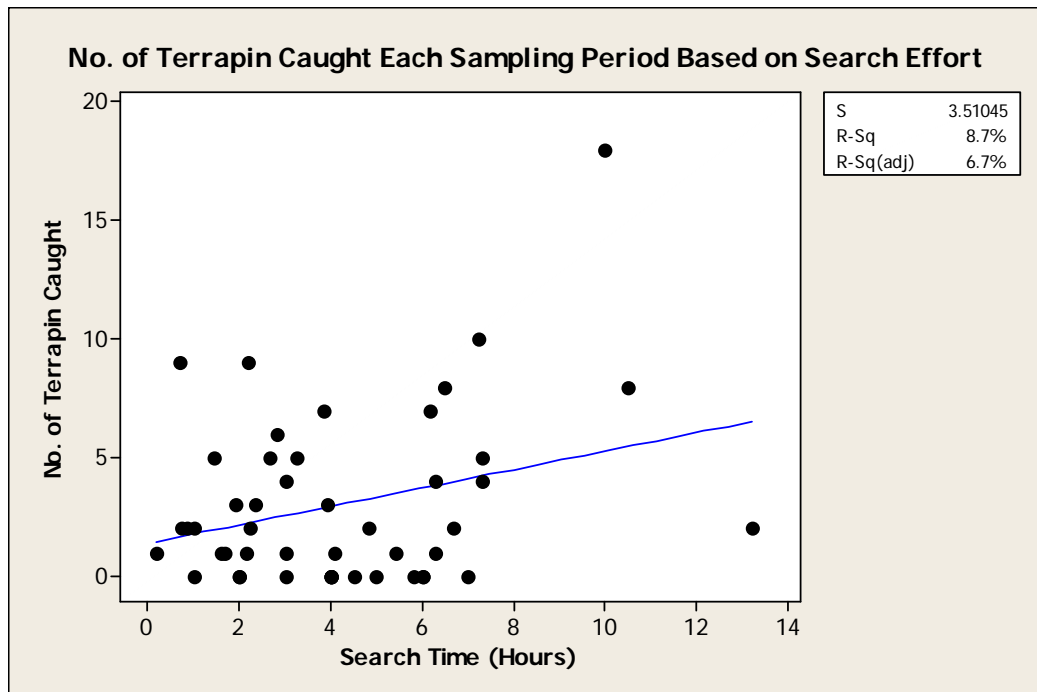


Figure 19. Number of terrapins caught each sampling period based on search effort.

Table 4. Search effort per sampling period.

Date	Island	Total # Caught	Sum Effort (min)	CPUE	% Males	Air Temp	Water Temp	Salinity
3/27/2008	South	1	n/a	n/a	100	23.30	21.23	24.27
3/28/2008	South	6	195	1.54	60	23.70	21.40	24.50
4/1/2008	South	7	230	1.83	86	25.50	24.90	23.90
4/7/2008	South	4	182	1.32	33	24.00	23.00	24.00
4/11/2008	South	6	170	2.12	50	31.50	24.50	24.00
4/18/2008	South	4	378	0.63	33	25.00	22.00	26.00
4/19/2008	South	5	440	0.68	40	22.00	20.50	26.00
4/23/2008	North	4	438	0.55	75	26.00	26.00	24.00
4/25/2008	South	1	128	0.47	100	22.80	24.40	27.00
4/29/2008	South	9	130	4.15	50	25.00	28.00	30.00
5/2/2008	North	3	235	0.77	0	24.50	24.00	25.00
5/8/2008	South	1	378	0.16	100	27.00	27.00	24.00
5/9/2008	South	5	87	3.45	60	26.00	27.00	29.00
5/10/2008	South	5	160	1.88	75	27.00	26.50	26.00
5/10/2008	North	2	50	2.40	50	27.00	26.50	26.00
5/16/2008	South	8	389	1.23	63	17.00	20.50	22.00
5/16/2008	North	3	115	1.57	67	17.00	20.50	22.00
5/21/2008	South	2	400	0.30	50	26.00	26.00	29.00
5/21/2008	North	3	140	1.29	50	26.00	26.00	29.00
5/29/2008	South	2	60	2.00	100	29.00	30.00	28.00
5/29/2008	North	1	10	6.00	100	29.00	30.00	28.00
5/31/2008	South	0	240	0.00	n/a	29.00	28.70	nd
5/31/2008	North	0	240	0.00	n/a	29.00	28.70	nd
6/2/2008	South	0	180	0.00	n/a	27.70	29.40	nd
6/2/2008	North	0	120	0.00	n/a	27.70	29.40	nd
6/14/2008	South	0	300	0.00	n/a	28.70	29.40	nd
6/14/2008	North	0	240	0.00	n/a	28.70	29.40	nd
6/15/2008	South	0	360	0.00	n/a	28.40	29.70	nd
6/15/2008	North	0	60	0.00	n/a	28.40	29.70	nd
6/16/2008	South	9	42	12.86	25	28.50	30.10	nd
6/30/2008	South	0	360	0.00	n/a	27.90	30.30	nd
7/13/2008	South	2	44	2.73	0	29.00	31.00	27.00
7/20/2008	South	1	96	0.63	100	31.00	34.00	30.00
7/27/2008	South	1	100	0.60	100	29.00	31.00	30.00
8/4/2008	South	2	134	0.90	50	29.00	25.00	31.00
8/11/2008	South	8	630	0.76	40	30.50	27.00	33.00
8/18/2008	South	18	599	1.80	40	26.00	30.00	33.00
8/25/2008	South	10	435	1.38	56	29.00	26.00	35.00
9/8/2008	South	0	350	0.00	n/a	28.00	27.00	25.00
9/8/2008	North	1	180	0.33	0	28.00	27.00	32.00
10/6/2008	South	2	290	0.41	0	nd	26.70	nd
10/21/2008	South	2	794	0.15	50	nd	25.70	nd
11/3/2008	South	0	420	0.00	n/a	nd	23.20	nd
11/3/2008	North	0	120	0.00	n/a	nd	23.20	nd
12/5/2008	South	0	270	0.00	n/a	10.00	13.00	28.00

Date	Island	Total # Caught	Sum Effort (min)	CPUE	% Males	Air Temp	Water Temp	Salinity
12/23/2008	South	0	240	0.00	n/a	29.00	26.00	25.00
1/19/2009	South	1	326	0.18	100	18.60	12.85	26.97
2/3/2009	South	1	244	0.25	n/a	18.00	12.85	26.97
2/17/2009	South	7	370	1.14	86	21.00	16.00	27.00
Totals		147	12099	1.22*	58	26*	25*	27*

* Average

Sex Ratios

The male to female sex ratio of diamondback terrapins caught in West Bay was 1.1 to 1. A total of 72 males and 64 females were captured during the study period. An additional 2 juveniles were captured, but without distinguishable sex characteristics it was impossible to determine whether they were male or female.

Seventy-six percent of terrapins (110 terrapins) captured during the study period were not found with any other known individuals within a distance of one meter (Figure 20). In some cases terrapin heads surfacing for air could be spotted near certain individuals that were captured, but these individuals were not close enough to be collected at the same time. However, 13% of the total terrapins (18 terrapins) that were captured in this study were found with one other individual. In 8% of the collections (12 terrapins), three terrapins were collected together, and in 3% of the collections, four terrapins were found within the same area. Forty-seven percent of the multiple catches had one male and one female (Figure 21). Twenty-six percent of multiple catches consisted of two males and one female. Additionally, 12% of multiple collections contained three females and one male. The smallest percentages of multiple collections were those that were composed of same sex groups. In 9% of the multiple collections three females were found, while in 6% of multiple collections two males were found together. In the case of the latter, two males were seen apparently fighting each other. One of the males was on top of the other male's carapace while biting at him. In one of the male/female sightings, the two individuals were caught in the act of mating.

