Bycatch Mortality and Critical Life History Parameters of the Texas Diamondback Terrapin

Prepared in cooperation with the Texas Parks and Wildlife Department
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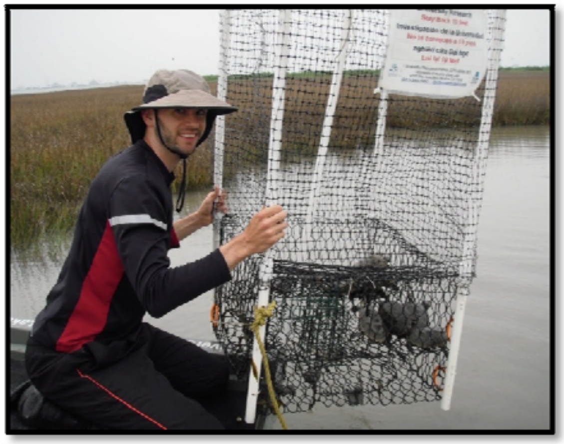
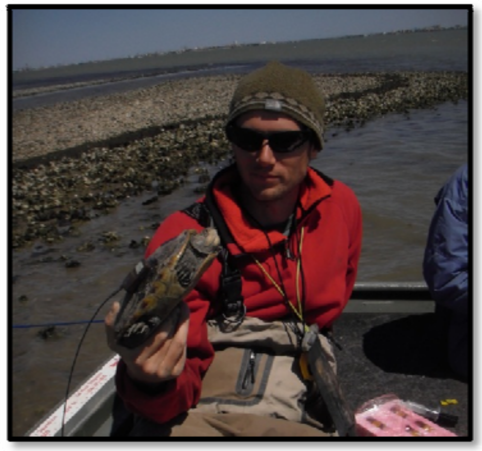
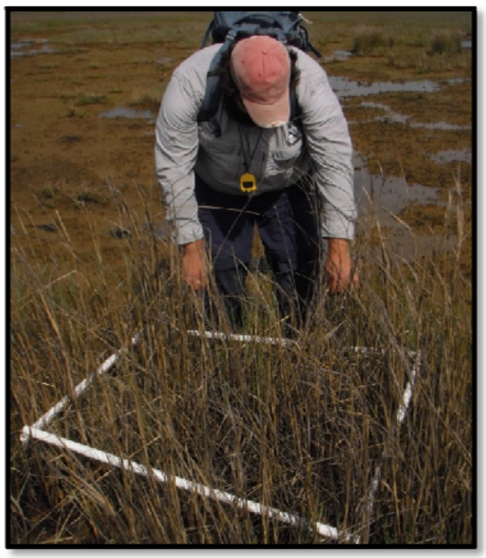


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Executive Summary

The Diamondback terrapin (*Malaclemys terrapin*) is the only species of brackish water turtle found in the United States. The Texas subspecies of diamondback terrapin (*M. terrapin littoralis*) is unique and found only from western Louisiana to Texas (Brennessel 2006). Lack of data on original diamondback terrapin numbers makes it very difficult to determine the impact of hazards on local populations and subspecies. However, recent limited data suggests that throughout the terrapins' range, their populations have seen significant declines. Currently Texas Diamondback terrapin is considered a species of concern in Texas and by the federal government. Critical data needs include estimation of life history parameters (numbers, density, mortality, fecundity, and growth), habitat needs and utilization, and quantification of mortality and management of impacts of the blue crab fishery.

Our study evaluated local populations of terrapin to estimate life history parameters and habitat needs by continuing and expanding a detailed study of the movement, habitat use, and demographics of terrapin in West Bay, Galveston, Texas. Additionally we are developing predictive habitat utilization and suitability models needed by managers to define the status of the population. During our study we observed a geo-correlation between wetland habitats and terrapin distribution on South Deer Island. This relationship was used in conjunction with a remote sensing technique that utilizes three-band infrared imagery and a Maximum Likelihood Classification method, to classify terrapin foraging habitat. Field validation tests using this HSI will be performed to determine its effectiveness and to recalibrate it as necessary.

During our study of the population status and demographics of the Deer Island terrapin we captured and/or attained past data on a total of 876 terrapin consisting of 431 unique individuals.. The sex ratios appear to be fairly stable at approximately 50%. Our telemetry and mark recapture studies have documented a range of site fidelity and inherent variability in individual movement. Time series estimates of population size at South Deer Island based on Jolly Seber mark recapture models were highly variable with relatively large confidence intervals. The average point estimate of the population size ranged between 0 and 850. The overall median estimate for the four year period between 2008 and 2013 was 258 terrapin for a 29 ha island or 10 terrapin/ha. Females on South Deer Island between the ages of 3 and 7 appear to exhibit a mean growth rate of 10 mm per year. Male terrapin appear to grow much faster at an earlier age and then experience erratic but slow rates possibly not more than 1 or 2 mm per year up to the age 8. As stated this suggests that more energy is placed in males growing faster and becoming sexually mature. In contrast the slower growing female, in terms of percentage of total maximum size, is more likely due to the higher metabolic costs associated with egg production. Based on examination of histograms of pseduocohorts we predict that males between the ages of 4 and 9 may experience an annual mortality rate of 20-22%. It was more difficult to estimate survival in females since it appears that the population was dominated by older age 8 females with few younger cohorts during the study period. Estimated annual survival rates based on the "pseudocohort" of age 8 to 12 females ranged between 80 and 85%. Based on the age distribution of the female, recruitment of younger individuals has been poor in recent years. Another explanation is that smaller younger females may more difficult to locate and capture or that they are utilizing different habitats where we are not surveying. This pattern needs to be investigated more closely since poor recruitment of younger females may eventually lead to a

population bottleneck were a large percentage of each generation is being produced by a small minority of older and larger females.

Based on the result of this study we can make several conclusions about the life history of terrapin in Texas and the relative risks of bycatch mortality associated with the commercial blue crab fishery of Texas. Based on information obtained from crabbers, past information surveys, TPWD fishery independent surveys and ongoing work by our institution and others it appears that several areas along the coast contain high numbers of terrapin. This includes the Nueces and Aransas Bay systems, upper portions of the Matagorda Bay system, the East Matagorda Bay system and interconnecting waterways and tidal streams, and the West Bay-Deer Island complex.

Although we have not investigated all of these sites thoroughly it appears they all provide several habitat features Diamondback Terrapin apparently may prefer. This includes relative isolation from predators, shallow water that prevents large numbers of boaters including crabbing boats from penetrating, a sufficient network of intertidal marsh and tidal creeks and shell hash beaches of sufficient elevation to provide suitable nesting habitat. Now each of these sites may not provide all of these features but they all seem to provide most of them. For example the East Matagorda complex is very shallow and difficult to navigate such that large expanses of it remain largely ignored by recreational and commercial fisherman. The Deer Island complex also provides a formidable barrier to most boaters via a large expanse of intertidal oyster reef with very few channel markers. In addition, it has had a long history of being predator free (at least coyotes and raccoons). The Nueces Bay area provides numerous isolated shell hash islands and relative shallow reefs for foraging by terrapin. The protection of these habitats and education of boaters and fisherman should help increase awareness for conservation of this species. Another feature that helps reduce terrapin mortality and disturbance from man is their general cryptic and cautious behavior.

Overall median and mean catch rates of blue crabs did not vary much between crab pots lacking or possessing either small or large BRDs. Although it did appear that catch rates of blue crab declined in pots with large and smaller BRDs, this was not statistically significant. However, the size of blue crabs captured in traps without BRDs yielded significantly larger crabs. The majority of crabs captured by crab pots with and without BRDs were however of legal harvestable size. A total of 73% of the crabs harvested in traps with no BRDs were above the legal harvestable length of 127 mm. In contrast, only 63% of the crabs captured in the traps with BRDs (either size) were above the size limit. This represents a 10% decline in the number legally captured crabs. In summary, it appears that both BRDs reduced the average size of captured crabs and resulted in a higher proportion of under sized crabs that cannot be legally harvested.

We found that terrapin bycatch rates in our experimental gear were low at many locations despite the historical occurrence and collection of terrapin at these sites. These sites represent areas where blue crab fishing effort has been observed but terrapin populations are low in comparison to nearby higher density areas (based on other studies – not presented). In contrast we found elevated bycatch rates in our experimental gear in areas where terrapin are abundant but observed commercial blue crab fishing effort is low. This low level of commercial blue crab fishing effort is directly due to navigational hazards associated with shallow water and numerous oyster reefs. In contrast, the areas with the highest risk to terrapin from bycatch mortality would be the deeper more accessible tidal creeks and channels crab fisherman can safely drive their vessels and where blue crab catch rates most likely higher. In these areas terrapin bycatch rates would like be much higher. During our studies of Galveston Bay we have attempted to monitor areas the fit this description and we have found consistently that they possess lower numbers of terrapin. This may be due to several factors including more accessibility to natural predators, less nesting beaches and perhaps elevated bycatch mortality.

In summary, it is difficult to determine if bycatch from the commercial blue crab fishery is a serious risk since the interaction with habitat and trends in the fishery also influence the likelihood that terrapin will be exposed to this type of risk. The highest risk from bycatch mortality would be from accessible areas (e.g. open water, deeper tidal creeks) which allows high blue crab fishing effort, that are located adjacent to suitable terrapin habitat. In addition, terrapin are often very active during the spring months during mating so this would potentially expose them to crab pots as well.

Our ongoing research has identified several habitat features that may provide suitable nesting and foraging habitat. We continue to work on development of this tool and the incorporation of these variables into predictive spatial models. . The combination of physical isolation, suitable habitat and abundant prey has led to the relatively high population levels observed at the South Deer Island complex. The lack of boat access to commercial fisherman and most recreational vessels, the apparent lack of terrestrial predators and the beneficial protection they share by inhabiting the island with federally protected colonial waterbirds has no doubt led to the establishment of this series of island populations that links South Deer Island, North Deer Island, Greens Lake and Galveston Island. We will continue to monitor and study this unique population into the future as funding allows.

The blue crab fishery supports one of the largest commercial fisheries in Texas, surpassed only by shrimp and oysters in annual landings. The overall impacts of potential BRD regulations on the Texas commercial blue crab fishermen and terrapin bycatch should be carefully considered by management professionals.

Introduction

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). Historically, diamondback terrapin have been collected for food and to supply restaurants. Commercial harvesting of diamondback terrapins began in the late 1800’s and did not wane until the economic collapse of the Great Depression. Texas diamondback terrapins were once hunted to the brink of extinction because many people thought that they were especially delicious in soup. Some believe that Prohibition helped save terrapins. Turtle soup was made with wine during the 1920s. When Prohibition laws made possessing wine illegal, turtle soup fell out of favor and thousands of trapped turtles were released into the ocean. According to the Texas Parks and Wildlife today most terrapins are killed by speeding cars or become trapped in baited blue crab traps and drown. Lack of data on original diamondback terrapin numbers make it difficult to determine the impact of harvesting on the population as a whole. However, recent limited data suggests that throughout the terrapins’ range, their populations have seen significant declines (Cecala et al. 2008).

Although terrapin numbers slowly began to increase following the Great Depression in the 1920’s, new factors now threaten their existence. Coastal development is eliminating their habitat and nesting areas. Female diamondback terrapins appear to return to the same areas to nest every year. Man-made structures such as bulkheads or fencing can prevent them from reaching their desired location. These man-made barriers can also affect water levels leading to inundation and drowning of the embryos (Hogan 2003). Many female terrapins are also killed while crossing coastal roads in an attempt to lay their eggs (Bossero and Draud). Many of the estuaries in which diamondback terrapins are found have become polluted by wastes, runoff, and pesticides (Brennessel 2006). These water bodies normally support the production of phytoplankton which feed invertebrates, worms, snails, mollusks and crustaceans. These organisms are the primary food source of the diamondback terrapin. Reductions in the prey species and the amount of suitable habitat for diamondback terrapin have been cited as major causes of their decline. Hatchlings and juveniles are also preyed upon by crows, gulls, eagles, rats and raccoons, which can substantially diminish their population size. Recently, collisions with watercraft, has been cited as a significant source of mortality and limb loss (Cecala et al. 2008).

Commercial crab traps can also account for a large number of terrapin deaths. As the terrapins enter the traps to eat the bait, they become unable to escape and soon drown (Morris et al. 2010). Certain states are beginning to notice the devastating effect that these traps can have on terrapins. By catch reduction devices (e.g. 2x6 inch or 1 ¾ x 4 ¾ inch rectangular excluder devices) have been adopted by some states. These bycatch reduction devices (BRDs) have been shown to reduce bycatch rates of the larger female terrapin while negligible affecting legal size crab retention rates (Guillory and Prejean 1998; Morris et al. 2010). (Morris et al. 2010) found that of 51 terrapin and 44 fish caught as bycatch throughout their study, all but three fish were captured in non-BRD (control) pots. Currently there are not BRD requirements on the commercial blue crab fishery in Texas.

Due to the size of the Texas blue crab fishery, bycatch may represent a significant source of mortality in terrapin populations. The blue crab (*Callinectes sapidus*) supports one of the largest commercial fisheries in Texas, surpassed only by shrimp and oysters in annual landings (Sutton and Wagner 2007). From 200 through 2004, an average of 2.3 million kg of crab worth $3.5 million, were harvested commercially from Texas coastal waters. The number of commercial crab fishermen (fishing effort) during this same time period declined from 277 licensed commercial crab fishermen in 2000 to 218 in 2005. Commercial landings have declined since 1987, which represented the height of crab landings yielding 5.3 million kg of crabs worth $4.5 million. Fishery-independent monitoring trends and relative biomass estimates have been declining in recent years (VanderKooy 2013). The fishing effort coupled with relatively high bycatch rates in areas inhabited by terrapin could represent a major source of mortality in Texas. Limited data based on recovered abandoned crab traps suggests very low bycatch rates of terrapin (Morris 2003). However, these data may be unreliable due to observer bias, loss of extremely decayed carcasses, and difficulty in identifying extensively decayed specimens.

The depletion of the diamondback terrapin populations can have detrimental consequences to the entire coastal ecosystem. These small reptiles are top-level predators, which control and sustain healthy, effective salt marsh food webs. Their diet consists of bivalves, snails, crustaceans, small fish and crabs. Therefore reductions in terrapin populations can directly influence the amount of secondary producers and consequently primary producers. The terrapin hatchlings are also a food source for many birds and native animals along the coast ((Bossero and Draud). Along with the losses from habitat degradation and predation, terrapins are at a disadvantage in terms of birth rates. A female breeds only every four years and doesn't reach sexual maturity until the age of six (Ernst and Lovich 2009).

With the numerous threats to their existence, the viability of the diamondback terrapin population throughout their range has become an increasing concern (Butler et al. 2006). Most research of the ecology of terrapin began after terrapins were harvested for the food industry. Therefore, there is little to no information available about the natural population numbers of diamondback terrapins throughout the United States prior to this period (Tucker et al. 2001). Due to their small numbers, several states now provide protection status for the diamondback terrapin ((Watters 2004); Diamondback Terrapin Working Group: http://www.dtwg.org/). 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. In Texas, diamondback terrapin can no longer be collected for personal or commercial use without a permit (http://www.tpwd.state.tx.us/).

Little information has been gathered on the numbers or health of local Texas populations. In 1984, TPWD sent out approximately 1,150 questionnaires to commercial crab trappers, fishermen, coastal fisheries biologists, and coastal game wardens to obtain information on range of terrapin along the Texas Coast (Mabie 1987). In 1997, 109 Texas diamondback terrapins were caught near Corpus Christi, Texas. During April 2001 to May 2002, one hundred and thirty five Texas diamondback terrapins were captured at South Deer Island, Galveston, Texas (Hogan 2003). Due to the small number of terrapins caught in these studies, population and range estimates were not conducted. In recent years studies on the Nueces and Aransas Bay populations of terrapin were conducted using stationary open water traps (Halbrook 2003; Koza 2006). Population estimates of 322 terrapin for the entire Nueces Bay were calculated by (Halbrook 2003). She indicated that several shell hash island may be providing suitable nesting habitat. (Koza 2006) found that terrapin were more frequently captured near river deltas in oligosaline water over shell hash substrates. In addition he proposed a HSI model based on distance to nearest shoreline, temperate, salinity. He indicated this model would still need to be tested. It appears that this was not a nesting habitat suitability model.

Problem Statement

As a species, the Diamondback Terrapin is considered apparently secure, but is uncommon throughout its range. There is however some cause for long-term concern due to declines caused by factors such as: 1) elimination or fragmentation of coastal marshes from urbanization and development, 2) concomitant changes to water quality and/or quantity, 3) mortality from crab traps and gill nets, 4) commercial exploitation, and 5) human ignorance of biological characteristics of this species. As a subspecies within Texas and nationally, the Texas Diamondback Terrapin is considered vulnerable due to a restricted range, and relatively few documented populations (<80) (TPWD 2005). Various conservation recommendations have been proposed to reduce risks to local populations of terrapin including: 1) Defining potential habitat utilizing GIS technology, 2) Determine the extent of existing populations, 3) Study the population ecology of several sites, 4) Protect sites supporting robust populations, 5) Develop cooperative efforts promoting conservation, and 6) Integrating activities with regional ecosystem conservation planning (TPWD 2005).

Study Objective

The primary study objectives were to:

1) To develop estimates of local population abundance and density of Texas Diamondback Terrapin
2) Estimate various demographic and population parameters including relative age, size, sex distributions and somatic growth, total and natural mortality and birth rates
3) To evaluate habitat preferences including physical and biological foraging and nesting attributes
4) To estimate blue crab trap bycatch mortality rates for the Texas Diamondback Terrapin.

In order to complete these objectives coast-wide historical and newly acquired fisheries dependent and independent data was also utilized to develop crude estimates of bycatch mortality risk to terrapin. Information generated from this study provides a baseline of critical life history parameters, life history requirements, and estimates of bycatch mortality of the Texas Diamondback Terrapin.

Methodology

Population Estimates, Demography, and Habitat Preferences

We attempted to provide a review of pertinent literature on what is known about Diamondback Terrapin ecology, movement and habitat utilization as it pertains to Texas populations. In addition we provide a synopsis of recent studies in Texas including our recent findings.

Our studies have focused on the Galveston Bay system and in particular the Deer Island complex in West Bay. South Deer Island has an area of 29 hectares and is characterized by frequently inundated low lying salt marsh dominated by smooth cordgrass (*Spartina alterniflora*) (Figure 1). An extensive tidal creek network is found on the interior of the entire island with outlets connecting to Galveston bay at the North and East ends, and to a large lagoon at the South end. Higher elevations are found along the perimeter of the island, as well as on a narrow, 1 hectare mound on the east side of the island. These areas are characterized by shell hash mounds and a shift in vegetation from S. alterniflora to Iva frutescens. The only documented terrapin nest in Texas was found in this elevated shell hash habitat indicating that it could provide critical nesting habitat for the Deer Island complex (Hogan 2003).

The majority of the methodology used in our current study has been documented by (Haskett 2011) and (Clarkson 2012). Our methodology utilized a combination of simple land and shallow water searches using manual searches using line transects supplemented by limited trap data and radiotelemetry. For the purposes of this study we present data from our mark recapture data generated from our manual search protocol supplemented by radio-telemetry data.

Figure 1. South Deer Island in Galveston Bay, Texas. The top pane shows location of the island in Galveston Bay and lower pane provides a close-up showing major features.

At the time of this study, over 350 terrapin were already tagged on South Deer and 120 were tagged at the nearby North Deer Island. There have been several previous instances of individual migrations between these two islands as well as a third study site on Galveston Island, indicating that the population on South Deer is not closed.

We employed several capture techniques to maximize effectiveness and minimize bias associated with any single method (Hurd et al. 1979). Our primary methods included active radio telemetry and randomized land searches. Some supplemental trapping was conducted earlier in the study. While these methods all provide data to answer the same questions, the results from each method were first treated separately because of differences in capture probability, and then combined to identify any overarching pattern and significant differences in the efficiency and information provided by different capture techniques.

For each sampling event, randomized land searches were conducted by 2-3 people for a 2-3 hour period beginning in the morning before 10:00. Randomized land searches began by randomly selecting a portion of the island as a starting position for transects. However, due to the presence of several sensitive species of nesting birds on the island, large portions of the island were restricted during their nesting season (Figure 2). This resulted in limited search areas with only one possible base camp and therefore one possible starting position for transects. From this point (Latitude: 29.274423°, Longitude: -94.910994°), the horizon was dissected into equal portions and randomly assigned to the available searchers. Once a transect was assigned to an investigator, the individual walked in a straight line toward their reference on the horizon and did not deviate from this line until they could not walk any further (i.e. when they arrived at the edge of the island or when they encountered a restricted avian nesting area). When they encountered an impasse such as this, they turned and walked a new straight line transect at a 45^o angle to the right of their previous transect. These transects crossed every habitat type on the island, including dense marsh as well as creeks and lagoons, and resulted in very little selection bias. Other areas that were surveyed intermittently included North Deer Island, Greens Lake, Galveston Island, and Bolivar Peninsula. Limited data from these sites are presented.

