Population Characteristics of Diamondback Terrapin at the Deer Island Complex: Galveston, Texas during 2008

Prepared for the Houston Zoo

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Abstract

A total of 134 diamondback terrapin were captured on North and South Deer Islands between November 16, 2007 and February 17, 2009. Additionally, 15 terrapin were recaptured during this period. One terrapin was recaptured twice during the study period. Of the 15 terrapin that were collected a more than once, the average time period between captures was 94 days, ranging between 1 and 258 days. Prior to March 27, 2008 no terrapin were captured. In addition, from November 3, 2008 to December 23, 2009, no terrapin were observed at South Deer Island. The average travel distance was 168 meters and ranged between zero and 1,453.5 meters. Two terrapin travelled between North and South Deer Island. Specimen 80 travelled from North Deer Island to South Deer Island at least once during the survey. The total minimum distance travelled between islands by this terrapin was 1,339.4 meters after 259 days. Terrapin 63 travelled a minimum distance of 1,453.5 meters from North Deer Island. 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. Greater numbers of terrapin were found throughout April and May, while population counts dramatically dropped from September 2008 through February 2009. Biological data collected on terrapin indicated a male to female sex ratio of 1.1 to 1. The average carapace length for male terrapin was 131.7 cm versus 186 cm for female terrapin. The average male and female weight was .38 kg and 1.2 kg, respectively. The estimated population size based on mark recapture data ranged between

Estimates the population size of terrapin on North Deer Island were not attempted due to the insufficient numbers of marked and recaptured terrapin. Estimates of the terrapin population size at South Deer Island for two periods (4/12-5/9/08) and (5/10-8/4/08) ranged between 595 and 1,365 terrapin respectively. However the 95% confidence interval for the number of terrapin present during these time periods were large ranging between 145 to 5,563, and 271 to 16,283 terrapin respectively.

As a result of this research, a large number of terrapin in West Bay have been individually marked and documented. This will provide future researchers and managers essential baseline population data needed for the further study and management of Diamondback terrapin populations residing on North and South Deer Islands. It also provides baseline information that will enable researchers to track the continued movement, habitat use and population status of this local population. Furthermore, this research provides critical environmental and habitat data that can be used to define habitat needs for this species coast wide and methodology needed to locate populations of this subspecies throughout the coastal areas of the state.

It is essential that monitoring of Diamondback terrapin be continued at the Deer Island complex to monitor long term trends associated with changes in climate, habitat and water quality. It is critical that habitat models be developed for Texas terrapin to identify critical habitat needs for this species. This will require additional years of data collection and intensive studies. Expanded monitoring to the entire Texas coast is needed to identify other populations and the larger demographic characteristic of this species.

Objectives

The study of diamondback terrapins on North and South Deer Islands is intended to provide a baseline population estimate of these animals for West Bay, Galveston, TX. Diamondback terrapin populations in Texas are largely unknown due to a lack of data collected on the subspecies throughout the state. By creating a baseline population estimate, researchers can determine if diamondback terrapin numbers are declining throughout the area over time. This information will assist resource agencies in determining if the Texas subspecies should be provided greater protection status throughout the state. In addition to population estimates, this research provides baseline measurements and sex ratios that are essential to monitoring the health of the West Bay population over time.

Background

Diamondback terrapin (*Malaclemys terrapin*) is the only species of brackish water turtle found in the United States. Seven subspecies of this turtle can be found throughout coastal waters ranging from Cape Cod, MA down to Corpus Christi, TX. The Texas Diamondback Terrapin (*M. terrapin littoralis*) is found from western Louisiana to Texas (Brennessel 2006). Harvesting of diamondback terrapins began in the late 1800's and did not wane until the economic collapse of the Great Depression. Terrapin meat was considered a delicacy and when the species population collapsed in one area, terrapin were shipped in from across the country to meet the demand (Hauswaldt and Glenn 2005). Texas diamondback terrapins were once hunted to the brink of extinction because many people thought that they were especially delicious in soup. Some believe that Prohibition helped save terrapins. Turtle soup was made with wine during the 1920s. When Prohibition laws made possessing wine illegal, turtle soup fell out of favor and thousands of trapped turtles were released into the ocean (TPWD 2007). According to the Texas Parks and Wildlife today most terrapins are killed by speeding cars or become trapped in baited blue crab traps and drown. Lack of data on original diamondback terrapin numbers make it difficult to determine the impact of harvesting on the population as a whole. However, recent limited data suggests that throughout the terrapins' range, their populations have seen significant declines (Cecala et al. 2008).

Although terrapin numbers slowly began to increase following the Great Depression, new factors now threaten their existence. Coastal development is eliminating their habitat and nesting areas. Female diamondback terrapins appear to return to the same areas to nest every year. Man-made 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 crossing coastal roads in an attempt to lay their eggs (Bossero & Draud 2004). Many of the 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 which feed invertebrates, worms, snails, mollusks and crustaceans (Brennessel 2006). These organisms are the primary food source of the diamondback terrapin. Reductions in the prey species and the amount of suitable habitat for diamondback terrapin have been cited as major causes of their decline. Hatchlings and juveniles are also preyed upon by crows, gulls, eagles, rats and raccoons, which can substantially diminish their population size. Recently, collisions with watercraft, has been cited as a significant source of mortality and limb loss (Cecala et al. 2008).

Commercial crab traps can also account for a large number of terrapin deaths. As the terrapins enter the traps to eat the bait, they become unable to escape and soon drown (Garber 1990; Morris et al. 2010; Cole and Helser 2001). Certain states are beginning to notice the devastating effect that these traps can have on terrapins. Although Texas Parks and Wildlife recently passed a law that prohibits the commercial collection of all native turtle species without a permit, the addition of terrapin bycatch reduction devices on crab traps was not required (TPWD 2008).

The depletion of the diamondback terrapin populations can have detrimental consequences to the entire coastal ecosystem. These small reptiles are top-level predators, which control and sustain healthy, effective salt marsh food webs. Their diet consists of bivalves, snails, crustaceans, small fish and crabs. Therefore reductions in terrapin populations can directly influence the amount of secondary producers and consequently primary producers. The terrapin hatchlings are also a food source for many birds and native animals along the coast (Bossero & Draud 2004). Along with the losses from habitat degradation and predation, terrapins are at a disadvantage in terms of birth rates. A female breeds only every four years and doesn’t reach sexual maturity until the age of six (TPWD 2007).

With all of these threats to their existence, the viability of the individual diamondback terrapin population throughout their range has become an increasing concern (Butler et al. 2006). Most research began after terrapins were harvested for the food industry. Therefore, there is little to no information available about the natural population numbers of diamondback terrapins throughout the United States prior to this period (Tucker et al. 2001). Due to their small numbers, several states now provide protection status for the diamondback terrapin (Watters 2004; DTWG 2010). Harvest and collection is illegal in the states of Rhode Island, Massachusetts, and Alabama. Additionally, Maryland, Mississippi, and North Carolina do not allow commercial collection of diamondback terrapin within the borders of the three states. Many other states within the range of diamondback terrapin 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 without a special permit (TPWD 2008).

Little information has been gathered on the numbers or health of local Texas populations. In 1984, TPWD sent out approximately 1,150 questionnaires to commercial crab trappers, fishermen, coastal fisheries biologists, and coastal game wardens to obtain information on range of terrapin along the Texas Coast (Hogan 2002). Based on this survey they found terrapin were observed at various coastal locations from Nueces Bay to

Galveston Bay from 1973 to 1984 (D.W. Mabie 1988 written communication cited by Hogan 2002). A study was conducted in 1997 on the coast near Corpus Christi (K.A. Holdboork and L.F. Elliot, written commun. 2000, cited in Hogan 2002). During that study 109 individual terrapin were captured near Nueces Bay and the mouth of the Nueces River. They found terrapin most near riverine habitat with salt marshes, shell islands and oyster reefs in shallow turbid water.

Recently, Huffman (1997) compiled data on sightings of Diamondback terrapin in several bays near Galveston. He also surveyed the North Deer Island complex in West Bay near Galveston, Texas. During that study only one terrapin was captured. During April 2001 to May 2002, one hundred and thirty five Texas diamondback terrapins were captured at South Deer Island, Galveston, Texas (Hogan 2002). Due to the small number of terrapins caught in these studies, population and range estimates have not been conducted. This research is the first data gathered on the Texas Diamondback terrapin population numbers and home ranges in West Bay, Galveston. This analysis also includes North Deer Island, which was not investigated in the previously mentioned study.