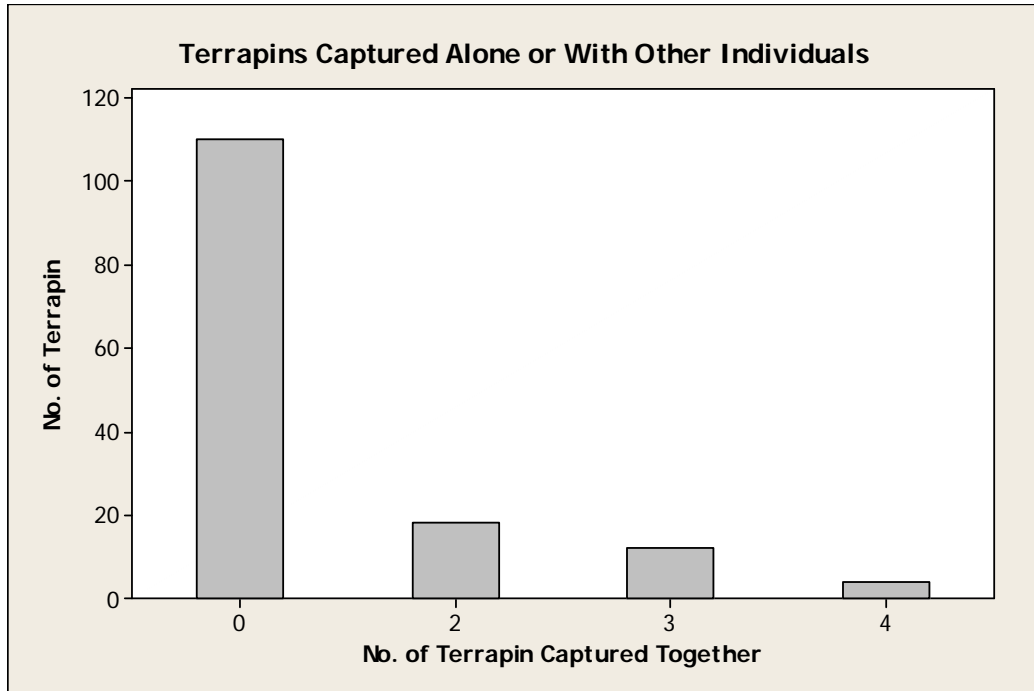


Figure 20. Percentage of terrapins captured alone and with other terrapins.

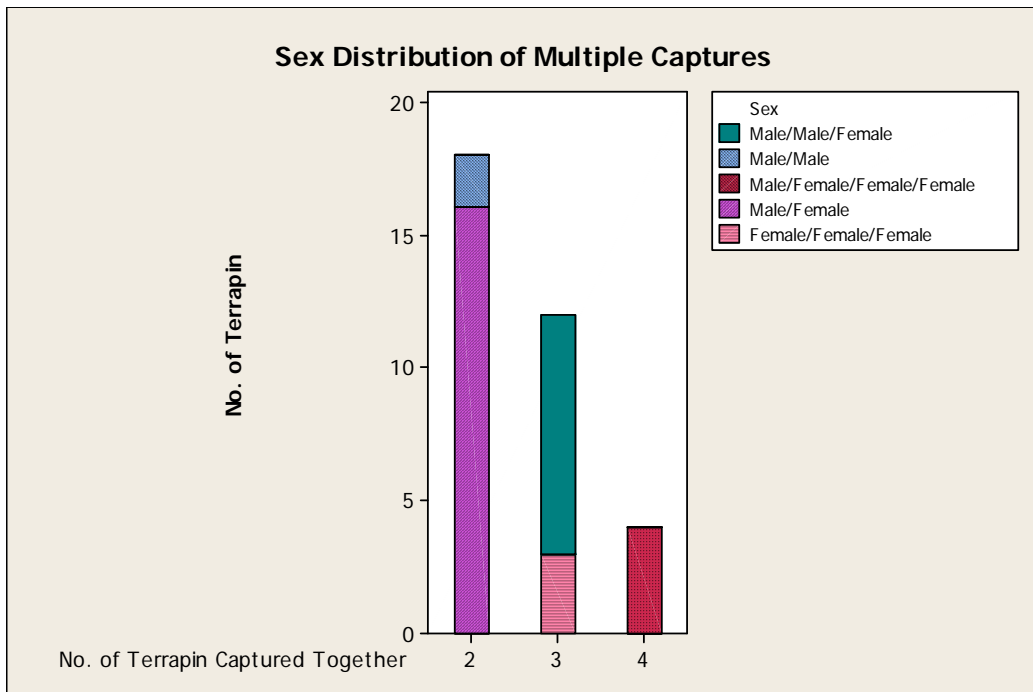


Figure 21. Number and sex distribution of terrapins captured with other individuals.

No nesting behavior was documented during the course of this study. Moreover, no evidence of potential terrapin nesting sites was discovered. This, however, could be due to the fact that most of the sandy areas present on the islands are completely covered in shell. As a result, tracks are not created as terrapins enter and leave nesting sites. Although two juvenile terrapin were collected over the study period, no hatchlings were ever seen on either of the two islands.

Morphometrics

The mean carapace length for male terrapins was 131.7 mm (SD=7.6) versus 186 mm (SD=27.3) for female terrapins (Figure 22). Male carapace length was significantly smaller than female carapace length (Table 5). Maximum and minimum carapace length for males was 150 mm and 115 mm, respectively. In contrast, the maximum and minimum carapace length for females was 285 mm and 109 mm, respectively. Additionally, the mean carapace width for males was significantly smaller (M=95 mm, SD=6.3) than the mean carapace width for female terrapins (M=134.1 mm, SD=16.2). The maximum and minimum male carapace width was 113 mm and 80.6 mm, respectively. The maximum and minimum female carapace width was 161 mm and 85.5 mm, respectively.

Plastron measurements also showed the size differentiation between the sexes with male length and width averages equaling 111.1 mm (SD=6.4) and 58.7 mm (SD=5.5), respectively. Female mean plastron length and width measurements equaled 164.2 mm (SD=21.4) and 87 mm (SD=12.7), respectively (Figure 23). The mean depth of male terrapins, measured from the plastron to the highest point on the carapace equaled 49.7 mm (SD=4.9). The mean female depth was significantly larger at 76 mm (SD=9). The size of a terrapin's head is also a key factor in differentiating males and females. Male head width averaged 24.8 mm (SD=4.5) and was significantly smaller than the mean female head width of 43.6 mm (SD=8.6).

Similar to body length measurement, terrapin weight showed similar trends between gender. In general female terrapins were the larger sex (Figure 24). The average

weight recorded for male terrapins was 0.38 kg (SD=.07). The average female weight (M=1.2 kg, SD=.36) was significantly larger than male weight. The maximum and minimum male weight observed was 0.65 kg and 0.21 kg, respectively. Additionally, the median and mode of male weight measurements were 0.37 kg and 0.40 kg, respectively. The heaviest female weight recorded was 1.8 kg, while the lowest female weight was 0.26 kg. Median and modal female weight was 1.2 kg and 1.5 kg, respectively.

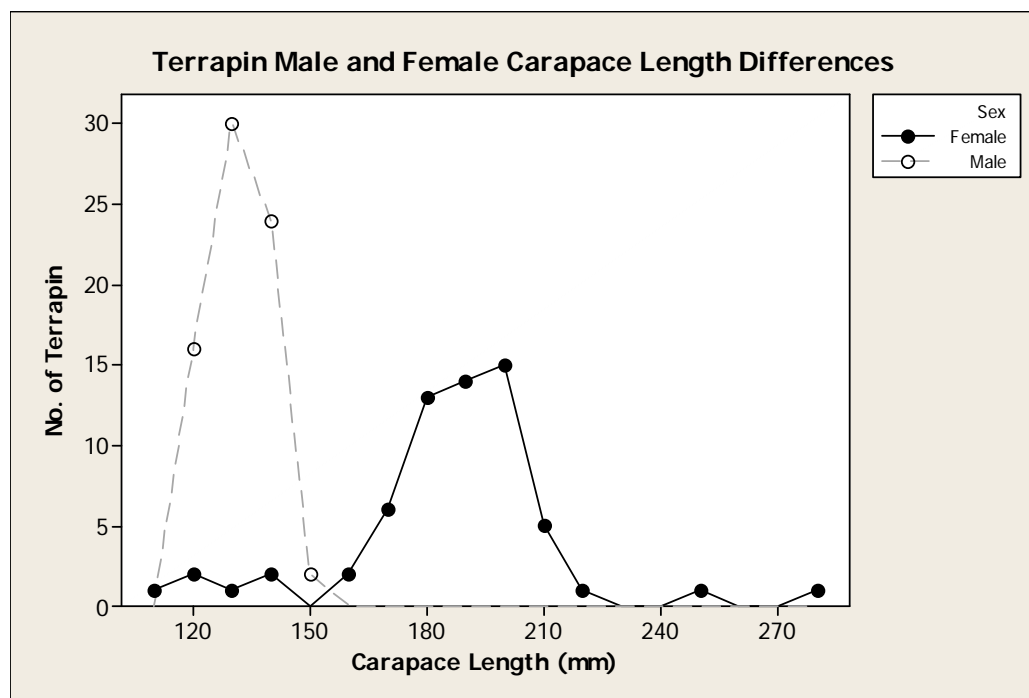


Figure 22. Comparison of male and female terrapin carapace length.

