



Identifying Diamondback Terrapin Nesting Habitat in the Nueces Estuary, Texas

**Publication CBBEP – 103
Project Number – 1527
October 2015**

Prepared by

Aaron S. Baxter, M.S., Principal Investigator
Center for Coastal Studies
Texas A&M University-Corpus Christi
Natural Resources Center
6300 Ocean Drive, Suite 3200
Corpus Christi, TX 78412

Submitted to:
Coastal Bend Bays & Estuaries Program
1305 N. Shoreline Blvd., Suite 205
Corpus Christi, TX 78401

Identifying Diamondback Terrapin Nesting Habitat in the Nueces Estuary, Texas

Prepared for:

Coastal Bend Bays and Estuaries Program
615 N. Upper Broadway, Suite 1200
Corpus Christi, Texas 78401

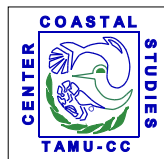
Contract No. 1527



Prepared by:

Aaron S. Baxter, M.S., Principal Investigator

Center for Coastal Studies
Texas A&M University-Corpus Christi
Natural Resources Center
6300 Ocean Drive, Suite 3200
Corpus Christi, Texas 78412



October 2015

TAMU-CC-1502-CCS

Table of Contents

List of Figures	iv
List of Tables	v
Acknowledgments.....	vi
Executive Summary.....	1
Introduction	2
Materials and Methods.....	3
Study Area.....	3
Field Sampling	3
Terrapin Captures	4
Meteorological/Hydrological Data	4
Trail Cameras	6
Radio Telemetry.....	7
Acoustic Telemetry	7
Walking Surveys.....	8
Nest Site Characterization	9
Results.....	9
Terrapin Captures	9
Trail Cameras	9
Radio Telemetry.....	11
Acoustic Telemetry	12
Walking Surveys	12
Nest Site Characterization	14
Discussion.....	14

Terrapin Captures	14
Trail Cameras	16
Radio Telemetry.....	17
Acoustic Telemetry	17
Walking Surveys	17
Nest Site Characterization	18
Conclusions and Recommendations.....	20
Literature Cited	22

List of Figures

Figure 1.	Map of the Nueces Estuary, Texas including Nueces Bay, Nueces River, and Nueces Delta (Bureau of Reclamation 2000).....	5
Figure 2.	Photograph of a modified crab trap used to capture diamondback terrapins in the Nueces Estuary, Texas.....	5
Figure 3.	Photograph of a custom turtle trap used to capture diamondback terrapin in the Nueces Estuary, Texas.....	5
Figure 4.	Locations of digital trail cameras placed within potential nesting sites in the Nueces Estuary, Texas.....	6
Figure 5.	Position of radio and acoustic transmitters attached to the carapace of sexually mature female diamondback terrapins in the Nueces Estuary, Texas	7
Figure 6.	Locations of four acoustic receivers placed within the Nueces Estuary, Texas.....	8
Figure 7.	Trail camera photograph of mature female terrapin travelling from Nueces Bay onto elevated shell hash beach in the Nueces Estuary, Texas	10
Figure 8.	Trail camera photograph of mature female terrapin digging in shell hash substrate in the Nueces Estuary, Texas	10
Figure 9.	Map showing high site fidelity of female diamondback terrapin 148182 documented by radio telemetry in the Nueces Estuary, Texas.....	11
Figure 10.	Site fidelity displayed through acoustic telemetry for female diamondback terrapin 148182 in the Nueces Estuary, Texas	12
Figure 11.	Photograph showing an aborted nesting terrapin nesting attempt in the Nueces Estuary, Texas.....	13
Figure 12.	Photograph depicting a depredated terrapin nest in the Nueces Estuary, Texas	13
Figure 13.	Photograph of a depredated adult female diamondback terrapin in the Nueces Estuary, Texas.....	14
Figure 14.	Map showing the location of sediment cores taken for nest site characterization in the Nueces Estuary, Texas.....	15

List of Tables

Table 1.	Nest site characterization for nesting attempts and raided nests in the Nueces Estuary, Texas. NA = nesting attempt, RN = raided nest	15
----------	--	----

Acknowledgements

We would like to thank the Coastal Bend Bays & Estuaries Program (CBBEP), the Environmental Protection Agency (EPA), and the Center for Coastal Studies (CCS) at Texas A&M University-Corpus Christi (TAMUCC) for funding this project. In particular, we'd like to thank Rosario Martinez for her help and support throughout the study. This project would not have been possible without the help of Beth Almaraz of the Center for Coastal Studies. TAMUCC graduate students Lindsey Ramirez and Shantel Swierc provided invaluable assistance in the field.

Identifying Diamondback Terrapin Nesting Habitat in the Nueces Estuary, Texas

Aaron S. Baxter, M.S., Principal Investigator

Executive Summary

Diamondback terrapins are North America's only brackish water species occurring in a narrow band of coastal habitats from Massachusetts to Texas. It is widely accepted that terrapin populations are declining throughout their range and the loss of nesting habitat is a contributor to this trend. This study sought to identify nesting habitat for Texas diamondback terrapin in the Nueces Estuary, Texas and to provide a habitat characterization to be applied throughout other Texas estuaries.

It is imperative to identify nesting sites so that they can be preserved as functional habitat. Bulk heading and other forms of hardened shorelines associated with coastal development restrict access to nesting areas. Wind and wave driven erosion can reduce the area available for nesting. Terrapins exhibit nest site fidelity, meaning they return to the same nesting beaches each year. If these areas are altered or made unavailable, recruitment becomes limited and the population may eventually become extirpated.

Several methods were used to locate nesting beaches in the Nueces Estuary including the use of trail cameras, radio and acoustic telemetry, and walking surveys. All contributed to the eventual discovery of terrapin nesting sites. Results of this study showed that diamondback terrapins utilize elevated areas of vegetated shell hash as nesting sites in the Nueces Estuary. These areas exist as narrow bands of substrate sandwiched between the open bay and tidal marsh. All nests identified had been raided by predators.

Because of the scarcity of this habitat type in the Nueces Estuary it is suggested that these areas first be protected from erosive wave action and then enhanced to provide larger areas of suitable nesting habitat. The creation of additional nesting sites could also provide more appropriate nesting habitat. Predator removal/relocation during the nesting season may also prove to increase nesting success for this species. It is also recommended that the nesting habitat characterization described in this report, be applied to other Texas estuaries to identify diamondback terrapin nesting sites throughout the state.

Introduction

As the only brackish water turtle in North America, diamondback terrapins (*Malaclemys terrapin*) inhabit a narrow band of estuarine habitats from Cape Cod, MA to Corpus Christi, TX. The Texas subspecies (*Malaclemys terrapin littoralis*) occurs in marshes, tidal creeks, and embayments from western Louisiana throughout much of Texas. Terrapins are a long lived species and are slow to reach sexual maturity, taking up to 8 years in females and 4 years in males (Brennessel 2006). It should be noted that sexual maturity relates more to size than age and that southern populations may achieve maturity faster than those at northern latitudes (Seigel 1984).

