Mid-Texas Coast Complex Texas Diamondback Terrapin (*Malaclemys terrapin littoralis*) Ecology Project

EIH Results Report # 12-004

FWS Agreement Number: 201819J605

Prepared by:
George Guillen, Emma Clarkson & Jenny Oakley
University of Houston-Clear Lake

Principal Investigator
George Guillen

Environmental Institute of Houston
University of Houston Clear Lake
2700 Bay Area Blvd
Houston, Texas 77058

Revised December 31, 2011

PREPARED IN COOPERATION WITH THE
United States Fish & Wildlife Service, Region 2

USFWS Contact:
Jennifer Wilson

Project Officer
U.S. Fish & Wildlife Service
2547 CR 316
Brazoria, TX 77422
(979) 964-4011 x34
Jennifer_Wilson@fws.gov

Table of Contents

List of Figures

List of Tables

Appendices

Introduction

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). Recent limited data suggests that throughout the terrapins' range, their populations have seen significant declines (Cecala et al. 2008). Terrapin are characterized by having a type III survivorship curve with a clutch size averaging 12 eggs (Roosenburg and Dunham 1997) and a maximum life span of over 50 years (Roosenburg 1990, Tucker et al 2001), although some studies have found the average life span in the wild to be closer to six years (Tucker et al 2001). This life history leaves terrapin extremely susceptible to population depletion due to human induced adult mortality. Diamondback terrapin was an extremely inexpensive source of food until the late 1930's, and over 200,000 diamondbacks were processed in Maryland alone between 1800 and 1936 (Orenstein 2001).

Due to their present day 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. Texas Diamondback Terrapin were recently afforded protection in Texas and can no longer be collected for personal or commercial use without a state issued permit (TPWD 2008).

Threats and Consequent Ecosystem Effects

Even though terrapin are presently protected from overharvest, there are still many threats to the survival of the species. Drowning in blue crab traps or pots, often referred to as bycatch, is one of the biggest sources of terrapin mortality. Terrapins enter the traps lured by the bait and then are unable to escape which results in drowning (Garber 1990; Morris et al. 2010; Cole and Helser 2001).In one case, whole shells of 49 terrapin, along with the remains of several others, were recovered from a single crab pot (Roosenburg 1990). The Texas Parks and Wildlife Department recently passed a law that prohibits the commercial collection of all native turtle species without a permit, however to date there are no requirements of terrapin bycatch reduction devices on crab traps (TPWD 2008).

Due to nesting site philopatry, nesting habitat destruction is a major threat to terrapin populations. Alteration of the coastline to reduce erosion and hurricane damage can alter the microclimate of the nesting area, and consequently alter the sex ratios.[1] Planting beach grasses as erosion control for dunes can increase grass root predation on terrapin eggs[2] (Roosenburg 1990). Erosion control bulkheads effectively exclude terrapin from historic nesting grounds, causing them to nest in nearby lower sandy habitat that is frequently inundated by high tide. Under this scenario, nests typically exhibit low hatching success due to embryo drowning (Roosenburg 1990). Additionally, females will endanger themselves trying to revisit destroyed or altered historic nesting areas by exposure to increased boat traffic, predation, and human interaction (Roosenburg 1990). Reproductive migration leaves females vulnerable to boat propeller injury.

---

[1] Terrapin exhibit environmental sex determination (ESD) that is heavily influenced by temperature. A constant incubation temperature of 28.5°C to 29.5° C is required to produce mixed sex ratios, while temperatures outside this range produce mono-sex clutches (Roosenburg and Place 1994).

[2] Dune grass roots often penetrate terrapin eggs and absorb the eggs' nutrients. Roosenburg 1990.

In one case, 19.7% of a studied population's females had carapace boat propeller scars, while males only had a 2.2% injury rate (Roosenburg 1990). In another case, 27.7% of terrapin in an Everglade population had carapace injuries associated with boat propellers (Hart and McIvor 2007).

Other threats to nesting female terrapin include boat and vehicular traffic collisions while crossing coastal roads in an attempt to reach nesting grounds (Bossero and Draud 2004). There are several additional threats to terrapin populations, including pollutants from runoff and pesticides entering the estuaries in which diamondback terrapin are found. (Garber 1990). Hatchlings and juveniles are also preyed upon by crows, gulls, eagles, rats and raccoons, which can substantially diminish their population size.

Along with the losses from habitat degradation and predation, terrapins are at a disadvantage in terms of their low innate birth rate. A female breeds only every four years and doesn't reach sexual maturity until the age of six (TPWD 2007). Due to the vulnerability associated with this type III survivorship curve along with high human induced mortality, terrapin populations are at great risk. The importance of terrapin conservation is evident when their role in the salt marsh is observed. Aside from the intrinsic value of being the only turtle able to live constantly in brackish water, they also play an integral part in invertebrate population control. In the absence of Diamondback terrapin, the periwinkle snail *Littorina littorea* can become overabundant and overgraze on the senesced (and sometimes living) portions of the marsh grass *Spartina alterniflora,* causing mass mortality. The damage from the rasping of the snails results in more biomass loss than consumption itself, as well as stimulated microbial infection. (Sillimian and Vieman 2001).

Population Estimates

Little information has been gathered on the numbers or health of Texas populations of the Diamondback Terrapin. 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 that 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 that riverine habitat with salt marshes, shell islands and oyster reefs in shallow turbid water was the most common habitat containing terrapin.

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.

Halbrook (2003) reported on the result of terrapin population studies conducted in Nueces Bay during 1997 to 1999. She found that the population estimate for this bay system was approximately 322 terrapin with a female to male ratio of 2.9 to 1. Habitat analyses revealed that four of the five surveyed island in that bay system appears to be suitable for terrapin using a HSI model (Palmer and Cordes, 1988).

Koza (2006) examined Texas Diamondback terrapin distribution, critical habitat, and feeding methods within four bay complexes including Ayres Bay, Mesquite Bay, Aransas Bay and St. Charles Bay. He captured 154 individuals using modified crab traps. They found terrapin in areas off of spoil islands near river deltas in oligosaline waters over shell hash substrates.