Table 5. Results of t-tests for morphometric terrapin data.

	p value	t Statistic	N (female)	N (male)
Carapace Length	1.88E-24	15.38148	64	72
Carapace Width	1.68E-29	17.88344	63	66
Plastron Length	1.16E-29	18.92498	63	69
Plastron Width	1.56E-27	16.53743	62	74
Depth	1.20E-36	20.61565	63	70
Head Size	1.18E-27	15.57495	64	70
Weight	2.13E-24	16.25102	61	71
Growth Rings	3.73E-10	6.851303	53	65

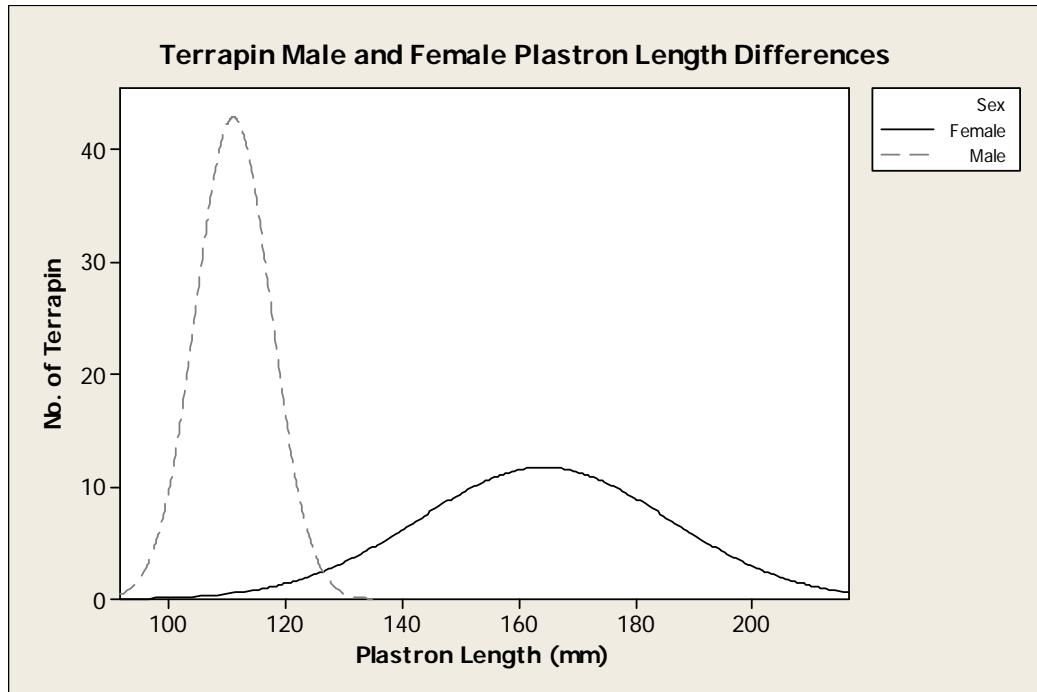


Figure 23. Comparison of male and female terrapin plastron length.

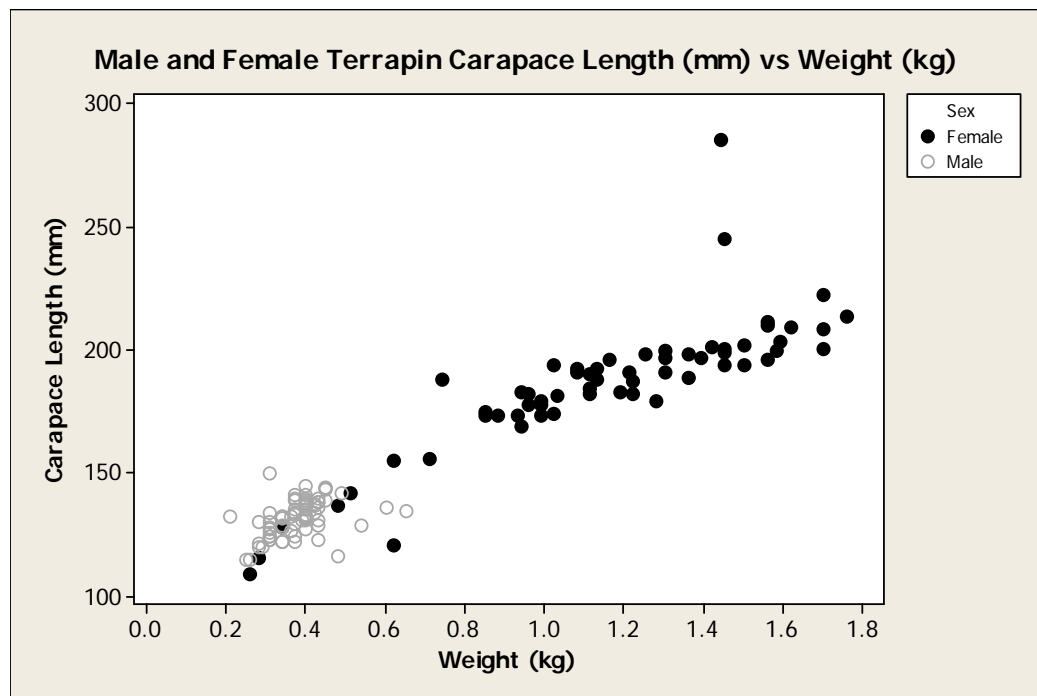


Figure 24. Length and weight differences between male and female terrapins.

An average of 6 growth rings ($SD=1.8$) were counted on male terrapins throughout the study period with a maximum of 14 rings counted on a male and a minimum of three rings visible on another. Females averaged 8 growth rings ($SD=2$) with a maximum ring count of 13 and a minimum ring count of 3 (Figure 25). Using a two-sample t-test for equal variances, female terrapins had significantly more growth rings than male terrapins.

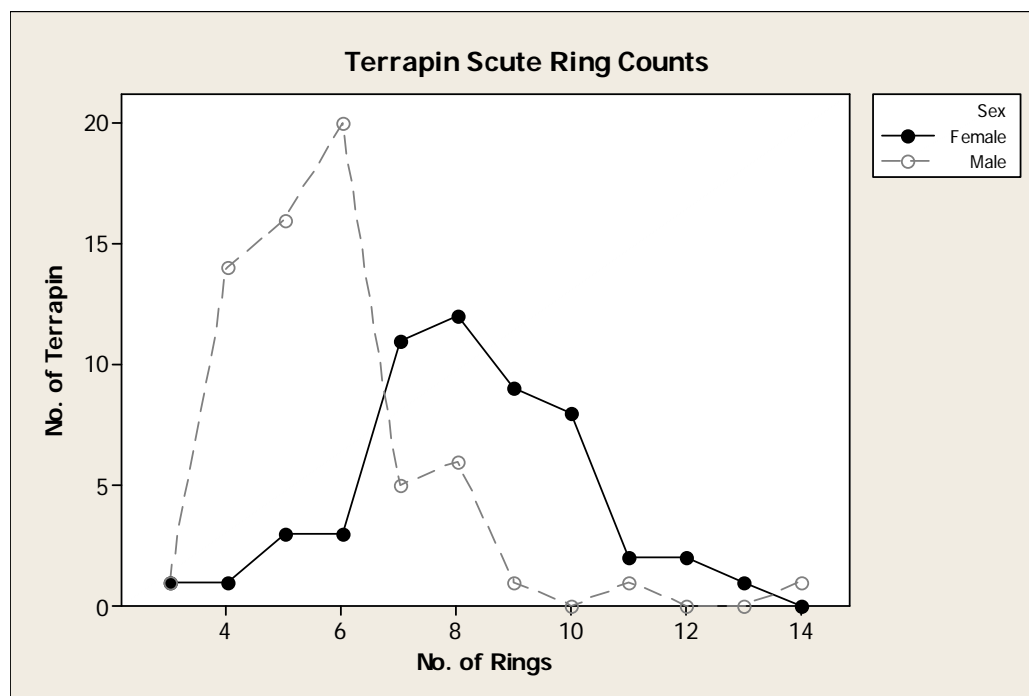


Figure 25. Terrapin scute ring counts.