Mating occurs in early spring once water temperatures rise above 24° C. There is some evidence to suggest that terrapins form mating aggregations during this time (Seigel 1980). Females often mate with multiple males and have the ability to store sperm for several years. Once a female has been fertilized, egg development continues internally until the female is ready to nest. Female terrapins exhibit nest site fidelity, or philopatry, meaning that they return to the same nesting areas each year. Nesting is perhaps the most well understood aspect of terrapin reproduction and multiple studies have been conducted throughout their range. A female may lay multiple clutches in one nesting season, which normally lasts from May-July. Warmer, or colder, than normal conditions may advance or delay the start and end of nesting.

Like all turtles, terrapins nest on land and there have been studies to characterize nesting habitat. In most states, terrapins seem to prefer sandy, non-vegetated areas for nesting although they are limited by the available habitat and substrate type. Nesting occurs above the normal high tide line, although above normal rainfall or tides may result in the inundation of normally exposed nesting sites. Nesting may occur both day and night and appears to be population dependent. Females often make several nesting attempts before actually depositing eggs. These aborted nesting forays may be the result of a disturbance, the presence of a predator, or may occur for no obvious reason. Terrapins begin digging a nest by “sniffing” at the ground and then using their forelimbs to move the substrate. The turtle will then begin digging in an alternating fashion using her rear limbs to steadily dig out a nest. Nests are flask shaped and usually 14-16 cm deep (Butler 2000). Nest depth is important as shallower nests are prone to desiccation, erosion, and temperature related stress (Brennessel 2006).

Once satisfied with the excavated nest chamber, the female positions its cloacal opening over the nest and deposits between five and twelve soft, oval shaped eggs into the nest. There does appear to be a correlation between the size of the female and clutch size, with larger females producing more eggs. The complete process of nesting takes approximately 30 minutes, and upon completion, the females reenters the water.

Egg development continues in the nest for 60 to 90 days. The incubation time is directed by temperature with higher temperature inducing faster development. Temperature also plays a role in determining sex, with higher nest temperatures (>30° C) producing more females and lower temperatures (<28° C) producing more males. During this time, the nest remains vulnerable to predation and it is not unusual for over 90% of nests to be depredated by raccoons, birds, and ghost

crabs (Feinberg and Burke 2003). The majority of nests are raided within the first 24-48 hours after the eggs are deposited and predators likely use a cue, such as scent, to locate the nests (Butler et al. 2004; Brennessel 2006).

If a nest remains intact, hatchlings will begin to emerge once incubation is complete. Not all hatchlings exit the nest, as some may choose to overwinter within the nest only to emerge the next spring. This event may bring on a second wave of predation, and the majority of hatchlings quickly leave the nest in search of cover (Brennessel 2006). Unlike other turtle species, terrapin hatchlings do not seek open water, instead choosing to move into vegetated areas. This completes the nesting cycle for diamondback terrapins.

Access to nesting beaches is the most vital component of the nesting process therefore it is imperative that these areas remain accessible. Nest site disturbances, including development and shoreline hardening, can destroy entire nesting colonies or force them to nest in less suitable areas such as roadsides or parking lots. This can lead to an increase in vehicular mortality and an overall decline in numbers. Without knowing the location of these nesting sites, it is impossible to ensure their continuance as functional nesting habitat. Therefore it is imperative that these sites be identified throughout the state of Texas.

While numerous studies have been conducted on all stages of terrapin reproduction, there is virtually nothing known about this process in Texas. A USGS technical report includes one observation of a nesting terrapin on South Deer Island in Galveston Bay on an exposed shell hash beach (Hogan 2003). This is believed to be the first, and only, published account of an actively nesting terrapin in Texas. The purpose of this study was to document terrapin nesting sites in the Nueces Estuary, Texas and to provide a framework for locating these habitats in other Texas estuaries.

Materials and Methods

Study Area

The Nueces Estuary is located on the southern Texas coast and contains a primary bay, Corpus Christi Bay, and two secondary bays, Nueces Bay and Oso Bay (Fig. 1). The two freshwater inflows for the estuary are the Nueces River and Oso Creek. This study took place in the west end of Nueces Bay between the mouth of the Nueces River and the Nueces Delta.

Field Sampling

A variety of approaches were used during this study to locate terrapin nesting sites in the Nueces Estuary, Texas. Most methods were previously documented for locating nesting sites and recording habitat usage during the nesting season, while one unpublished method (trail cameras) was used to identify nesting sites within the estuary. Before leaving to sample, a Garmin GPSMap78SC handheld GPS unit was used to mark a known survey benchmark on the Texas A&M University-Corpus Christi campus. This was done to attain a measure of accuracy for the handheld GPS unit used in the field.

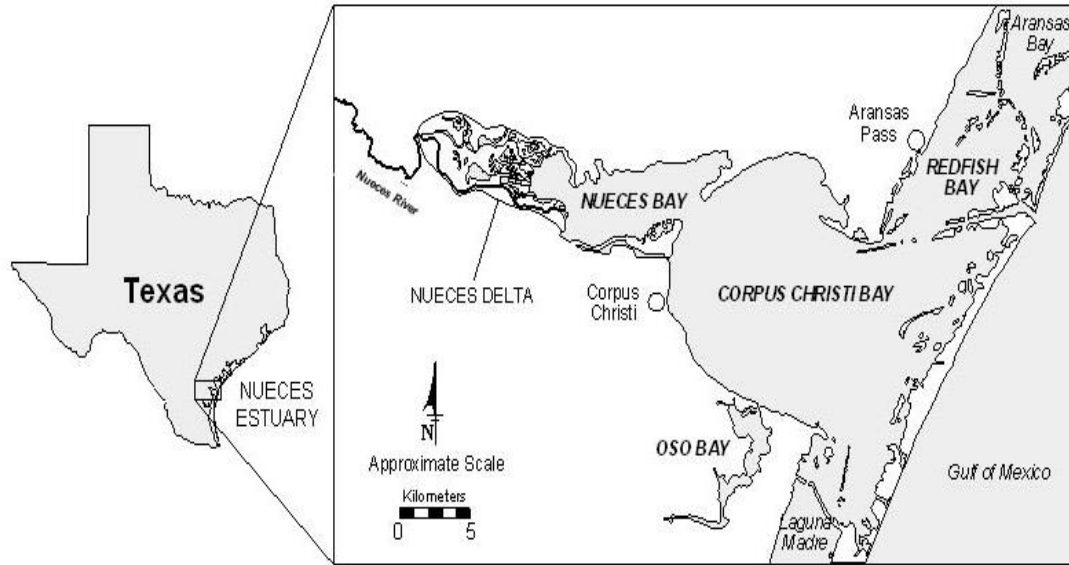


Figure 1. Map of the Nueces Estuary, Texas including Nueces Bay, Nueces River, and Nueces Delta (Bureau of Reclamation 2000).