Haskett (2011) captured a total of 151 terrapin on North and South Deer Islands during 2008 to 2009. She found that some terrapin traveled a minimum distance of between 44 to 414 meters.

Habitat Suitability

The majority of information regarding habitat selection and general life history of Diamondback terrapin (*Malaclemys terrapin*) comes from knowledge of Atlantic coast populations. Therefore, when using previously determined habitat suitability indexes and research on habitat selection, differences between Texas habitat and Atlantic coast habitat must be considered. Optimal foraging habitat is characterized by low-lying salt marsh dominated by cordgrass (*Spartina alterniflora)*. However, populations of terrapin can continue to thrive in areas that have had dyke construction and a consequent overgrowth of other marsh vegetation (Seigel 1979). Female terrapin are less restricted by gape size (due to sexual dimorphism, females have a larger tomium width than males) and therefore prefer larger periwinkle snails (*Littorina littorea*) with higher nutrient and available energy levels. These snails inhabit sparsely vegetated cordgrass marsh further from tidal creeks. Therefore, females utilize high tide to access these less densely vegetated areas (Tucker et al 1995). A second factor contributing to habitat suitability is the ease of access to prey such as mollusks and crabs. Shallow tidal creeks and subtidal mudflats are presumed to be the best habitat for prey availability (Palmer and

Cordes 1988). Shallow tidal creeks are also very important for hibernation activity, as terrapin retreat and burrow in the banks and bottom of creeks during the winter (Yearicks et al 1981).

Methods

In the Spring and Summer of 2010, weekly field surveys were conducted on U.S. Fish and Wildlife Service (USFWS) refuge property to determine habitat use, long-term movement, and basic population demographics for the Texas Diamondback Terrapin.

Study Area

The study area for this project was the Mid-Texas Coast USFWS Refuge Complex (Figure 1) defined by three refuges: the Brazoria National Wildlife Refuge (NWR), the San Bernard NWR, and Big Boggy NWR. Terrapin search efforts were restricted to brackish marshes, thus the full extent of the refuge properties are not pictured in Figure 1. The refuges are located in Brazoria and Matagorda Counties and managed by the USFWS Texas Mid-Coast Complex office in Brazoria, Texas.

Habitat Assessment

A Habitat Suitability Index (HSI) for Atlantic Coast terrapin was published in 1988, (Palmer and Cordes, 1988), but currently there is no HSI calibrated for Gulf Coast terrapin. Using recent local population data and concurrent habitat mapping, updates to the Atlantic Coast HSI were made to reflect the physical attributes of the Gulf Coast that differ from the Atlantic Coast. This information and other published articles on habitat requirements for terrapin led us to use the following criteria to classify potential suitable terrapin habitat sites in the Mid-Coast Refuge Complex.

1. Presence of *Spartina alterniflora* as dominant macrophyte.

2. Presence of common prey sources
3. Presence of small tidal creeks throughout marsh and/or proximity to water.
4. Extent of tidal inundation (elevation of marsh).
5. "Softness" of mud for burrowing (estivation and hibernation)
6. Density and species composition of vegetation.

Presumed habitat suitability was determined at each site and a priority level was given to each site visited. Highest or "first" priority habitat included areas that had excellent habitat, terrapin sightings, and are suggested as continued search areas. Second priority habitat included areas that had fair to good habitat, showed signs of terrapin, and are suggested as continued search areas. Third priority habitat included areas that have not been searched to date, but that are thought to exhibit the requirements for good habitat based on aerial imaging and surrounding habitat type. Low or no priority habitat includes areas in which the habitat was deemed poor and we suggest concentrating continued search efforts elsewhere.