Observations on Terrapin Diet

Terrapin stomach contents and fecal material were not analyzed in this study, however, voluntary expulsions from individuals were noted and the observable contents recorded. Two males captured on South Deer Island had fecal material that contained blue crab shells. A female from North Deer Island expelled fecal material that appeared to be made up completely of vegetation. Additionally, a male from North Deer Island expelled a thick, white, mucous-like substance that contained no obvious shell material.

Radio Tracking

Over the course of a year, 6 terrapins were fitted with radio tags to track their movement over time. Four females and one male were tagged on South Deer Island and one female terrapin was tagged on North Deer Island (Figures 26 and 27). One radio-tagged female (specimen #25) was located 7 days after the initial receiver attachment (Figure 26). She had traveled a minimum straight-line distance of 30.9 meters. One radio tagged female (specimen #89) on South Deer Island was captured a second time during a regular search effort and not as a result of radio tag detection. Twenty-nine days after initial radio tag attachment, she was located 67.9 meters from the original capture site. The radio-tagged male's signal (specimen # 39) was tracked to a location 103.9 meters from original capture location 45 days after initial attachment. Although the transmitter was discovered intact, the male terrapin was found deceased. Only the shell of the terrapin remained, so it is assumed the animal had been deceased for some time. The cause of death of the male terrapin is unknown, although there were no signs of predation. A transmitter belonging to a female (specimen #38) on South Deer Island was located 193.9 meters from the original capture site. It was no longer attached to the shell of the terrapin and appeared to have come loose from the carapace. Though the receiver was found 45 days after placement on the terrapin, it is unknown how long it had been there. The terrapin was not found. The remaining two tagged females from North and South Deer Islands were never relocated.



Figure 26. Distribution of radio tagged terrapin on South Deer Island. Numbers refer to specific tagged terrapin

DISCUSSION

The study site was selected based on historical sightings and a past study conducted by Hogan (2002). Based on the results of this study it appears the most likely population level of terrapins on South Deer Island during the survey period ranged between 139 and 700. However, a longer period of monitoring and additional sequential tagged terrapins are needed to improve the precision of this estimate. The capture rate was higher in this study (139 original captures in 11 months) than in Hogan's study (116 original captures in 13 months). Hogan (2002) did have more recaptures (19 vs. 12 for this study). We recaptured no marked terrapins from Hogan's (2002) study. It appears that Hogan (2002) did not insert PIT tags into the terrapins and instead used the external marking system. Notches on marginal scutes become indistinguishable over time, therefore, it is unknown whether any of the terrapin captured in the 2001-2002 study were recaptured during this study.

The estimated population density is no doubt supported by the variety of critical habitats observed during this study. South Deer Island, the main research location, contains 24.36 hectares of tidal marsh. The numerous channels created by tidal currents throughout the island provide a refuge for terrapin. In these marsh areas, terrapins are able to find plentiful prey items and hatchlings may seek cover in the thick vegetation. Small shell beaches provide potential nesting areas and mud along the stream banks facilitates temperature regulation by providing areas for basking or burrowing.

The 144-acre North Deer Island provides a similar habitat for terrapins. This island has much more elevated areas and provides nesting habitat for many more species of birds and is reported to have a large snake population (Bob Gallaway pers. comm.). Additionally, North Deer Island contains less of the narrow channels that terrapin seem to prefer. However, terrapins were seen and captured in the large, shallow lagoon area of North Deer Island.

Turtles are relatively long-lived animals. The lifespan of a diamondback terrapin has been frequently observed to exceed 40 years. While researching long-lived species, determining the age of an individual animal is important to judge the health of the overall population. If a varied age distribution of animals in a population is discovered, it may be concluded that the population is stable and resistant to local extinction (Mitro 2003).

However, if only older individuals are encountered and juvenile survival is low, the long-term viability of the population may be at risk. As the mature animals reach the end of their life and begin to die off, the population will eventually become extirpated without replacement from younger, sexually mature individuals. Additionally, if older animals are dying off and the sole remaining individuals are juvenile turtles that have not yet reached sexual maturity, this could inhibit population growth for many years. Several factors contribute to selective mortality of various age groups in terrapin. For terrapin, crab trap bycatch mortality would be selective toward medium sized adults. Larger females would be excluded from entering the traps and hatchlings and juveniles are small enough to escape through the wire mesh and/or openings. Conversely, in an area with dense populations of mammalian or avian predators, hatchling terrapins may experience high mortality in comparison to adults.

Different scutes were used for ring counts, depending on the clarity of the rings within the scute. No more than 14 rings were ever counted on the scute of any terrapin, leading to the conclusion that diamondback terrapins in West Bay develop growth rings at a reduced rate after reaching sexual maturity. Many terrapins had no visible growth rings due to the heavily worn appearance of the carapace. This would indicate that the terrapin was most likely an older individual.

Sex ratios are important in determining the ability of a population to produce sufficient offspring to sustain the population over time. The optimal ratio varies based on the species, but is generally thought to be stable at 1:1 (Fisher 1930). The prime ratio to reach the greatest fecundity in diamondback terrapins is unknown, but a greater proportion of females would be assumed to produce an increased number of offspring. Previous studies of diamondback terrapins in northern states have documented both female and male biased ratios, depending on the study area (Cagle 1952, Lovich and Gibbons 1990, Roosenburg 1991).

There are four demographic factors that are thought to influence sex ratios in a natural population (Gibbons 1990). The sex ratios of terrapin hatchlings may be unequal as a result of environmental factors. Terrapins, like many reptiles, have temperature dependant sex determination. Cooler nest temperatures produce more males and warmer temperatures produce more females. Nest temperatures vary within an individual nest

due to nest depth or between nests based on the location of the nest site. Nesting areas shaded by heavy vegetation will produce more males in a clutch, while the open sunny sites will produce more females. However, according to Gibbons (1987), animals, such as terrapins, with late maturation and long lifespans, will have enough diversity in nest site selection throughout the females reproductive life to stabilize uneven sex ratios. Because no nesting areas were found in this study, it is impossible to know if nest temperatures effect the sex ratios of the West Bay population.

Differential mortality between the sexes can also distort the sex ratio. Adult male terrapins are more likely to drown in crab traps than adult females due to their smaller size and subsequent ability to enter the small opening of the trap (Butler and Heinrich 2007, Roosenburg & Kelley 1996). Unfortunately we were not able to determine this source of mortality during this study. Although we saw crab pots near the Deer Island complex, it is illegal in Texas to check the contents of commercial crab traps without permission of the owner. One trap was visible when it washed ashore and a male terrapin was found inside. Of the modified crab traps that researchers placed near the islands, three males and two females were captured. This, however, is not an accurate measurement to determine sexual bias of crab traps due to the fact that these were not standard commercial crab traps and, therefore, had larger openings. As a result, it is unknown whether differential mortality plays a role in the sex ratio found at North and South Deer Islands. However, sampling bias was not a factor in the collection of terrapin by our traps since we utilized large trap openings and the majority of terrapins were captured by hand.

According to Lovich and Gibbons (1990), male and female terrapins also have different emigration and immigration patterns that could skew the sex ratio at different times of the year. Male terrapins tend to venture further during mating season and often move between populations to increase their chances of finding a mate. Conversely, females are more active during nesting season as they search for an ideal site to lay their eggs. To reduce this bias, we conducted our surveys in West Bay throughout both the mating and nesting season.

Differential age at maturity can also explain sex ratio distortion as was found in a study conducted on diamondback terrapins by Lovich and Gibbons (1990). With all

other factors being equal, a species with a faster maturing sex will have more adults of that sex at any given time. Male terrapins, after 3 years, reach their adult size at around 90 mm (Cagle 1952). Within the same time frame, female terrapins are only half of their adult size of 160 to 176 mm. The fact that male terrapins reach maturity at an earlier age could have distorted the observed sex ratio in West Bay. However, because the terrapin sex ratio was relatively balanced in this study (1.1:1) and falls within the range of values reported in the literature for healthy populations, it is our conclusion that the terrapin population in West Bay is at a stable level to produce sufficient offspring over time (Fisher 1930). Additionally, the sex ratio in this study did not vary greatly from that recorded by Hogan (2002). The sex ratio in that study was reported to be 1:1.

The most numerous prey species seen on the island was the mud snail *Littorina irrorata*. This gastropod was commonly seen clinging to the stands of *Spartina alterniflora* along the creeks that ran through the islands. Frequently, numerous snails could be found on each blade of grass. Although these snails were located out of the water, terrapins have been found to feed terrestrially. Unlike the majority of aquatic turtles, diamondback terrapins do not seem to have a problem feeding on land. In a study conducted by Kinneary (2008), terrapin easily accepted and swallowed food without the presence of water.