Study Area

The location of the study sites were chosen based on a past study conducted by Hogan (2002), which confirmed the presence of terrapin in and around South Deer Island. Both South and North Deer Islands are located in West Bay, part of the Galveston Bay complex immediately north of Galveston Island, Texas (Figure 1). South Deer Island is a privately owned island which served as the primary study area (Figure 2). South Deer Island has an approximate perimeter of 2.71 kilometers and an area of 24.36 hectares. It possesses numerous tidal creeks throughout the island which provide potential habitat and food for terrapin. Small shell beaches provide potential nesting areas and mud along the stream banks facilitates temperate regulation by creating areas for basking or burrowing (Figures 3-5). Land cover consisted of a mixture of *Spartina alterniflora* and Salicornia/Batis marshes. The elevation ranges between sea level and approximately 1.2 meters although most of the island is less than 0.3 meters (Figure 2). South Deer Island contained several tidal creeks, ponds, and an enclosed bay.

North Deer is approximately 1.1 kilometer north of South Deer Island, and exhibits similar habitat and conditions (Figure 6). 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 and approximately 1.5-2.1 meters); however most of the island was below 0.3-0.6 meters. The North Deer Island contained habitat similar to South Deer Island. However, this island has much more elevated areas and provides more diverse habitat for birds. North Deer Island also contained less tidal creek channels (Figure 6). Like South Deer Island, North Deer Island contained a large shallow lagoon. We could not monitor North Deer Island as thoroughly as South Deer Island because it is an Audubon bird sanctuary. Consequently, only about 1/10th of the effort was expended on North Deer Island.

Figure 1. Map of study area.

Figure 2. South Deer Island study area.

Figure 3. South Deer Island tidal creeks.

Figure 4. Shell hash mound located on South Deer Island.

Figure 5. Shell hash beach located on South Deer Island.

Figure 6. Map of North Deer Island.

Methods

These two islands were chosen as the study sites so that data collected on them could be used as a representative sample of West Bay as a whole. Our goal was to sample South Deer Island on a weekly to bi-weekly basis during most months of the year. However, bi-weekly to monthly sampling was generally conducted during the winter (December to February). Terrapin were collected by a combination of methods including shallow-water crab traps, crab traps with modified chimneys, and hand capture of terrapin by researchers (Table 1). On some dates both stationary trapping and/or manual searches were used to collect terrapin. However, the majority of terrapin were captured by hand throughout the study period. 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 terrapin as they swam or walked by. Land areas were also searched on South Deer Island, including vegetated areas and muddy locations outlining the channels. Sampling on land was not generally conducted at North Deer Island due to prohibitions established by the Audubon Bird Sanctuary staff. 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 periods when minimal staff were available for searching, one or two researchers would follow the channels across the island and search land areas on the way back or vice versa.

Modified crab traps were also deployed in the lagoon opening of North Deer Island and around the perimeter of South 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 terrapin could surface for air. However, even with the chimneys attached, these traps could not be deployed in water over 4.5 feet.

In order to identify individual terrapin we used a combination of external physical marks and internal tags. The marginal carapace scutes were notched with a metal file using a modified Cagle numbering system which assigns each terrapin with a unique number (Figures 7 and 8)(Cagle 1939). These notches also create external marks that allow quick visual identification of previously captured animals. We also tagged terrapin with more permanent Passive Integrated Transponder (PIT) tags (Figure 9 and 10). These tags, manufactured by AVID were initially provided by the Texas Parks and Wildlife Department. These tags have a unique identification number. These tiny devices which have been used since the mid-1980's range 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. PIT tags were injected by a 12-gauge needle under the terrapin's skin near the back leg and underneath the carapace to provide permanent identification for each individual (Gibbons & Andrews 2004). After allowing the terrapins to mix 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.

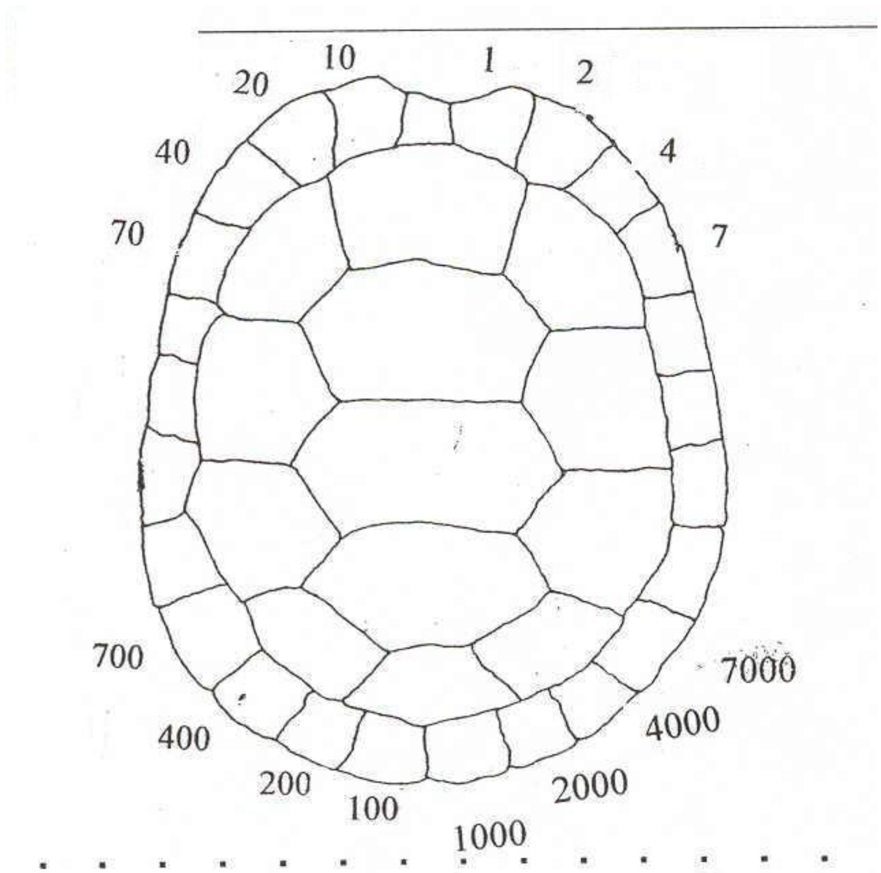

Figure 7. Modified Cagle marking system used during the terrapin study.

Figure 8. Notching method used to externally mark individual terrapin using Cagle system.

Figure 9. AVID pit tag, injector and reader.

Figure 10. Injection of PIT tags into rear leg of terrapin.

Each diamondback terrapin was also weighed and measured to determine size, growth rates, and relative age and size distribution within populations. Calipers were used to measure carapace length from the nuchal scute down the midline of the carapace, ending between the posterior marginal scutes (Figure 11). 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. Weight was measured by placing each animal in a mesh bag and hanging the bag from a digital scale. The weight of the bag was then subtracted to obtain a weight measurement for each terrapin (Figure 12). Male to female sex ratios were determined based on secondary characteristics associated with a particular sex such as body and head size, tail size and shape, cloacal opening placement, and carapace shape. Additionally, habitat utilization by Texas diamondback terrapins was quantified during field surveys. Time of collection was recorded during all surveys. Each researcher also recorded starting and ending search times, which was necessary to calculate the terrapin catch per unit effort.

Figure 11. Measurement of terrapin morphometrics with calipers. Larger calipers were used to measure depth of carapace.

Figure 12. Measurement of terrapin weight with hanging bag and scale.

Physical observations made at the time of capture include latitude and longitude as determined with a GPS location. We also collected information on whether terrapin were captured on land, in the water, or buried in the mud. When captured on land, additional information on the type of vegetation and substrate type as well as the distance from the closest channel was recorded. Terrapin collected in the water were almost always in the small channels that run the length the islands. The depth of the water and turbidity during high tide events was the greatest factor prohibiting researchers from capturing terrapin within the channels. Depth of water and unlimited escape routes was the greatest factor in preventing researchers from capturing terrapin in water surrounding the islands. Prey types present on the islands were also noted in this study, in addition to air temperature, water temperature, and salinity during collection periods.