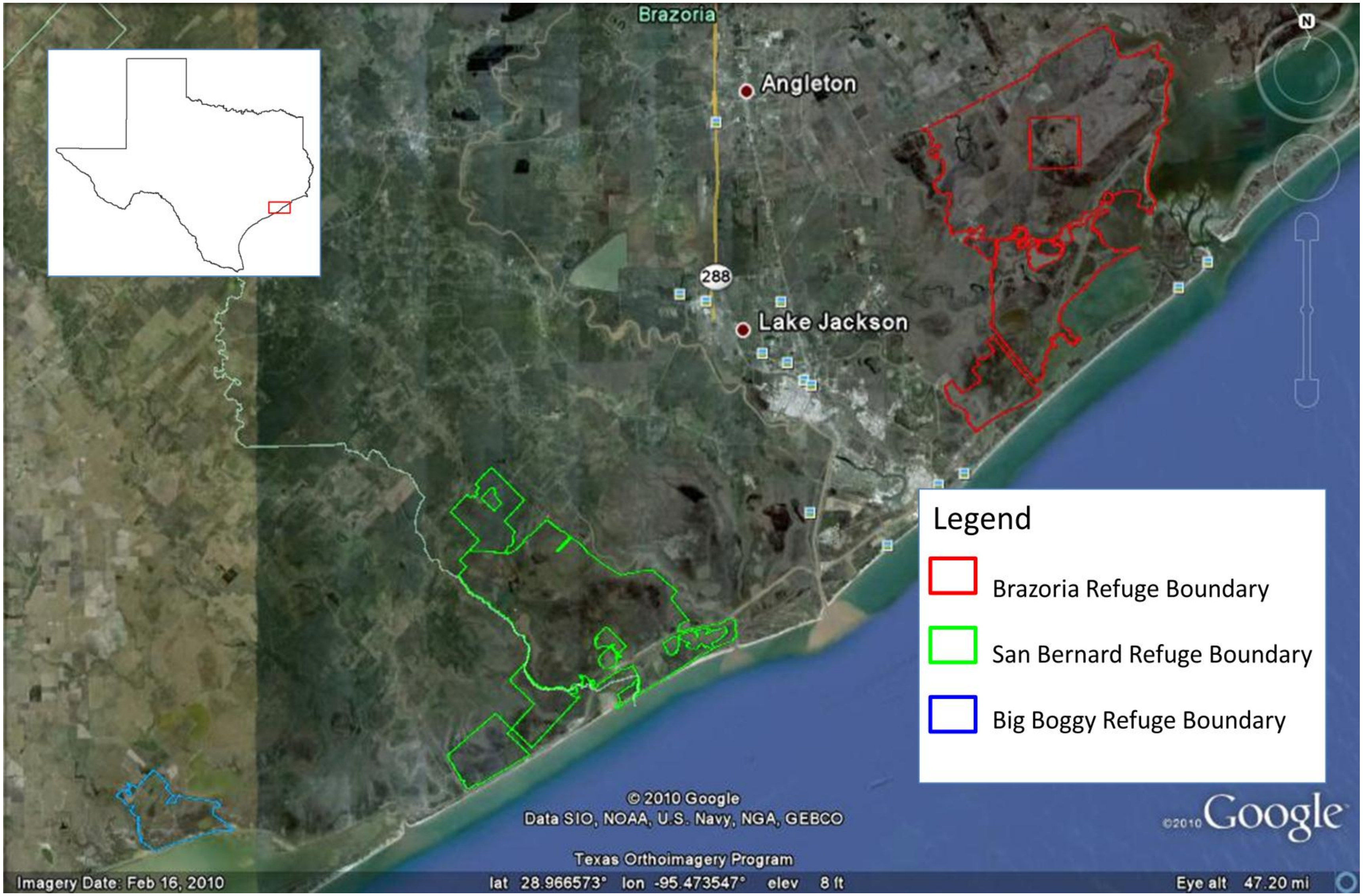

Figure 1: Mid Coast Refuge Boundaries Sampled

Terrapin Collection Methods

Terrapin collection incorporated a combination of methods including crab traps with modified chimneys and land searching of terrapin by researchers. Our largest effort was spent on conducting land searches and hand capture. Land searching was done using random line transects, which involved beginning at a random location in a predetermined search area, dividing the search area into equal areas by assigning straight line transects beginning at even degree intervals, and walking in straight lines that divided this area. When we reached an obstacle that prevents further search, we turned 90° and walk in another straight line until the next obstacle, and so on. These transects presumably cross every habitat type in the area, including creeks and lagoons.

We also put considerable effort into aquatic trapping using self-designed terrapin traps. Modified crab traps (Figure 2) were set in open bay, tidal creeks, and the lagoons to determine utilization of these aquatic habitats. They were be baited with mullet and shad, and the bait type was recorded to note any discrepancies or bait preference. These traps were designed with a 3 foot high chimney to allow access to air. This chimney was built on top of two crab traps with the bottom removed from the upper traps and connected with zip ties, allowing 8 access points and no roof preventing easy movement up the chimney. These traps have only one bias associated with them. Each individual trap cannot catch the same sex of terrapin due to sexual size dimorphism: the openings that are large enough for females to enter the traps allow males to escape, while any trap with an entrance small enough to prevent male escape is too small for female entry. To correct this, we built several traps with both size openings.

In order to identify individual terrapin a combination of external physical marks and internal tags were used. The marginal carapace scutes were notched with a metal file using a modified Cagle numbering system which assigns each terrapin with a unique number (Figure 3)(Cagle 1939). Captured Terrapin were also tagged terrapin with more permanent Passive Integrated Transponder (PIT) tags. These tags have a unique identification number. 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 and Andrews 2004). All sequential terrapin catches were scanned with a PIT tag scanner and if tagged, identified by their personal alphanumeric code.

Figure 2**.** Modified crab trap, designed by Emma Clarkson. This terrapin trap consists of two crab pots wired together, with both roofs removed ensuring the terrapin's ability to find the chimney. The top 3 feet of the trap is open chimney surrounded by plastic fencing, preventing terrapin death by drowning.