Crabs, known to be a highly prized food item for diamondback terrapins, were also numerous throughout the islands (King 2007). It was not uncommon to see recent blue crab molt discards scattered along the interior channels of South Deer Island. Additionally, fiddler crabs were abundant during the warmer months of the study period. Although no formal quantitative survey of terrapin prey was conducted we believe that based on qualitative surveys prey abundance should be sufficient to support the terrapins observed during our survey.

Color, shape, and pattern differed with each individual caught. Coloration of the Texas subspecies appears to be darker than that of more northern terrapin subspecies. Skin colors ranged from beige to a dark gray. Males seemed to have darker skin coloration, with some individuals lacking almost all pigment. This is consistent with observations of other male turtle species that tend to lose pigmentation as they increase in

age (Buhlmann, Tuberville, and Gibbons, 2008). Several males had a bright blue coloration present on their heads.

The carapace shape of male terrapins tended to be flat, while the females' carapace had a more rounded appearance. Knobs along the vertebral scutes of the carapace were much more prominent in males than in females. Additionally, younger specimens had distinct knobs present, while many older males possessed a flat carapace that was likely worn down with age. The two juvenile animals collected had vertebral scute knobs that nearly formed spheres at their highest point. Dark markings similar to a moustache were found on the upper beak of certain individuals and were not correlated with gender.

Terrapin nesting sites were not identified in this study. It appears that nesting habitat is present on the islands. Studies conducted in other areas of the terrapins range have shown that terrapins prefer to nest in sparse to densely vegetated sandy or gravel substrates above the high tide line (Feinberg and Burke 2003, Burger and Montevecchi 1975). Both North and South Deer Island have narrow strips of sandy areas unevenly distributed throughout their perimeters. Much of the sand is covered in dense shell. These areas were searched in this study; however, no terrapins were seen nesting. Hogan (2002) documented one incident of a terrapin nesting in the shell hash on South Deer Island.

Although different nesting habitats, from large dunes to narrow sandy beaches, have been observed throughout the terrapins' range, the common factor seems to be sandy soils (Roosenburg 1994). It is assumed that the terrapins nest above the high tide mark on the small strips of sand around the islands, but this was not observed in this study. However, in a study conducted by Hogan (2002), one female was recorded nesting on a shell beach on South Deer Island in April 2001. Due to the thick shell that covers the sandy areas of the island, detecting terrapin tracks leading from a nest would be unlikely. Any other potential nesting sites are unknown. However, terrapins have been recorded several hundred meters from water, presumably for the purposes of locating preferable nesting habitat and it is possible that nesting occurred outside of the study area (Roosenburg 1994).

Development on the mainland and on Galveston Island continues to increase and bulkheads are a frequent sight. A sandy area with no shell is located on the bay side of Galveston Island near South Deer Island. A terrapin was spotted swimming in a small lagoon adjacent to the sandy area. This could be a potential nesting site for terrapins, however, locating tracks in this area was difficult due to tire tracks that covered much of the ground. Additionally, because this area is on Galveston Island, predation of nests would be much more likely than on South Deer Island.

Raccoons, the main predator to terrapin nests and hatchlings, were not found on either island, nor was there any evidence of their presence. Two gulf salt marsh snakes (*Nerodia clarkii clarkii*) were found on South Deer Island during the study period. Although their diet consists mainly of fish, crabs, and invertebrates, snakes have the ability to eat both terrapin eggs and hatchlings (Werler and Dixon 2000). However, the infrequent sightings of this potential predator make it an unlikely threat to the terrapin population as a whole. Although never seen by researchers in this study, diamondback rattlesnakes are known to inhabit North Deer Island (Bob Gallaway pers. comm.). This 144-acre island is the most heavily used colonial waterbird nesting island in Galveston Bay (U.S. Fish and Wildlife Service 2011). It is thought that the presence of rattlesnakes on the island, while predators of bird eggs and nestlings, prevents the presence of much more devastating mammalian predators, such as raccoons. Likewise, rattlesnakes may provide protection for terrapin nests as well. The nesting birds of the island are however a potential threat to terrapin hatchlings, although it is unknown to what extent due to the lack of data on the subject.

The Jolly-Seber mark-recapture method was used to calculate the terrapin population on both North and South Deer Islands. This method estimates the population in open systems where fluctuations are common due to additions and deletions from natural migrations, births, and deaths. Therefore, this technique presents an estimate of the population at a specific point in time and does not assume that the estimate will be accurate at a given time period in the future. Although calculations for this research show variation in population levels throughout the study period, it is unlikely that the terrapins moved in and out of the area at such an extreme rate. It is believed that diamondback terrapins do not have large home ranges and show high site fidelity to a

particular area (Tucker et al. 2001). It has also been found that subadult and adult terrapins stay in the same general area throughout their lives and rarely travel to nearby creeks. Therefore, the population instability seen in this study probably reflects the difficulty in locating terrapins on the islands during certain times of the year and not actual additions or deletions of terrapins to the study area.

The increased population estimates in April could be due to the moderate air and water temperatures present on the islands at that time of year. Hogan (2002) likewise captured more terrapins during the months of April-May. The decrease in terrapin population readings during the summer months may have actually been a result of the animals modifying their behavior to stay cool. It is unlikely that the terrapins left the study area, and instead were probably just much harder to find. The lower probability of observing these organisms on land during summer and winter are most likely due to the differential seasonal behavior observed during this study and documented in the literature (Yearicks et. al. 1981). During the winter and mid-summer when temperatures are extremely high or low, terrapins generally will burrow and/or brumate. Also, increased swimming activity during daytime hours would reduce the likelihood of detection on land. Terrapins, as is true with all other reptiles, cannot regulate their own body temperature and therefore use behavior modification to adjust to changing ambient temperatures. Terrapins aestivate to stay cool during the warmer portions of the year. Burying themselves in the cool mud provides temporary relief during the mid-day heat. In addition, terrapin heads were frequently spotted in the open bay waters surrounding the islands during the summer months. The deeper and much cooler bay waters provide relief from the extreme temperatures observed in the shallow pools and streams found within the islands. Likewise, the extreme drop in terrapin population during the winter months was probably a result of brumation. This behavior was observed in several terrapins captured on South Deer Island throughout the winter sampling events. In at least two instances, the terrapins were almost completely hidden under the soft mud of a stream bank on the island. Capture was only possible when surveyors noticed an abnormal appearance of the overlying mud. Therefore, it is reasonable to assume that many buried terrapins went unnoticed during the winter months.

In addition to reactions to temperature variations, the observed population estimates could also be a result of terrapin mating behaviors. Breeding season for diamondback terrapins begins in April and thus spotting one of these animals while out in search of a mate is more likely. Terrapins are known to travel longer distances during the mating season where they amass with hundreds of other terrapins (Hauswald and Glenn 2005). Females are also known to travel out of their home range during nesting season.

A reduction in terrapin catches in the fall could have been influenced by Hurricane Ike, a category 2 storm that made landfall along the Texas coast on September 13, 2008 near Galveston Island. Not only did this environmental disturbance prevent surveying of the islands for some time, but it also reduced the amount of higher quality habitat that the terrapin historically have utilized. The higher portions of the islands were inundated by saltwater, resulting in the destruction of nearly all of the upland vegetation. The once abundant prey items used by terrapin appeared to be reduced and were difficult to find or were absent. It is unknown to what degree South Deer island was eroded, but with no protection from the powerful waves and an ongoing problem of diminishing acreage, it is certain that some terrapin habitat was lost. Additionally, many of the channels that cut through the island were blocked by debris that had washed onto shore with the intense tidal surge. The exact direct impact of Hurricane Ike on terrapin populations is difficult to assess based on this study alone which ended shortly after the storm. However, continued monitoring on these islands will likely provided additional data to help answer this question. Shortly after this study was completed reports of stranded juvenile terrapin washing up on Mustang Island with Hurricane Ike debris weeks after the storm hit were received from the a stranding network in the area (Pers. Comm. Tony Amos reported to G. Guillen- UHCL).