External radiotelemetry tags and manual receivers manufactured by Advanced Telemetry Systems (ATS) were used in this study for the purpose of estimating home ranges, migration patterns, dispersal, habitat use, and mating behavior of the diamondback terrapins in West Bay (Garton et al. 2001). Each tag has 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 13). 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. The proportion of tag to animal weight was maintained at less than 5% to reduce impacts on animal movement.

Figure 13. Female terrapin with ATS radio-tag attached.

Tracking was conducted by both boat and on foot using a Yagi antenna attached to an ATS manual receiver. This apparatus was intended to track the short-term movements of each terrapin from South Deer Islands in West Bay. Radio tracking was conducted several times each month throughout the study period. Data from this portion of the study is not presented in this report due to the low number (8) of animals tagged late in the study. Of these only three tags were recovered including one tag that fell off, one dead terrapin and one live terrapin. The cause of death for the dead terrapin is unknown. However, we will attempt to track the remaining 6 organisms and additional organisms tagged in subsequent years to obtain more definitive information. Data from radio-track recaptures are not included in our recapture totals for computation of population size but are noted for movement calculation.

We attempted to determine the population size of diamondback terrapin at both islands using the Jolly-Seber mark recapture method (Krebs 1999 and 2009). This was attempted by marking individual terrapins, releasing them, and recapturing them at a later date. Each terrapin was individually marked to distinguish it from the others. The Jolly-Seber mark-recapture method is designed for estimation of populations 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. In order to accommodate the Jolly Seber experimental design we would pool recapture data from multiple dates into larger continuous temporal time units as necessary. This procedure usually truncates the first and last time step in terms of providing a population estimate.

These estimates of population size using mark recapture data should be considered tentative based on this first year data which yielded highly variable and low recapture rates during the first year of our study. We are in the process of producing an estimate using other more robust methods that may be less sensitive to low tag return data (Cooch and White 2010). Results of analyses using these techniques will likely be presented by the senior author in their thesis report. In addition, after accumulation of additional years of data we plan to attempt to utilize the Jolly-Seber model again or other models once sufficient data (recaptures) have been accumulated.

Results and Analysis

A total of 56 sampling trips were conducted at the North and South Deer Island complex during the study period (Table 1). Based on this effort a total of 134 diamondback terrapin (*Malaclemys terrapin littoralis*) were captured on North and South Deer Islands between November 16, 2007 and February 17, 2009 (Figures 14-16). A total of 15 terrapin were recaptured at least once, while one was recaptured twice (Figures 17-19; Table 2). Of the 15 terrapin that were collected a second time, the average time period between captures, including the second recapture of terrapin 13, was 94 days (Table 2). This includes one individual that was collected one day after the original capture and one specimen that was recaptured 258 days after the original collection date. Specimen 13 was collected twice, 7 and 122 days between captures with a minimum travel distance of 171.2 and 364.8 meters respectively (Table 2). Two terrapin travelled between North and South Deer Island (Figures 17-19). Specimen 80 travelled from North Deer Island to South Deer Island at least once during the survey (Figures 17-19, Table 2). The total minimum distance travelled between islands by this terrapin was 1,339.4 meters after 259 days. Terrapin 63 travelled a minimum distance of 1,453.5 meters from North Deer Island. It was found 94 days after initial capture on South Deer Island. Prior to March 27, 2008 no terrapin were captured. In addition, from November 3, 2008 to December 23, 2009, no terrapin were observed at South Deer Island.

The majority of terrapin were collected on South Deer Island due to higher search effort on this island (Tables 1 and 2, Figures 17-19). Additionally, North Deer Island collections were limited to those animals collected or sighted only in adjacent open water and/or collected in traps. However, terrapin were frequently seen in deeper portions of the large, shallow lagoon area of North Deer Island. As previously mentioned this island is a protected bird sanctuary and researchers were forbidden to trespass on the land. Nearly 60% of terrapin captures occurred within the channels that span the length of South Deer Island (Figures 20 and 21). However, strict randomized sampling was not followed this first year of the study so this pattern of occurrences and recaptures may not represent true habitat selection patterns.

Table 1. Sampling dates when collections were attempted during the study period.

Date	Location	Gear	# Deployed	Cumulative Effort (min)	# People
11/16/2007	South Deer	Trap/Seine	3	170	2
11/20/2008	South Deer	Trap	7	390	3
12/4/2008	South Deer	Trap	6	240	2
12/11/2007	South Deer	Trap	6	300	2
1/4/2008	South Deer	Trap	7	300	4
1/11/2008	South Deer	Trap	7	360	4
1/30/2008	South Deer	Trap	3	300	4
2/29/2008	South Deer	Trap	3	150	2
3/5/2008	South Deer	Trap	7	240	5
3/11/2008	South Deer	Trap	8	360	5
3/14/2008	South Deer	Trap	5	150	2
3/20/2008	South Deer	Trap	6	240	3
3/27/2008	South Deer	Trap	8	245	2
3/27/2008	South Deer	Search	0	127	2
3/28/2008	South Deer	Trap	8	245	4
3/28/2008	South Deer	Search	0	195	4
4/1/2008	South Deer	Trap	5	180	3
4/1/2008	South Deer	Search	0	230	3
4/7/2008	South Deer	Search	0	182	2
4/11/2008	South Deer	Search	0	170	2
4/18/2008	South Deer	Search	0	378	3
4/19/2008	South Deer	Search	0	440	3
4/23/2008	North Deer	Search	0	438	3
4/25/2008	South Deer	Search	0	128	2
4/29/2008	South Deer	Search	0	130	2
5/2/2008	North Deer	Search	0	180	3
5/8/2008	South Deer	Search	0	378	4
5/9/2008	South Deer	Search	0	60	2
5/10/2008	North Deer	Search	0	160	3
5/10/2008	South Deer	Search	0	50	2
5/16/2008	North Deer	Trap	9	390	2
5/16/2008	North Deer	Search	0	105	3
5/16/2008	South Deer	Search	0	385	5
5/21/2008	North Deer	Search	0	140	2
5/21/2008	South Deer	Trap	5	345	2
5/21/2008	South Deer	Search	0	340	4
5/29/2008	North Deer	Search	0	10	2
5/29/2008	South Deer	Search		180	3
5/31/2008	South Deer	Search	0	240	2
6/2/2008	South Deer	Search	0	150	2
6/13/2008	South Deer	Trap	8	380	3
6/13/2008	South Deer	Search	0	60	3
6/14/2008	South Deer	Trap	7	11	2
6/14/2008	South Deer	Search	0	270	2
6/15/2008	South Deer	Search	0	210	2
6/16/2008	South Deer	Search	0	1,582	4
6/30/2008	South Deer	Search	0	360	2
7/13/2008	South Deer	Search	0	44	2
7/20/2008	South Deer	Search	0	96	3
7/27/2008	South Deer	Search	0	100	2
8/4/20085	South Deer	Search	0	724	6
8/11/2008	South Deer	Search	0	210	3
8/18/2008	South Deer	Search	0	541	2
8/25/2008	South Deer	Search	0	435	2
9/8/2008	North Deer	Search	0	760	7
10/6/2008	South Deer	Search	0	290	4
10/21/2008	South Deer	Search	0	1,694	4
11/3/2008	South Deer	Search	0	270	2
12/5/2008	South Deer	Search	0	180	2
12/23/2008	South Deer	Search	0	240	3
1/19/2009	South Deer	Search	0	446	4
2/3/2009	South Deer	Search	0	244	2
2/17/2009	South Deer	Search	0	370	7
Total			118	18,918	
Total North Deer			9	2,183	
Total South Deer			109	16,735	

Figure 14. Captures and recaptures at all sites during the study period, November 2007 to February 09.

Figure 15. Capture (blue) and recaptures (green) of terrapin on North Deer Island.

Figure 16. Capture (blue) and recaptures (green) of terrapin on South Deer Island.

Figure 17. Capture and recaptures (capture period: blue = 1, green = 2, yellow = 3) of terrapin at South and North Deer Islands. Numbers refer to specimen number (notch).

Figure 18. Capture and recaptures (capture period: blue = 1, green = 2, yellow = 3) of terrapin at North Deer Islands. Numbers refer to specimen number (notch).

Figure 19. Capture and recaptures (capture period: blue = 1, green = 2, yellow = 3) of terrapin at South Deer Island. Numbers refer to specimen number (notch).

Table 2. Location of terrapin captured and recaptured at the Deer Island complex during 2007 to 2009.