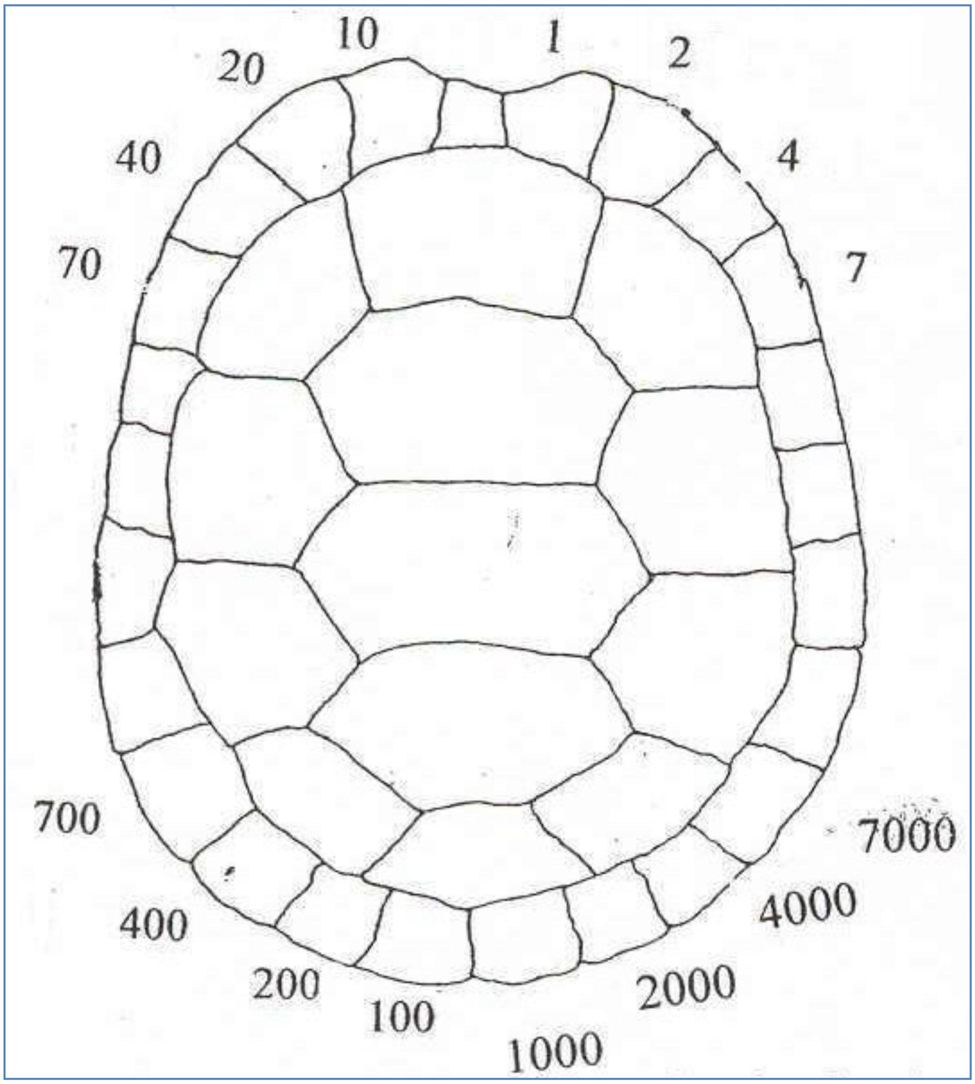

Figure 3. Modified Cagle marking system used to mark captured terrapin during the study.

Each diamondback terrapin was weighed and measured to determine size, growth rates, 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 4 [A& B]). Carapace width was measured from the widest point on either side of the carapace (Figure 4 [C]). Plastron length was measured from between the gular scutes down the midline of the plastron and ending between the anal scutes (Figure 5 [A&B]). Plastron width was measured posterior to the bridges and perpendicular to the midline (Figure 5 [C&D]). Depth was measured from the highest vertebral scute on the carapace down to the plastron. Weight was measured by placing each animal in a tarred mesh bag and hanging the bag from a digital scale. 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 terrapin was quantified during field surveys. Time of collection was recorded during all surveys. Each researcher also recorded starting and ending search times, used to calculate the terrapin catch per unit effort.

Physical observations made at the time of capture include latitude and longitude as determined with a handheld 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. Prey types present on the islands were also noted in this study, in addition to air temperature, water temperature, turbidity as measured by secchi tube depth and salinity during collection periods.

Figure 4. Texas Diamondback Terrapin carapace measurements: A – Minimum carapace length. B- Maximum carapace length. C – Carapace Width

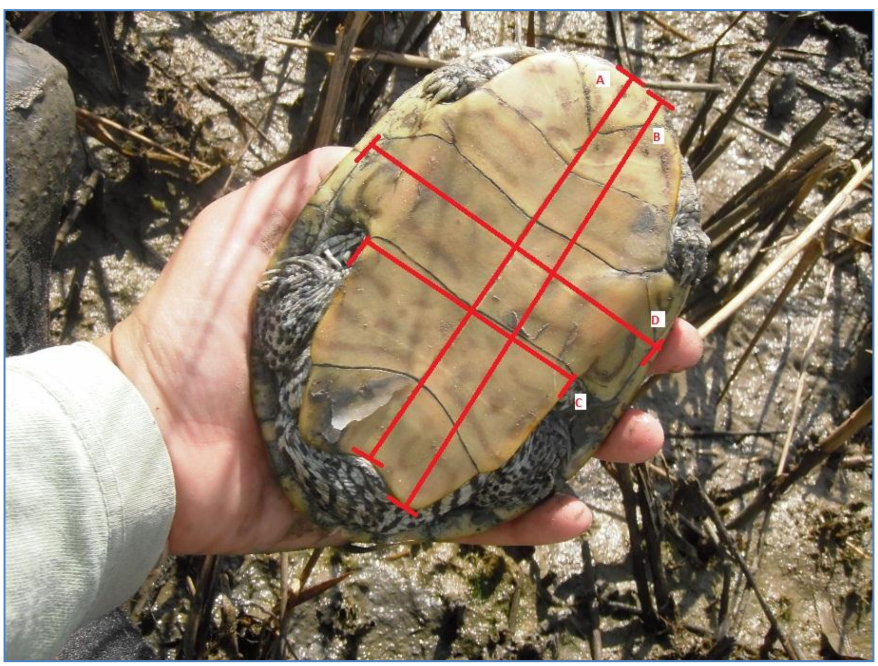

Figure 5. Texas Diamondback Terrapin plastron measurements: A- Plastron midline length. B – Plastron maximum length. C- Plastron width at the bridge of the rear legs. D – Width at the suture of plastron and carapace.

Results

From March – September 2010, 51 sites in Brazoria, San Bernard, and Big Boggy Refuges were surveyed for terrapin and suitable habitat. Over 149 hours of land search time and 20 hours of aquatic trapping were completed (Table 1). However, only two terrapin were captured as a result of the 2010 surveys. These terrapin were captured on West Bird Island in West Galveston Bay. This island is not technically part of refuge land; however it is located directly adjacent to refuge property. No terrapin were captured on any of the individual refuges, but terrapin were observed in the water at two locations on the refuge. Six terrapin were seen at the entrance to Cowtrap Lake, and one was observed in the marsh surrounding Oyster Lake. The remains of four or more terrapin were found in an abandoned crab trap in a marsh near GPS coordinates 29.07494, -95.18914. The marsh around this ghost trap was determined to be first priority habitat.

Table 1. Summary of all search locations and temporal effort.