Terrapin Captures

Diamondback terrapins were captured within the Nueces Estuary using modified crab traps and a custom designed turtle trap. Pictures of both trap types are found in Figures 2 and 3. All trapping activities were performed under scientific research permit TPWD SPR-0910-148. For each capture, standard measurements were taken including carapace length, carapace width, shell height, plastron length, plastron width, head width, and weight. Terrapins were sexed based on size and position of the cloacal opening relative to the posterior edge of the carapace. Each terrapin was marked using a modified Cagle (1939) scute notching system and a passive integrated transponder was implanted at the base of the hind right leg. These two systems of marking allowed for positive identification in the case of a recapture.

Meteorological/Hydrological Data

During each sampling event, meteorological data was collected immediately upon arrival and once again before sampling concluded for the day. Parameters included air temperature (°C), relative humidity (%), wind intensity (mph), wind direction, cloud cover (%), and present weather. Meteorological measurements were made with a Kestrel 3500 Pocket Weather Meter. Tide stage was recorded using the Nueces Bay station of the Texas Coastal Ocean Observation Network (TCOON). Moon phase was attained through the US Navy Astronomical Applications Department (aa.usno.navy.mil).



Figure 2. Photograph of a modified crab trap used to capture diamondback terrapins in the Nueces Estuary, Texas.



Figure 3. Photograph of a custom turtle trap used to capture diamondback terrapin in the Nueces Estuary, Texas.

Trail Cameras

Nine trail cameras (Bushnell Trophy Cam HD Essential) were set in areas thought to provide suitable nesting habitat by attaching them to PVC pipe inserted several feet into the substrate (Fig. 4). Location decisions were based on previously published work in other states, as well as anecdotal reports from within Texas. Cameras were set to capture images of female terrapins traveling to and from nesting beaches, actively nesting, and documenting the presence of known terrapin predators. Cameras were triggered by way of a motion sensor and were set to record a picture any time movement occurred in the camera's viewing range. Cameras also had the ability to take pictures based on a pre-set time interval. For this study, cameras were programmed to take one photograph per minute over the course of the sampling period. Cameras were initially set on April 20, 2015 and removed July 16, 2015. If a location was deemed unproductive (no evidence of terrapin or predators), it was moved to another likely nesting site. Photographs were reviewed on a weekly basis throughout the study.



Figure 4. Locations of digital trail cameras placed within potential nesting sites in the Nueces Estuary, Texas.

Radio Telemetry

Radio telemetry was used to track sexually mature females during the nesting season. Radio telemetry is an effective tracking method on land as radio waves are highly absorbed in water and therefore less effective for tracking in an aqueous medium. It should be noted that radio signals can be received when a terrapin surfaces for air or is near the water's surface. Ten sexually mature females were fitted with a radio transmitter (Advanced Telemetry Systems R1910) using a two-part marine epoxy (Loctite Fast-Dry Marine Epoxy). The transmitter was attached to the carapace of the terrapin with the transmitter antennae angled up (Fig. 5). A 3-element folding Yagi antenna connected to a receiver was used to scan for the presence of tagged females and allowed for the active tracking of these individuals when on land. The tag life for each radio transmitter was approximately 182 days.

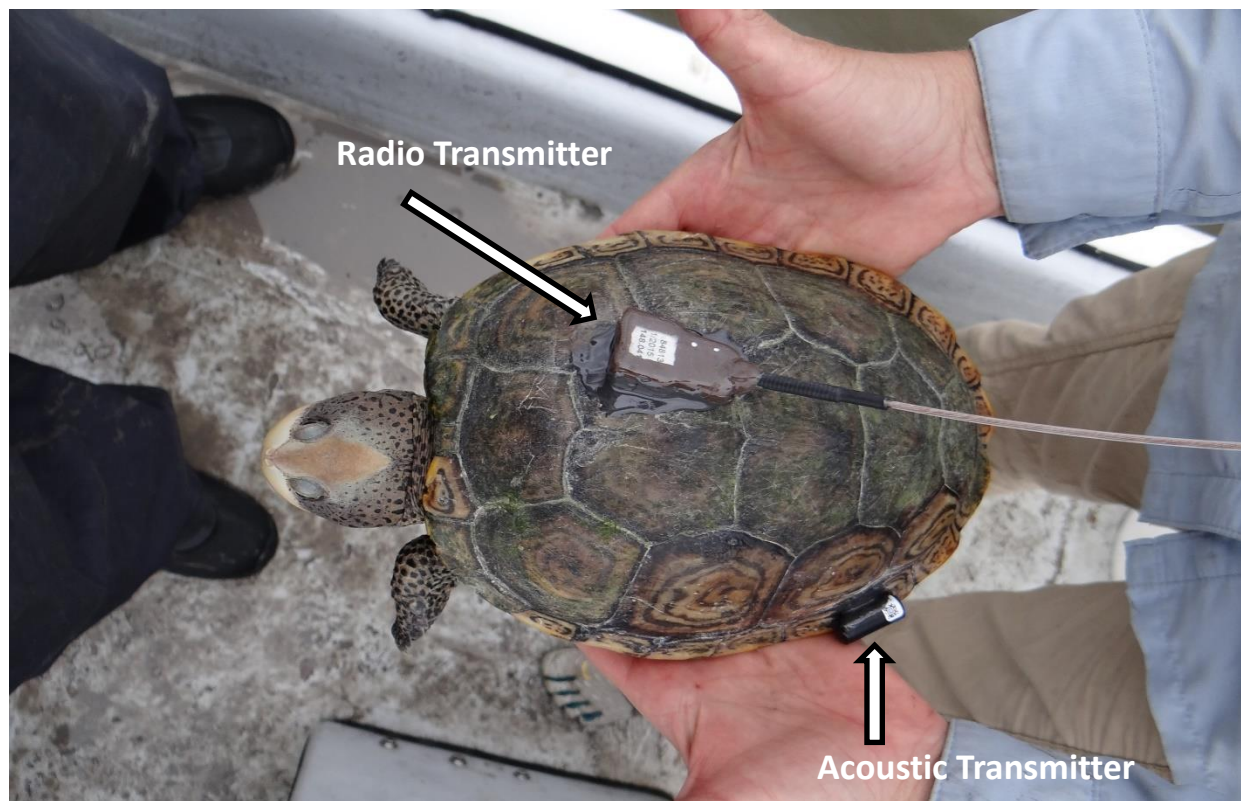


Figure 5. Position of radio and acoustic transmitters attached to the carapace of sexually mature female diamondback terrapins in the Nueces Estuary, Texas.