Notch#	Pit Tag #	Radio #	Type	Latitude	Longitude	Location	Min. Distance (m)	Date	Elapsed Days	Capture Period	Radio	Method
1	47016C5200	N/A	C1	29.27000	-94.91139	South		3/28/2008		1	0	Grab
1	47016C5200	N/A	C2	29.27	-94.91139	South	0.0	8/11/2008	136	2	0	Grab
6	4701541C3D	N/A	C1	29.27139	-94.91222	South		3/28/2008		1	0	Grab
6	4701541C3D	N/A	C2	29.27179	-94.91228	South	44.7	8/18/2008	143	2	0	Grab
12	467A630379	N/A	C1	29.27500	-94.91167	South		4/1/2008		1	0	Grab
12	467A630379	N/A	C2	29.27389	-94.91083	South	147.7	4/29/2008	28	2	0	Grab
R3	4701394B0E	N/A	C1	29.27278	-94.91222	South		4/1/2008		1	0	Grab
R3	4701394B0E	N/A	C2	29.27365	-94.90995	South	240.8	8/25/2008	146	2	0	Grab
13	467A2E4423	N/A	C1	29.27033	-94.91126	South		4/11/2008		1	0	Grab
13	467A2E4423	N/A	C2	29.27111	-94.91278	South	171.2	4/18/2008	7	2	0	Grab
13	467A2E4423	N/A	C3	29.27439	-94.91247	South	364.8	8/18/2008	122	3	0	Grab
21	none	N/A	C1	29.270533	-94.91230	South		4/7/2008		1	0	Grab
21	none	N/A	C2	29.27	-94.91139	South	106.4	8/11/2008	126	2	0	Grab
38	O15797075	113	C1	29.27444	-94.91167	South		4/29/2008		1	1	Radio
38	O15797075	113	C2	29.27483	-94.91344	South	177.4	6/13/2008	45	2	1	Radio
39	O15861836	253	C1	29.27389	-94.91083	South		4/29/2008		1	1	Radio
39	O15861836	253	C2	29.27373	-94.90930	South	149.7	6/13/2008	45	2	1	Radio
25	467A373A60	74/183	C1	29.27111	-94.91278	South		4/18/2008		1	0	Grab
25	467A373A60	74/183	C2	29.27188	-94.91186	South	123.6	4/25/2008	7	2	1	Grab
43	O15836092	N/A	C1	29.27361	-94.90972	South		4/29/2008		1	0	Grab
43	O15836092	N/A	C2	29.27439	-94.91247	South	280.9	8/18/2008	111	2	0	Grab
47	O15859080	N/A	C1	29.28399	-94.92165	North		5/2/2008		1	0	Grab
47	O15859080	N/A	C2	29.28417	-94.92139	North	32.2	5/29/2008	27	2	0	Grab
54	O15840791	N/A	C1	29.27083	-94.91306	South		5/9/2008		1	0	Grab
54	O15840791	N/A	C2	29.27111	-94.91278	South	27.2	5/10/2008	1	2	0	Grab
63	19050381	N/A	C1	29.28306	-94.92250	North		5/16/2008		1	0	Grab
63	19050381	N/A	C2	29.27431	-94.91136	South	1453.5	8/18/2008	94	2	0	Grab
80	O19042377	N/A	C1	29.28194	-94.92139	North		5/21/2008		1	0	Grab
80	O19042377	N/A	C2	29.27389	-94.91111	South	1339.4	2/3/2009	258	2	0	Grab
89	O21008631	293	C1	29.27056	-94.91139	South		7/13/2008		1	0	Grab
89	O21008631	293	C2	29.27	-94.91139	South	62.1	8/11/2008	29	2	0	Grab

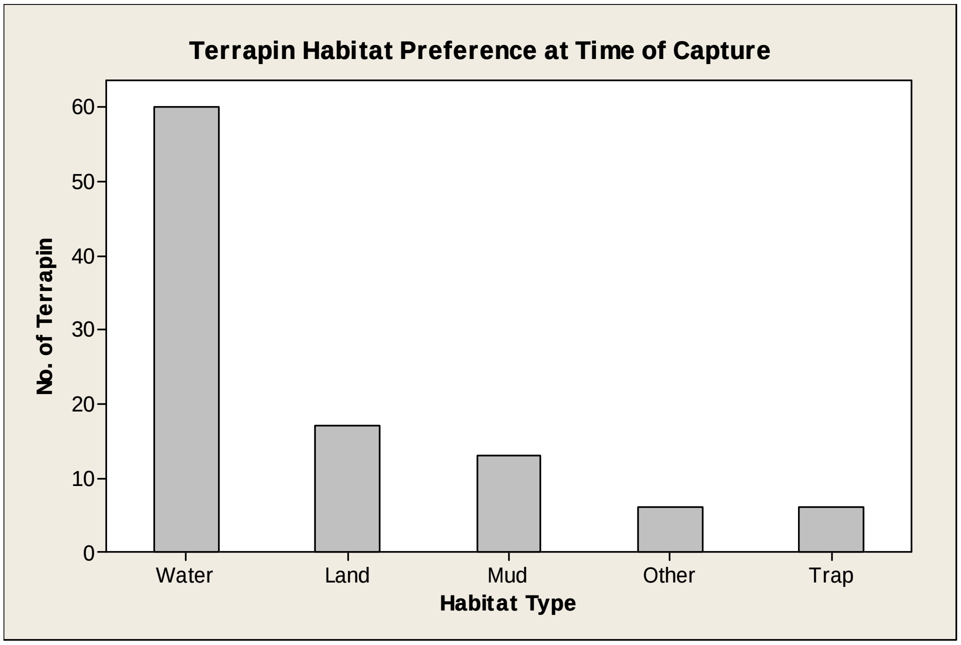

Figure 20. Habitat associated with terrapin captures during the survey period.

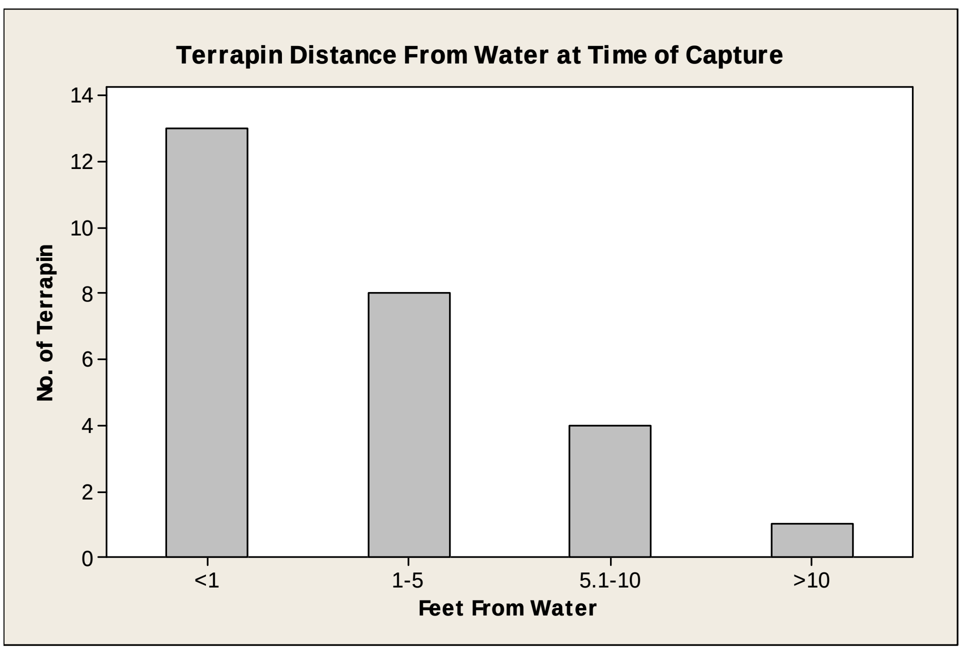

Figure 21. Distance of terrapin captures from open water.

A total of 202 hours of search time was expended between both islands during the study period. Using the on foot search and grab method, the average terrapin catch per hour of effort was 1.2 terrapin/hour. Following the first terrapin capture, on the ground surveys were conducted approximately once per week over a twelve-month period. Based on this sampling regime, higher numbers of terrapin were collected at South Deer Island during the months of April and May (Figures 22 and 23). Although overall numbers dropped during June sampling, the highest peak occurred in a sample taken mid-June. August saw another increase in catch rates during each sampling period. However, catch rates declined to very low levels throughout the remaining samples collected from September 2008 through February 2009.