Once terrapin were found, the location of the captured terrapin was noted with a GPS. The time and date was recorded. Information was also gathered on whether the terrapin was captured on land, in the water, or buried in the mud. Physicochemical data collected for land captured terrapin included air temperature, vegetation and substrate type as well as the distance from the closest channel. Observations made when terrapin were captured in the water included tide stage, water depth of the water, water temperature, salinity, and turbidity. Air and water temperature and salinity were also measured at the beginning of each terrapin survey day.

Captured terrapin are examined immediately for scute notch marks and scanned with a PIT tag scanner to determine if this was a recapture. Previously tagged and marked terrapin were classified as recaptures and the recapture interval was noted (e.g. 1st recapture, 2nd, etc). Obvious wounds or injuries were noted. If terrapin had been tagged within the last 12 months no other data was collected. If however, the period since prior capture exceeded 12 months we would also collect additional morphometric data similar to terrapin captured for the first time.

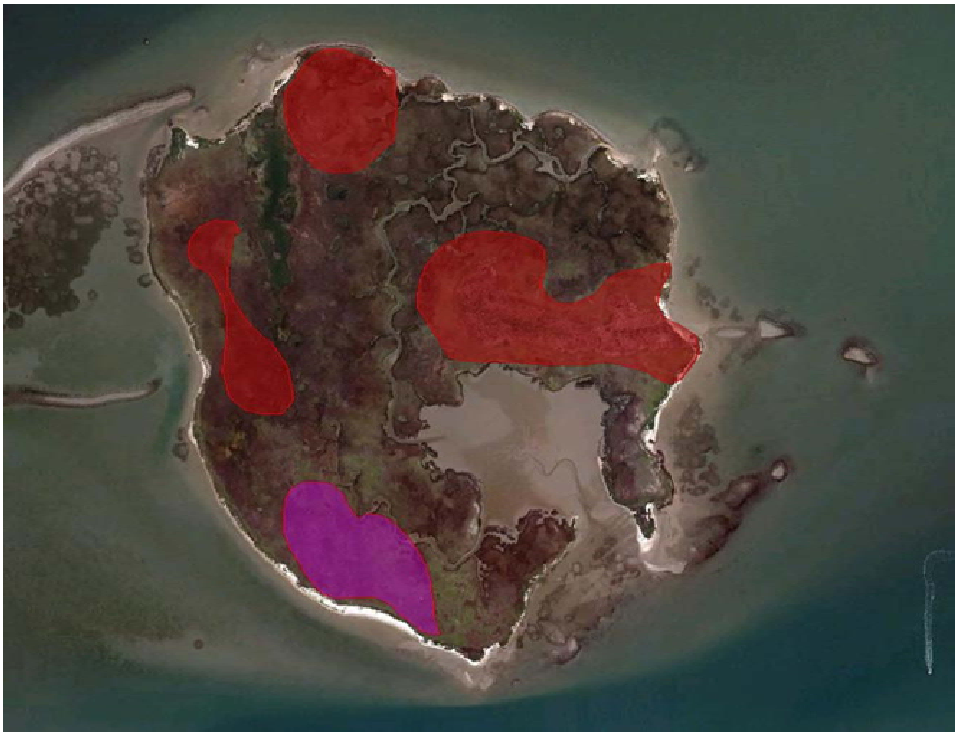

Figure 2. Restricted portions of South Deer Island during study period. Shaded areas were restricted during the months of April and September for the majority of the study period.

Each diamondback terrapin was also weighed and measured to determine weight, size and relative age distribution and growth rates 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 3). Carapace width was measured from the widest point on either side of the carapace. Depth was measured from the highest vertebral scute on the carapace down to the plastron. Body weight was measured by placing each animal in a tared mesh bag and hanging the bag from a digital scale (Figure 4). We attempted to obtain relative age by counting scute circuli. Aging of terrapin by this method is however unreliable, since the scutes of older specimens will be extremely worn and hard to age. After six to eight years, when growth rates decline, it is very difficult to distinguish annuli at the margins of the scutes (Brennessel 2006). The specific scute used to count the rings varied based on the visibility of the scute rings. Without past studies of growth rings on terrapins along the Texas Coast, it is difficult to determine if and how many growth rings are added annually. Despite this lack of past research, terrapin growth rings in this study were counted to give a rough estimation of age. Together with size, the use of growth rings aids in the estimation of relative age.

Male to female sex ratios were determined based on certain secondary sex characteristics such as body and head size, tail size and shape, cloacal opening placement, and carapace shape. Certain turtle species, including diamondback terrapins, exhibit sexual dimorphism (Stephens and Wiens 2009). Females have larger heads, greater body mass, and longer and wider plastron and carapace lengths than do males upon reaching sexual maturity (Brennessel 2006). Male terrapins have a longer, thicker tail than females, with a cloacal opening located well past the posterior edge of the carapace.

Figure 3. Measurement of body dimensions of terrapin with calipers. Large tree calipers were normally used for larger terrapin.

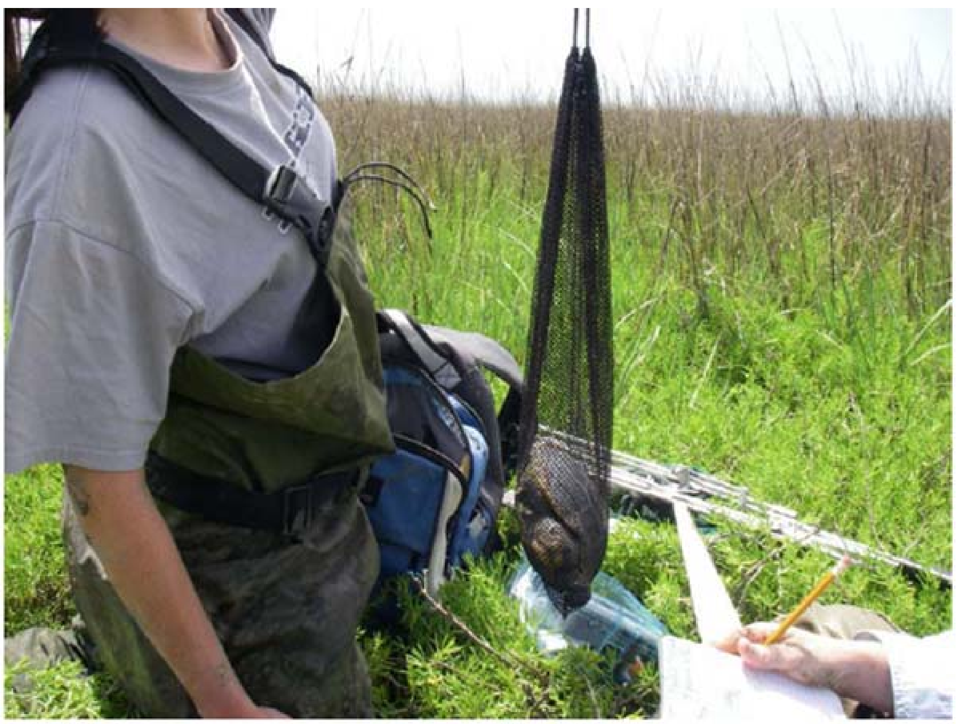

Figure 4. Determination of terrapin body weight by hanging scale.

In order to estimate the population size of terrapins inhabiting South Deer Island, a Jolly-Seber mark-recapture study design was used (Krebs 1999). In order to utilize the Jolly Seber population method, individual terrapin need to be recognized. This was done by first capturing and marking individual terrapins, releasing them, and recapturing them at a later date. Each terrapin was individually marked externally and internally tagged to distinguish it from the others. External marking consisted of marginal carapace scutes that were notched with a metal file following a system that marks each terrapin with a unique number (Cagle 1939; Ferner 2007) (Figure 5 and 6). These external notches also provide a means for quick visual identification of previously captured animals. A more permanent and reliable marking method was also used in the form of Passive Integrated Transponder (PIT) tags (Figure 7). These tiny devices have been used since the mid-1980's to successfully provide long-term identification of reptiles in scientific studies (Ferner 2007). They ranged between 10 and 14 mm in length and 2 mm in diameter. The tag consists of an electronic microchip surrounded by biocompatible glass that prevents tissue irritation. PIT tags were injected by a 12-gauge needle under the terrapin's skin near the back leg and above the plastron to provide permanent identification for each individual (Figure 8) (Gibbons and Andrews 2004). After all processing the terrapins were released at the point of captured and allowed to join the overall population for a minimum of a week prior to re-surveying the area. Terrapin movement was also calculated for recaptured terrapins. This was calculated by measuring the shortest straight-line distance between the location of original capture and the location of recapture. This provides the minimum distance the terrapins traveled between capture times.

One potential source of error associated with random land searches was differences in detection ability due to differing habitat. This might lead to a false conclusion about habitat preference because they are easier to detect in certain areas. One way to circumvent this concern is to use a less biased method such as radio-telemetry. During our study we tagged a limited number of terrapin with an ATS R2000 2.5 KHz radio tag transmitter that was affixed to the second right carapace scute with marine Epoxy (PC) (Figure 9). This location reduces the probability that the tags will alter terrapin behavior. The location also minimizes behavioral, physiological, and reproductive effects. The transmitters were placed entirely on a single front costal scute. This method has been shown to not interfere with normal activity (Boarman et al. 1998).

We used two different sizes of transmitters for males and females, weighing 12 and 24 grams, respectively. These tags were set at a pulse rate of 40 ppm and a pulse width of 22 ms. The 12 gram transmitters typically had a battery life of 182 days while the 24 gram transmitter had a battery life of approximately 843 days. Tag size, weight, and pulse rate were specified to maximize battery life while minimizing weight. The proportion of tag to animal weight was maintained at less than 5% to reduce impacts on animal movement and behavior. Studies have shown the 5% rule to be effective without impairing activity even on flying animals such as the big brown bat ((Neubaum et al. 2005). In consideration of this rule, larger terrapins were usually the only animals tagged in order to not exceed this target weight percentage.

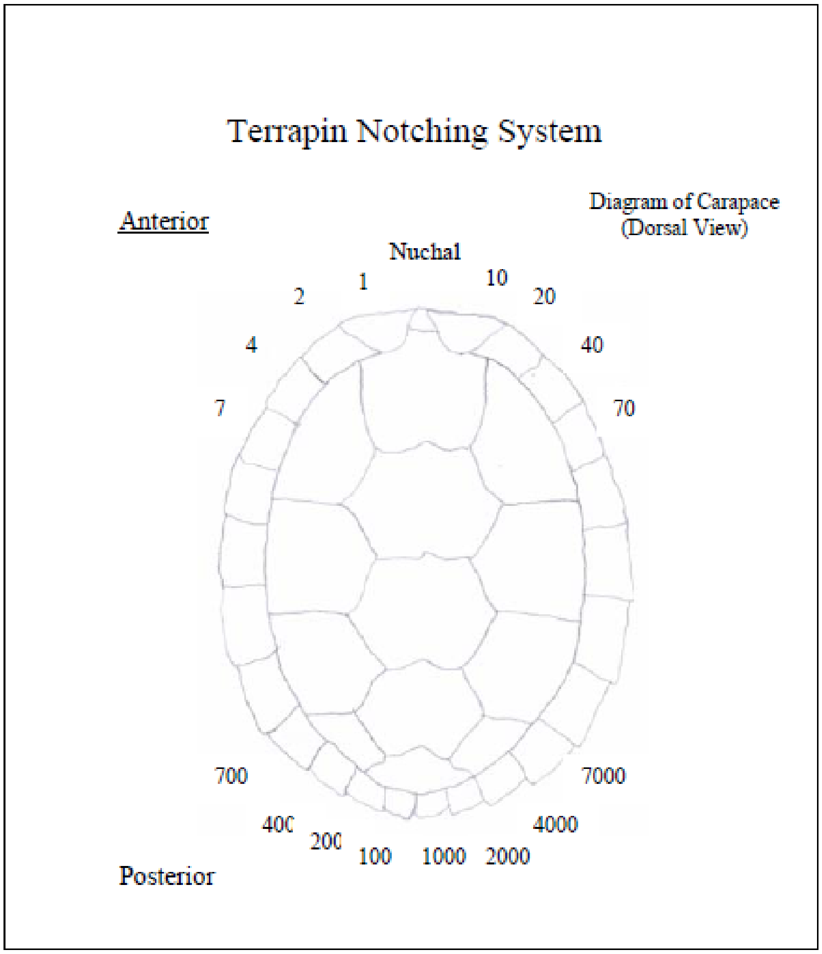

Figure 5. Modified Cagle marking system used to identify individual terrapin.

Each radio tag had its own unique frequency in order to discern an individual terrapin from the others. These individuals were tracked with ATS R2001/2100 receiver and Yagi antenna. During multiple sampling events we attempted to located and track terrapin using radiotelemetry for a period of up to 3 hours. Radiotelemetry is only effective on land and in freshwater water. The salt content of marine waters interferes with the signal, rendering ineffective. Data collected using radiotelemetry was used in this study for the purpose of estimating home ranges, short-term migration patterns, dispersal, and habitat use of diamondback terrapins in West Bay (Garton et al. 2001.).

We conducted a range test for the ATS2001/2100 receiver and found that the detection limit is variable based on depth of submersion in water as well as the tag size. In air, a female (24 gram) transmitter can be detected from over 1.07 km, but the detection limit is drastically reduced to 0.1 km and 0.07 km when submerged at 0.05 m and 0.1 m in salt water, respectively. The receiver was not able to detect the transmitter when submerged past 0.1 m. A total of sixteen terrapins had been affixed with radio tags as of July 2011 for the purposes of this study.

Figure 6. File used to notch carapace using the modified Cagle method.

Figure 7. AVID model PIT tags, injector and reader used to individually mark terrapin.

Figure 8. Injection of PIT tag into right rear leg cavity of terrapin.

Figure 9. Attachment of radio-tag on the back of a female terrapin.

Because of the high salinity at the South Deer Island site (typically 30+ psu), radio signals are severely attenuated when the transmitter is submerged in only a few inches of water. After approximately half a meter of submersion, they are nearly undetectable. Therefore, we also employed limited acoustic telemetry, with which we could detect terrapin in water but not on land. We used VEMCO VR2W stationary receivers in conjunction with VEMCO V13-1H pinger transmitters. The stationary VR2W receivers were deployed in an array around the South Deer Island 4 around the perimeter of South Deer Island and two in the interior water bodies: one in the center of the main creek and one in the center of the inner lagoon. One receiver was stationed at the mouth of the lagoon on North Deer Island (Figure 10). The transmitters had an estimated battery life of 370 days, transmitted at a frequency of 69 kHz, and used A69-1303 coding space. A total 4 terrapins were affixed with acoustic transmitters for the length of this study. We also utilized data from an intense diel behavioral study investigating short term movement and habitat selection conducted by the senior authors graduate student Ms. Emma Clarkson who used this for her thesis research (Clarkson 2012). In a very few cases larger female terrapin were double tagged with both radiotags and acoustic tags (Figure 11).

Data from our telemetry data was summarized by sex and collection method and plotted in ArcGIS. Home range was estimated using the minimum convex polygon (MCP) estimator. This was only done with terrapin which were recaptured at least 3 times. We employed a corrected MCP = MCP/ 0.257 ln (number of captures) - 0.31. This was utilized to reduce sample size effect (Barrett 1990; Butler 2002).

This mark recapture method has been successfully used in the past for determining population levels and developing management plans for other species of turtles (Mitro 2003). We utilized the “Simply Tagging” software package produced by PISCES to assist us in our analysis(Conservation 2009). Statistical data analysis of terrapin occurrence versus habitat variables and physicochemical factors was also conducted were warranted to determine apparent habitat associations.

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

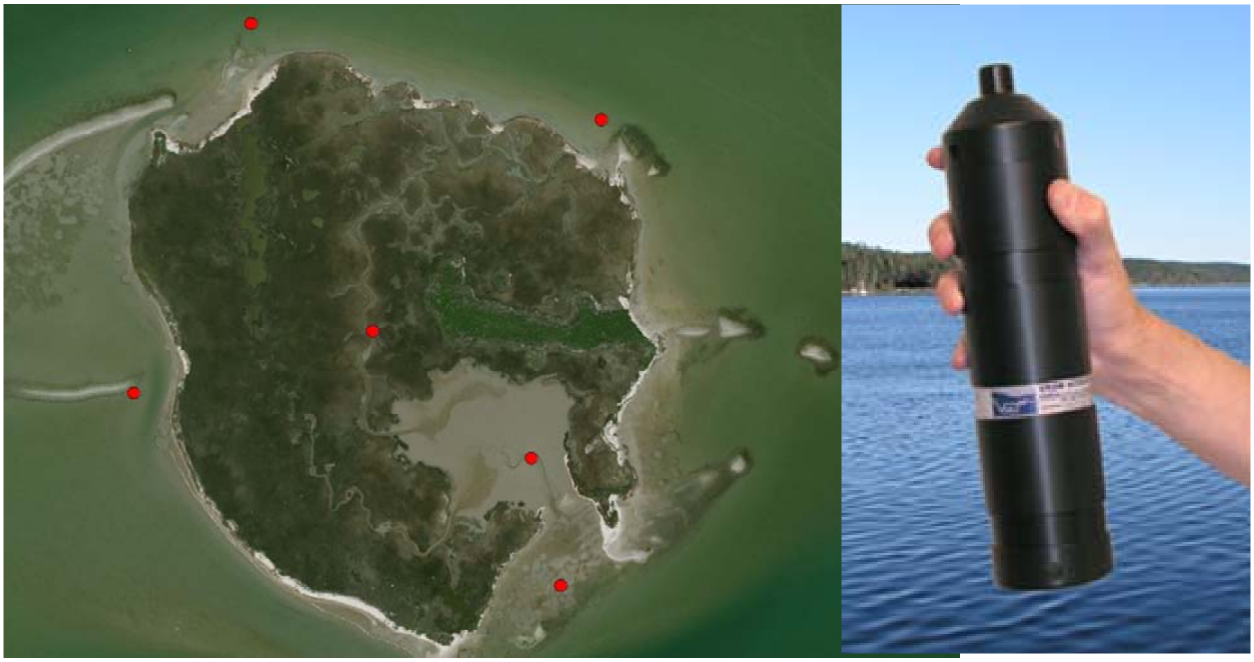

Figure 10. Location of stationary acoustic receivers deployed around the South Deer Island and photo of the VR2W acoustic receiver attached to a terrapin.

Figure 11. One female diamondback terrapin affixed with a V13 acoustic transmitter tag (left) and another larger female double tagged with an acoustic tag and ATSR2000 radio transmitter tag

With the Jolly-Seber method, the proportion of animals marked was estimated by the following formula:

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

a_t = proportion of marked diamondback terrapin

m_t = Number of marked diamondback terrapin caught in sample t

u_t = Number of unmarked diamondback terrapin caught in sample t

n_t = Total number of animals caught in sample t $= m_t + u_t$

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

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

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

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

s_t = Total number of animals released after sample t = (n_t – accidental deaths or removals)

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

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

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

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

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

To measure habitat selection, we deployed 0.5-m2 quadrats around the capture location of each terrapin to characterize vegetation cover and species abundance. We recorded the percent coverage of each individual vegetation species, as well total percent vegetative cover. Due to variation in vegetation height in each quadrat, vegetation height was classified in an ordinal ranking scale of 20 cm, increasing from zero to greater than a meter (0-20, 21-40, 41-50…91-100 cm).

Soil and water temperature for the Deer Islands are logged hourly using HOBOware ® tidbits deployed 6 cm under the shell hash on the north beach on South Deer Island and in the main tidal creek of South Deer Island, respectively. At the time of each capture, instantaneous air and water temperature were also recorded using a Kestrel ® and a thermometer, respectively. At each site, daily salinity, water temperature, and turbidity were recorded using a refractometers, thermometer, and Secchi tube, respectively.