Due to the low numbers of terrapins that were radio tagged in this study, it is difficult to determine to what extent terrapin move throughout the islands within a short time period and calculate home range. The lack of funding and manpower were the main constraints that prohibited the radio tagging of more terrapins. Our data did show that terrapins can travel a minimum of 414 meters within days. Additionally, unsuccessful attempts to locate tagged animals made data collection on terrapin movement difficult. Constraints that impeded relocating tagged terrapins include saltwater interference with

the submerged radio transmitter signals. Only the terrapins whose carapace (and transmitter) was located above the water line could transmit a signal to the receiver. Furthermore, finding the location of a tagged terrapin during a search depended upon whether or not the animal was within the detectable distance of the antenna.

CONCLUSION

As a result of this research, a large number of terrapins in West Bay have been individually marked and documented. This will provide a baseline population for future researchers wishing to further study the population dynamics of terrapins on North and South Deer Islands, by providing a starting point for each terrapin's location. Future monitoring and research will be needed to track the movement of these animals, along with changes in sex ratios and population fluctuations. It also provides baseline measurements of the animals, which will allow researchers to track the growth and health of this population. Future monitoring of this site will also provide insight on the impacts of hurricanes on local terrapin populations. It will be interesting to evaluate the overall impacts of Hurricane Ike on the Deer Island complex terrapin population. Future monitoring should be able to determine if a significant number of terrapins were lost from this area. Furthermore, this research provides environmental and habitat data that can be used to locate populations of this subspecies throughout the coastal areas of the state and possibly begin development of habitat suitability models.

The traps used in this study were somewhat ineffective in capturing terrapins. The openings may have been too large and allowed the escape of not only terrapins, but also the prey that would normally have been caught in the traps to lure in the terrapin. The larger trap openings were meant to limit catch bias and allow both male and female terrapins to enter the traps. Standard commercial crab traps fitted with chimneys were successfully used in catching terrapins on this island in a study conducted by Hogan (2002) and, therefore, are recommended for use in further studies.

Deploying crab traps without chimneys for short amounts of time would help to quantify the distance that terrapins travel away from the islands. This research was restricted to areas in and directly around the island due to chimney traps being used. If actual commercial crab traps were deployed and checked on a regular basis, this would provide more range data as well as data on terrapin mortality caused by the commercial crab industry. Furthermore, studies to determine the extent of terrapin bycatch mortality in the blue crab fishery are needed to evaluate impacts on terrapin population viability.

In the future, a more consistent approach to collecting terrapin within transect lines will provide data on the amount of time that terrapins spend on land. This study was limited by the number of people that could cover the entire island during each sampling period. Additionally, we were unable to cover any of the land area on North Deer Island because of the restrictions placed on it as a bird sanctuary. It would be important for future research to cover all of North Deer Island and get a more comprehensive estimate of terrapin populations.

The most important conservation action to protect diamondback terrapins in Galveston Bay would be to protect South Deer Island from erosion and implement restoration of marsh habitat on the island. North Deer Island, being such an important bird rookery island, is protected and partially owned by the Texas and Houston Audubon Societies. In addition to numerous no trespassing signs throughout the island, Audubon employs a warden that frequently patrols the island for violators. Additionally, an 8-year, \$3.2 million protection and restoration project was implemented to provide erosion control structures and marsh restoration for the island.

Although South Deer Island provides less habitat for birds, it provides habitat and presumably nesting areas for the largest known population of the Texas diamondback terrapin subspecies, and the only known terrapin population in Galveston Bay. It is essential that this critical terrapin habitat be protected.

Ultimately, in order to provide more protection for the Texas diamondback terrapin subspecies, populations need to be located throughout the state. Once these terrapin populations are discovered, state and federal conservation agencies will have the necessary information to determine if the subspecies should be listed as threatened or endangered and/or whether additional management action is needed in regards to the blue crab fishery.

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APPENDICES

Appendix A. Initial collection date and time for each terrapin.

Notch	Date	Time	Island	Gear	Lat	Long	Sex
20	3/27/2008	1150	South	Comm. Crab Trap	29.269458	94.910703	Male
1	3/28/2008	1150	South	Grab	29.270000	94.911390	Male
2	3/28/2008	1110	South	Grab	29.271110	94.912220	Male
3	3/28/2008	1140	South	Grab	29.272780	94.912220	Male
4	3/28/2008	1140	South	Grab	29.272780	94.912220	Female
5	3/28/2008	1410	South	Trap	29.272969	94.908728	Male
6	3/28/2008	1400	South	Grab	29.271390	94.912220	Female
3 right	4/1/2008	1030	South	Grab	29.272780	94.912220	Male
7	4/1/2008	1050	South	Grab	29.273556	94.911558	Male
8	4/1/2008	1110	South	Grab	29.273889	94.911389	Female
9	4/1/2008	1110	South	Grab	29.273889	94.911389	Male
10	4/1/2008	1315	South	Grab	29.274720	94.912500	Male
11	4/1/2008	1320	South	Grab	29.274720	94.912220	Male
12	4/1/2008	1410	South	Grab	29.270556	94.908056	Male
14	4/7/2008	1258	South	Grab	29.271944	94.912222	Female
17	4/7/2008	1315	South	Grab	29.270278	94.911667	Female
21	4/7/2008	1454	South	Grab	29.270556	94.912222	Juvenile
22	4/7/2008	1423	South	Grab	29.270139	94.911944	Male
13	4/11/2008	1021	South	Grab	29.270330	94.911260	Male
15	4/11/2008	1118	South	Grab	29.269992	94.911292	Female
16	4/11/2008	1154	South	Grab	29.272633	94.912269	Male
18	4/11/2008	Afternoon	South	Grab	29.272958	94.911444	Male
19	4/11/2008	Afternoon	South	Grab	29.272978	94.911372	Female
23	4/11/2008	Afternoon	South	Grab	29.270081	94.910969	Female
24	4/18/2008	1330	South	Grab	29.271111	94.912778	Male
25	4/18/2008	1418	South	Grab	29.271110	94.912417	Female
26	4/18/2008	1459	South	Grab	29.271653	94.912028	Female
27	4/19/2008	1030	South	Grab	29.273983	94.911025	Female
28	4/19/2008	1100	South	Grab	29.271025	94.912864	Female
29	4/19/2008	1315	South	Grab	29.273611	94.911667	Male
30	4/19/2008	1320	South	Grab	29.273611	94.911583	Male
31	4/19/2008	1400	South	Grab	29.274167	94.911667	Female
32	4/23/2008	1140	North	Grab	29.283056	94.922222	Female
33	4/23/2008	1245	North	Grab	29.284161	94.923681	Male
34	4/23/2008	1412	North	Grab	29.283889	94.921111	Male
35	4/23/2008	1422	North	Grab	29.283889	94.920833	Male
36	4/25/2008	1212	South	Grab	29.271389	94.911944	Male
37	4/29/2008	1220	South	Grab	29.274444	94.911667	Male
38	4/29/2008	1246	South	Grab	29.274281	94.911361	Female
39	4/29/2008	1352	South	Grab	29.273889	94.910833	Male
40	4/29/2008	1441	South	Grab	29.273889	94.910053	Male
41	4/29/2008	1439	South	Grab	29.273889	94.909444	Female