Date	Site	Latitude	Longitude	Water Temp (◦C)	Air Temp (◦C)	Salinity (ppt)	Secchi Disk Depth (m)	Search Time (min)
3/4/2010	Bird Island West Bay	29.10398	-95.16064	14	14.5	26	0.466	216
3/4/2010	North Bank Bastrop Bay	29.11139	-95.18694	18	15	17	0.22	116
3/4/2010	East Bank Bastrop Bay w/ Bay pass & Christmas bay Pass	29.08822	-95.1626	19	17.1	25	0.716	99
3/18/2010	West shore christmas bay	29.03163	-95.21732	16	16	23	0.932	159
3/18/2010	NW shore drum bay	29.02498	-95.22712	17	16	20	0.148	136
3/18/2010	Nicks lake, N side (by skimer lot)	29.03223	-95.23836	19	21	23	0.28	144
3/25/2010	Old Essex Bayou	28.98642	-95.26976	16	16.7	30	0.274	223
3/25/2010	Inlet north of Old Essex Bayou	29.00296	-95.2507	19.5	18.1	30	0.364	80
4/1/2010	South of Nick's Lake	29.02	-95.23645	19	21	30	0.242	86
4/1/2010	South of Nick's Lake along ICW	29.01372	-95.24123	19	21	30	0.242	122
4/1/2010	South of Nick's Lake along ICW	29.0075	-95.2437	24	20	26	0.59	225
4/1/2010	Lake in "V" of Old ICW-New ICW split, Brazoria	28.99478	-95.24953	24	20	26	0.59	113
4/15/2010	Brazoria Auto Tour	29.06119	-95.23836	22	24	28	-	126
4/15/2010	Brazoria Auto Tour	29.03784	-95.2672	25.2	24	29	0.15	113
4/22/2010	Brazoria Intersection fo Bastrop Bayou and ICW	29.10176	-95.1954	24	21.5	20	0.15	188
4/22/2010	Brazoria Intersection fo Bastrop Bayou and ICW #2	29.09335	-95.21198	24	24	20	0.198	150
5/12/2010	Blue Water Highway marsh	28.97951	-95.25282	25	28	33	0.16	380
5/13/2010	Inner Cedar Lakes	28.85543	-95.4716	24	27.5	22	0.176	93
5/13/2010	Inner Cedar Lakes	28.85097	-95.48821	26	28	22	0.294	197
5/20/2010	Inner Cedar Lakes	28.84201	-95.48484	26	25	24	0.12	360
5/20/2010	First Cedar Lake	28.86714	-95.47578	28	27.2	11	0.11	159
5/27/2010	First Lake on Right of ICW San Bernard	28.8653	-95.47583	28	29.7	20	0.15	38
5/27/2010	Lake N of ICW Before large Levee	28.85822	-95.48906	29	33.4	19	0.06	135
5/27/2010	Cowtrap Lake	28.84769	-95.50994	29.5	32.2	16	0.14	130
6/4/2010	Sargent Unit, San Bernard	28.77977	-95.60506	30	30.9	28	0.153	86
6/10/2010	Lake in "V" of Old ICW-New ICW split, Brazoria	28.996	-95.25045	29	26.7	33	0.2	231
6/10/2010	Old Essex Bayou- south	28.98219	-95.25958	31	31	33	0.14	291
6/11/2010	San Bernard 1st site	28.86301	-95.45455	30	29.6	22	0.056	285
6/11/2010	San Bernard 2nd site	28.86184	-95.4594	30	31.2	24	0.036	306
6/11/2010	San Bernard 3rd site	28.86184	-95.4594	30	31.2	24	0.036	305
6/15/2010	Cowtrap Lake Saw 6 Terrapin Heads	28.84769	-95.50994	NA	NA	NA	NA	360
7/9/2010	San Bernand- traps	28.84755	-95.50986	NA	NA	15	0.354	150
7/9/2010	San Bernard - traps	28.86281	-95.45503	NA	NA	9	0.216	105
7/20/2010	Oyster Lake - Saw 1 Head	29.115157	-95.167686	NA	NA	NA	NA	720
7/22/2010	Traps at San Bernard and Cowtrap	28.84789	-95.50987	31	33.6	25	0.134	78
7/22/2010	End of waterway w/ Boat ram	28.83303	-95.53851	33	31.6	21	0.089	112
7/23/2010	Across ICW from Nick's Lake entrance	29.02823	-95.22897	27	30.6	22	0.153	150
7/23/2010	Nick's Lake, S. of entrance creek	29.0274	-95.23417	29	33	27	0.198	70
7/29/2010	San Bernard Traps	28.84427	-95.5069	31	37.2	20	0.099	30
7/29/2010	E. side of boat channel, S. of ICW - San Bernard	28.84427	-95.5069	31	36.2	21	0.153	90
7/29/2010	S. of above search	28.83306	-95.50385	33	36.2	22	0.123	94
7/29/2010	W. Side of Boat Channel	28.84403	-95.50751	31	36.2	21	0.153	40
7/30/2010	San Bernard	28.85326	-95.49282	32	33.8	22	0.085	240
8/6/2010	San Bernard Cedar Creek Lake	28.83229	-94.54378	29	31.7	21	0.99	120
8/6/2010	San Bernard Last Cut to Cedar Lake	28.82732	-95.53363	32	33.6	21	0.099	190
8/11/2010	San Bernard 3rd marsh in cedar lake	28.86097	-95.45967	28	32	28	0.104	132
8/11/2010	longer finger marsh	28.85818	-95.46489	28	32	28	0.104	132
8/11/2010	Penninsula on Gulf side of San Bernard	28.85632	-95.44366	30	34.5	30	0.19	127
8/17/2010	Big Boggy 1	28.74144	-95.8313	34	37.7	15	0.24	80
8/17/2010	Big Boggy 2	28.74213	-95.81225	34	34.5	26	0.132	34
8/17/2010	Big Boggy 3	28.74795	-95.78729	34	34.5	26	0.132	34
9/10/2010	Brazoria Refuge- drum bay search	28.99641	-95.24065	27	29.2	30	0.26	140
9/24/2010	Brazoria Refuge- site1: long, straight channel N of Christmas &	29.07494	-95.18914	26	31.8	20	0.242	270
9/24/2010	Brazoria Refuge- site2: NE tributary	29.07709	-95.20065	26	32.2	10	0.469	105
9/24/2010	Brazoria refuge- site3-NE side of Nicks Lake	29.02883	-95.23431	26	32.9	20	0.152	60

Brazoria National Wildlife Refuge

Twenty One sites were surveyed for terrapin and suitable habitat in the Brazoria National Wildlife Refuge. Of those, twelve were documented as having suitable habitat for terrapin and recommended for future terrapin surveys (Table 2). In particular the peninsula between Christmas Bay and Drum bay, Oyster lake, the Southwest corner of Drum Bay and the area near the mouth of the Old Intercoastal Waterway have been described as first priority sites, containing the habitat with a high likelihood of supporting terrapin (Figure 6).