Acoustic Telemetry

Acoustic telemetry was used to track sexually mature females during the nesting season. Acoustic telemetry is an effective method for tracking animals in water as sound waves are not readily absorbed and travel faster through saltwater than through air. Seven mature females were fitted with an acoustic transmitter (Vemco V9 69k) using a two-part marine epoxy (Loctite Fast-Dry Marine Epoxy). The transmitter was attached to the rear margin of the carapace (Fig. 5). The seven females that received an

acoustic transmitter were also fitted with a radio transmitter resulting in a total of seven double-tagged females. The remaining three females were not given an acoustic tag, leaving them with only an attached radio transmitter. Four stationary acoustic receivers (Vemco VR2W) were placed in the water in areas of observed terrapin activity (Fig. 6). Data was uploaded to Vemco's program VUE using a Bluetooth adapter and laptop computer. The tag life for each acoustic transmitter was approximately 146 days.



Figure 6. Locations of four acoustic receivers placed within the Nueces Estuary, Texas.

Walking Surveys

Walking surveys were conducted at least once a week between April 20, 2015 and July 17, 2015. Surveys consisted of slowly walking in areas of exposed, dry substrate looking for nesting terrapins and signs of attempted nesting or depredated terrapin nests. These areas were located in the Nueces Delta, Nueces River, and shorelines bordering Nueces Bay.

Nest site characterization

Sediment cores were collected for nine aborted nesting sites and five raided terrapin nests. Parameters included sediment grain size, elevation, distance from water, percent vegetative cover, slope, and nest depth. Sediment grain size was calculated by taking a sediment sample to 15 cm with a metal scoop. Sediment samples were separated, using a set of sieves, into percent silt, clay, sand, and gravel (TCEQ 2012). Elevation was determined using the Nueces Delta Digital Elevation Model. Distance from water was measured using a tape measure from the current water level to the nesting site. Percent vegetation was approximated using a 1 m² quadrat, and slope was determined using the tape and level method. Nest depth was measured as the distance from the bottom of the nest to the sediment surface. This measurement was only taken for predated terrapin nests. All sampled sites were recorded on a Garmin GPSMap78SC handheld GPS unit.

Results

Terrapin Captures

A total of 31 terrapins were captured using modified crab traps and a custom turtle trap, and included 18 females and 13 males. All terrapins were captured near the mouth of the Nueces River on April 22 2015. Of the 18 females captured, 10 were equipped with radio transmitters. Seven of those 10 females were also given an acoustic transmitter.

Trail Cameras

Trail cameras provided more than one million photographs during the course of the study and proved effective out to 14 m during daylight hours and out to 7 m at night. Trail cameras provided valuable data on terrapin usage of terrestrial habitats as several behaviors were documented. Pictures showing terrapins swimming close to shore were common in April and May 2015. Basking behavior was documented on multiple occasions in the early spring. One series of photos on April 30, 2015 showed communal basking of multiple large females on a nesting beach.

Female terrapins traveling over land were documented eleven separate times. An example of this can be seen in Figure 7. In this picture, the female is seen coming from Nueces Bay on the left and moving onto an area of elevated shell hash. The marsh can be seen on the right side of the photograph. Terrapins were documented coming both from open water and the marsh, and were often photographed leaving the area in a different direction than they approached.

On eight occasions, female terrapins were photographed digging in the substrate. An example of this can be found in Figure 8. In this picture the female is seen with hind end raised and front limbs beginning to push substrate to the sides.

All terrapins were documented between 0700 and 2000, with none being photographed after dark. Photographs of terrapins on land occurred 60% of the time during a rising tide with the remaining 40% occurring during high, low, or falling tides. The moon was in a waning phase for 60% of the photographs showing terrapins on land.



Figure 7. Trail camera photograph of mature female terrapin travelling from Nueces Bay onto elevated shell hash beach in the Nueces Estuary, Texas.



Figure 8. Trail camera photograph of mature female terrapin digging in shell hash substrate in the Nueces Estuary, Texas.

Trail cameras were also effective for documenting the presence of known, and potential, terrapin predators. Raccoons, coyotes, herons, and grackles were all photographed on multiple occasions. While raccoons were only observed when dark, coyotes were documented both night and day.

Radio Telemetry

One of the ten radio transmitters was defective from the manufacturer, although the other nine transmitters functioned properly allowing for active tracking. Eight of the nine functional transmitter signals were received at least once after they were attached. Generally speaking, tagged terrapins showed remarkable site fidelity during the nesting season with a noted decline in frequency as the summer months progressed. Although recaptures were only possible when a terrapin was located on land (i.e. flooded marsh), their presence could be documented when surfacing for air or swimming near the water's surface. On multiple occasions individual terrapins were positively identified in the water due to the transmitter's antenna being visible. Figure 9 shows an example of this site fidelity for tagged female 148182.



Figure 9. Map showing high site fidelity of female diamondback terrapin 148182 documented by radio telemetry in the Nueces Estuary, Texas.

There were two observed behaviors for recaptured terrapins using radio telemetry. Individuals were found either foraging in a flooded marsh or buried several inches into the mud of these same marshes. Regardless of activity, each recaptured terrapin was found within close proximity to a tidal creek or open water.

Acoustic Telemetry

All seven acoustic tags functioned properly throughout the course of the study. Acoustic telemetry data reaffirmed the high site fidelity revealed through radio telemetric data. All acoustically tagged turtles were documented in the water in close proximity to nesting sites. These occurrences were frequent during the spring and early summer, but like radio telemetry data showed, the frequency of detections declined as the summer progressed. Figure 10 demonstrates site fidelity during the nesting season for the same terrapin shown in Figure 9. Refer to Figure 6 for locations of each acoustic receiver. This method did not result in any recaptures as it is a passive monitoring method.