We used previous data explaining terrapin biology and requirements to construct a rating system of our own reconnaissance sites. The rating system was based off of the following parameters: Presence of Spartina alterniflora as dominant macrophyte, presence of most common prey (mainly Littorina littorea and small crabs), presence of small tidal creeks throughout marsh and proximity to water bodies, extent of tidal inundation (elevation of marsh), “softness” of mud for burrowing (estivation and hibernation), and thickness of vegetation and vegetation type. Based on these parameters, we assigned a standardized rank at each site that explained the potential of the site for terrapin habitat suitability. Using this ranking system, we were able to identify potential terrapin habitats for future surveying

Table 1. Rating scale used to assess the suitability of new sites for potential terrapin populations.

Rating	Explanation
0	A terrapin has been captured and processed, and a population is present at the site.
1	A terrapin has been observed but not captured (i.e., a terrapin was observed swimming in a creek but we were unable to capture it), or positive presence of terrapin has been observed (such as tracks, dead terrapin, etc).
2	Habitat is "very" good and the site needs to be revisited with highest priority. "Very good" is indicated by high prey availibity, an extensive network of available stream and pond habitat, vegetation that is not too thick for movement but is thick enough to provide cover from predators, and availabe burrowing and nesting habitat.
3	Habitat is "intermediate", and should be revisited with secondary priority. "Intermediate" indicates that one of the above parameters listed in rating 3 is not met.
4	Habitat is "poor" and there is no priority for revisitation. "Poor" means that most or all of the parameters listed in rating 3 are not met.

Refinement and Development of Habitat Suitability Index

Prior to evaluating potential habitat suitability models we first mapped the known occurrences of terrapin along the Texas coast based on past studies and reported information. Utilizing data from our study and reviewed literature we will then determine whether sufficient data is available to evaluate and/or modify the existing *Habitat Suitability Index Models for Diamondback Terrapin (Nesting) – Atlantic Coast* so that it could be applied to the Texas subspecies of terrapin(Palmer and Cordes 1988). The existing nesting model is dependent on several variables including V_1 = % canopy cover of shrubs, 2) V_2 = % canopy cover of grasses and 3) V_3 = mean substrate slope. The total available nesting habitat (U) is a function of all three and assumes the form of: HIS = (SI V_1 + SI V_2 + SI V_3)/3 (Figure 12). The model makes several assumptions including that assumption that terrapin nest on sandy beaches. Based on our study and other literature we will make proposed changes to this model that may lead to development of a Texas HSI model. This model could then be used to assess, quantify, and rank habitat in regards to potential terrapin nesting and perhaps other critical life history functions.

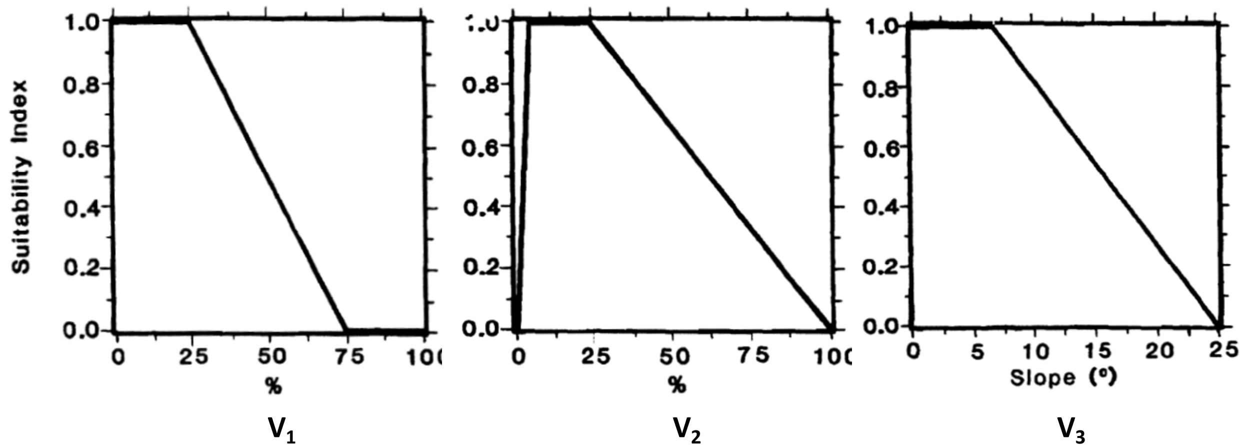

Figure 12. Habitat suitability graphs for % canopy cover as shrubs (V1), % canopy cover of grasses (V2), and mean substrate slope (V2). From: (Palmer and Cordes 1988)

Blue Crab Bycatch Study

The blue crab bycatch study consisted of multiple interrelated components including:

1. Review of literature on effects of the blue crab fishery on terrapin mortality
2. Review of literature on BRD effectiveness and blue crab catch rates
3. Review of the TPWD derelict blue crab trap database
4. Evaluation of blue crab fishery catch statistics and TPWD fishery independent surveys
5. A field study which tested two common sizes of BRD
6. A survey of blue crab fisherman fishing behavior
7. Ride along observer program

These study components were focused on attempting to quantify the level of commercial blue crab fishing effort in Texas, the influence of BRDs, and how these factors interact with the biology of terrapin and the resulting risk to terrapin population viability. Information from these various components along with information on the relative distribution of terrapin can serve as a baseline for assessing risks to terrapin populations Texas from the commercial blue crab fishery.

Review of Literature on Effects of the Blue Crab Fishery on Terrapin Mortality

We conducted a thorough review of pertinent literature on the effects of the blue crab fishery on terrapin mortality. Specific resources that were reviewed include the Diamondback Terrapin Working Group (DTWG) web site (http://www.dtwg.org/), Google Scholar, academic search engines, the Gulf States Marine Fisheries Commission (GSMFC) and Atlantic States Marine Fisheries Commission (ASMFC).

Review of Literature on BRD effectiveness and Blue Crab Catch Rates

We also conducted a similar review of pertinent literature on the effectiveness of BRD's and effects on blue crab catch rates in the commercial fishery.

Review of the TPWD Derelict Blue Crab Trap Database

During February of each year beginning in 2002, the TPWD has sponsored a volunteer derelict trap pickup across the Texas coast. Data is collected on the presence of bycatch including terrapins. This database is maintained by Art Morriss at TPWD and was provided to assist us in determining the rate of terrapin bycatch. Unfortunately this data is of limited use since derelict traps are picked up during the winter when terrapin are usually inactive. Any carcasses are likely older decomposed remains. In addition to data obtained from the TPWD database we included any narrative information provided by participating groups.

Evaluation of blue crab fishery catch statistics

We attempted to quantify spatial and temporal distribution of commercial crabbing effort within the coastal waters of Texas using historical data. Unfortunately long-term data on daily crabbing effort (e.g. # traps, #trap-hours) by licensee or boat has not been collected by TPWD or any other organization by geographic area. Specific data sources that were provided included trip ticket data, annual landings by bay system, and creel (intercept) survey data. We will attempt to utilize this information to construct relative measures of effort.

BRD Evaluation Field Study

Multiple sites were selected within the Galveston Bay system to evaluate the potential effect of the BRDs on terrapin and other species bycatch, and blue crab catch and size distribution. These included Greens Lake, South Deer Island, Bolivar Peninsula (2 sites), and Trinity Bay (Figure 13). The locations were selected to reflect a range of salinity, relative density of terrapin density based on past literature, and potential risk from the blue crab fishery based on visual observation of and accessibility to blue crab fishing vessels.

Greens Lake is a small tributary bay located in the upper portion of West Bay (Figure 14). This site is characterized by having relatively shallow depths (< 1.5 m) and being surrounded by saltmarshes dominated by extensive stands of saltmarsh cordgrass, *Spartina alterniflora*. Greens Lake is connected to several large tidal creeks along its northern shoreline. Numerous commercial blue crab pots have been observed in this area and we have captured terrapin in this area in the past. The Intercoastal Canal (ICWW) is located immediately to the southeast of this waterbody. Numerous spoil islands consisting of sand, silt and clay and oyster shell are located adjacent to Greens Lake in West Bay and the ICWW. This site is located approximately 7.8 km northwest of the Deer Island complex where high numbers of terrapin have been documented (Hogan 2003) and (Haskett 2011). Based on past anecdotal observations this site has exhibited a moderate levels of commercial blue crab fishing since the early 2008.

South Deer Island is a 29 hectare low elevation (< 0.61 m) island in West Bay (Figure 15). It is characterized by frequently inundated low lying salt marsh dominated by smooth cordgrass (*Spartina alterniflora*) and *Salicornia* stands. An extensive tidal creek network is found on the interior of the entire island with outlets connecting to Galveston bay at the North and East ends, and to a large lagoon at the South end. Higher elevations are found along the perimeter of the island, as well as on a narrow, one hectare mound on the east side of the island. These areas are characterized by shell hash mounds and a shift in vegetation from *S. alterniflora* to marsh elder, (*Iva frutescens*). The only documented terrapin nest in Texas was found in this elevated shell hash beach habitat, indicating that it could provide critical nesting site for the Deer Island complex (Hogan 2003). South Deer Island also provides nesting habitat to large numbers of colonial waterfowl during the spring and summer. The area around South Deer Island and in between this island and North Deer Island consists of extensive shallow subtidal and intertidal oyster reefs. Navigation through this area can be therefore hazardous. Very little commercial blue crabbing effort has been observed at this site. High numbers of terrapin have been previously documented on this island (Haskett 2011).

The third site was located in upper Trinity Bay (Figure 16). This site was located in the open bay near the Trinity River delta. Water depth in this area averages 5-7ft. The bottom consists of soft mud. The salinity in this area is usually the lowest within the Galveston Bay system (Lester et al. 2002). Extensive commercial blue crab fishing has been observed within Trinity Bay and the lower Trinity River in the past. Diamondback terrapin have never been reported from this portion of Galveston Bay.

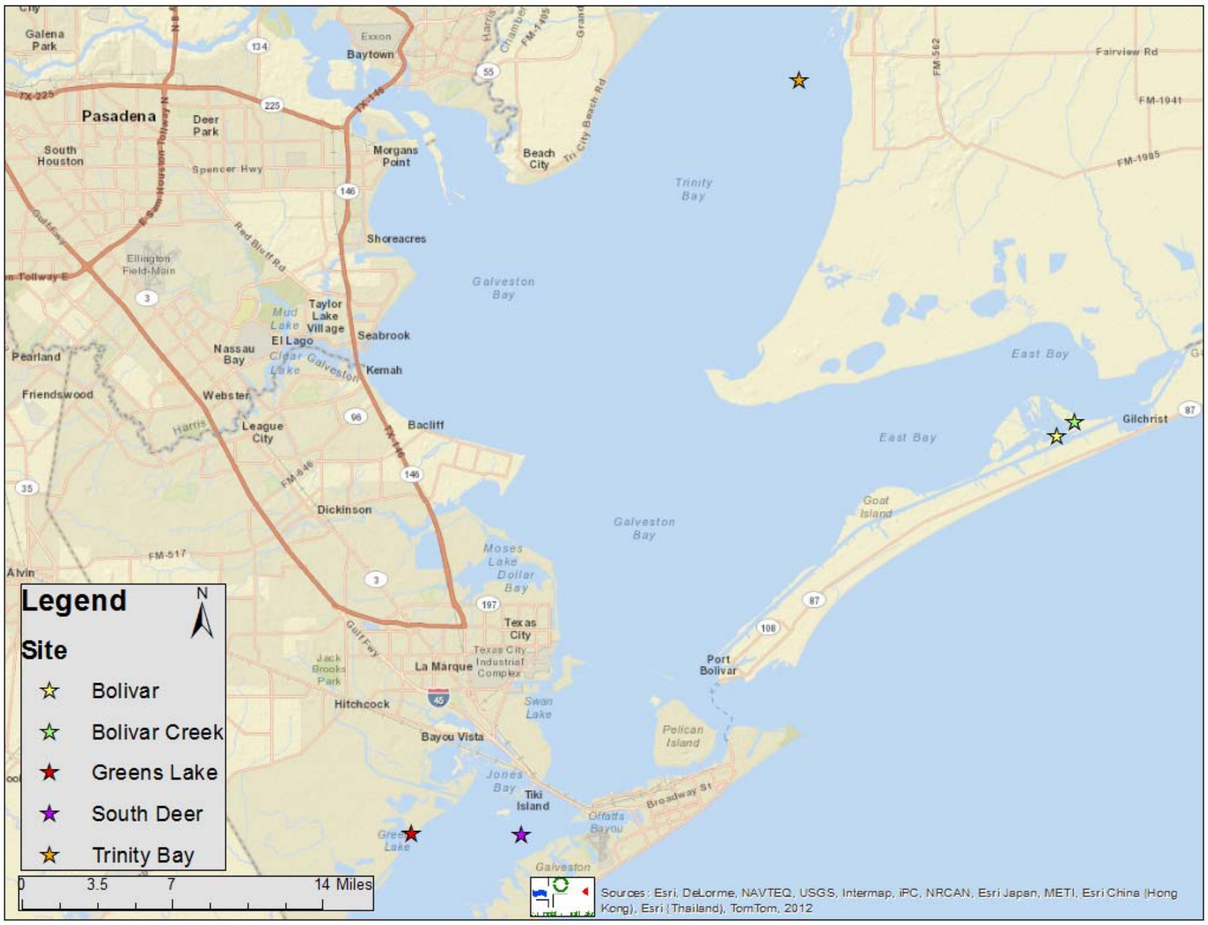

Figure 13. Location of sites in the Galveston Bay system where bycatch reduction devices (BRDs) were tested.

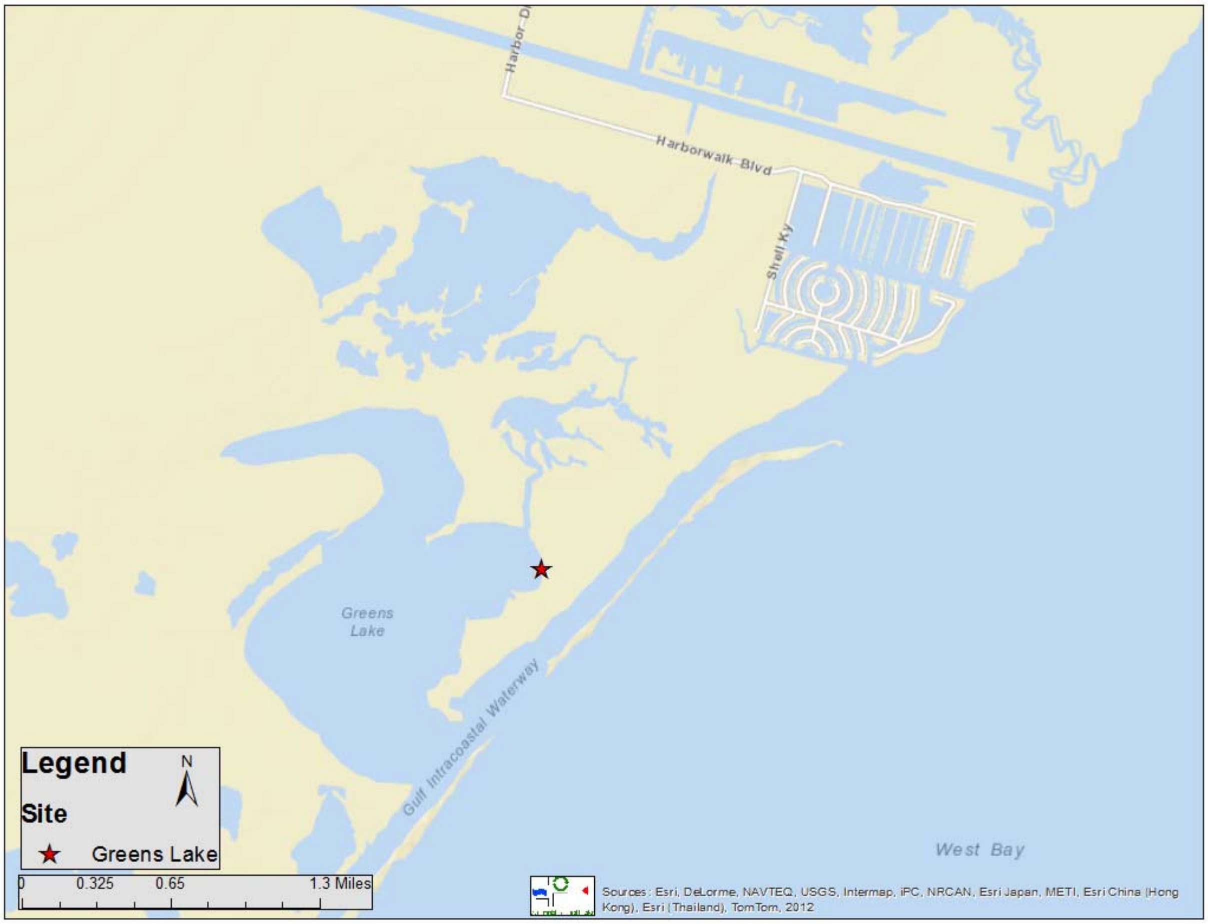

Figure 14. Location of Greens Lake site in the Galveston Bay system where bycatch reduction devices (BRDs) were tested.

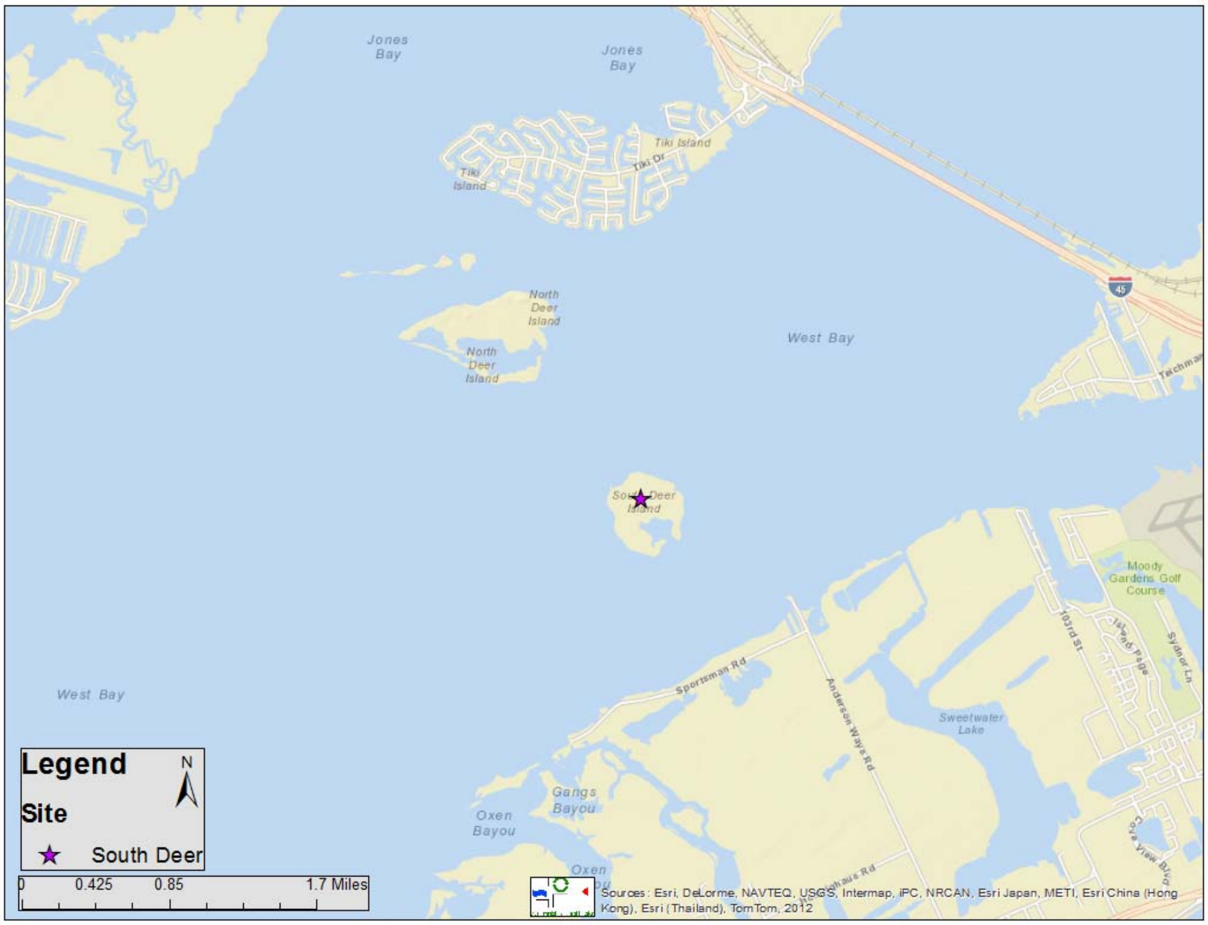

Figure 15. Location of South Deer Island site in the Galveston Bay system where bycatch reduction devices (BRDs) were tested.