Brazoria			
	First Priority Sites		
Map Legend	**Description**	**Latitude**	**Longitude**
B17	Penninsula Between Christmas and Drum Bay	29.075213	-95.188557
B20	Oyster Lake	29.115157	-95.167686
B6	Lake in "V" of Old Intercoastal	28.995425	-95.248607
B7	Southwest Corner of Drum Bay	28.997552	-95.239885
	Second Priority Sites		
B8	1st Inlet North of ICW after South Boat Ramp	29.002853	-95.251406
B3	North Old Essex Bayou	28.985755	-95.267292
B1 and B2	South Old Essex Bayou	28.981487	-95.260058
	Third Priority Sites		
B21	Marshes East of Oyster Lake	29.114914	-95.199154
B4	Northern North Essex Bayou	28.989843	-95.269016
B5	South of Old ICW	28.988679	-95.248734
B15	North Side of Salt Lake	29.049088	-95.248603
	No Prioirty Sites		
B12	North Side of Drum Bay	29.031441	-95.223442
B13	North East Side of Drum Bay	29.023701	-95.230111
B11	North Side of Nick's Lake	29.031895	-95.236493
B14	East Side of Salt Lake	29.043784	-95.262818
B9	Areas Bordering ICW	29.011775	-95.242697
B10	Areas Bordering ICW	29.005312	-95.240619
B16	Marsh From Auto Tour	29.058389	-95.241356
B18	Unnamed Location 1	29.098896	-95.197887
B19	Unnamed Location 2	29.091601	-95.210843

Table 2. Summary of survey activities conducted at the Brazoria National Wildlife Refuge. First priority habitat includes areas that had excellent habitat and terrapin sightings, and are suggested as future search areas. Second priority habitat includes areas that had fair to good habitat, may contain terrapin, and are suggested as future search areas. Third priority habitat includes areas that we have not yet searched but may be good habitat based on aerial imaging and surrounding habitat type, and we hope to search there in the future. No priority habitat includes areas in which the habitat was deemed poor. While it is possible that terrapin inhabit these "poor" areas, we suggest concentrating search efforts elsewhere.

Figure 6. Search effort summary of Brazoria National Wildlife Refuge. Purple areas indicate habitat of good to excellent quality. Yellow areas represent poor habitat, and blue areas represent habitat that has not yet been searched but future search is suggested. Numbers correlate with rankings in Table 2. Please see the Interactive Google Earth Map provided in Appendix 2.

San Bernard National Wildlife Refuge

Twenty three sites were surveyed for terrapin and suitable habitat in the San Bernard National Wildlife Refuge. Of those, fifteen were documented as having suitable habitat for terrapin and recommended for future terrapin searches (Table 3). In particular the area adjacent to North Cedar Lake, Cow Trap Lake, and isolated marshes north of the Intracoastal Waterway have been described as first priority sites, with the highest potential to find terrapin (Figure 7). Also notable, six terrapin were sighted in the water by SB17, thus this area is recommended as a high priority site for future surveys (Figure 7).

San Bernard			
First Priority Sites			
Map Legend	**Description**	**Latitude**	**Longitude**
SB1	North Cedar Lake 1	28.864425	-95.444469
SB2	North Cedar Lake 2	28.863903	-95.45227
SB3	North Cedar Lake 3	28.863995	-95.456705
SB5	Cedar Lake Peninsula	28.856498	-95.463368
SB21	Southernmost Cedar Lake	28.819462	-95.532152
SB17	Entrance to Cowtrap Lake	28.854309	-95.505344
SB11	Long Fringing Marsh	28.856846	-95.485909
SB19	Marsh North of ICW Tributary	28.834114	-95.539062
SB9	North of Lake North of ICW	28.868009	-95.47524
SB14	Mid Cedar Lakes Misc.	28.833476	-95.499712
Second Priority Sites			
SB4	Fringe Marsh in North Cedar Lake	28.856778	-95.452311
SB18	Inner Cowtrap Lake	28.865059	-95.52751
SB16	Fring Marsh in Mid Cedar Lake	28.84399	-95.507105
SB22	Southern Cedar Lake, Gulf Side	28.816937	-95.53081
SB23	Sargent Unit	28.787519	-95.600008
No Priority Sites			
SB6	End of San Bernard River	28.856302	-95.444623
SB7	Mid Cedar Lakes Misc.	28.85552	-95.472461
SB12	Mid Cedar Lakes Misc.	28.849232	-95.487883
SB13	Mid Cedar Lakes Misc.	28.84177	-95.482005
SB15	Mid Cedar Lakes Misc.	28.832951	-95.507104
SB10	North Edge of ICW	28.859407	-95.490346
SB8	North Edge of ICW by First Lake	28.864987	-95.474889
SB20	Lake at South End	28.829031	-95.545897

Table 3. Summary of survey activities conducted at the San Bernard National Wildlife Refuge. First priority sites includes areas that have good to excellent vegetation cover, may have terrapin or have had terrapin sightings, and is suggested for future efforts. Second priority habitat includes areas that we have not yet searched but may be good habitat based on aerial imaging and surrounding habitat type, and we hope to search there in the future. There is no third priority as in table 1 because no habitat stood out as “great” and separate from “good”. No priority habitat includes areas in which the habitat was deemed poor. While it is possible that terrapin inhabit these “poor” areas, we suggest concentrating search efforts elsewhere.

Figure 7. Search summary of San Bernard National Wildlife Refuge. Purple areas indicate habitat of good to excellent quality. Yellow areas represent poor habitat, and blue areas represent habitat that has not yet been searched but future search is suggested. The numbers on the areas correlate with those in Table 3. Please see the Interactive Google Earth Map provided in Appendix 2.