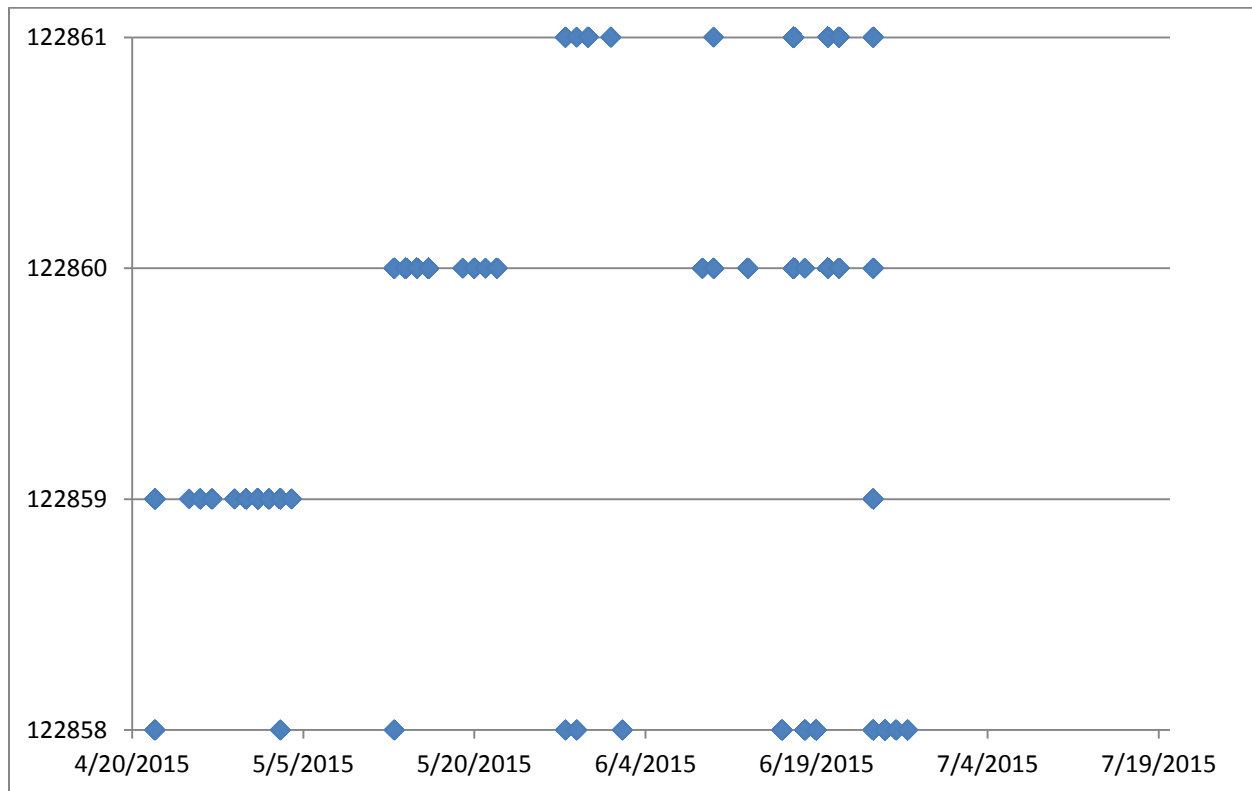


Figure 10. Site fidelity displayed through acoustic telemetry for female diamondback terrapin 148182 in the Nueces Estuary, Texas.

Walking Surveys

Walking surveys proved to be the most effective method for documenting nesting sites for diamondback terrapins in the Nueces Estuary. The photographic and telemetric data described above suggested certain sites as nesting beaches due to the site fidelity shown by mature females during the nesting season. The discovery of aborted nesting attempts and raided terrapin nests during walking surveys showed with certainty that these areas were used for nesting by diamondback terrapins. Pictures of both an aborted nesting attempt, and raided terrapin nest can be found in Figures 11 and 12, respectively. All five raided nests contained the remains of terrapin eggs.



Figure 11. Photograph showing an aborted terrapin nesting attempt in the Nueces Estuary, Texas.



Figure 12. Photograph depicting a depredated terrapin nest in the Nueces Estuary, Texas.

One dead adult female terrapin was found during a walking survey on May 27, 2015. The terrapin appeared to have been killed and partially eaten by a raccoon. A pile of fresh raccoon scat was found in close proximity to the turtle. A picture of this female is shown in Figure 13.



Figure 13. Photograph of a depredated adult female diamondback terrapin in the Nueces Estuary, Texas.

Nest Site Characterization

Data collected at nine aborted nesting attempts and five raided terrapin nests can be found in Table 1. For the nesting sites discovered in the Nueces Estuary, “gravel” consisted entirely of shell hash of various sizes. The location of collected sediment cores is found in Figure 14.

Discussion

Terrapin Captures

The concentration of both male and female terrapins during the early spring in an area proximate to nesting beaches may provide evidence for breeding aggregations. Watermen from Chesapeake Bay told of large concentrations of terrapins in specific areas that may have represented mating aggregations (Brennessel 2006). This event has also been reported from Merritt Island, Florida and Wellfleet Harbor on Cape Cod, Massachusetts (Seigel 1980, Brennessel 2006). In addition to capturing 31 individual terrapins of both sexes within a 24 hour period, Center for Coastal Studies researchers observed large numbers of terrapins near the mouth of the Nueces River for the preceding two weeks. Caution should be taken in assuming that this was indeed a mating aggregation, but there is evidence that this may

Table 1. Nest site characterization for nesting attempts and raided nests in the Nueces Estuary, Texas.
NA = nesting attempt, RN = raided nest.

Description	Distance from water (m)	Elevation (m)	Slope (%)	Vegetative Cover (%)	% Clay	% Silt	% Sand	% Gravel	Nest Depth (cm)
Core 1, NA	4.3	1.5<N<3.0	14.0	0.0	0.0	0.3	19.7	80.0	
Core 2, NA	3.0	1.5<N<3.0	36.7	0.0	0.0	0.1	0.4	99.5	
Core 3, NA	3.4	1.5<N<3.0	3.3	0.0	0.0	0.3	2.7	97.0	
Core 4, NA	4.3	1.5<N<3.0	12.5	1.0	0.0	1.0	5.0	94.0	
Core 5, NA	2.7	1.5<N<3.0	8.0	0.0	0.0	0.6	29.7	69.7	
Core 6, NA	5.5	1.5<N<3.0	0.0	0.0	0.0	1.0	44.0	55.0	
Core 7, NA	5.5	1.5<N<3.0	13.9	0.0	0.0	0.1	27.0	72.0	
Core 8, NA	8.9	1.5<N<3.0	16.7	10.0	0.0	1.0	4.0	95.0	
Core 10, NA	3.0	1.5<N<3.0	32.0	0.0	0.0	0.0	31.0	69.0	
Average	4.5		15.2	1.2	0.0	0.5	18.2	81.2	
Core 9, RN	6.8	1.5<N<3.0	11.1	85	0.0	1.0	27.0	72.0	10.2
Core 11, RN	3.7	1.5<N<3.0	5.6	95	0.0	3.0	34.0	63.0	7.6
Core 12, RN	6.5	1.5<N<3.0	13.9	95	0.0	1.0	11.0	88.0	8.9
Core 13, RN	6.0	1.5<N<3.0	13.9	95	0.0	1.0	7.0	92.0	8.9
Core 14, RN	3.9	1.5<N<3.0	5.6	80	0.0	1.0	6.0	93.0	10.2
Average	5.4		10.02	90	0	1.4	17	81.6	9.16



Figure 14. Map showing the location of sediment cores taken for nest site characterization in the Nueces Estuary, Texas.

have been what was occurring. This warrants further investigation into whether this assemblage of males and females occurs annually in this same location.