Estimates the population size of terrapin on North Deer Island were not attempted due to the insufficient numbers of marked and recaptured terrapin. Due to low recapture rates we pooled collections into four time periods (Table 3). The Jolly Seber model produces population estimates for the second through next to the last time period. Estimates of the terrapin population size for periods 2 (4/12-5/9/08) and 3 (5/10-8/4/08) ranged between 595 and 1,365 terrapin respectively (Figure 24). However the 95% confidence interval for the number of terrapin present during these time periods were large ranging between 145 to 5,563, and 271 to 16,283 terrapin respectively.

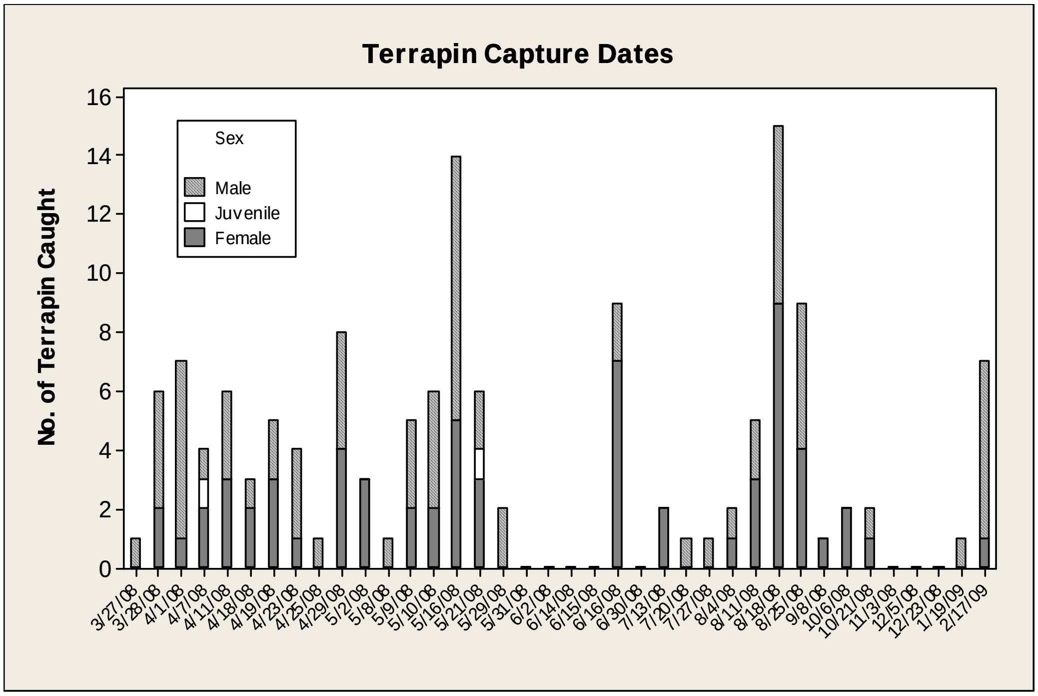

Figure 22. Diamondback terrapin captured during study period at South and North Deer Islands.

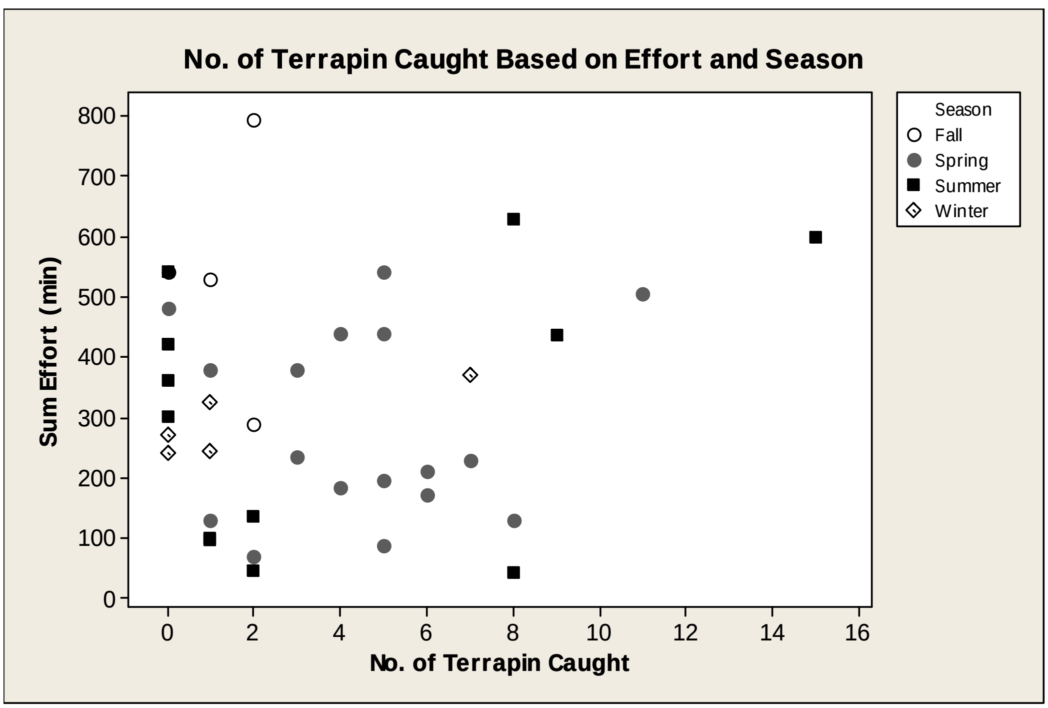

Figure 23. Number of terrapin caught versus effort during each season at both islands.

Table 3. Capture recapture matrix used to input data for Jolly Seber model for South Deer Island.

Time of last capture	Time Period			
	3/27-4/11/08	4/12-5/9/08	5/10-8/4/08	8/5-2/17/09
	1	2	3	4
1		1	0	4
2			1	2
3				1
Total marked (mt)	0	1	1	7
Total unmarked (ut)	24	32	28	38
Total caught (nt = mt + ut)	24	33	29	45
Total released (st)	24	33	29	45

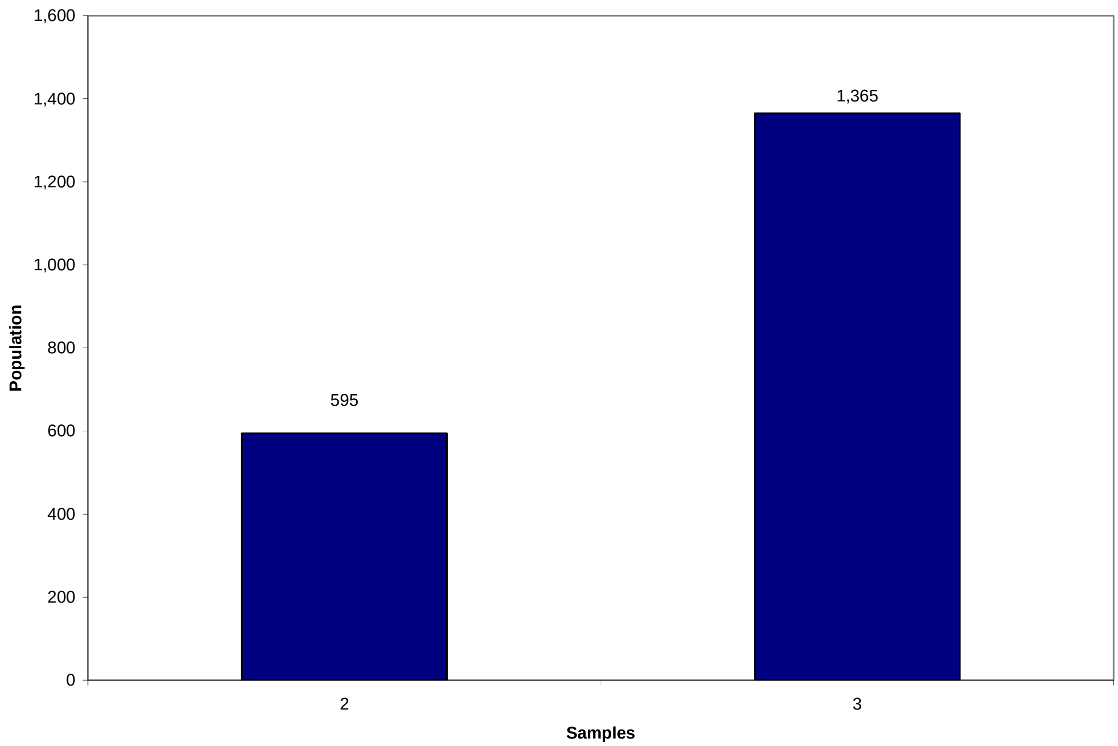

Figure 24. Jolly Seber population estimates at South Deer Island during two sample periods (2 = 4/12 to 5/10/08; 3 = 5/10-8/4/08).