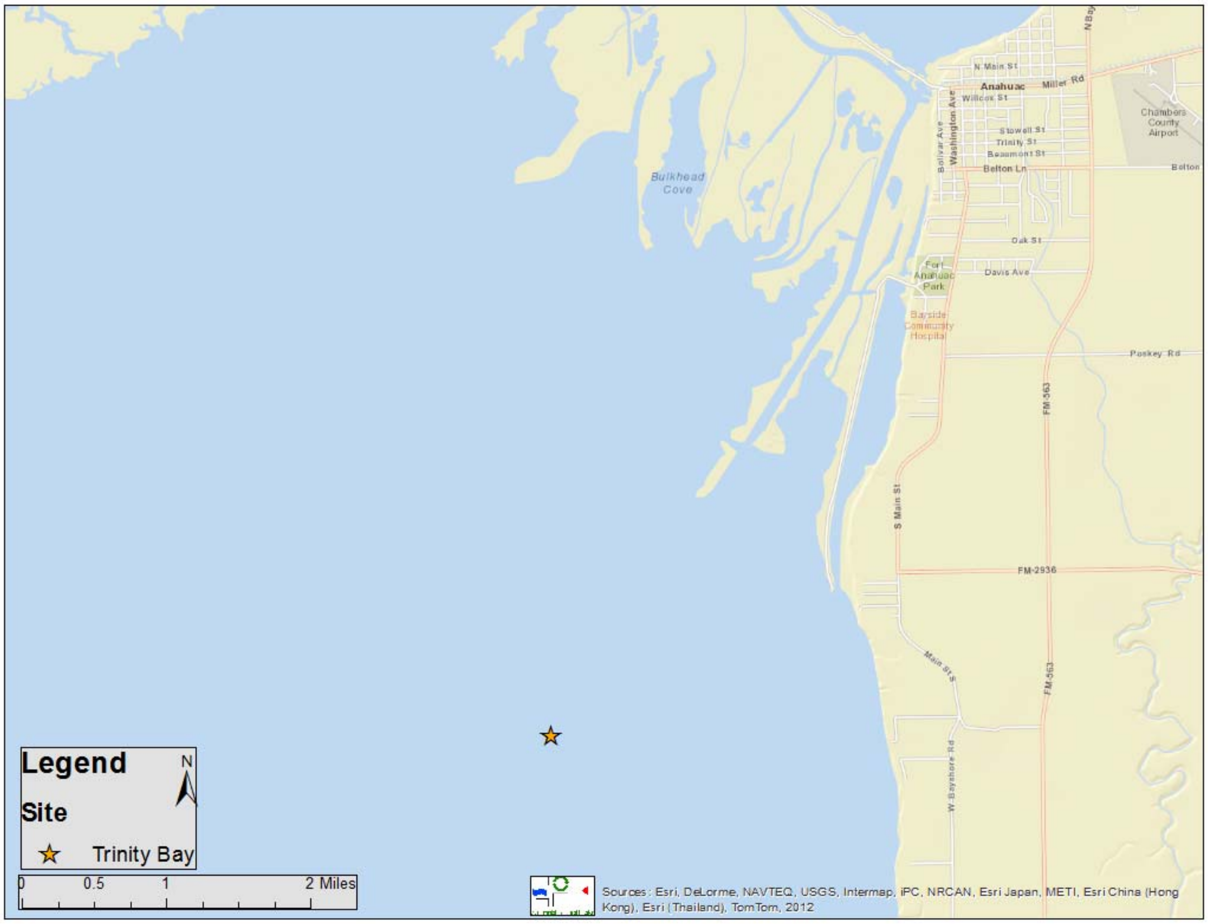

Figure 16. Location of the Trinity Bay site in the Galveston Bay system where bycatch reduction devices (BRDs) were tested.

The final two sites were located on Bolivar Peninsula (Figure 17). These sites have been monitored infrequently for terrapin presence and/or crabbing activity by the USFWS and EIH. Commercial blue crab traps have been observed both at the open bay and tidal creek sites in the past. Terrapin have also been sighted and observed in the vicinity of both of these locations by both USFWS and EIH staff. The area is characterized by having extensive stands of saltmarsh cordgrass and relatively muddy bottoms. Depths in this area varied between 0.5 to 1 meters.

A total of 36 modified 4 opening commercial crab pots were deployed at each site for a total 5 days and checked daily for 4 days. All pots, with the exception of those deployed at the Trinity Bay were modified with a chimney to allow captured terrapin access to air until the trap was checked (Figure 18 and 19). At each site we utilized three treatment groups consisting of 12 control traps, 12 pots equipped with small BRDs (1 ¾ x 4 ¾ inch), 12 pots with large BRDs (2 x 6 inch)(Figure 20). The traps were deployed in an array spaced 20m apart (Figure 21 - 25). We surveyed each open bay site with the exception of Trinity Bay four times during the blue crab fishing season in 2012 and 2013. The pots were deployed for a total of four days. During deployment, the pots were monitored daily. Pots were baited with mullet or menhaden, and re-baited daily (Figure 26 and 27). Any terrapin that were captured were marked using carapace notching and PIT tags. Subsequent captures were not counted as a new capture. The length, width, and depth of the carapace were measured. Captured terrapin were weighed and the sex determined and recorded. Counts of legal and under-sized blue crab were tallied. Crabs of legal size (127 mm) were removed from the study area while sublegal crabs were released at the site of capture. Species composition of other bycatch was also compiled.

A survey of blue crab fisherman

To gain information on encounter rates by commercial blue fisherman, we submitted a mail questionnaire and follow-up phone interview survey of licensed commercial fisherman. An example of the letter is provided in (Appendix 1). We recognize that this data may be biased especially if commercial crabbers feel that the information might be used for future regulation. However, based on preliminary examination of the data and approach that we used to assess the data we believe the information is useful. For data analysis purposes we considered a true encounter (i.e. past record of capture of terrapin in traps) to be a true occurrence. However, we did not interpret a "no" response or negative response as denoting no capture of terrapin. Rather these responses were interpreted as "no evidence of bycatch" and not as "no bycatch".

Ride along observer program

We attempted to contact individual fisherman to gain access and ride along on with them during deployment or checking of traps and gain a better understanding of their standard practices and terrapin bycatch issues. We specifically targeted areas where terrapin have been documented in the past. Almost all refused with the exception of a few individuals. From this pool we were only able to find one commercial crab fisherman who would allow us to ride with them during their operations, who also met our criteria of fishing in areas with previously documented populations of terrapin.

Figure 17. Location of the Bolivar and Bolivar Creek sites in the Galveston Bay system where bycatch reduction devices (BRDs) were tested.

Figure 18. Experimental crab pot with escape chimney used to test various BRD devices at all sites except the Trinity site. Note orange BRD devices installed on this trap.

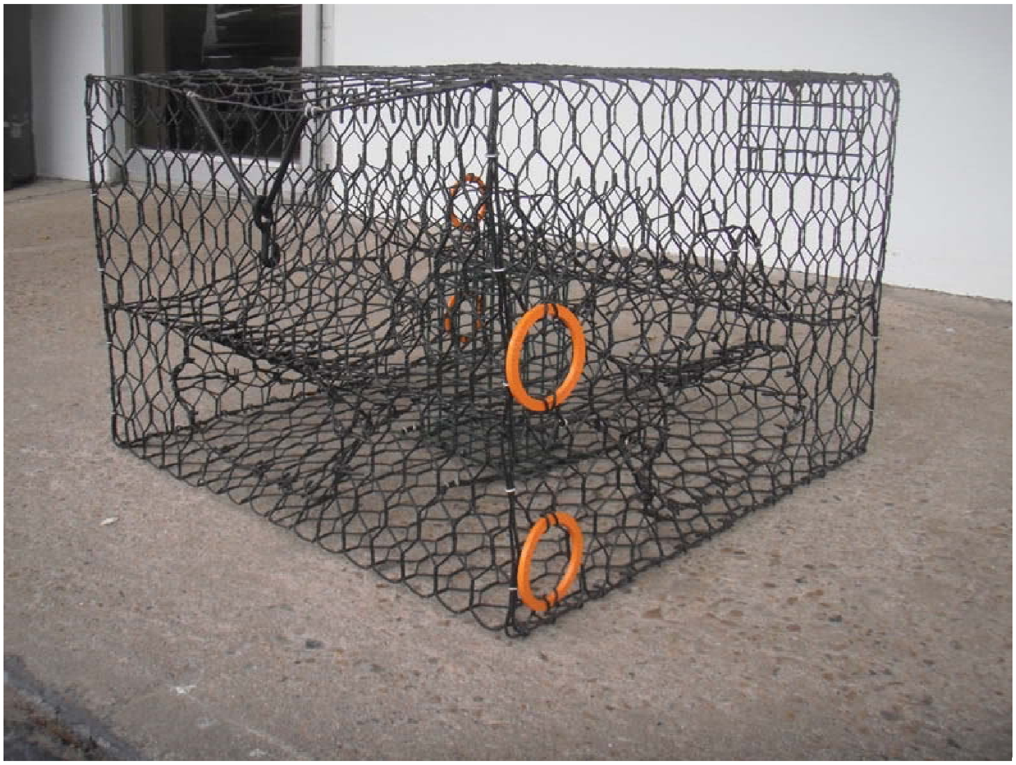

Figure 19. Unmodified crab pot used at the Trinity Bay site.

Figure 20. Comparison of large (left) and small (right) BRDs evaluated during the study.

Figure 21. Typical crab pot array used at the Greens Lake site. Note the rows were rotated between sampling events.

Figure 22. Crab pot array used at the Trinity Bay site.

Figure 23. Typical crab pot array used at the Bolivar open bay site.

Figure 24. Typical crab pot array used at the Bolivar creek site.

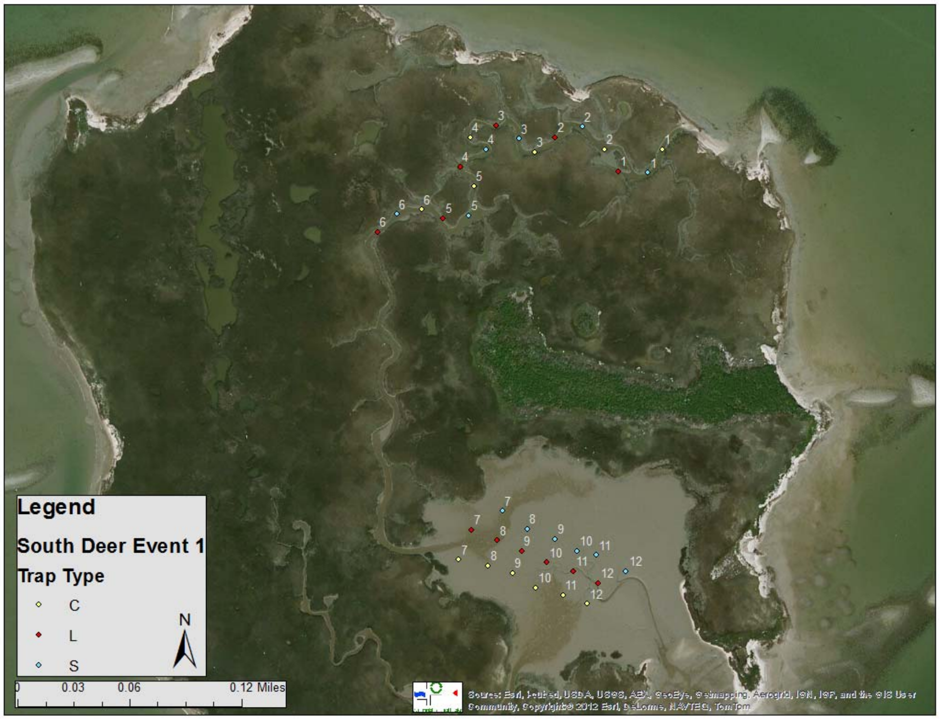

Figure 25. Typical crab pot array used at the South Deer Island site.

Figure 26. Deployment of experimental crab pots.

Figure 27. Example of experimental crab pots deployed at various open bay and tidal creek sites during the study period.

Results

Movement and Habitat Utilization Study

Literature Review

The historical occurrence of terrapin in Texas has been documented from Sabine Lake to Corpus Christi Bay Texas (Brennessel 2006; Ernst and Lovich 2009). However, known populations occur in Nueces Bay and there are records from Baffin Bay (Halbrook 2003). We recently reviewed the historical occurrence of terrapin in Texas. Using reported sightings from over 150 years, from over 38 sites we plotted the distribution of terrapin in Texas (Figure 28) (Wilson 2009). Our review suggests that terrapin may also occur in the upper Laguna Madre near Baffin Bay based on one sighting.

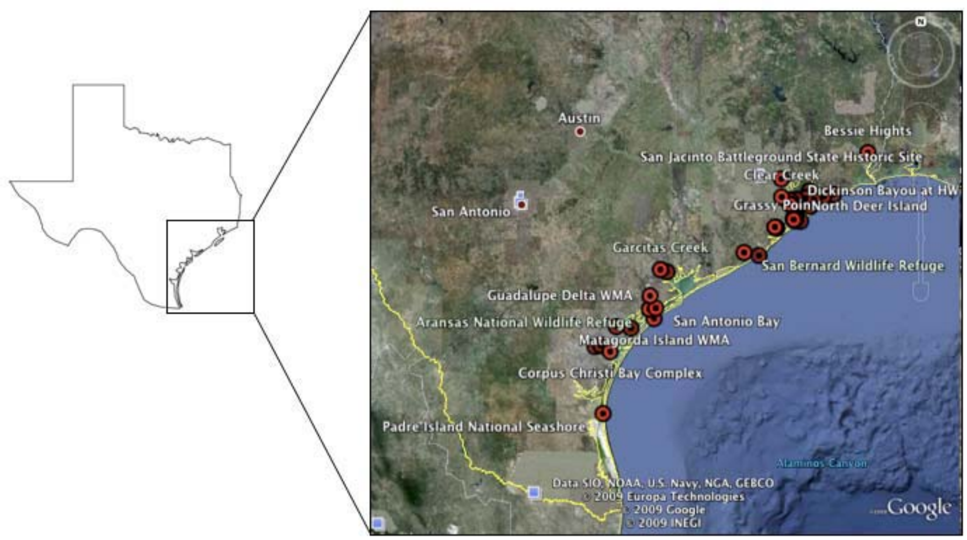

Figure 28. Location data from terrapin sightings over a 320-mile range along the Texas coast (Wilson 2009).

Terrapin habitat selection is largely influenced by sexual dimorphism and diet. The considerable large difference in gape size between males and females may promote gender-based resource partitioning (Tucker et al. 2001). In a South Carolina study, the females' large gape size facilitated a diet of large *Littorina littorea* (or periwinkle snail), as well as crabs and scavenged fish. In contrast, the smaller gape size of males restricted them to small periwinkle. Because larger periwinkle snails inhabited less dense vegetation at higher elevations further from creeks, it was more common to find females foraging in these areas. High tide and marsh flooding enabled easy access into the marsh above the creeks and therefore increased foraging opportunities. Males were constricted to foraging on the small periwinkle snails that inhabit the thick, tall vegetation adjacent to creeks. However, these trends have only been observed along the Atlantic coast where tidal range is greater, and no research has been done in Texas on tidal influence on prey availability and habitat selection.

Sexual size dimorphism has also been found to be strongly correlated with habitat use. Larger females have been found to swim further into open water, and distance from shore is positively correlated with plastron length (Roosenburg et al. 1999). In the Chesapeake Bay, larger clams are found further from shore, and only larger terrapin may possess sufficient crushing strength associated with larger jaw size to feed on these clams. They also found a higher abundance of female terrapin in the upper reaches of the marsh and male terrapin along the edges of the marsh and channels, which supports gape size limitation hypothesis (Tucker et al. 2001).

While terrapin utilize various habitats over the course of their life, including tidal creeks and salt marshes, nesting habitat is regarded as critical for the viability of local populations. Loss of nesting habitat can cause extirpation of local populations (Brennessel 2006). Terrapin exhibit environmental sex determination (ESD) that is heavily influenced by temperature. The maintenance of equivalent ratios of male and female terrapin is essential for maintaining population viability (Mills 2007). A constant incubation temperature of 28.5^{o}C to 29.5^{o} C is required to produce clutches with males and females, while temperatures outside this range produce mono-sex clutches (Roosenburg and Place 1995). Maintaining appropriate sex ratios may be difficult for terrapins due to the large daily variation in the temperature of Diamondback terrapin nests as compared to sea turtle nests (2-12^{o} variation)(Burger 1976b). Female terrapins therefore need to have a wide variety of nesting microhabitat choice in order for sex ratios to be balanced within a population (Roosenburg and Place 1995). Consequently, obtaining an equal sex ratio is very dependent on nesting site selection. Terrapin nesting habitat is also more variable compared to sea turtles, and includes dike roads, sand dunes, and shell hash beaches (Roosenburg 1994). Only one terrapin nest, which occurred on South Deer Island, has been documented in Texas, and so characteristics of ideal nesting habitat is largely unknown, but nesting is assumed to occur in high elevated shell hash (Hogan 2003). More recently we have also observed signs of nesting activity (nest scrapes) in shell hash mounds near the Moses Lake and Dickinson Bayou area.

Very little is known about the early life history of juvenile terrapin ((Gibbons et al. 2001). Juveniles and hatchlings appear to be absent from habitats where adults are found, suggesting a difference in hatchling habitat preference. This different habitat has been largely unknown until recently, although released hatchlings have shown a preference for shore vegetation and tidal wrack rather than water (Burger 1976a). Recent studies have found hatchlings in under *Spartina patens* and *Distichlis spicata* in the intertidal zone of the upper marsh ((Draud et al. 2004). The hatchlings appear to move toward higher elevated upland marsh in the fall and toward water, away from upland habitats, in the spring (Muldoon 2010). High nocturnal predation rates on hatchling Diamondback terrapin by the Norway rat has been documented in New York estuaries (Draud et al. 2004). Predation by raccoons, Norway rats, ants, and birds has been documented by (Muldoon 2010).

As temperature decreases in November through January, terrapin must select locations to brumate, a form of reptilian hibernation (Brennessel 2006). This involves reduction in metabolism, cessation of foraging, and burrowing into the sediment of marshes and tidal creeks. During brumation, terrapin have been found in the bottom of deep creeks and in the side of creek banks. Burrows can either be singular or in groups (Yearicks et al. 1981). During a 1997-2000 radiotelemetry study in a Florida salt marsh, a radio-tagged female was found burrowed in 3-5 cm of mud in lower elevations near creeks that flooded at high tide. During November through January, her burrowing location varied suggesting limited movement. However, from January through February, she remained burrowed in one location {Butler, 2002 #969.

In Texas, we have found active (walking and swimming) terrapins year round, although the majority of terrapin burrow in late November through late February and apparently enter a state of brumation {Haskett, 2011 #948} and (Clarkson 2012). Burrowing sites vary in vegetation cover and location, and includes terrapins burrowed in creeks, creek banks, and terrestrial marshes with up to 100% vegetation cover a half a meter or more. However, in one case, a single active female terrapin swam a distance of approximately 2.3 km between sites (from South Deer to North Deer) in February, while water temperatures averaged 18^{o} C.

Current Study

Results of the current data 2009 to 2013 are presented. During the study period, we exerted over 200 hours of effort surveying new sites beyond the Deer Island Complex, Green's Lake, and Sportsman's Road marshes (Figure 29). The figure summarizes our search effort at most of these new sites, as well as providing a site ranking for each location. The sites displayed on the map were color coded based on habitat ratings. The colors ranged from green (better sites, ratings for 0-2) to red (poor habitat, ratings from 3-4). The blue icons represent "established" sites. Habitat features that resulted in high scores included presence of shell hash beaches, wetlands, relative isolation (e.g. islands) and tidal creeks. Low rankings result from developed shorelines, lack of wetlands and or other disturbance. Sites with ratings of 0-2 may be revisited in the future since they appear to have habitat features that would support terrapin. Based on the results of efforts over a period of 5 years (2008 to 2013) to capture terrapin on land and on open water, the only areas were we have collected terrapin versus were we have searched are depicted in Figure 30 and 31.

Our evaluation of recent terrapin demographic data collected during the study period suggests the sex ratio of adults is 1:1 at South Deer Island, the Galveston Island (Sportsmen Road) and North Deer Island area (Figure 32). This suggests that sex biased mortality or survival is not occurring in adult terrapin. Of the 135 individual terrapins captured from July 2011-October 2012, 66 were females and 70 were males. This slightly male-biased sex ratio was present at every site. However, females were recaptured more often than males (Table 2), suggesting that males may potentially migrate away from their capture site while females may show higher site fidelity.