Trail Cameras

While trail cameras have been widely applied throughout wildlife science, this is the first documented use of trail cameras to study diamondback terrapins. This method provided valuable data in several ways. Trail cameras were highly effective at documenting presence/absence of terrapins while in the water and on land. Individual heads were easily made out as terrapins surfaced for breath or made their way to or from the water. This method could easily be applied in estuaries where terrapin occurrence is unknown. Through the use of multiple cameras, a researcher has the ability to monitor several locations simultaneously, increasing both efficiency and the area covered within a given time frame. Photographs taken by trail cameras also proved helpful in directing walking surveys. By reviewing the pictures taken by trail cameras on a weekly basis, it was possible to narrow the search area to allow the most efficient use of time during walking surveys.

That no terrapins were documented on land between 2000 – 0700, may imply that this population nests mainly during the day. There is published evidence for diurnally nesting populations (Montevecchi and Burger 1975; Seigel 1980; Goodwin 1994), although there are also studies that document nocturnal nesting in this species (Auger and Giovannone 1979; Butler 2000; Butler et al. 2004). It should be stated that although nocturnal nesting was observed in the previously mentioned studies, diurnal nesting was also noted for those populations. That a dead adult female was found does suggest some degree of nocturnal nesting for the Nueces population, as raccoons are nocturnal predators. There would be no other reason for this terrapin to have come onto land other than to nest, as basking only occurs during daylight hours.

Trail cameras also proved valuable in recording the presence of known terrapin predators. Raccoons are known to be the number one terrestrial predator of terrapins as they feed on all terrapin life stages including eggs, hatchlings, and nesting adult females (Brennessel 2006). In some cases, up to 92% nest loss has been observed due to raccoon depredation (Feinburg and Burke 2003). Other known predators of terrapin eggs recorded by trail cameras were laughing gulls and grackles. These species are common in the Nueces Estuary and were photographed often in areas now known to contain terrapin nests. Burger (1977) suggested that avian predators may be most successful during egg deposition. In several photographs, a terrapin was seen digging only to stop and return to the water at the appearance of laughing gulls, great tailed grackles, and large wading birds, including great egrets and great blue herons. Not all of these birds are documented predators of terrapins, but all have the potential to do so.

Another potential predator of terrapin nests is the coyote. This species was photographed widely throughout the nesting area, both day and night, and is fully capable of excavating a nest to gain access to eggs. While there are no published accounts of coyote predation of terrapin nests, there is one observation of a coyote digging up a terrapin nest in Massachusetts (Brennessel personal communication), and the remains of terrapin eggs have been found in coyote scat in Mississippi (Morphman personal communication).

The absence of grey foxes on trail cameras suggests that they are not a major predator of terrapin nests in the Nueces Estuary. Throughout their range, foxes are known predators of terrapin nests (Brennessel 2006) and the study area is known to contain gray foxes. Perhaps the presence of numerous coyotes along nesting beaches is responsible for the lack of foxes recorded by trail cameras. Coyotes are much larger and as a predator of foxes, are known to have an effect on their distribution (Voigt and Earle 1983).

There were a few drawbacks to using trail cameras including limited visual range, especially at night. This may have also contributed to the lack of terrapins seen in the pictures after dark, although it was possible to identify small animals including snakes, frogs, and rats in the dark. Heavy rain and high winds also created problems with the trail cameras. During heavy rain events, water seeped inside of the weatherproof housings and although the cameras continued to function, the lens would often become foggy as a result. This was alleviated by drying the wet cameras in a commercial grade desiccant (Drierite). It should also be noted that raccoons and birds sometimes altered the camera angle requiring it to be readjusted to its proper orientation.

Radio Telemetry

While no actively nesting turtles were discovered as a result of radio tracking, it was highly successful in demonstrating site fidelity during the nesting season. Tagged females spent a large amount of their time in open water or marshes directly adjacent to exposed sand hash beaches throughout the nesting period. The marked dispersal of tagged females later in the summer suggests the conclusion of nesting activities.

Due to above average rainfall, the marshes adjacent to the nesting beaches remained inundated throughout most of the nesting season. During normal years, these marshes are dry. High usage of the marsh was documented through radio tracking and although not considered nesting behavior, this method showed high usage of this habitat type by females during the nesting period when available. These flooded marshes provided access to food resources in the form of mollusks, decapods, and insects as all were present in large numbers while the marshes were flooded. As the marsh began to dry up, terrapin activity in these areas decreased drastically.

Acoustic Telemetry

For the purposes of this study, acoustic telemetry served to document the presence and frequency of tagged terrapins in relation to nesting beaches. Throughout the nesting season, tagged females were shown to remain in close proximity to nesting sites with a marked reduction in frequency as the summer progressed. This indicates that nesting occurred throughout the spring and early summer, with females dispersing more widely as the nesting season concluded.

Walking Surveys

This on the ground approach provided the data necessary to state with certainty that terrapins were utilizing specific areas for nesting. Photographic and telemetric data were helpful in narrowing the

search area, but did not provide the location of actual nests. By conducting thorough searches of these areas, the locations of both attempted, and actual, nests were discovered.

Terrapin populations in other states often utilize sandy beaches or dunes as nesting habitat. In these cases, terrapins often leave a crawl as they exit the water in search of a nesting site. A second crawl is created once nesting is complete and the terrapin travels back towards the water. By finding the intersection of two crawls, researchers are often able to locate the nest. Because nesting does not occur in sandy substrates in the Nueces Estuary, it was not possible to use this approach to locate nests and for this reason, no intact nests were found over the course of the study.

Instead, raided nests were used to document the use of certain habitats as nesting sites in the Nueces Estuary. These excavated nests were likely depredated by raccoons, although other known terrapin predators were documented in these areas. Coyotes are a potential mammalian predator of nesting adult females, eggs, and hatchlings and although their role in this process has not been published, there is anecdotal evidence to suggest that it occurs.

Nest Site Characterization

For the identified nesting beaches in the Nueces Estuary, available nesting area was limited to a narrow band of elevated, and vegetated, shell hash sandwiched between the open bay and marsh ranging from 1-3 m in width. While portions of the shoreline were substantially wider, the elevated areas were restricted in terms of width. It is vital that terrapins nest above the high tide line to avoid inundation and complete nest failure. Examples of this narrow band of appropriate nesting area can be seen in Figures 5 and 6.

Terrapins may often dig in several places before settling on a suitable nest site and the remains of these failed forays were easily noticeable during walking surveys. Actual nests were only identifiable after being depredated by predators. Reasons for abandoning nesting attempts may vary. The presence of a predator may cause a terrapin to relinquish nesting efforts and return to the water. There may also be physical factors that determine nest site suitability. There were several aspects that were similar for both raided nests and aborted digs including sediment grain size. This is to be expected as shell hash is the major sediment type available to terrapins in the Nueces Estuary. Elevation was also similar for all sediment cores. As stated before, nests are laid above the high tide line to reduce the chance of nest flooding. Distance from water was slightly greater for raided nests, but not by a substantial difference. This is due to the limitation in elevated sites for this area and their close proximity to open water. There were two parameters for which noticeable differences did occur regarding raided nests and aborted nesting attempts. For actual nests, the average slope was about 5% less than for abandoned nesting attempts. The most distinct difference between actual nests and nesting attempts was percent vegetative cover. Aborted nesting attempts almost always occurred in areas with 0% vegetation, while actual nests averaged 90% vegetative cover.