Although estimated population levels and densities varied throughout the study period, it is unlikely that many terrapin moved in and out of the area at such an extreme rate. This is supported by the fact that only two specimens had moved between the two islands that were monitored (Figures 17-19). Current research suggests the belief that diamondback terrapins do not have large home ranges and show high site fidelity (Tucker et al., 2001). It has 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 fluctuations observed during this study probably reflects the difficulty in locating terrapin on the islands during certain times of the year and not actual additions or deletions of terrapin to the study area.

The increasing number of captured terrapin in April and May could be due to the moderate air and water temperatures present on the islands at that time of year and the beginning of the active breeding season. The breeding season for diamondback terrapin begins in April in Texas and thus spotting one of these animals while out in search of a mate is more likely. The decrease in observed terrapin densities during the summer months may be due in part to the animals modifying their behavior to stay cool. During the summer terrapin will frequently burrow into the mud to avoid the heat of the day. This would have made them much harder to find. Terrapin, as is true with all other reptiles, cannot regulate their own body temperature and therefore use behavior modification to adjust to changing ambient temperatures and reduce loss of water. Terrapin aestivate to stay cool during the warmer portions of the year. Later in this study we observed increased terrapin activity shortly after a thunderstorm deposited large amounts of rain in the study area during a summer collection. This increased activity was associated with the acquisition of newly deposited freshwater. This change behavior made them more detectable and increased the apparent population size dramatically. It should be noted however that the population estimates obtained from mark recapture data showed a trend that was not consistent with the observed density estimates from terrapin catch records. That is the estimated population actually increased in later summer months and winter. This may be due in part to the low recapture rates that inflate the estimated population number.

Reductions in terrapin catches in the fall of 2008 were likely attributable to the impacts of Hurricane Ike, a major hurricane that made landfall along the Texas coast on September 9, 2008 near Galveston Island. Not only did this environmental disturbance prevent surveying of the islands for some time, but it also completely inundated all of South and most of North Deer Island with saltwater for at least 48 hours resulting in the destruction of nearly all of the upland vegetation. Although not surveyed, it appeared that epibenthic prey items such as snails and crabs were severely reduced. 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, we are fairly certain that some terrapin habitat was lost. Additionally, many of the channels that cut through the island were blocked by extensive debris that had washed onto shore with the intense tidal surge.

The impact of Hurricane Ike is difficult to evaluate based on these data alone since it occurred in the fall and terrapin become less active during the winter months. The extreme drop in observed terrapin numbers during the winter months can also be caused by the normal seasonal brumation. Diamondback terrapins will brumate during colder winter months. This is a type hibernation observed in terrapin incorporates burrowing into the mud at the bottom and sides of creeks. Once burrowed, they can remain submerged under the water for months at a time. During this period, much of their metabolic activity ceases, and they remain dormant until water temperatures increase. This behavior was observed in several terrapin captured on South Deer Island throughout the winter. In at least two instances, the terrapin 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.

Patterns in terrapin catch per unit effort appeared to be slightly correlated with increasing water temperature (Figure 25). However there was not observable relationship with salinity during the study period (Figure 26).

The male to female sex ratio of diamondback terrapins caught on the islands were 1.1 to 1. A total of 71 males and 61 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. Although many turtle species are sexually dimorphic, terrapins exhibit significant observable characteristics that differentiate the males from the females. Unlike female terrapins, the males don a longer and thicker tail with a cloacal opening located well past the ventral edge of the carapace. Females have larger heads, greater body mass, and longer and wider plastron and carapace lengths than do males upon reaching sexual maturity. 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 terrapin in northern states have resulted in both female and male biased ratios, depending on the study area.

The average carapace length for male terrapin was 131.7 cm versus 186 cm for female terrapin (Figure 23). Maximum and minimum carapace length for males was 150 cm and 115 cm, respectively. In contrast, the maximum and minimum carapace length for females was 285 cm and 109 cm, respectively. The size of a terrapin’s head is also a key factor in differentiating males and females (Figure 24). Head width was measured from the widest point of the terrapin head. Male head width averaged 24.8 cm; while female head width was nearly double that at 43.6 cm.

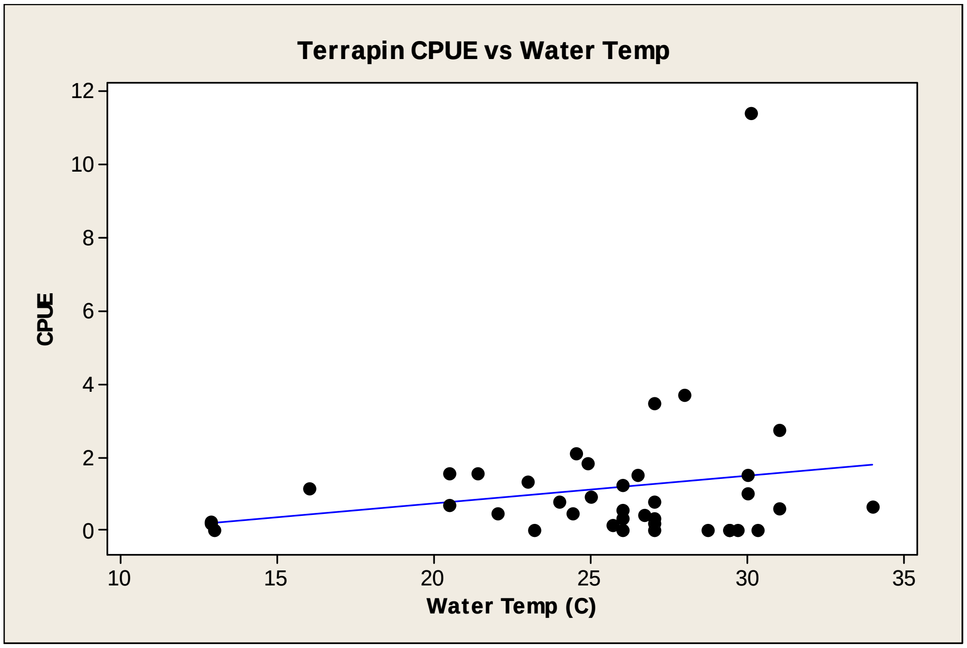

Figure 25. Terrapin catch per unit effort versus observed water temperatures.

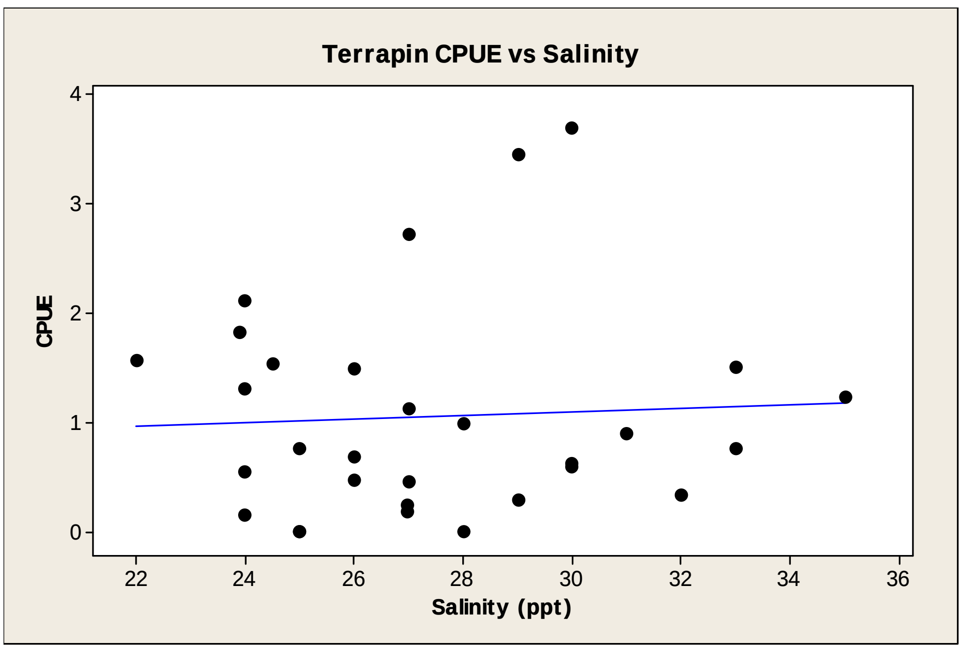

Figure 26. Terrapin catch per unit effort versus observed salinity.