Table 3 shows the average size and weights of female and male terrapins caught between July 2011 and October 2012. In this study period, 29 individual terrapins were found dead, 20 of which had previously been captured and tagged.

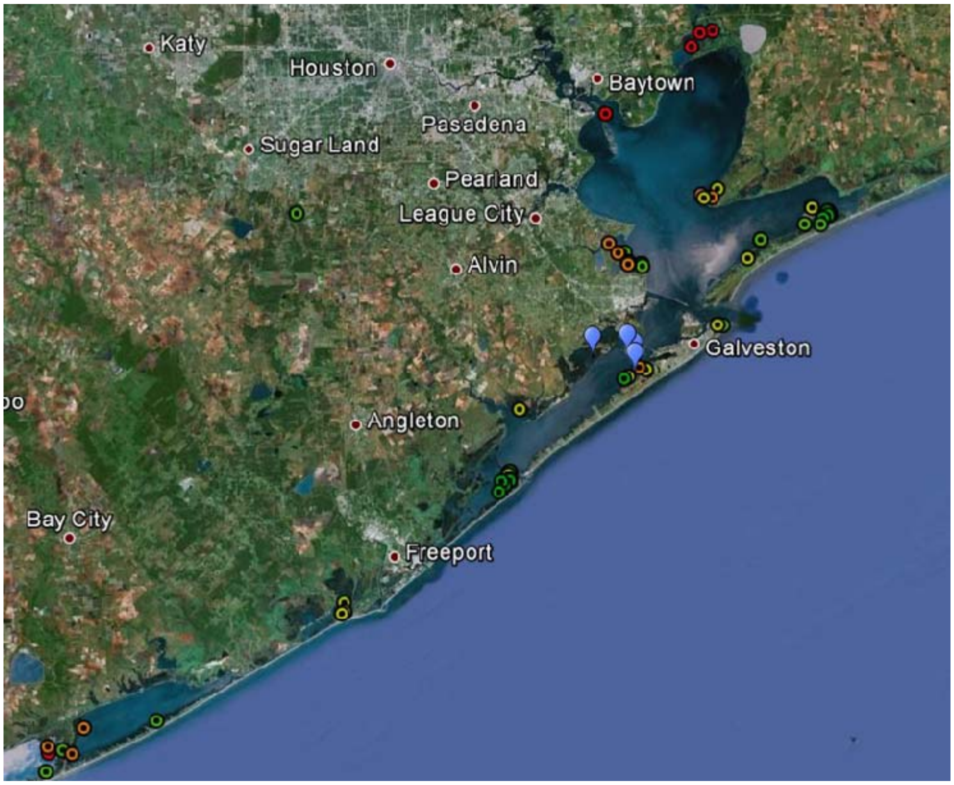

Figure 29. Summary map showing the majority of sites that were surveyed for Diamondback terrapin during the study period. Sites were ranked by habitat quality and color coded with a rank: "better quality" sites (Rank 0-2) are represented by greens and yellows and "poorer" quality sites (Ranks 3-4) are represented by orange and reds.

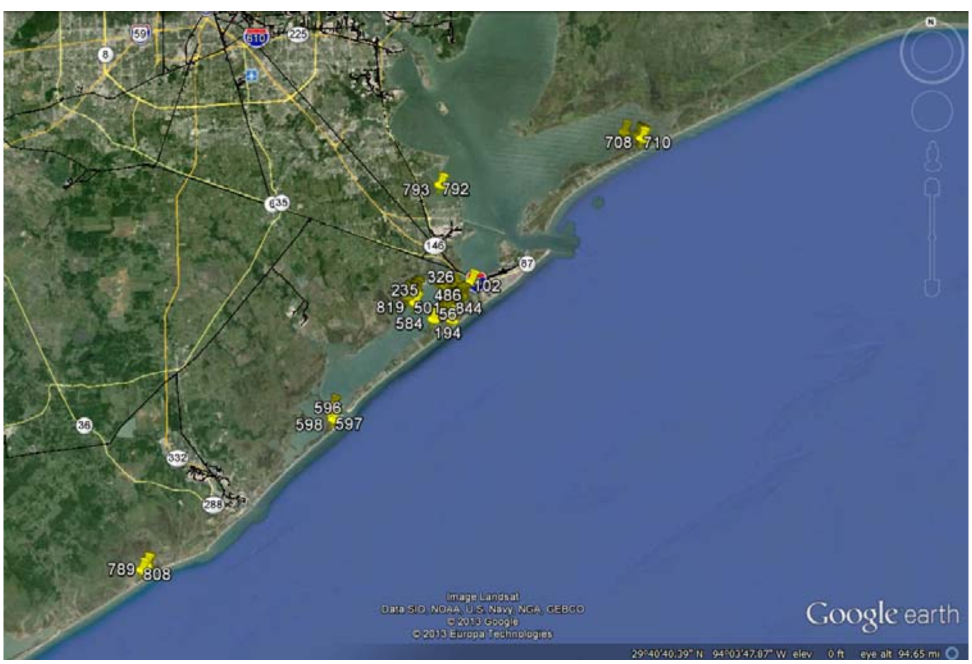

Figure 30. Locations where terrapin have been captured or recaptured during February 2008 to November 2013.

Figure 31. Close up of Deer Island complex showing locations of terrapin captures and recaptures during February 2008 to November 2013.

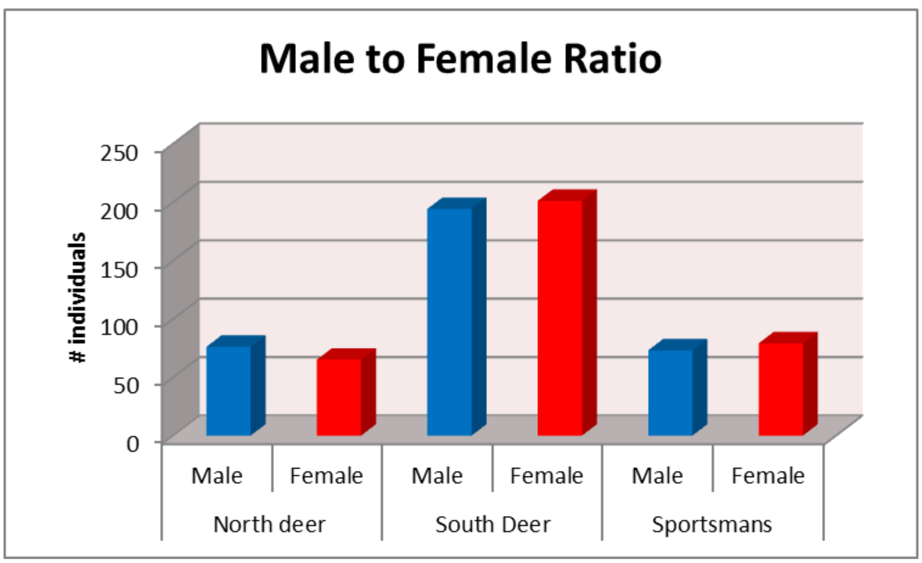

Figure 32. Sex ratios of captured terrapin during the study period (February 2009- August 2012).

Table 2. Number of females versus males capture at each site during the study period July 2011 to October 2012.

Site	Number of Females Captured	Number of Males Captured	Number of Recapture Events, Female	Number of Recapture Events, Male
Bird Island	1	0	0	0
Churchill Bayou	1	0	0	0
Goat Island	1	0	0	0
Greens Lake	2	5	2	0
Little Pasture Cove	1	2	0	0
Melagar Cove	1	2	0	0
North Deer	14	16	23	8
South Deer	29	33	198	63
Sportsmen	16	11	16	3
Grand Total	66	70	239	74

Table 3. Average measurements (and standard deviation) of male and female terrapins captured between July 2011 to October 2012.

Meristics	Female	Male
Average of Carapace Midline Length (mm)	189 ± 15	133 ±7
Average of Plastron Midline Length (mm)	169 ± 14	111±6
Average of Head Width (mm)	44 ± 6	25±2
Average of Weight (kg)	1 ± 0	0
Average of # Growth Rings	5 ± 4	4 ±2

Demographic Analysis

We supplemented our analysis of terrapin populations at South Deer park by conducting additional population analyses for the entire period of our study of South Deer Island population and surrounding areas which generally ranged from February 2008 to November 2013 (Figure 33 to 36). During this period we captured a total of 876 terrapin consisting of 431 unique individuals. The highest capture rates occurred during 2011 when this study supplemented our past population study effort. The spatial distribution of sights were terrapin were captured were previously depicted in Figure 29 to 31. We also examined trends in size, weight, apparent age, and sex using this larger data set.

We attempted to estimate the population size of terrapins on South Deer Island since that site possessed the longest data series of sufficient density to support development of a Jolly Seber model. It was necessary to focus on a shorter time series because during 2008 sampling was done less frequently. Based on this data which included 348 uniquely marked individuals during the period of February 2009 to August 2012 we observed highly variable fluctuations in estimated population size, each with a relatively large confidence interval (Figure 37 - 40). The average point estimate of the population size ranged between 850 and negative values (extirpation). The overall summary statistics for the population estimates included a minimum estimate of zero, and a lower quartile, median, upper quartile and maximum estimate of 118, 258, 417 and 957 respectively. There appeared to be an increase in the population size estimates of terrapin during 2011. This was followed by a decline during 2012. Seasonally overall population levels appeared to decline during summer months, however this did not appear to be statistically significant (Figure 44).

To facilitate analysis of sex, age and size we conducted preliminary analyses to evaluate overall patterns of distribution of these parameters and filtered out unreliable data (e.g. unknown sex, age or missing paired values). Using data from this study and historical data we found that mature females exhibited an average size of 190 mm mid-carapace length while males had a mean length of 130 mm (Figure 41 and 42). We developed a length weight model that predicts total weight based on medial carapace length (Figure 43). Although the size of male and females differed their functional relationship between length and weight did not (Figure 44).

We examined the relationship of terrapin size and number of scute rings. It appears that there seems to be a visible increase in carapace length with number of scute rings or estimated "age" after adjusting for sex based size differences (Figure 45). This is most obvious in male terrapin between the ages of 3 and 8. However, after 10 years the growth of the organism slows or stops. One interesting observation is the apparent lack of two year old (two ring) terrapin and numerous terrapin without rings that were definitely grown adults. Also, the age 0 based on their size, were as supported by their size distribution also represented older individuals with worn or missing annuli. We therefore reanalyzed the data excluding older individuals and age 0 and 1 (Figure 46 and 47). Using this data we were able to provide crude estimates of annual growth for females.

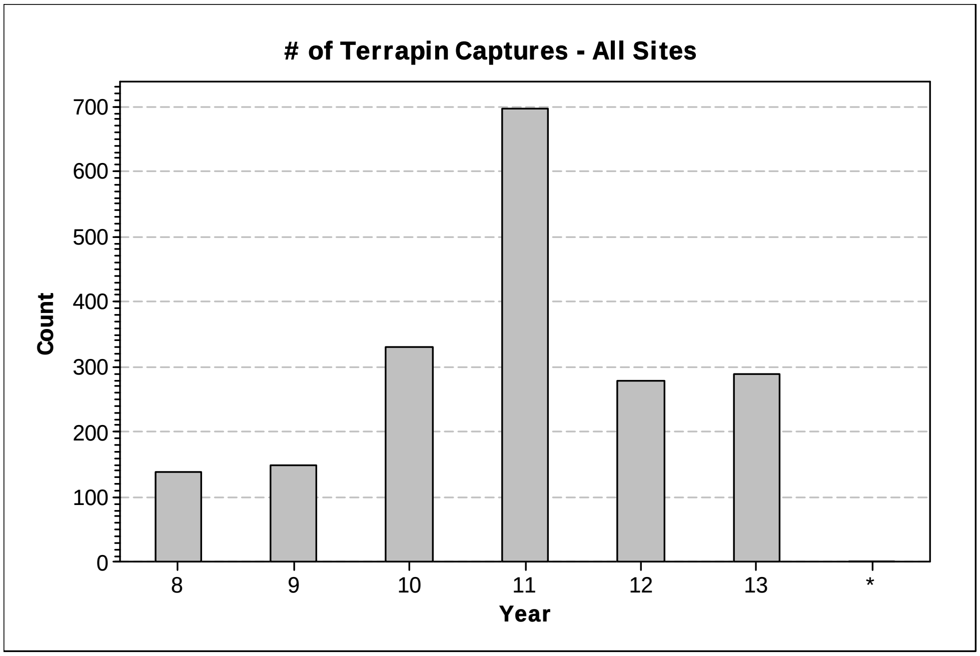

Figure 33. Number of terrapin captured each year from 2008 to 2013 at all surveyed sites.

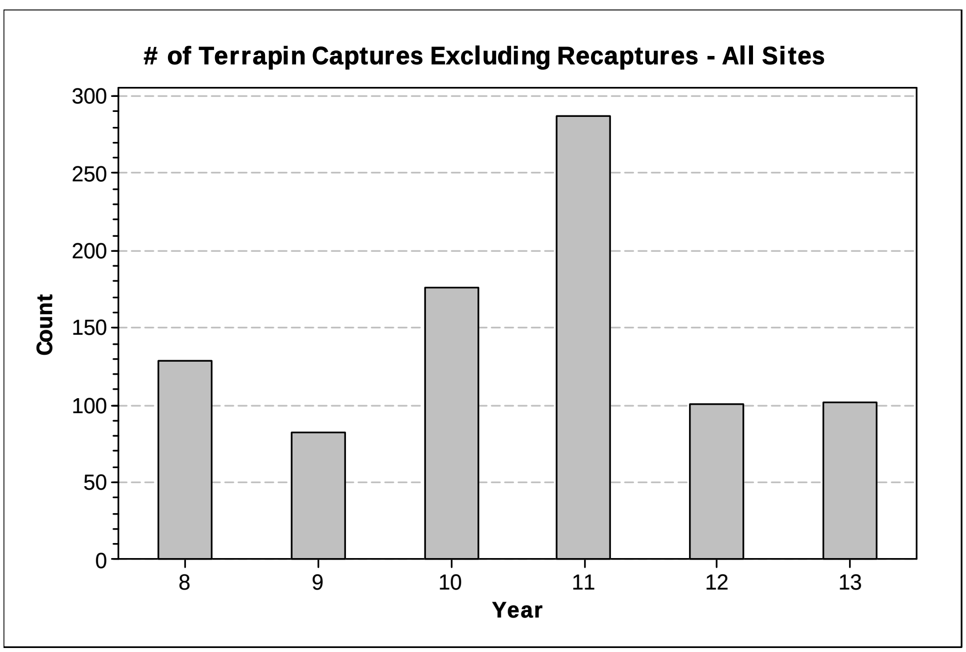

Figure 34. Number of terrapin captured each year from 2008 to 2013 at all surveyed sites. Recapture data is excluded.

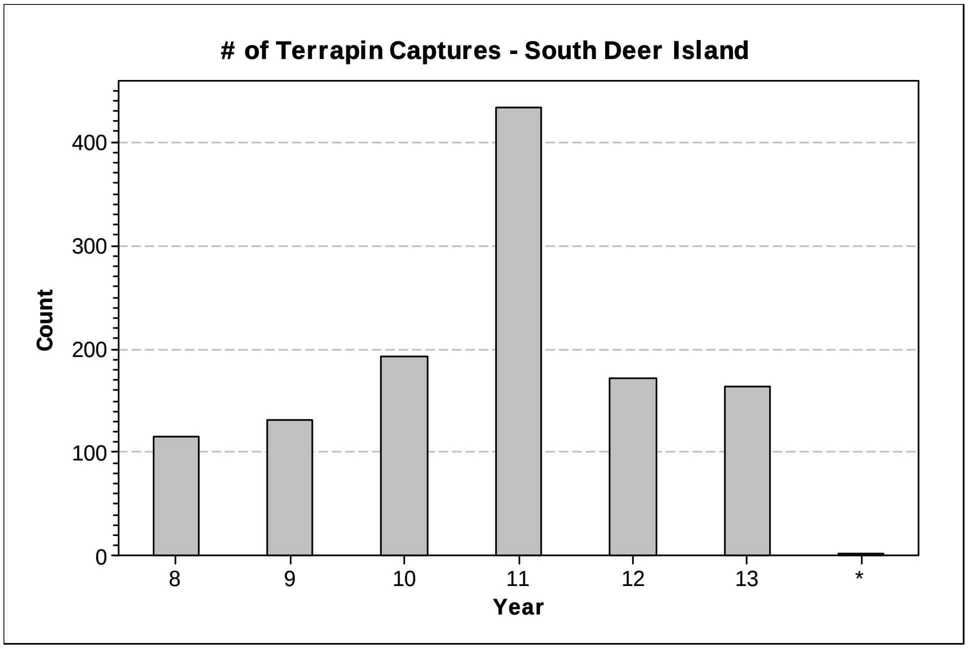

Figure 35. Number of terrapin captured each year from 2008 to 2013 at South Deer Island.

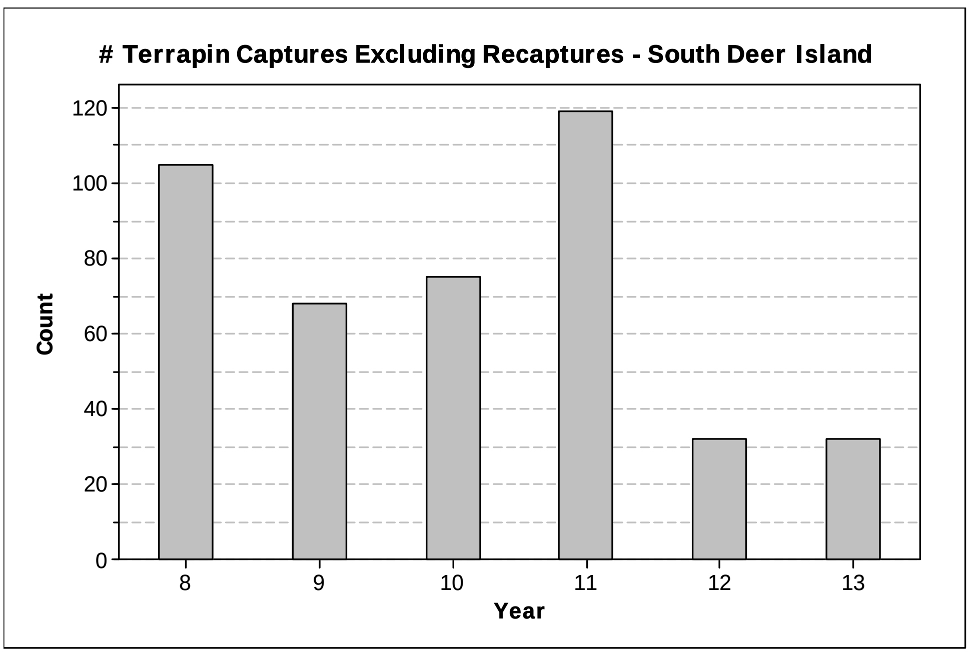

Figure 36. Number of terrapin captured each year from 2008 to 2013 at South Deer Island. Recapture data is excluded.

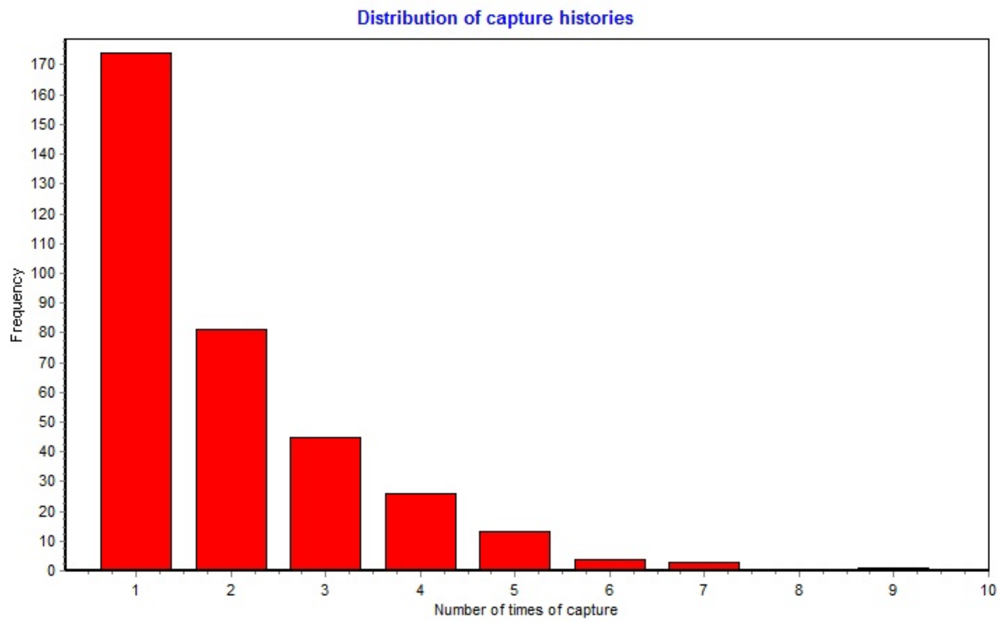

Figure 37. Frequency distribution of individual terrapin captures and recaptures at South Deer Island from February 2009 to August 2012.