Palmer and Cordes (1988) gave an ideal slope of $\leq 7^\circ$ for terrapin nesting. Average slope for raided nests in the Nueces Estuary was 10%, which converts to a slope of 5.7° , which is within the existing nesting habitat suitability index (Palmer and Cordes 1988). For aborted nesting attempts, average slope was

15.2%, or 8.64°, which is outside of the optimum slope for terrapin nesting. Digging and laying may be easier in areas with low slope as the terrapin must hold itself at a 30°-40° angle while laying. This position would be difficult to hold on higher slopes (Burger and Montevicchi 1975). Low slope also reduces the amount of wind erosion preventing eggs from becoming exposed, although in shell hash substrate the wind would have a minimal effect, as these heavier sediments are not often moved by wind.

There is conflicting data surrounding the issue of substrate type and vegetative cover and what is ideal for terrapin nesting. Generally, terrapins have been shown to prefer flat to softly sloping sandy beaches with little to no vegetation (Seigel 1980; Palmer and Cordes 1988). Of course, there are exceptions and in some areas terrapins nest in partially vegetated areas or in non-sandy substrates (Auger and Giovannone 1979; Feinburg and Burke 2003). Preferred nesting substrate is often easily explained, as terrapins must nest in the substrate(s) available. In Nueces Bay, there are no areas of elevated, exposed sand. Instead there is only river silt and shell hash made available. Silt is an inappropriate nesting substrate as the small sediment grain size, and the resultant lack of air space, does not allow for adequate gas exchange crucial to proper egg development (Butler personal communication). Shell hash contains larger sediments with a large amount of airspace allowing for gas exchange in and out of the egg. This larger sediment type would also be well draining which could prevent the nest from flooding during heavy rains.

Heavy vegetation suggests heavy root biomass which can lead to egg destruction and difficulty in nest excavation. However, nests in areas with no vegetation risk increased desiccation and wind erosion (Brennessel 2006). Palmer and Cordes (1988) suggested an optimum nesting habitat as having 5% - 25% vegetative cover. In the Nueces Estuary, all actual nests were found in heavily vegetated areas, containing species such as sea oxeye daisy (*Borrchia frutescens*), camphor daisy (*Rayjacksonia phyllocephala*), green thread (*Thelesperma filifolium*), and annual seepweed (*Suaeda linearis*). Raided nests were found directly adjacent to the stem of a plant. On one occasion, two raided nests were found on opposite sides of the same plant. While these areas may lead to increased egg loss due to root infiltration, there is perhaps a trade-off when compared to nesting in non-vegetated areas. By nesting in heavy vegetation, terrapins may avoid avian predators such as grackles and laughing gulls. Perhaps nest survival is higher in vegetated areas due to the hot, dry climate that is typical of the Nueces Estuary. Plant growth provides shade and retains moisture which may prevent eggs from overheating or drying out during development.

Halbrook (2003) formulated a habitat suitability index (HSI) for nesting in Nueces Bay. She suggested that bird rookery islands located in the west end of Nueces Bay may be appropriate nesting habitat for diamondback terrapins. Terrapins are known to nest on South Deer Island and Shell Island in Galveston Bay (Hogan 2003, George 2014), but there are important differences between the islands in Nueces and Galveston Bays. Throughout their range, terrapin nesting beaches are found in close proximity to marsh habitat. Marshes provide shelter for hatchlings and it is thought that newly hatched terrapins spend their first few years in these areas. South Deer Island is a large island containing tidal creeks and marsh habitat, as well as elevated shell hash substrate on the perimeter, making it appropriate terrapin nesting habitat (George 2014). The islands in Nueces Bay are comparatively small and contain no marsh habitat.

They consist almost entirely of vegetated shell hash and the nearest marsh can only be reached by crossing open water. Terrapin hatchlings are not known to make open water forays in order to reach their preferred marsh habitat. For this reason, it does not appear that the islands in Nueces Bay provide the habitat necessary for successful hatchling dispersal and are therefore not likely used as nesting sites by mature females.

The presence of colonial nesting birds on the islands in Nueces Bay may also deter the use of them as nesting sites. As mentioned before, there are several documented avian predators of terrapin eggs, including laughing gulls, which are known to nest on these islands. There are also high numbers of herons and egrets that nest in the shrubs on these islands. While nest predation has not been documented, these large birds would easily prey on hatchlings as they emerged from the nest. Even if female terrapins chose to nest on these islands, the combination of avian induced mortality and lack of appropriate marsh habitat would prevent any degree of successful recruitment.

Historically, nesting substrate for diamondback terrapins has been reported as sandy, with some populations using roadsides when access to nesting beaches was restricted. Recently, shell hash substrate has been recognized as an often used nesting substrate. Nesting in shell hash has now been documented in Texas by (Hogan 2003) and this study, in Mississippi by Coleman et al. (2014) and in Georgia (Butler personal communication).

Conclusions and Recommendations

While this study was successful in identifying nesting habitat for diamondback terrapin in the Nueces Estuary, several new concerns were identified in regards to the nesting success for this species in those areas. The documented presence of predators during the nesting season undoubtedly affects the rate of nest predation and the resultant nesting success rates. In other parts of the terrapin's range, exclusion fences are often constructed around individual nests to prevent them from being raided by mammalian predators. These fences, often electrified, may be dug into the substrate to prevent predators from digging under the fence and are closed on top, restricting access from above. Unfortunately, this is not possible for the Nueces Estuary as the shell hash substrate does not allow for the identification of terrapin nests, unless they have already been raided. Because nests cannot be protected in this fashion, alternative predator exclusion methods should be explored.

Predator removal or relocation is an option that could be utilized. The seasonal trapping and removal of raccoons from the nesting area from May-July could drastically reduce the number of terrapin nests that are depredated possibly resulting in higher nesting success for this population. It is difficult to estimate nesting success for this population due to the substrate in which nesting occurs, but it can be assumed that by removing raccoons from nesting sites, that nesting success would increase as a result. Raccoon removal has been shown to be effective, lowering nest predation by over 60% in a single year (Munscher et al. 2012). When raccoons were not removed the following year, nest predation returned to previously high levels.

Another method for increasing nesting success for terrapins in the Nueces Estuary is the restoration and enhancement of existing nesting habitat. Burger (1977) showed that areas of high-density nesting were

more heavily predated than more dispersed nests. Because suitable nesting habitat is limited in the Nueces Estuary, terrapins are forced to nest in high densities, allowing predators to locate a high percentage of total nests within a small area. If these narrow bands of elevated shell hash were made wider, it would increase the available nesting habitat and allow terrapins to nest in lower densities within a given area.