Big Boggy National Wildlife Refuge

Three sites were surveyed for terrapin and suitable habitat in the Big Boggy National Wildlife Refuge. None of those were documented as having suitable habitat for terrapin thus future terrapin searches are recommended for other areas of this refuge (Table 4 & Figure 8). Researchers interviewed fishermen and crab-trappers in the Big Boggy Refuge area, and they claimed to have never seen a terrapin or caught one in their traps. Taking these interviews, and the habitat surveys completed by the field researchers into consideration, the Big Boggy Refuge is not thought to sustain a large terrapin population, and future search efforts may be better spent at the San Bernard and Brazoria Refuges.

Big Boggy Searched Areas

Map Legend	Description	Latitude	Longitude
BB1	First Lake	28.74795	-95.78729
BB2	North Inlet on ICW	28.74213	-95.81225
BB3	Big Boggy Creek	28.74144	-95.8313

Table 4. Summary of survey activities conducted at the Big Boggy National Wildlife Refuge. All three sites were deemed "poor" habitat due to lack of low inundated *Spartina* marshes.

Figure 8. Search Summary of Big Boggy National Wildlife Refuge. The numbers refer to the areas searched in Table 4. Please see the Interactive Google Earth Map provided in Appendix 2.

Interviews

Researchers casually interviewed several people on the water or at the boat launches during field surveys. The owner of a small bait store near the San Bernard boat launch communicated that a local crab-trapper often finds dead terrapin in his traps. The individual verified that they were Diamondback terrapin by showing a terrapin shell. When the crab-trapper was called for an interview, he declined the interview. The store owner “hinted” that most terrapin were caught in the Cedar Lakes and the nearby Pelican Lake, which is not on the refuge land. In Brazoria National Wildlife Refuge, a young couple claimed to have sighted a small terrapin swimming in the middle of Drum Bay. When shown a picture of a Diamondback terrapin, they confirmed that the turtle they saw was a terrapin. In Big Boggy National Wildlife Refuge, nearby fisherman and crab-trappers claimed to have never seen or caught a terrapin.

At the beginning of our surveys, a gentleman by the name of Steve Riopelle called us concerning the article in the local paper about the diamondback terrapin research. He claimed to have had a lucrative business capturing gravid females and stimulating them to lay eggs for sale. He had intimate knowledge of terrapin hotspots throughout the bays. When asked about the refuge land, he claimed to have found “hundreds” of terrapin in a small pond on the southern stretch of Old Essex Bayou (area B5 in Figure 6). While we did not find any terrapin in this area, the habitat was suitable enough that future surveys are recommended in this area. He also claims to have found them nesting along the Inter-Coastal Waterway and in the dunes along the side of the road. He also claimed to have found terrapin further down the coast in Lavaca Bay and Cox Bay.

Conclusion and Recommendations

As a result of this study terrapin sightings and suitable habitat have been identified and documented. Baseline data collected during this study on suitable habitat and search areas will aid in future terrapin research efforts. By defining priority terrapin habitat, future terrapin monitoring efforts can be concentrated in areas with the highest probability of capturing terrapin. Future mark-recapture efforts on the Texas Diamondback Terrapin on refuge property will allow researchers to track the status of these populations. Furthermore this research provides critical environmental and habitat data that can be used to define habitat needs and availability for this species. Continued terrapin conservation actions on the refuge could include protection from shoreline erosion as well as continued conservation and restoration of marsh habitat. Awareness and education about the Texas Diamondback Terrapin for refuge visitors and crab-trappers is an essential tool in terrapin habitat and population protection and conservation. Attached in Appendix 1 is the "Have you seen me" flier that will aid researchers in collecting information from the public about terrapin sightings in the area. Continued research on the Texas Diamondback Terrapin in the Mid-Coast Refuge Complex is critical for defining baseline population, long-term trends associated with changes in climate, habitat and water quality. Along the east coast several states have terrapin monitoring programs that have collected data on known terrapin populations for over 30 years. These programs have documented severe declines in population size associated with crab bycatch, and loss of nesting habitat. The large expanses of coastal marshlands contained in the Mid-Coast refuge lands affords great potential for long-term protected terrapin habitat on the Texas Coast that could be key in helping sustain future populations of the Texas Diamondback Terrapin.

Literature Cited

Bossero, M., Draud, M. 2004. Diamondbacks at water's edge. *New York State Conservationist*. 59(2):6-9.

Brennessel, Barbara. Diamonds in the Marsh: A Natural History of the Diamondback Terrapin. Lebanon, NH: University Press of New England, 2006.

Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 1939: 170-173.

Cecala, K. K., J. W. Gibbons, and M. E. Dorcas. 2008. Ecological effects of major injuries in diamondback terrapins: implications for conservation and management. Aquatic Conservation: Marine and Freshwater Ecosystems DOI: 10.1002/aqc.

Cole R.V. and T.E. Helser. 2001. Effect of three bycatch reduction devices on Diamondback Terrapin *Malaclemys terrapin* capture and Blue Crab *Callinectes sapidus* harvest in Delaware Bay. North American Journal of Fisheries Management 21:825-833.

DTWG (Diamonback Terrapin Working Group). 2010. Regional initiatives and rulings that either directly or indirectly impact terrapin populations. Listed on: http://www.dtwg.org/Regional.htm Accessed October 1, 2010.

Garber, S.D. 1990. Diamondback terrapin. Focus 40(1): 33-36.

Gibbons, J.W., Andrews, K.M. 2004. PIT tagging: simple technology at its best. Bioscience 54(5): 447-454.

Halbrook, K.A. 2003. Population estimate of Texas Diamondback Terrapin (Malaclemys terrapin littoralis) in Nueces Estuary and Assessment of nesting habitat suitability. M.S. Thesis. Texas A&M University - Corpus Christi.

Haskett, K. 2011. Abundance and movement of the Texas Diamondback Terrapin in the Deer Island Complex, Galveston, Texas. M.S. Thesis. University of Houston Clear Lake. TX. 77 p.

Hogan, J.L. 2003. Occurrence of the Diamondback Terrapin (*Malaclemys terrapin littoralis*) at South Deer Island in Galveston Bay, Texas, April 2001-May 2002. U.S. Geol. Surv. Open-File Rep. (03-022):iv + 24 p.