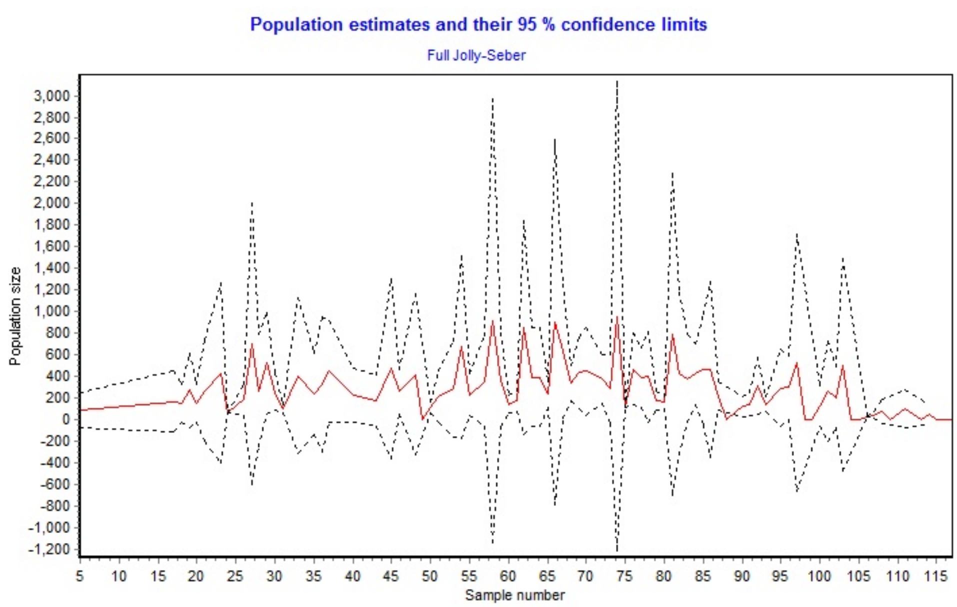

Figure 38. Result of Jolly Seber mark recapture estimates from February 2009 to August 2012.

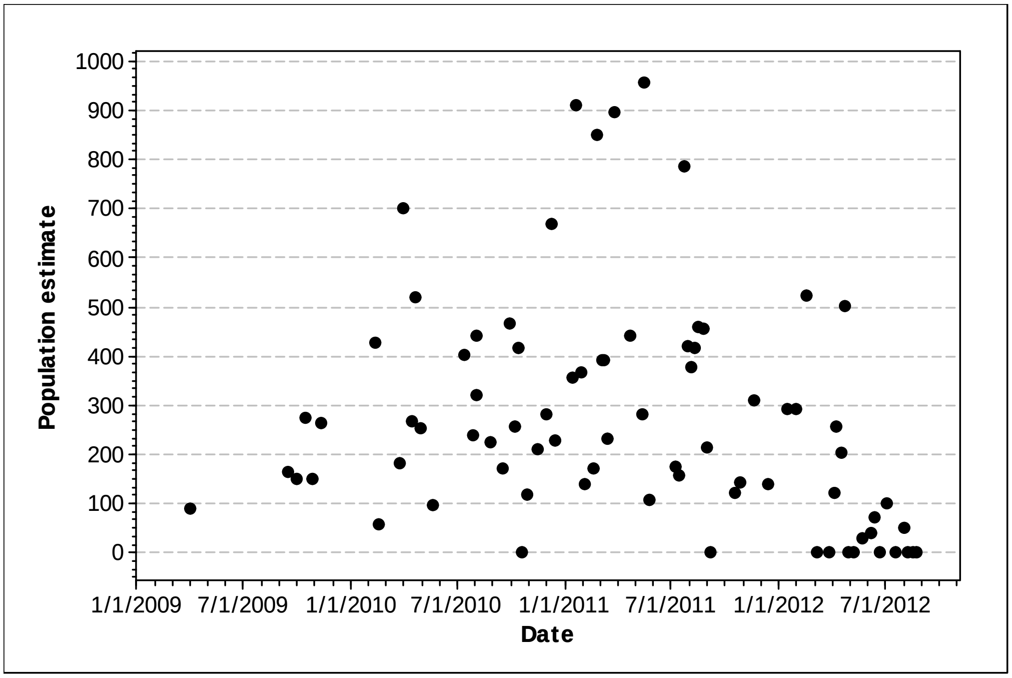

Figure 39. Results of Jolly Seber point estimates of population size by date for South Deer Island.

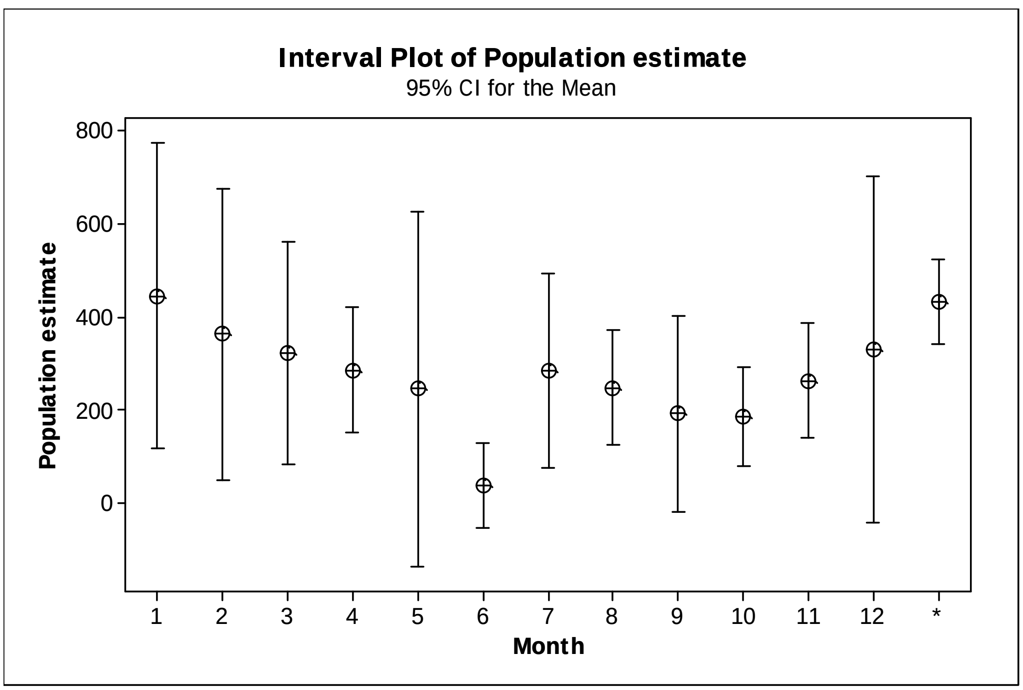

Figure 40. Confidence interval for average Jolly Seber estimates of population size at South Deer Island by month for all years compiled.

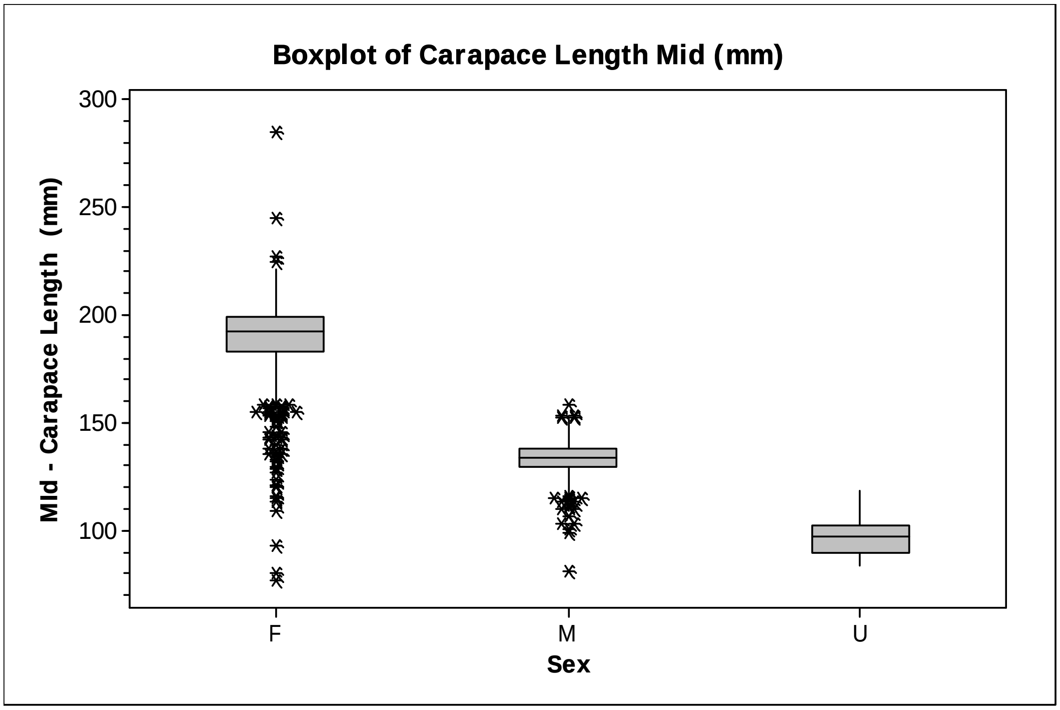

Figure 41. Size distribution of terrapin at all sites by sex (U = unknown or immature) for the period of February 2008 to November 2012.

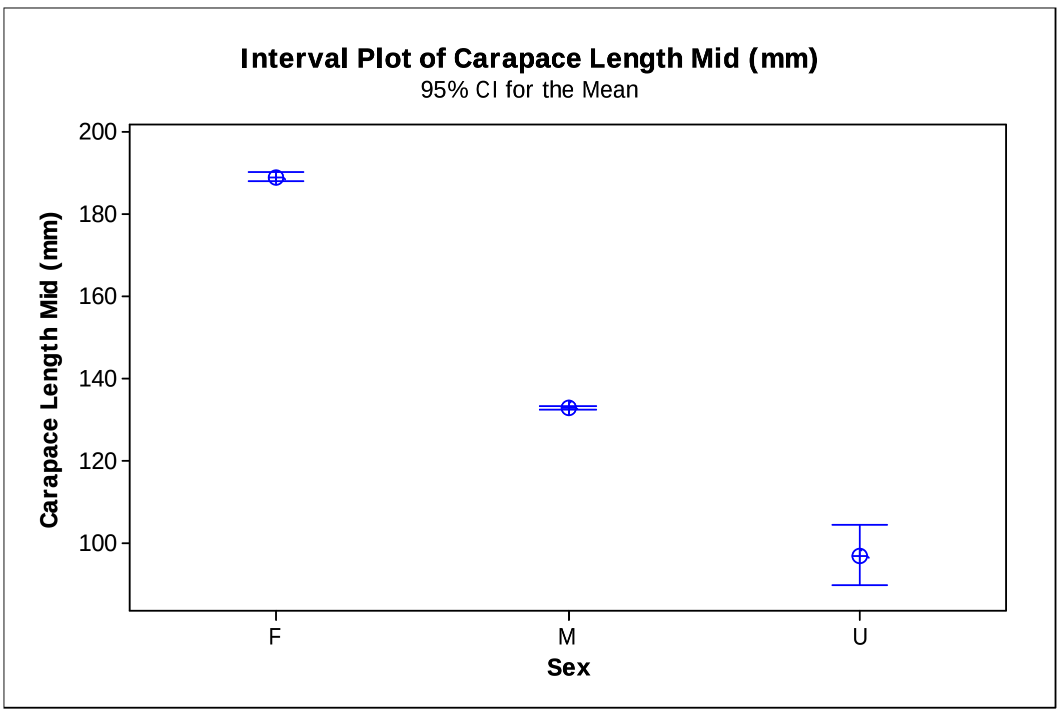

Figure 42. Confidence interval for the average size of male and female terrapin at all sites (U = unknown or immature) captured during the period of February 2008 to November 2012.

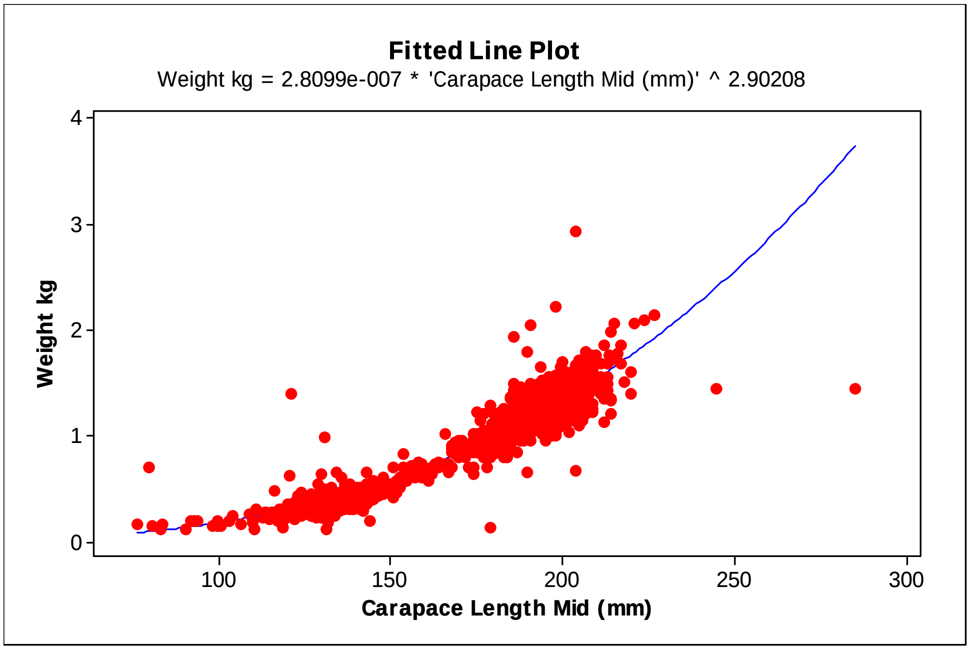

Figure 43. Relationship of weight and length of terrapin based on all captures during 2008 and 2013.

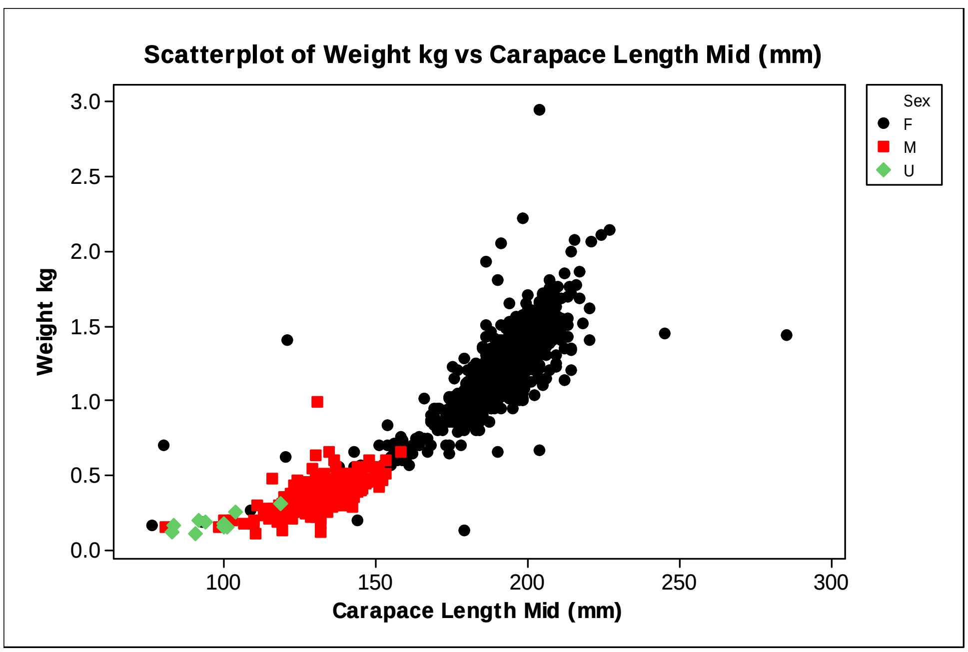

Figure 44. Relationship of weight and length of male and female terrapin based on all captures during 2008 and 2013.

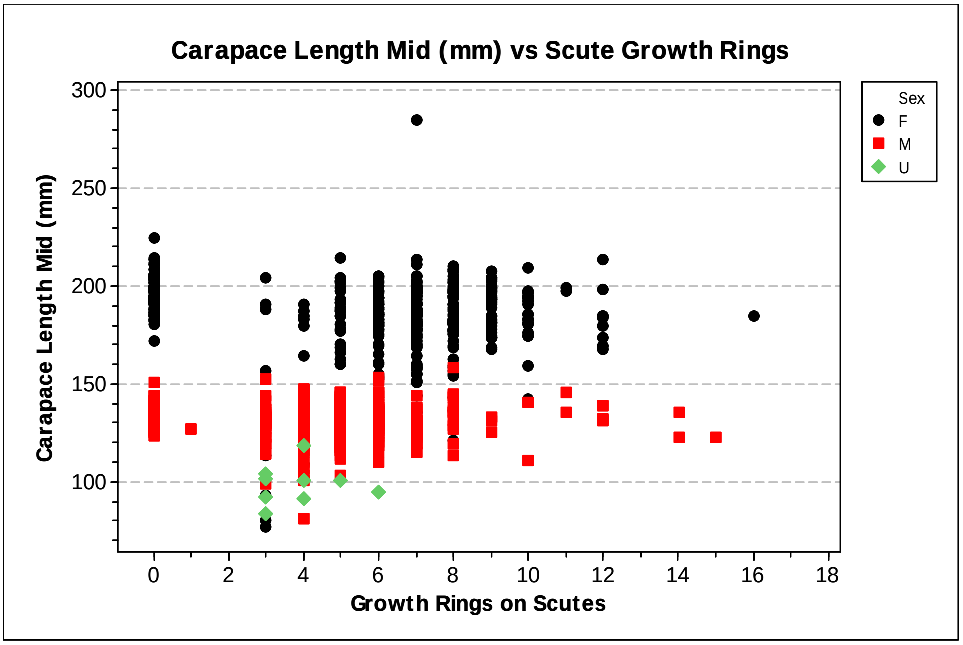

Figure 45. The relationship of growth rings and size and sex of terrapins based on all captures during 2008-2013.

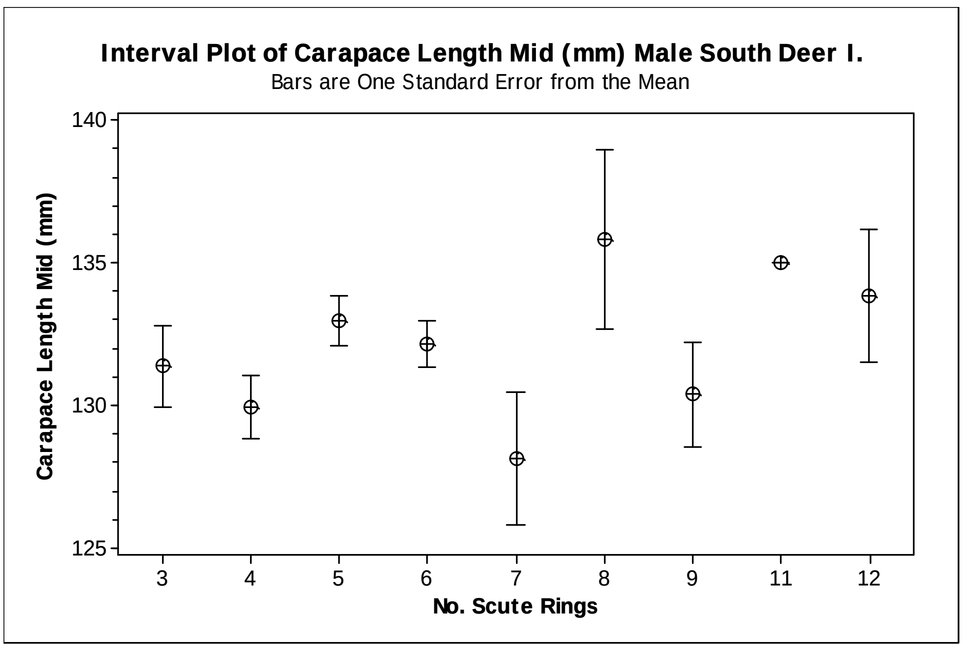

Figure 46. Size at age for age 3 to 12 male terrapin captured at South Deer Island during 2008 to 2013.