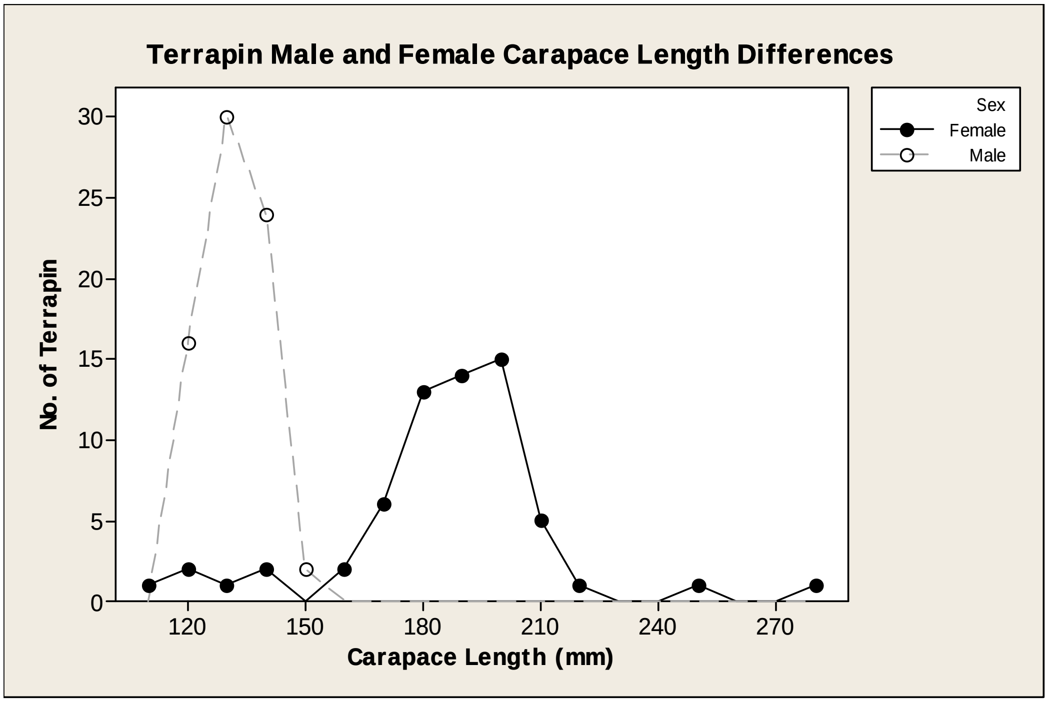

Figure 27. Terrapin carapace length versus gender.

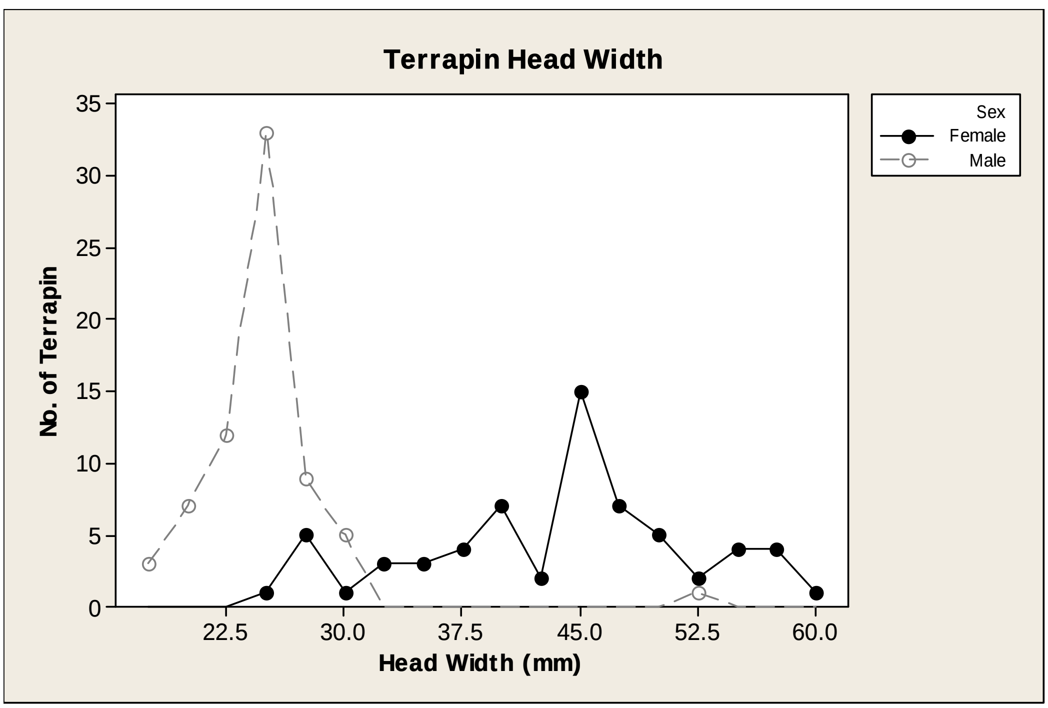

Figure 28. Terrapin carapace width versus gender.

Terrapin weight measurements coincided with body measurements in distinguishing females as the larger sex (Figure 29). The average weight recorded for male terrapin was 0.38 kg. The female weight average was over three times that amount at 1.2 kg. The maximum and minimum male weight was recorded at 0.65 kg and 0.21 kg, respectively. The largest female weight recorded was 1.8 kg, while the lowest female weight was 0.26 kg.

Carapace scute ring counts have been used as a qualitative measure of age in turtles in the past. However, this method is extremely subjective due to erosion of scute rings in older terrapin. Therefore this method should only be used to obtain a relative estimate of age. The terrapin captured during our study showed a definite gender related scute count and relative age distribution (Figure 30). The majority of males appeared to be younger individuals in comparison to females.

Although males and females exhibited a difference size distribution there appeared to be a fairly constant relationship between size and weight despite gender differences in size (Figure 31).

Over the course of a year, 6 terrapin 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. One radio-tagged female was tracked down 7 days after the initial receiver attachment. She had traveled a straight-line distance of 30.9 meters. One radio tagged female 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 was tracked to a location 103.9 meters from original capture 45 days after initial attachment. Although the transmitter was discovered in tact, 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 a mystery and it is unknown if the radio tag may have been a factor. A transmitter belonging to a female 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 appears 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.

Due to the low numbers of terrapin that were radio tagged in this study, it is unknown to what extent terrapin move throughout the islands within a short time period. Additionally, unsuccessful attempts to locate tagged animals made data collection on terrapin movement difficult. Constraints that impeded relocating tagged terrapin include saltwater interference with the receiver signals. Only the terrapin whose carapace (and transmitter) was located above the water 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 a readable distance of the receiver.