Huffman, J. 1997. Preliminary study of Diamondback terrapin (Malaclemys terrapin) populations in West Bay, Galveston, Texas. Master's Project. University of Houston-Clear Lake.

Hurd, LE, Smedes, GW, and Dean, TA. 1979. An ecological study of a natural population of Diamondback terrapins (*Malaclemys t. terrapin*) in a Delaware salt marsh. Estuaries 2(1): 28-33.

Koza, B. 2006. Distribution, habitat selection, and resource partitioning of Texas Diamondback Terrapin (Malaclemys terrapin littoralis) in the Aransas National Wildlife Refuge Area, TX. M.S. Thesis. Texas A&M at Corpus Christi. TX. 185 p.

Morris, A.S., S.M. Wilson, E.F. Dever and R.M. Chambers. 2010. A test of bycatch reduction devices on commercial crab pots in a tidal marsh creek in Virginia. Estuaries and Coasts

Orenstein, R. Turtles, Tortoises, and Terrapins: Survivors in Armor. 2001. Firefly Books. Buffalo, New York.

Palmer, W.M., and Cordes, C.L. 1988. Habitat suitability index models: Diamondback terrapin (nesting) – Atlantic coast. Biological report, National wetlands research center.

Roosenburg, W. M. 1991 The diamondback terrapin: Habitat requirements, population dynamics, and opportunities for conservation. New Perspectives in the Chesapeake System: A Research and Management and Partnership. Proceedings of a Conference. Chesapeake Research Consortium Pub. No 137. Solomons, Md. pp. 237 – 234.

Roosenburg, WM, and Dunham AE. 1997. Allocation of reproductive output: Egg and clutch size variation in the diamondback terrapin. Coepia 2, 190-197.

Roosenburg, W. M. and A. R. Place. 1995. Nest predation and hatchling sex ratio in the diamondback terrapin: Implications for management and conservation. Towards a Sustainable Coastal Watershed: The Chesapeake Experiment, Proceedings of a Conference. Chesapeake Research Consortium Pub. No 149. Solomons, MD. pp. 65-70.

Seigel, R.A. 1979. The reproductive biology of the Diamondback Terrapin, Malaclemys terrapin Tequesta. M.S. Thesis, University of Central Florida, Orlando. 40 p.

Sillimian, BR, Vieman JC. 2001. Top down control of *Spartina alterniflora* production by periwinkle grazing in a Virginia salt marsh. Ecology 82(10) 28-30.

TPWD (Texas Parks and Wildlife Department). 2007. Texas diamondback terrapin (*Malaclemys terrapin littoralis*). Available at: http://www.tpwd.state.tx.us/huntwild/wild/species/terrapin/. Accessed January 28, 2007.

TPWD. 2008. Texas turtle regulations. Texas administrative code: Title 31 natural resources and conservation, Part 2 Texas Parks and Wildlife Department, Chapter 65 Wildlife Subchapter O Commercial Nongame Permits Rule §65.331 Commercial Activity PWD LF W7000-1667 (7/08). Available online at: (a)http://www.tpwd.state.tx.us/publications/pwdpubs/media/pwd_lf_w7000_1667.pdf

Tucker, AD., FitzSimmons, NN, and Gibbons, JW. 1995. Resource partitioning by the estuarine turtle Malaclemys terrapin: trophic, spatial, and temporal foraging constraints. Herpetologica, 51(2): 167-181.

Tucker, AD, Gibbons, JW, and Greene, JL. 2001. Estimates of adult survival and migration for Diamondback Terrapins: Conservative insight from local extirpation within a metapopulation. Canadian Journal of Zoology, 79: 2199-2209.

Watters, C. F. 2004. A Review of the range-wide regulations pertaining to diamondback terrapins (Malaclemys terrapin). Wetlands Institute, Stone Harbor, NJ. pp. 12.

Yearicks, E.F., R.C. Wood, and W.S. Johnson. 1981. Hibernation of the northern diamondback terrapin, Malaclemys terrapin terrapin. Estuaries 4(1): 78-80.

Appendix 1

Terrapin Outreach Flier

Have you seen me?

The Environmental Institute of Houston (EIH) is researching Diamondback Terrapins, in cooperation with the U.S. Fish and Wildlife Service and the Houston Zoo. If you have sighted one of these turtles, please call our main office at 281-283-3950 or email eih@uhcl.edu with the following information: date, time, specific location (GPS coordinates if available), any pictures you may have taken, and your name and contact information. Please do not pick up or disturb any of the Terrapins you may see. Thank you!

Environmental Institute of Houston

Please visit our website for more information about the project
http://prtl.uhcl.edu/portal/page/portal/EIH/Research/TERRAPIN

University of Houston Clear Lake

¿Me ha visto Usted?

El Instituto Ambiental de Houston está investigando Tortugas Acuáticas de Espalda Diamantada, en la cooperación con El Servicio de Pez y Fauna de EE.UU. y el Zoológico de Houston. Si Usted ha visto una de estas tortugas, por favor llame a nuestra oficina principal al 281-283-3950 o correo electrónico eih@uhcl.edu con la información siguiente: fecha, el tiempo, la ubicación específica (coordenadas geográficas si disponible), cualquier imagen que Usted pueda haber tomado, y su información de nombre y contacto. Por favor no recoja ni perturbe cualquiera de las Tortugas Acuáticas que Usted pueda ver. ¡Grácias!

Tomado por EIH en el pantano de la bahía de Galveston

Tomado por EIH en el pantano de la bahía de Galveston

Tomado por USFWS en Isla de Arbol de Ciruela Refugio Nacional

Environmental Institute of Houston

Por favor visite nuestra página de internet para más información sobre este proyecto.
http://prtl.uhcl.edu/portal/page/portal/EIH/Research/TERRAPIN

University of Houston Clear Lake

Appendix 2

Interactive Google Earth Map (Electronic Supplement)

Appendix 3

Photographs (Electronic Supplement)