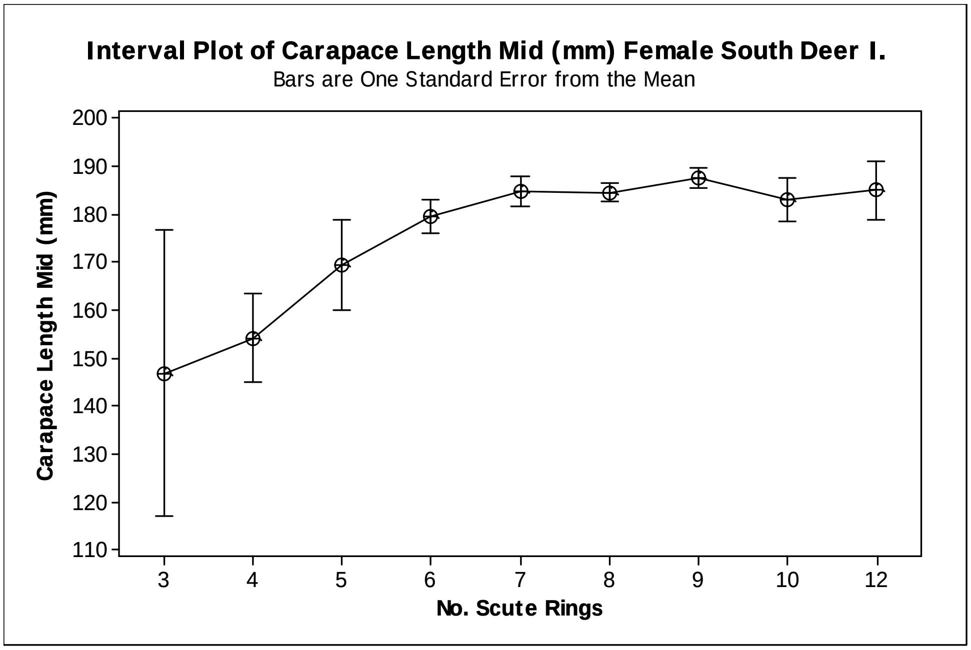

Figure 47. Size at age for age 3 to 12 female terrapin captured at South Deer Island during 2008 to 2013.

Females on South Deer Island between the ages of 3 and 7 appear to exhibit a mean growth rate of 10 mm per year (Figure 47). However, male terrapin appear to grow much faster at an earlier age and then experience erratic but slow rates possibly not more than 1 or 2 mm per year up to the age 8. This suggests that more energy is placed in males growing faster and becoming sexually mature. In contrast the slower growing female, in terms of percentage of total maximum size, is more likely due to the higher metabolic costs associated with egg production.

We examined the distribution of male and females upon a pseudo-cohort age composition generated from the period of 2008 to 2013. Based on examination of these histograms we propose that males between the ages of 4 and 9 may experience an annual mortality rate of 22% (Figure 48 and 49) . However, if we just use data from initial captures and exclude recapture data, the mortality rate is approximately 20%. It was more difficult to estimate survival in females since it appears that the population was dominated by older age 8 females with few younger cohorts during this period. Estimated annual survival rates based on the "pseudocohort" of age 8 to 12 females ranged between 80 and 85%. However, based on the age distribution of the female, recruitment of younger individuals has been poor in recent years. Another explanation is that smaller younger females may more difficult to locate and capture or that they are utilizing different habitats where we are not surveying. This pattern needs to be investigated more closely since poor recruitment of younger females may eventually lead to a population bottleneck were a large percentage of each generation is being produced by a small minority of older and larger females.

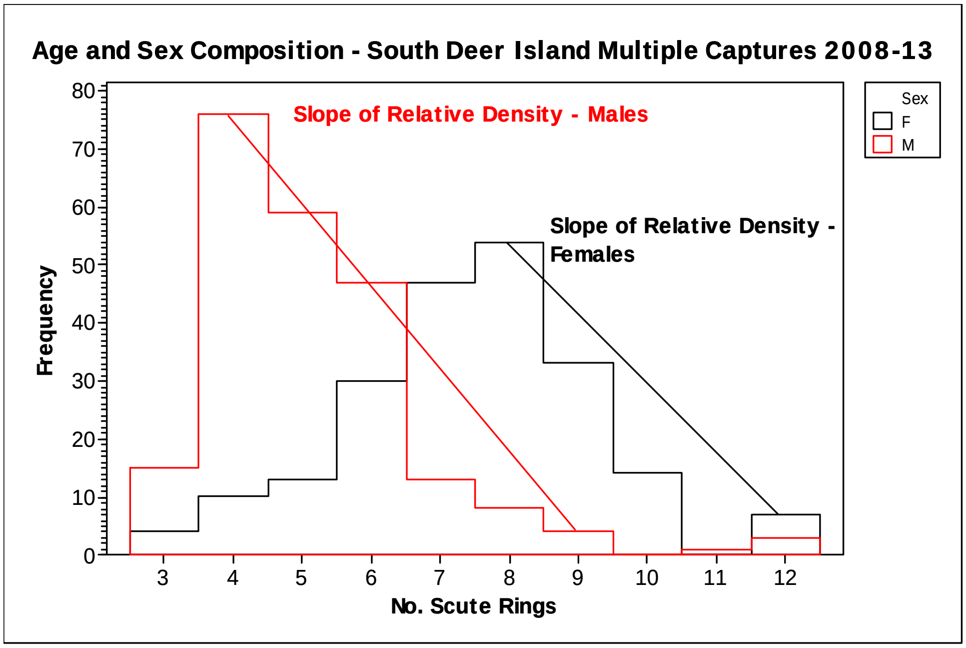

Figure 48. Age distribution of male and female terrapin at South Deer Island during 2008 to 2013 based on multiple captures and recapture data.

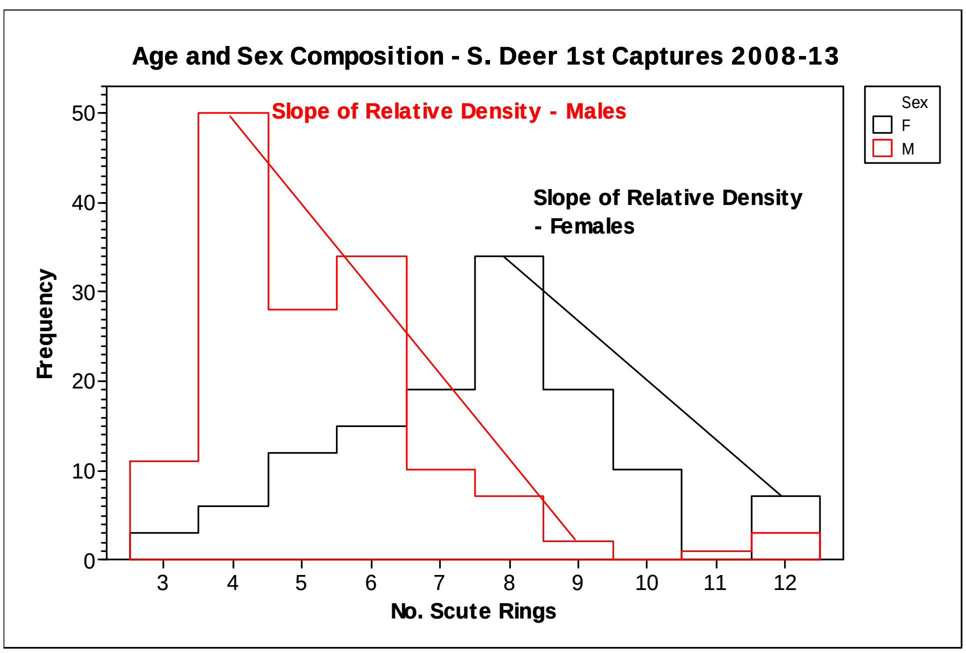

Figure 49. Age distribution of male and female terrapin at South Deer Island during 2008 to 2013 based on initial capture data only.

Habitat Utilization

We used a combination of data sets including our historical data and/or the more recently collected data that included more information on the distribution of terrapin in relation to physicochemical variables and habitat utilization.

During the current study we collected habitat preference data for each of the 316 capture events occurring from July 2011-October 2012. Analysis of this data shows that habitats selected by terrapins are characterized mostly by vegetation that ranges in height from 20-60 cm (Figure 50). Terrapins showed no significant trends in selection of vegetation cover (Figure 51). The data shows a high variability in both vegetation height and percent cover, and these preferences may also change seasonally. The histograms below display the frequency of captures in each vegetation height class, varying vegetation covers, and varying dominant vegetation species. Terrapin were recaptured most often in close proximity to saltmarsh cordgrass (Figure 52).

We examined the relationship of the distribution of terrapin and water and air temperature. The majority of terrapin collected during our study and previous years indicate that terrapin are seldom found when air temperature drops below 15 ºC in land or water (Figure 53 and 54). Furthermore, it appears that terrapin are seldom found when air or water temperature exceeds 35 ºC. This suggests active behavioral thermoregulation. Burrowing during summer and winter months has been observed by our past graduate student researchers. To better characterize the "response" of terrapin to environmental factors we similarly present the interaction of terrapin catch rates and remaining factors in the form of cumulative distribution functions. This will facilitate the future construction of habitat metric based models.

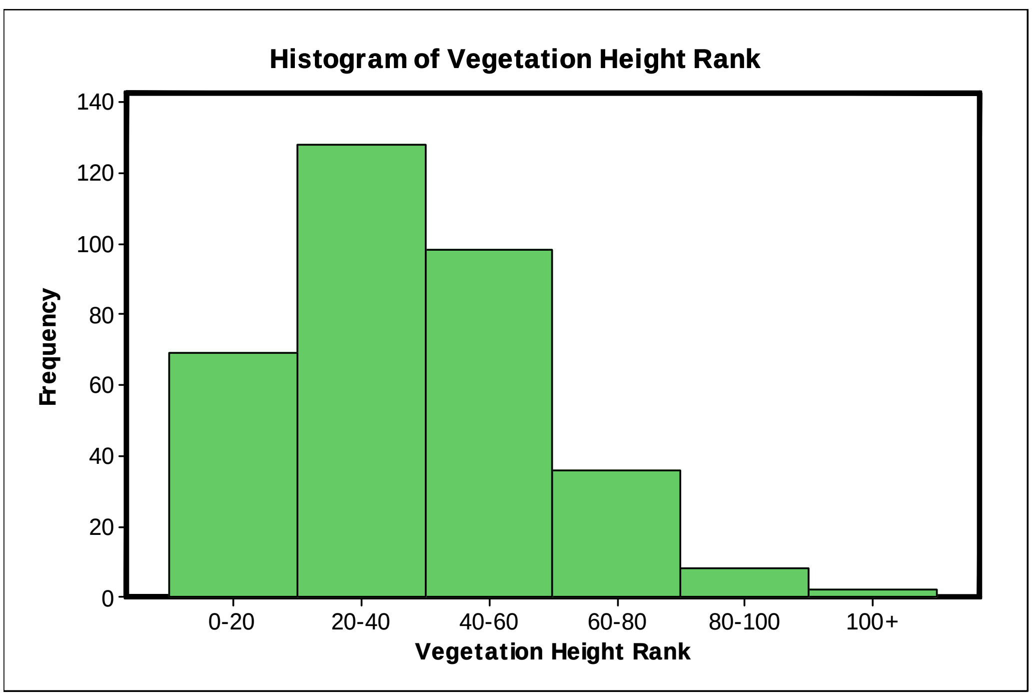

Figure 50. Histogram showing frequency of terrapin capture in habitats classified by differing vegetation height, in cm. This data was collected from July 2011-present and represents both male and female terrapins between all seasons.

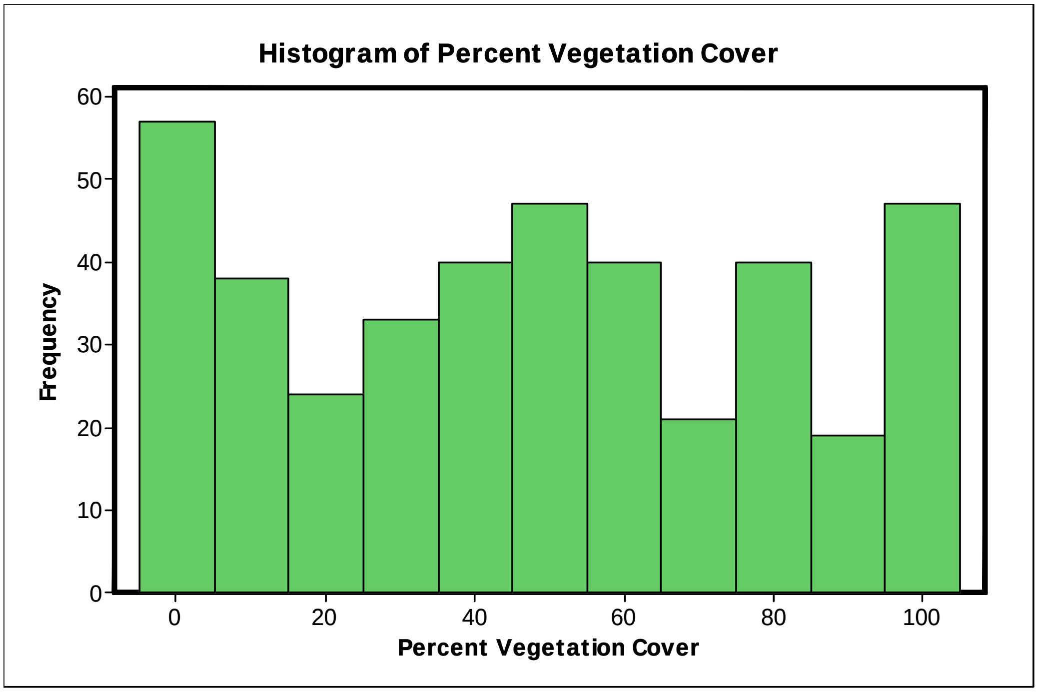

Figure 51. Histogram showing frequency of terrapin capture in habitats classified by varying percent vegetation cover. This data was collected from July 2011-present and represents both male and female terrapins between all seasons.

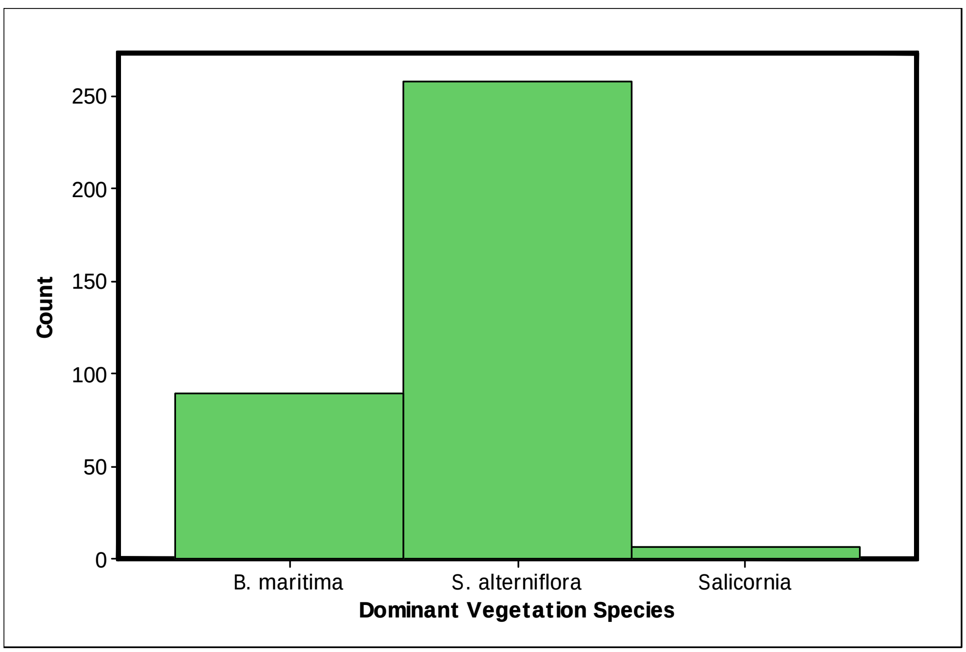

Figure 52. Bar chart showing the number of terrapin captures events that occurred in habitat dominated by either *B. maritima, S. alterniflora,* or *Salicornia spp*.

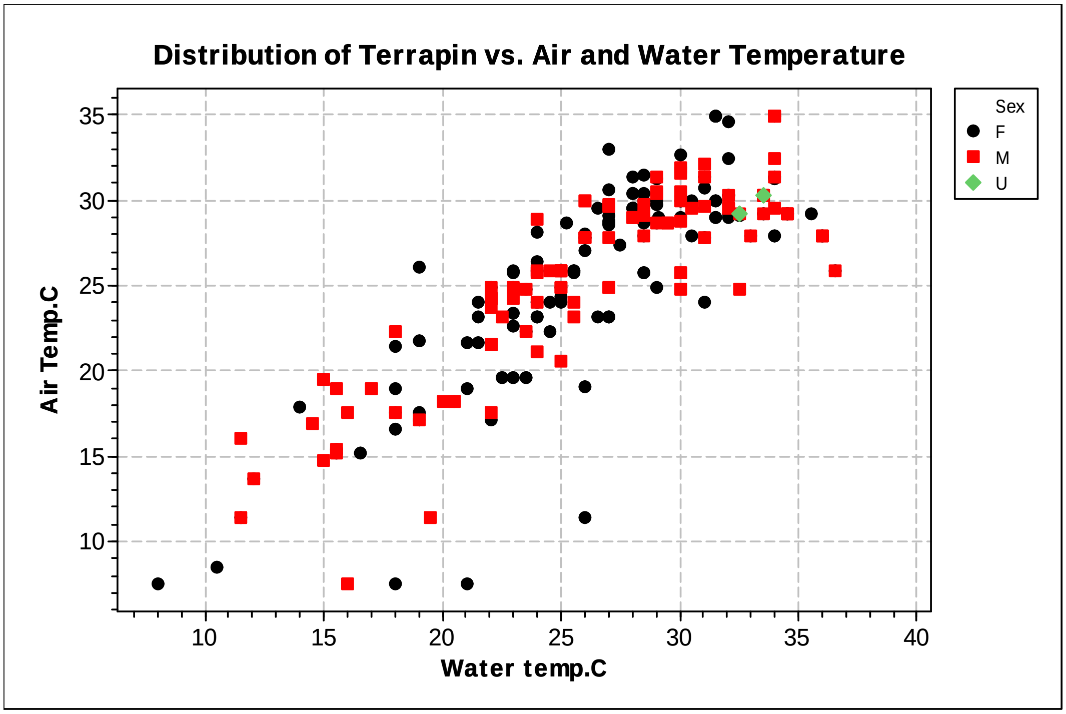

Figure 53. Distribution of terrapin across air and water temperature gradients for the period of February 2008 to November 2013.