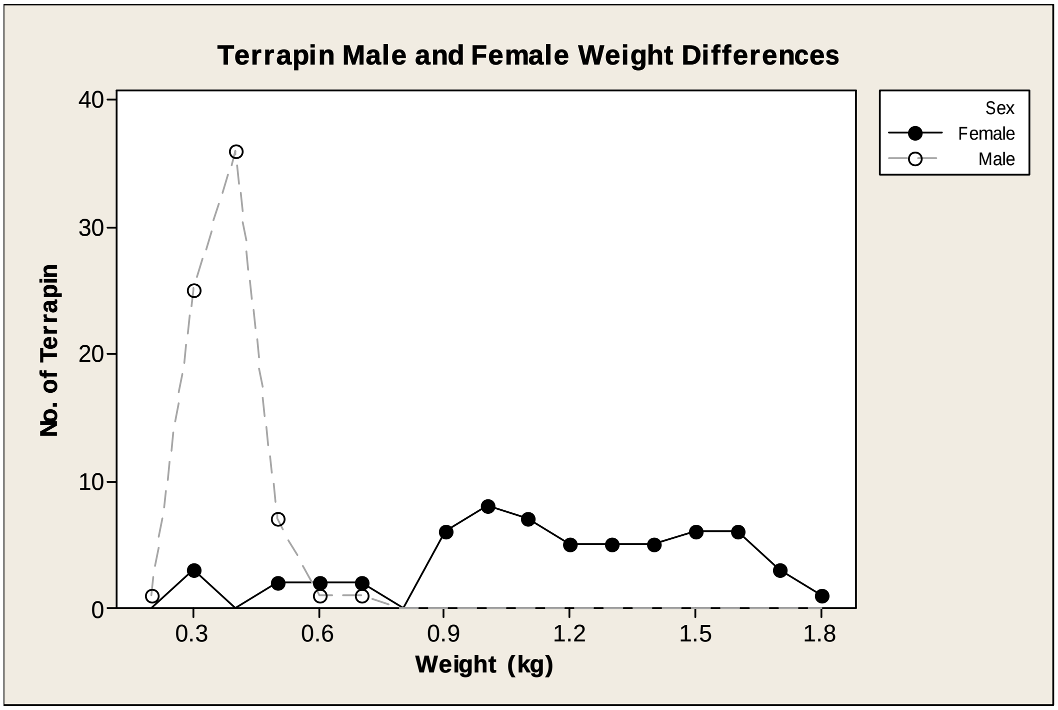

Figure 29. Terrapin weight versus gender.

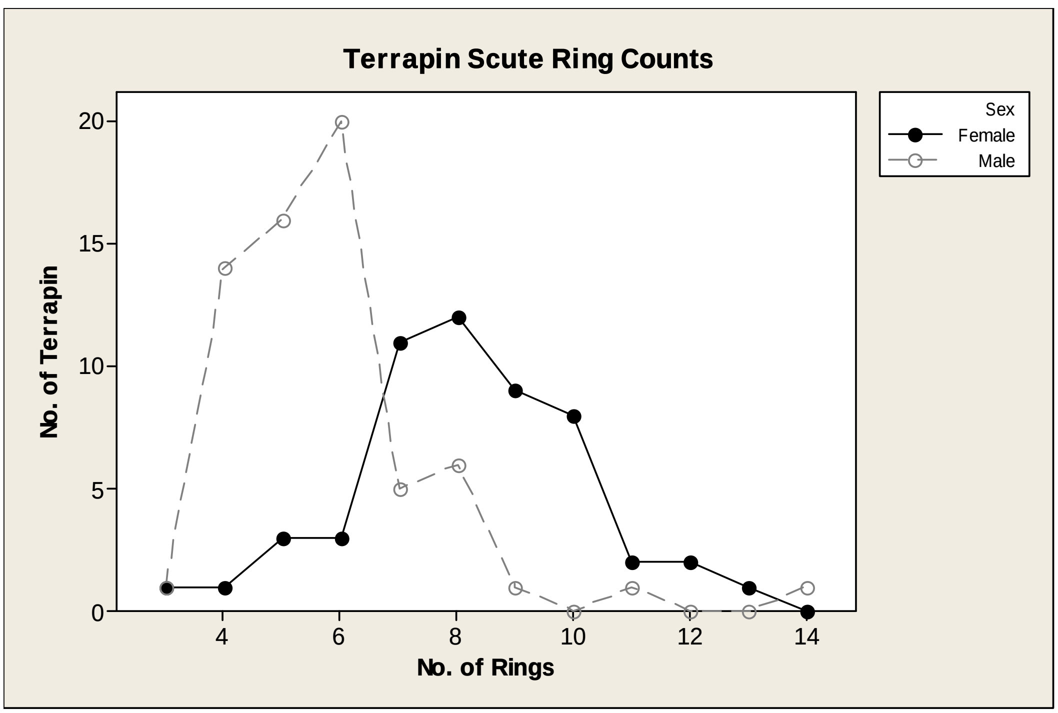

Figure 30. Distribution of scute counts versus gender.

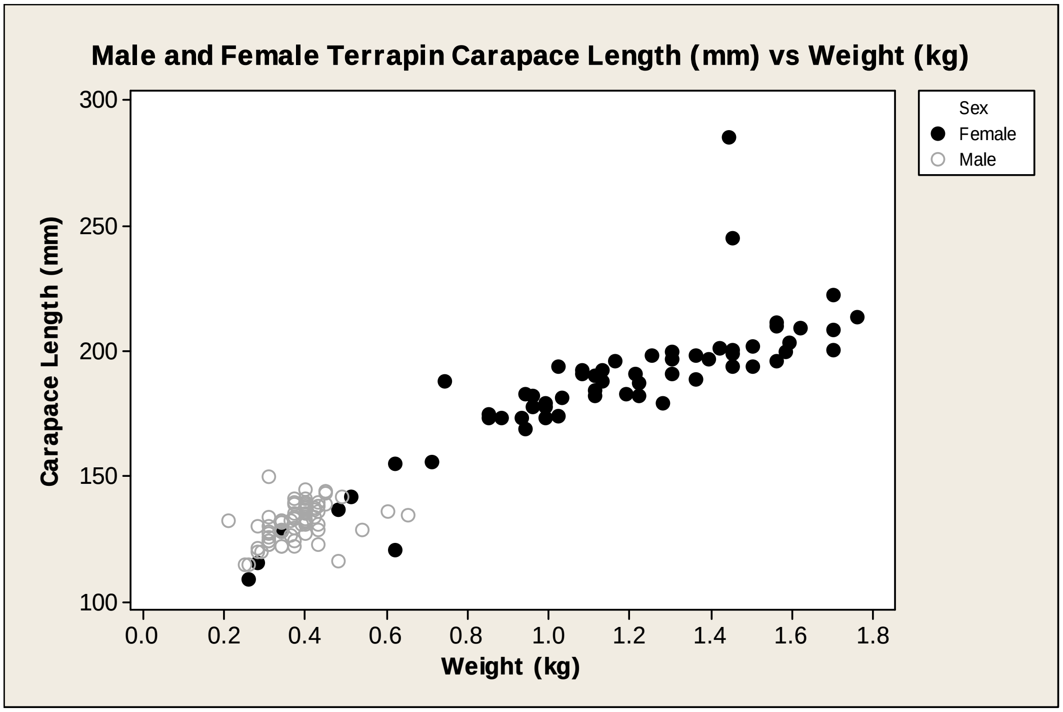

Figure 31. Relationship between length and weight observed in terrapin during the study period.

Conclusion and Recommendations

As a result of this research, a large number of terrapin in West Bay have been individually marked and documented. This will assist future researchers wishing to further study the terrapin population on North and South Deer Islands by providing a starting point for each terrapin's location. Future researchers will then be able to track the movement of these animals, along with changes in sex ratios and population increases or declines. It also provides baseline information on population status of these animals, which will allow researchers to track the status of this population. Furthermore, this research provides critical environmental and habitat data that can be used to define habitat needs for this species and locate populations of this subspecies throughout the coastal areas of the state.

The most important conservation action to protect diamondback terrapin in Galveston Bay would be to protect South Deer Island from erosion and conservation and restoration of marsh habitat on the island. North Deer Island, being such an important bird rookery island, is already 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. Measures being taken to protect bird habitat on North Deer Island including exclusion of predators, reduction of human disturbance and protection and enhancement of wetlands should also enhance terrapin habitat.   South Deer Island also supports numerous colonial waterbirds and appears to possess both foraging and 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.

It is essential that continued monitoring of Diamondback terrapin be continued at the Deer Island complex to monitor long term trends associated with changes in climate, habitat and water quality. Along the east coast several states have monitoring programs that have collected data on known terrapin populations for over 30 years. These programs have documented severe declines associated with crab bycatch, automobile and vessel collisions and loss nesting habitat. No such program existing in Texas despite having an extensive coastline and historical occurrences of terrapin spanning over 80% of the coast. The majority of habitat models for terrapin have been developed in the east coast. It is critical that similar habitat models be developed for Texas terrapin to identify critical habitat needs for this species. This will require additional years of data collection and intensive studies. Currently, the only monitoring that occurs for terrapin are the incident bycatch data reported from the annual derelict blue crab collection program and the TPWD Coastal Fisheries fishery independent sampling program. Both of these efforts have yielded very low numbers of terrapin because of gear bias and in the case of crab traps, the inability to sample active commercial fishing traps due to legal restrictions. The traps that are collected are typically old and frequently show evidence of terrapin bycatch although only pieces of skeletal remains are present, which reduces our ability to estimate numbers caught in these gear.

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