Notch	Date	Time	Island	Gear	Lat	Long	Sex
42	4/29/2008	1521	South	Grab	29.273333	94.909722	Male
43	4/29/2008	1543	South	Grab	29.273611	94.909722	Female
44	4/29/2008	1610	South	Grab	29.273611	94.910556	Female
45	5/2/2008	1048	North	Grab	29.283122	94.921678	Female
46	5/2/2008	1110	North	Grab	29.284264	94.921658	Female
47	5/2/2008	1155	North	Grab	29.283558	94.923506	Female
49	5/8/2008	1310	South	Grab	29.273330	94.910560	Male
50	5/9/2008	1104	South	Grab	29.270278	94.911389	Female
51	5/9/2008	1110	South	Grab	29.269722	94.911111	Male
52	5/9/2008	1155	South	Grab	29.270830	94.913060	Male
53	5/9/2008	1155	South	Grab	29.270830	94.913060	Male
54	5/9/2008	1155	South	Grab	29.270830	94.913060	Female
55	5/10/2008	905	South	Grab	29.270833	94.912778	Male
56	5/10/2008	915	South	Grab	29.270556	94.912500	Female
57	5/10/2008	930	South	Grab	ND	ND	Male
58	5/10/2008	920	South	Grab	29.270560	94.912780	Male
59	5/10/2008	1210	North	Grab	ND	ND	Male
60	5/10/2008	1215	North	Grab	29.283056	94.922500	Female
62	5/16/2008	925	North	Grab	29.284539	94.920836	Male
63	5/16/2008	1008	South	Grab	29.273911	94.910064	Male
64	5/16/2008	1107	South	Grab	29.273611	94.910556	Male
65	5/16/2008	1015	South	Grab	29.271619	94.912194	Female
66	5/16/2008	1107	South	Grab	29.273611	94.910556	Male
67	5/16/2008	1040	South	Grab	29.272961	94.912244	Male
68	5/16/2008	1225	South	Grab	29.271806	94.911417	Female
69	5/16/2008	1130	South	Grab	29.271389	94.909722	Female
70	5/16/2008	1135	South	Grab	29.271389	94.909722	Male
71	5/16/2008	1535	North	Trap	29.283972	94.920847	Female
72	5/16/2008	1535	North	Trap	29.283972	94.920847	Male
73	5/16/2008	1535	North	Trap	29.283972	94.920847	Male
74	5/16/2008	1635	North	Grab	29.283056	94.921944	Female
75	5/16/2008	1710	North	Grab	29.281903	94.925586	Male
80	5/21/2008	1010	South	Grab	29.290556	94.910833	Female
81	5/21/2008	ND	South	Grab	29.273611	94.910000	Male
82	5/21/2008	1545	North	Trap	29.283889	94.920833	Female
83	5/21/2008	1620	North	Grab	29.283333	94.921667	Female
84	5/21/2008	1550	North	Grab	29.284167	94.921667	Male
90	5/21/2008	1615	North	Grab	29.284444	94.920833	Juvenile
93	5/29/2008	1000	South	Grab	29.270103	94.911333	Male
94	5/29/2008	1235	North	Grab	29.284167	94.921389	Male
48	6/16/2008	705	South	Grab	29.270278	94.910833	Female
61	6/16/2008	709	South	Grab	29.270278	94.911389	Female

Notch	Date	Time	Island	Gear	Lat	Long	Sex
76	6/16/2008	712	South	Grab	29.270000	94.911389	Male
77	6/16/2008	714	South	Grab	29.270278	94.911944	Female
78	6/16/2008	714	South	Grab	29.270278	94.911944	Female
79	6/16/2008	718	South	Grab	29.270000	94.911667	Female
85	6/16/2008	721	South	Grab	29.270000	94.911667	Male
86	6/16/2008	722	South	Grab	29.270833	94.912778	Female
87	6/16/2008	726	South	Grab	29.270556	94.912222	Female
88	7/13/2008	744	South	Grab	29.270278	94.911944	Female
89	7/13/2008	834	South	Grab	29.270556	94.911389	Female
91	7/20/2008	712	South	Grab	29.274003	94.909858	Male
92	7/27/2008	1745	South	Grab	29.271722	94.912278	Male
95	8/4/2008	844	South	Grab	29.271175	94.911933	Female
98	8/4/2008	750	South	Grab	29.270194	94.911861	Male
96	8/11/2008	738	South	Grab	29.270000	94.911111	Male
99	8/11/2008	708	South	Grab	29.271111	94.910000	Female
100	8/11/2008	715	South	Grab	29.271208	94.909978	Male
101	8/11/2008	704	South	Grab	29.270278	94.910556	Female
102	8/11/2008	815	South	Grab	29.269961	94.911250	Female
105	8/18/2008	714	South	Grab	29.272180	94.912280	Male
106	8/18/2008	729	South	Grab	29.273550	94.911920	Female
108	8/18/2008	735	South	Grab	29.270800	94.912900	Female
109	8/18/2008	701	South	Grab	29.269960	94.911240	Male
110	8/18/2008	730	South	Grab	29.270700	94.912700	Female
111	8/18/2008	ND	South	Grab	29.274490	94.912090	Female
112	8/18/2008	ND	South	Grab	29.274530	94.912060	Female
113	8/18/2008	739	South	Grab	29.274040	94.912250	Male
114	8/18/2008	719	South	Grab	29.272830	94.912210	Female
115	8/18/2008	748	South	Grab	29.274420	94.912530	Female
116	8/18/2008	803	South	Grab	29.274470	94.912320	Female
117	8/18/2008	ND	South	Grab	ND	ND	Male
118	8/18/2008	730	South	Grab	29.273390	94.912160	Male
119	8/18/2008	758	South	Grab	29.273350	94.911220	Male
120	8/18/2008	838	South	Grab	29.273060	94.909430	Female
121	8/25/2008	728	South	Grab	29.272990	94.912310	Male
122	8/25/2008	725	South	Grab	29.273420	94.912280	Male
123	8/25/2008	719	South	Grab	29.273170	94.911570	Female
124	8/25/2008	704	South	Grab	29.273580	94.910390	Male
125	8/25/2008	715	South	Grab	29.274130	94.911320	Male
126	8/25/2008	710	South	Grab	29.272210	94.911580	Female
127	8/25/2008	742	South	Grab	29.273610	94.912970	Female
128	8/25/2008	745	South	Grab	29.273600	94.913000	Male
129	8/25/2008	750	South	Grab	29.273250	94.912850	Female

Notch	Date	Time	Island	Gear	Lat	Long	Sex
150	9/8/2008	659	North	Grab	29.283540	94.921120	Female
151	10/6/2008	1405	South	Grab	29.271150	94.912058	Female
152	10/6/2008	1450	South	Grab	ND	ND	Female
148	10/21/2008	1811	South	Grab	29. 2715	94. 9130	Male
149	10/21/2008	1811	South	Grab	29. 2715	94. 9130	Female
96 b	1/19/2009	1130	South	Grab	29.273056	94.911667	Male
99 b	2/17/2009	Afternoon	South	Grab	29.274444	94.912222	Male
100 b	2/17/2009	Afternoon	South	Grab	29.274440	94.912220	Male
101 b	2/17/2009	Afternoon	South	Grab	29.270830	94.912780	Male
102 b	2/17/2009	Afternoon	South	Grab	29.271110	94.912780	Female
103	2/17/2009	Afternoon	South	Grab	29.271110	94.912780	Male
104	2/17/2009	Afternoon	South	Grab	ND	ND	Male
107	2/17/2009	1300	South	Grab	ND	ND	Male

Appendix B. Morphometrics of each terrapin collected during the study.

Notch	Rings	Carapace Length (mm)	Carapace Width (mm)	Depth (mm)	Plastron Length (mm)	Plastron Width (mm)	Head Width (mm)	Weight (kg)
20	5	ND	92	ND	ND	ND	ND	0.3
1	5	121	ND	46	ND	54.5	24	0.28
2	5	132	93	52.5	ND	60	27	0.21
3	5	115	86	46	ND	52.5	24	0.25
4	7	190.5	136	78	ND	85	45	1.21
5	Unknown	136.5	96	52	114	60	26	0.42
6	10	173	133	69.5	152	84.5	40	0.85
3 right	5	137.13	95.05	52.5	109.13	60.82	25.58	0.42
7	4	132.03	96.83	49	109.84	59.11	24.42	0.36
8	7	173	119.01	67	153	82	37.87	0.93
9	6	119.68	86.58	49	101.66	53.55	21.57	0.29
10	6	131.93	94.99	51	108.24	57.17	24.08	0.4
11	7	131.01	93.03	48	105.8	57.25	25.02	0.39
12	5	142	112.98	54	124	69.5	29.5	0.49
14	9	199.5	156	ND	170	93	50.5	1.58
17	11	181	133	75	160	89	36	1.03
21	5	81	62	36	70.5	40	14	0.15
22	5	126.5	100	50	111	61	20	0.36
13	4	133.5	104	50	121.5	66	26	0.42
15	10	175.6	130	70	157.5	82	35	ND
16	4	120.45	80.6	50.5	111	50.4	22	ND
18	4	130.9	92	ND	110	56.9	24	ND
19	7	199	144.9	86	180	90.2	45.9	ND
23	11	192	142	74.9	167	93	45.05	ND
24	4	134	93	46	109	58	ND	0.37
25	7	285	145.5	77	187	94	58	1.44
26	8	155	116	69	141.5	75	33	0.62
27	3	190	135	72	169	94	45	1.11
28	8	183	130	76	161.5	85	40	0.94
29	4	123	10	50	114	63	28	0.43
30	6	140	101	50	109	59	28	0.43
31	10	142	109	60	128	67	28	0.51
32	7	213.5	134.6	92	191	77.9	32.8	1.76
33	6	139	96	49	113.5	58	25.5	0.4
34	6	123	88	45.5	102	55.5	21.4	0.31
35	5	116.1	83.4	42.2	96.8	46.6	16.7	0.48
36	6	128	93.5	47	114.5	59.5	26	0.31
37	4	135	92.5	48	115	57	26	0.37
38	7	201	141	78	180	89	52	1.42
39	6	138	100.5	52	117.5	78	28	0.4
40	4	141	100	48.5	120.5	61	30	0.4
41	7	197	142	80	179	87	48	1.39