That current nesting habitat occurs as a thin strip of land between the open bay and marsh raises the issue of erosion. These beaches occur on high energy shorelines of Nueces Bay resulting in the loss of nesting habitat due to strong wave action. In order to ensure the existence of these nesting areas, erosion prevention measures could be enacted. Living shoreline stabilization methods should be utilized and could include oyster reef and *Spartina* placement. Hardened shorelines (bulk heading, rip rap, etc.) limit access to nesting areas and should be avoided. This measure should be taken to prevent any further loss of nesting sites and should occur whether or not the habitat is restored/enhanced as recommended above.

Another experimental method being utilized with varying degrees of success is the creation of new nesting habitat. Diamondback terrapins exhibit nest site fidelity and there have been questions regarding the possibility of creating new terrapin nesting habitat and whether it would be used as such. Initial results have shown that terrapins will indeed utilize created nesting habitats and will exhibit site fidelity in future years (Brennessel personal communication). These generated nesting sites are referred to as “terrapien gardens” and have been used as mitigation for development projects along the east coast. Terrapien gardens are also being installed by homeowners whose properties occur in areas of historic terrapien nesting (Lacey personal communication). It appears that the highest nesting success occurs when these areas are created where known terrapien nesting activity intersects with the newly constructed nesting habitat (Egger personal communication). There are some concerns regarding the artificial concentration of terrapien nests in terrapien gardens and increased accessibility to known terrapien predators, although initial results show this as an effective strategy to increase terrapien nesting habitat.

Finally, the data gathered at known nesting beaches in the Nueces Estuary should be applied in other Texas estuaries where the location of nesting beaches is unknown. With coastal development on the rise, it is imperative to locate these areas and to preserve them as functional nesting habitat. Shoreline hardening, road building, and habitat fragmentation are all parts of the developmental process and all have the capacity for restricting access to historical nesting sites for diamondback terrapins. By utilizing the framework provided by the nest site characterization in this study, it should be possible to identify nesting sites for populations outside of the Nueces Estuary, helping to ensure that terrapins are allowed continued access to nesting beaches.

Literature Cited

- Auger, P. J. and P. Giovannone. 1979. On the fringe of existence: Diamondback terrapins at Sandy Neck. *Cape Naturalist* 8(3).
- Brennessel, B. 2006. *Diamonds in the Marsh*. University Press of New England, Lebanon, NH. 219 pp.
- Burger, J. 1977. Determinants of hatching success in diamondback terrapin, *Malaclemys terrapin*. *American Midland Naturalist* 97:444-464.
- Burger, J. and W. A. Montevecchi. 1975. Tidal synchronization and nest site selection in the northern diamondback terrapin *Malaclemys terrapin terrapin* Schoepff. *Copeia* 1:113-119.
- Butler, J. A. 2000. Status and distribution of the Carolina diamondback terrapin, *Malaclemys terrapin centrata*, in Duval County. Florida Fish and Wildlife Conservation Commission. Tallahassee, FL.
- Butler, J. A., C. Broadhurst, M. Green, and Z. Mullin. 2004. Nesting, nest predation, and hatchling emergence of the Carolina diamondback terrapin, *Malaclemys terrapin centrata*, in northeastern Florida. *American Midland Naturalist* 152:145-155.
- Cagle, F. R. 1939. A system for marking turtles for future identification. *Copeia* 2:170-173
- Coleman, A. T., T. Wibbels, K. Marion, T. Roberge, D. Nelson, and J. Dindo. 2014. Dispersal behavior of diamond-backed terrapin post-hatchlings. *Southeastern Naturalist* 13:572-586.
- Feinberg, J. A. and R. L. Burke. 2003. Nesting ecology and predation of diamondback terrapins, *Malaclemys terrapin*, at Gateway National Recreation Area, New York. *Journal of Herpetology* 37:517-526.
- George, R. R. 2014. Nesting ecology of the Texas diamondback terrapin (*Malaclemys terrapin littoralis*). Unpublished Master's Thesis. University of Houston—Clear Lake. Clear Lake, TX.
- Goodwin, C. C. 1994. Aspects of nesting ecology of the diamondback terrapin (*Malaclemys terrapin*) in Rhode Island. Unpublished Master's Thesis. University of Rhode Island.
- Halbrook, K. A. 2003. Population estimate of Texas diamondback terrapin (*Malaclemys terrapin littoralis*) in Nueces Estuary and assessment of nesting habitat suitability. Unpublished Master's Thesis. Texas A&M University—Corpus Christi. Corpus Christi, TX.
- Hogan, J. L. 2003. Occurrence of the diamondback terrapin (*Malaclemys terrapin littoralis*) at South Deer Island in Galveston Bay, Texas, April 2001-May 2002. US Geological Survey. Report 03-022, Austin, TX. 31 pp.
- Montevecchi, W. A. and J. Burger. 1975. Aspects of the reproductive biology of the Northern diamondback terrapin *Malaclemys terrapin terrapin*. *American Midland Naturalist* 94:166-178.
- Munscher, E. C., E. H. Kuhns, C. A. Cox, and J. A. Butler. 2012. Decreased nest mortality for the Carolina

- diamondback terrapin (*Malaclemys terrapin centrata*) following removal of raccoons (*Procyon lotor*) from a nesting beach in northeastern Florida. *Herpetological Conservation and Biology* 7:176-184.
- Palmer, W. M. and C. L. Cordes. 1988. Habitat Suitability Index Models: Diamondback Terrapin (Nesting)—Atlantic Coast. National Wetlands Research Center, Slidell, LA. 27 pp.
- Seigel, R. A. 1980. Courtship and mating behavior of the diamondback terrapin *Malaclemys terrapin tequesta*. *Journal of Herpetology* 14:420-421.
- Seigel, R. A. 1984. Parameters of two populations of diamondback terrapins (*Malaclemys terrapin*) on the Atlantic Coast of Florida. In *Vertebrate Ecology and Systematics: A Tribute to Henry S. Fitch*, ed. R. A. Seigel, I. E. Hunt, J. L. Knight, L. Malaret, and N. L. Zuchiag, pp. 77-87. Museum of Natural History, Lawrence, KA. The University of Kansas.
- TCEQ. 2012. Surface Water Quality Monitoring Procedures, Volume 1: Physical and Chemical Monitoring Methods. Texas Commission on Environmental Quality. Austin, TX.
- Texas Coastal Ocean Observation Network. 2015. www.cbi.tamucc.edu/TCOON
- United States Navy Astronomical Applications Department. 2015. aa.usno.navy.mil
- Voigt, D. R. and B. D. Earle. 1983. Avoidance of coyotes by red fox families. *Journal of Wildlife Management* 47:852-857.