Notch	Rings	Carapace Length (mm)	Carapace Width (mm)	Depth (mm)	Plastron Length (mm)	Plastron Width (mm)	Head Width (mm)	Weight (kg)
42	5	141	99.5	30	118	63	52.5	0.37
43	ND	245	148.5	8.35	183	94.5	55	1.45
44	9	194	143	82	178	93	58	1.5
45	7	196	141.5	76	170.5	87	41	1.16
46	9	199.5	142	79	174.5	89	46	1.3
47	7	208.5	147	81.5	186.5	96	58	1.7
49	5	139	97.5	69	125.5	64.5	27.5	0.45
50	ND	182	126	72	160	79	34	0.96
51	ND	145	109	53	121	63	26	0.4
52	6	133	98	nd	112	59	25	0.37
53	5	120	85	47	103	55	24	0.28
54	10	209	157	85	190	103	55	1.62
55	4	122	93	49	106	56	22	0.34
56	12	179	139	70	157	89	39	0.99
57	8	138	95	57	113	56.5	22	0.43
58	5	144	107	51	121	66	25	0.45
59	8	128.5	96	51	109.5	58	23.5	0.34
60	6	187	143	77	166	90	42	1.22
62	4	124	92	51	104.5	56	22.5	0.37
63	6	128	94.72	51	107	56.205	26.02	0.34
64	4	134.5	94	52.5	111.5	58.5	25.5	0.65
65	5	120.5	91	56.5	111	56.5	27.5	0.62
66	7	136	95.5	58	110.5	58	26	0.6
67	6	129	91.5	50.5	112	61	25	0.54
68	8	182	134	77	167	91	46	1.22
69	4	109	86	52	97	53	26	0.26
70	5	139	94	48	115	57	24	0.37
71	8	136.4	102.1	57.5	115.5	68.8	28.2	0.48
72	6	126	89.6	52	105.2	64.6	24	0.31
73	3	129.2	94.8	47	106.3	67.8	23.1	0.37
74	ND	115.6	85.5	51	100	52.1	27.2	0.28
75	5	131.3	93.8	49	108.4	60.5	22	0.34
80	8	192.5	140	74	169	89	44	1.08
81	4	127.5	87	44.9	95.5	52	20	0.31
82	8	178	131	73.5	157	85.5	48	0.99
83	6	128.3	91.8	52.5	114.8	58.6	27.4	0.34
84	6	137.6	96.1	55	113.7	61.2	23.2	0.4
90	4	90.69	65.77	38	80.26	41	21.13	0.11
93	6	132	92.9	49.4	111	57	25	0.34
94	4	138	99.5	48.5	111.5	61	27	0.43
48	ND	183	141	82	178	88	45	1.19
61	8	156	117	69	140	77	32	0.71

Notch	Rings	Carapace Length (mm)	Carapace Width (mm)	Depth (mm)	Plastron Length (mm)	Plastron Width (mm)	Head Width (mm)	Weight (kg)
76	8	127	100	59	108	63	30	0.4
77	10	194	140	80	165	86	42	1.02
78	9	178	137	78	158	83	48	0.96
79	9	173	125	72	152	82	38	0.88
85	6	122	95	55	112	60	29.5	0.37
86	8	188	139.5	84	163	84	44	1.13
87	ND	199	150.5	86	178	94.5	50	1.45
88	10	196	141.5	77.5	178	91	47.5	1.56
89	8	198.5	148	78	173.5	95	45	1.36
91	ND	140	100	52	114.5	58	26	0.37
92	ND	137.5	97	52	117	58	26.5	0.4
95	8	175	123	73	158.5	88.5	38	0.85
98	ND	132	101	50	110	60	24	0.34
96	6	128	97	51	108	58	25	0.34
99	13	200	149	89	178	132	45	1.45
100	Unknown	150	104	55	124	62	30	0.31
101	10	191	131	79	172	ND	45	1.08
102	9	188	130	73	168	85	39	0.74
105	7	115	86	50	103	53	25	0.26
106	Unknown	198	136	81	172	87	46	1.25
108	9	174	129	69	160	90	38	1.02
109	8	143	103	52	122	63	23	0.45
110	12	169	122	72	151	77	31	0.94
111	8	203	150	85	179	97	51	1.59
112	7	197	142	89	177	84	47	1.3
113	5	140	97	50	116	60	ND	0.4
114	6	184	134	76	166	ND	44	1.11
115	5	191	143	80	167	92	45	1.3
116	5	202	144	89	182	104	52	1.5
117	6	129	96	57	109	56	26	0.43
118	7	137	100	48	114	63	27	0.4
119	ND	124	81	41	106	53	19	0.31
120	ND	200	148	82	185	95	51	1.7
121	6	131	97.5	49	110.5	59.5	24.5	0.4
122	6	133	92.5	48.5	115	58.5	24	0.4
123	ND	210	146	82	181	90	54.9	1.56
124	7	123	85.5	52	104.5	52	20	0.31
125	4	130	88	47	107	56	21.5	0.31
126	ND	182	134	80	163	81	40	1.11
127	9	194	139	80	177	88	49	1.45
128	6	124	87	51	100	55	18.5	0.31
129	9	179	133	79.5	164	89	48.5	1.28

Notch	Rings	Carapace Length (mm)	Carapace Width (mm)	Depth (mm)	Plastron Length (mm)	Plastron Width (mm)	Head Width (mm)	Weight (kg)
150	Unknown	222	161	90	202	101	59	1.7
151	10	211	152	82	194	95	58	1.56
152	8	192	140	75	171	92	48	1.13
148	5	130	100	49	109	57	26	0.28
149	7	173	126	73	156	115	39	0.99
96 b	6	134	96	50	111	61	28	0.31
99 b	11	135	100	47	114	59.5	25	0.4
100 b	8	144	ND	51.5	123	61.5	26	0.45
101 b	9	132.5	ND	42.5	107	55	20	0.4
102 b	Unknown	189	ND	79	165	90	56	1.36
103	14	122	ND	43	100	53	17	0.34
104	ND	131	ND	42.5	111	51	20	0.43
107	8	136	ND	43.5	110.5	56	21	0.43

Appendix C. Terrapin encounter history.

Notch	Collection	Date	Island	Gear	Latitude	Longitude
1	1	3/28/2008	South	Grab	29.270000	94.911390
1	2	8/11/2008	South	Grab	29.270556	94.912500
6	1	3/28/2008	South	Grab	29.271390	94.912220
6	2	8/18/2008	South	Grab	29.271790	94.912280
12	1	4/1/2008	South	Grab	29.270556	94.908056
12	2	4/29/2008	South	Grab	29.273889	94.910000
13	1	4/11/2008	South	Grab	29.270330	94.911260
13	2	4/18/2008	South	Grab	29.271044	94.912864
13	3	8/18/2008	South	Grab	ND	ND
21	1	4/7/2008	South	Grab	29.270556	94.912222
21	2	8/11/2008	South	Grab	29.270000	94.911389
25	1	4/18/2008	South	Grab	29.271110	94.912417
25	2	4/25/2008	South	Radio Transmitter	29.271294	94.912203
43	1	4/29/2008	South	Grab	29.273611	94.909722
43	2	8/18/2008	South	Grab	29.274390	94.912470
47	1	5/2/2008	North	Grab	29.283558	94.923506
47	2	5/29/2008	North	Grab	29.284444	94.921389
54	1	5/9/2008	South	Grab	29.270830	94.913060
54	2	5/10/2008	South	Grab	29.271111	94.912778
63	1	5/16/2008	South	Grab	29.273911	94.910064
63	2	8/18/2008	South	Grab	29.274310	94.911360
80	1	5/21/2008	South	Grab	29.290556	94.910833
80	2	2/3/2009	South	Grab	ND	ND
89	1	7/13/2008	South	Grab	29.270556	94.911389
89	2	8/11/2008	South	Grab	29.270000	94.911111
right 3	1	4/1/2008	South	Grab	29.272780	94.912220
right 3	2	8/25/2008	South	Grab	29.273650	94.909950