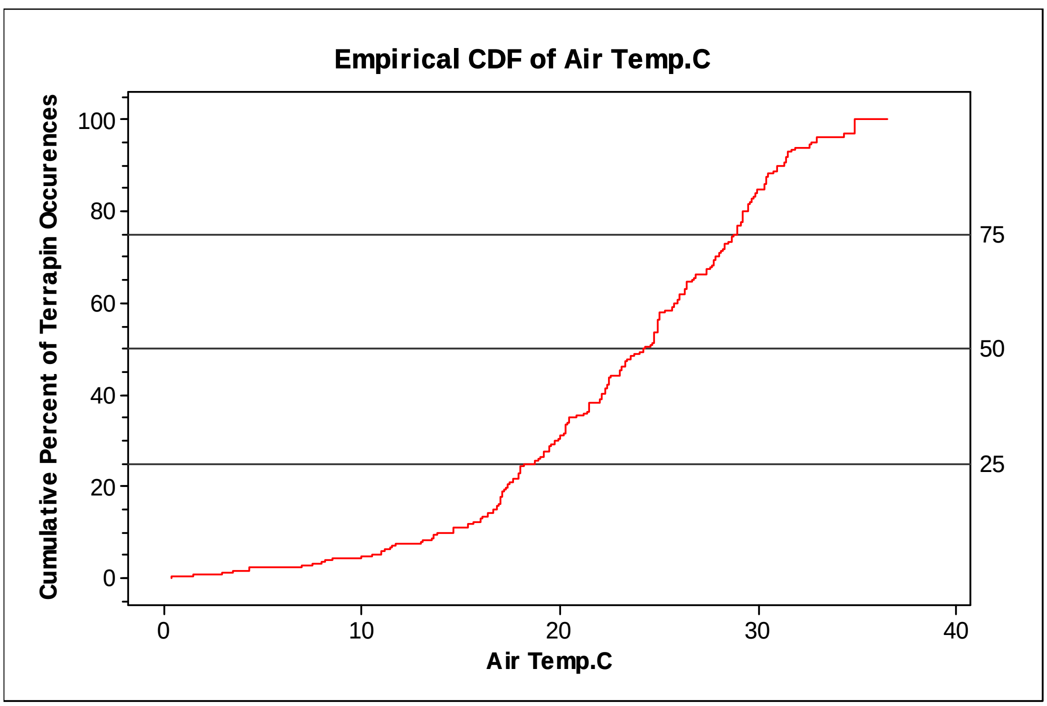

Figure 54. Cumulative distribution of terrapin versus air temperature for the period of February 2008 to November 2013.

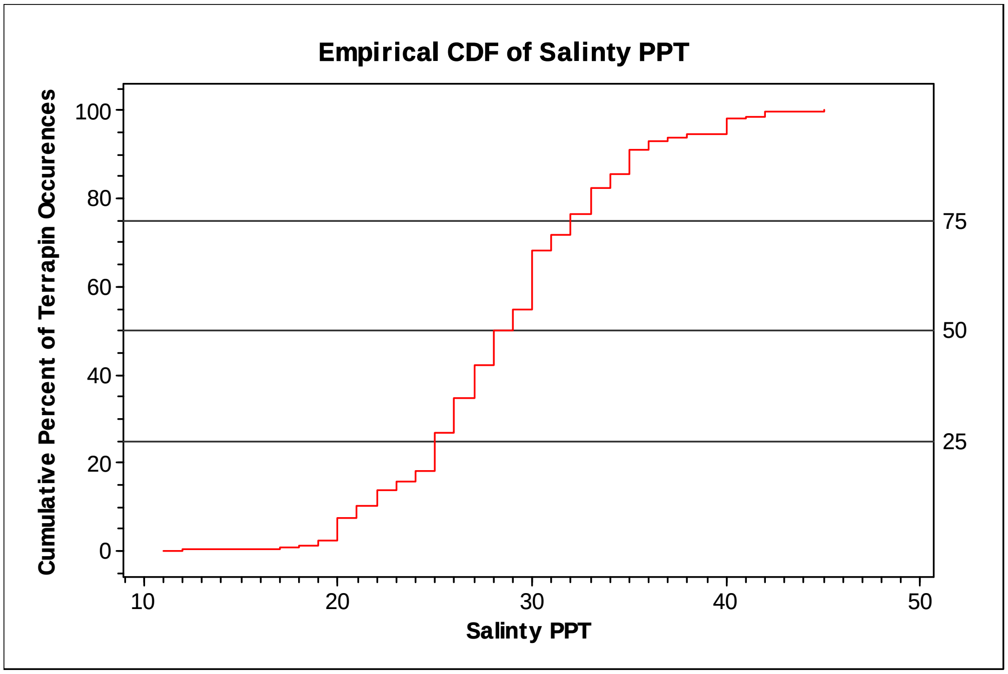

Figure 55. Cumulative distribution of terrapin versus salinity for the period of February 2008 to November 2013.

Although very few terrapin were captured at salinities below 20 psu, the distribution of terrapin occurrences spanned a large salinity range from 11 to 47 psu (Figure 55). However the vast numbers of terrapin were captured at salinities between 20 and 40 psu. It appears that terrapin are more commonly caught when Secchi disk clarity is > 0.2 m (Figure 56). It is difficult to interpret this however, since although most of our terrapin were captured on land, the relationship between terrestrial versus aquatic habitat utilization would be affected differently under conditions of varying turbidity. For example, terrapin may avoid turbid water on one hand and spend more time on land if they rely on sight primarily to find prey in water. However, if water clarity is high, they more spend more time submerged. Since there are real gradients in water clarity as you move east to west in Texas estuaries this may results in differential use of terrestrial habitat between populations. Interestingly terrapin exhibited an almost monotonic response to percent vegetation cover (Figure 57). This suggests that there is not a strong selection for heavily vegetated areas. There did not appear to be a major trend in differential distances from shore between male and female terrapin (Figure 58 and 59).

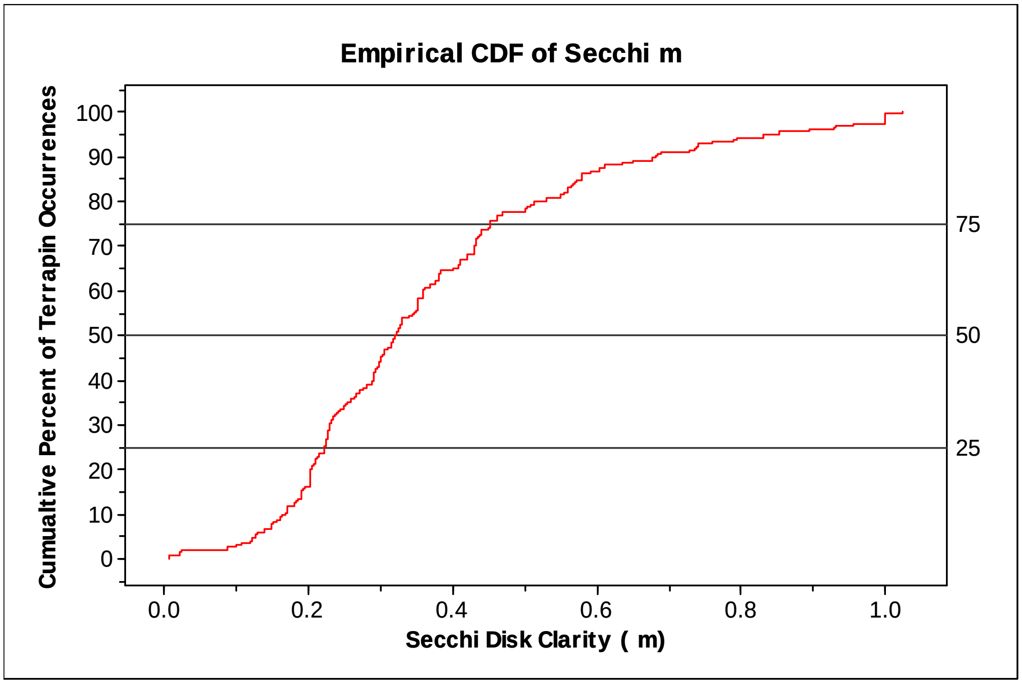

Figure 56. Cumulative distribution of terrapin versus water clarity for the period of February 2008 to November 2013.

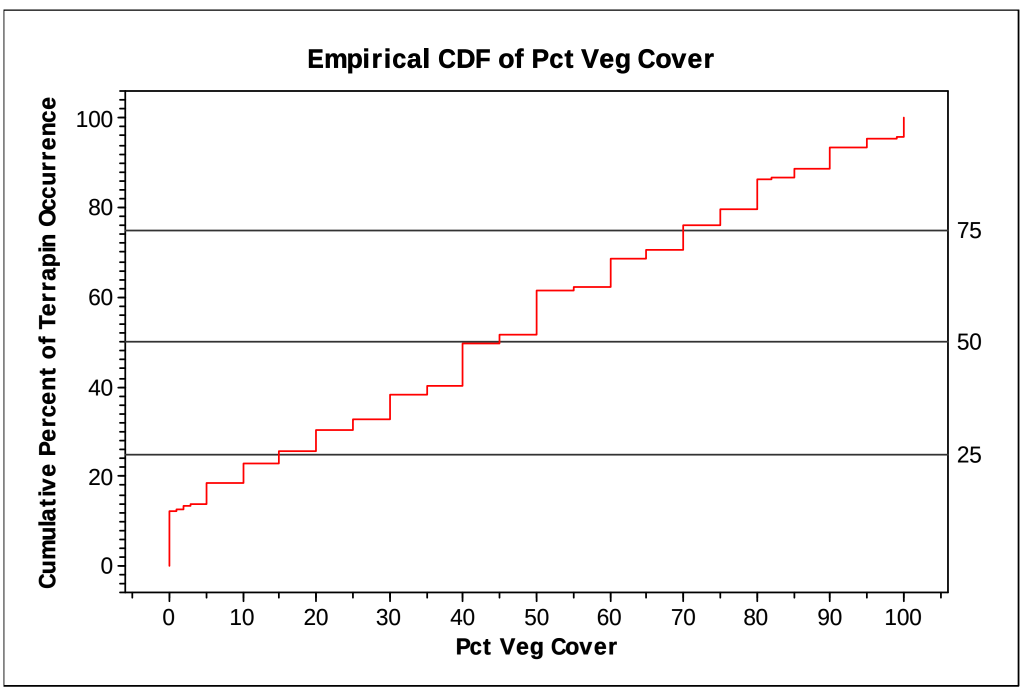

Figure 57. Cumulative distribution of terrapin versus percent vegetation cover for the period of February 2008 to November 2013

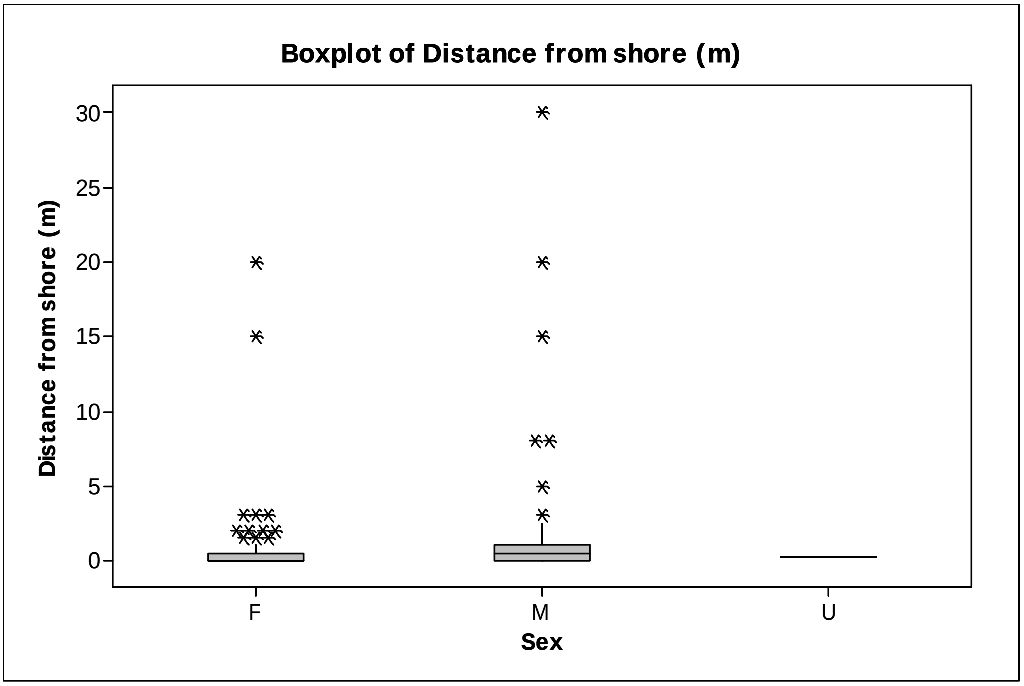

Figure 58. Distribution of male and female terrapin as a function of distance from shoreline based on data collected from 2008 to 2013.

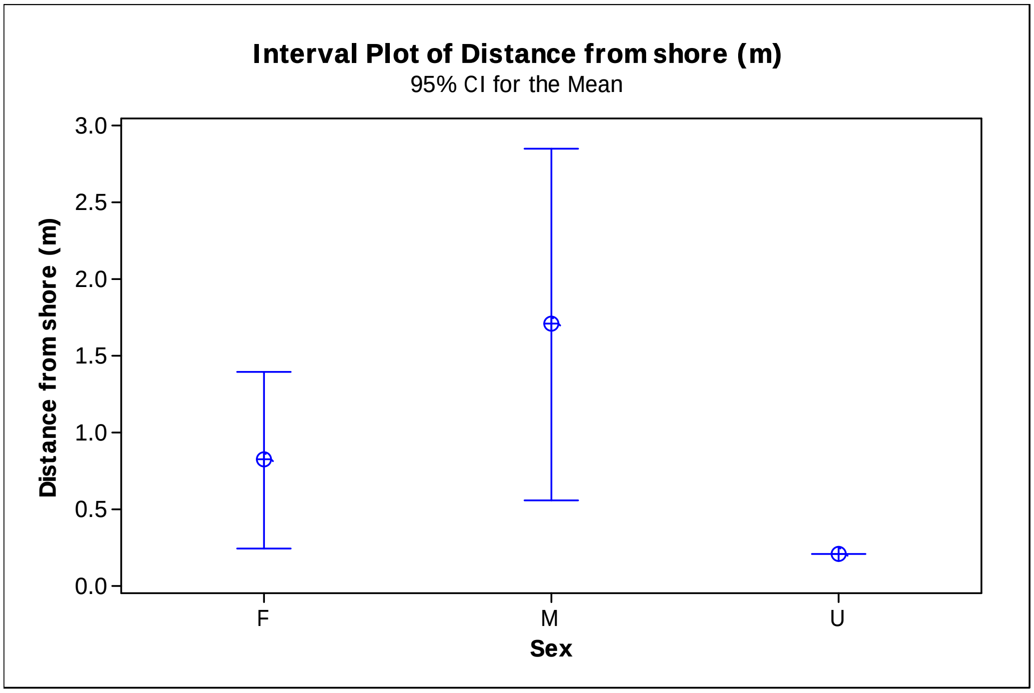

Figure 59. Confidence interval of means distance from shoreline for male and female terrapin based on data collected from 2008 to 2013.

We conducted over 56 hours of radiotracking from July 2011 – October 2012. Of the 16 terrapins affixed with radio transmitters, we were able to collect data from 10 individuals, but only 9 had sufficient data with which we could calculate Minimum Convex Polygon (MCP) based home range estimates. Table 4 summarizes daily radiotracking effort (in minutes) at each site from July 2011-October 2012. Analysis of data from this period showed little migration and high site fidelity, with MCPs ranging from 0.05-5.7 ha. While this provides us with useful information on small-scale movements and habitat selection within foraging marshes, much more research is required to assess potential large-scale home ranges and movement patterns. We plan to investigate movement and range further.

To expand our assessment of movement patterns to include long-term movement and observations of habitat utilization we compiled historical hand captured and radio-telemetry terrapin capture data from the Deer Island complex. This included a period starting in March 2008 and extending to December 2012 (Figure 60 and 61). This represents a total of 1044 capture events, 404 unique individuals, 28 radio-track individuals (>=3 captures), and 49 hand captured individuals having multiple recaptures. During this period terrapin were generally found in close vicinity to tidal creeks and open bay areas. However, a wide variety of movement was detected among recaptured individuals. Some showed very high site fidelity seldom moving more than a few meters within weeks of initial capture, while others underwent multiple kilometer migrations across open water (Figure 62 and 64).

We did not see any strong pattern between home range and number of recaptures (Figure 65). There did however appear to be a positive relationship between home range size as determined by radiotelemetry data and size and sex of terrapin (Figure 66). Larger females appeared to travel further and have larger home ranges than smaller males. However, this pattern was not observed with individuals captured by hand in transect searches (Figure 66). Terrapin captured using radiotelemetry appeared too generated smaller (10-18 ha) home range estimates than hand captures (28-30 ha) but this was not statistically significant (Figure 67 and 68). These estimates were substantially higher than the most recent estimates generated for use a subset of the data (0.8 to 2.7 ha). Radiotelemetry data did however yield higher numbers of recaptures, suggesting our current search methodology may be missing present but otherwise unobservable wild specimens of terrapin (Figure 69).

Table 4. Summary of daily radiotracking effort (in minutes) and capture rate at each site from June 2011- October 2012. MCP Range of each terrapin affixed with radio transmitter from July 2011-October 2012.

Date	Location	Radiotrack Effort (Minutes)	Number of Radiocaptured Terrapin
7/14/2011	Sportsmans	160	0
7/22/2011	South Deer	125	3
7/26/2011	Sportsmans	70	1
8/1/2011	Sportsmans	80	0
8/4/2011	South Deer	125	2
8/15/2011	Sportsmans	120	1
8/16/2011	South Deer	56	4
8/24/2011	South Deer	60	1
8/31/2011	South Deer	100	3
9/6/2011	Sportsman	110	0
9/7/2011	South Deer	137	5
9/27/2011	Sportsmans	101	0
9/28/2011	South Deer	75	4
10/12/2011	North Deer	80	1
10/19/2011	South Deer	158	6
11/2/2011	North Deer	136	1
1/3/2012	North Deer	138	1
1/16/2012	South Deer	77	3
1/23/2012	North Deer	120	0
1/30/2012	South Deer	108	3
2/8/2012	North Deer	103	1
2/15/2012	Greens Lake	10	0
2/17/2012	South Deer	35	1
3/5/2012	South Deer	176	1
3/13/2012	North Deer	52	0
4/23/2012	South Deer	75	0
4/30/2012	South Deer	174	1
5/7/2012	South Deer	60	0
6/6/2012	South Deer	81	1
8/1/2012	South Deer	5	0
8/8/2012	South Deer	20	0
8/16/2012	South Deer	16	1
8/29/2012	South Deer	144	0
9/19/2012	South Deer	137	2
9/26/2012	South Deer	45	2
10/3/2012	South Deer	126	2

Terrapin	Range Area (Ha)
1	1.8
2	1.737
3	1.578
4	0.0478
5	2.744
6	0.053
7	0.256
8	5.79
9	0.087

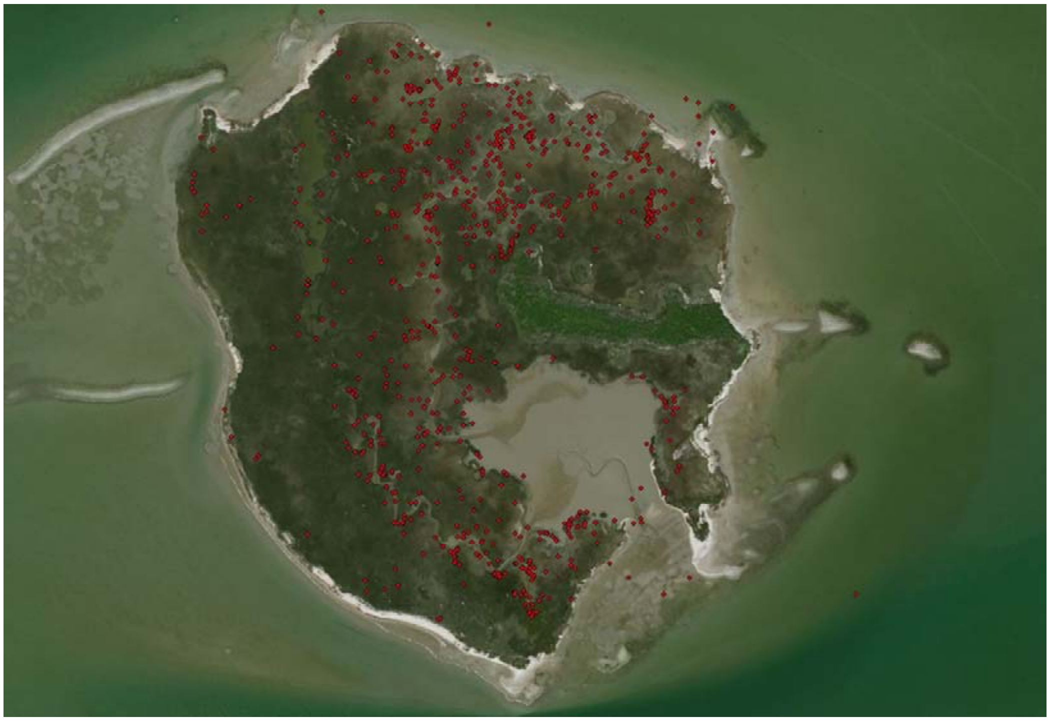

Figure 60. Spatial distribution of all captures on South Deer Island from March 2008 to December 2012.

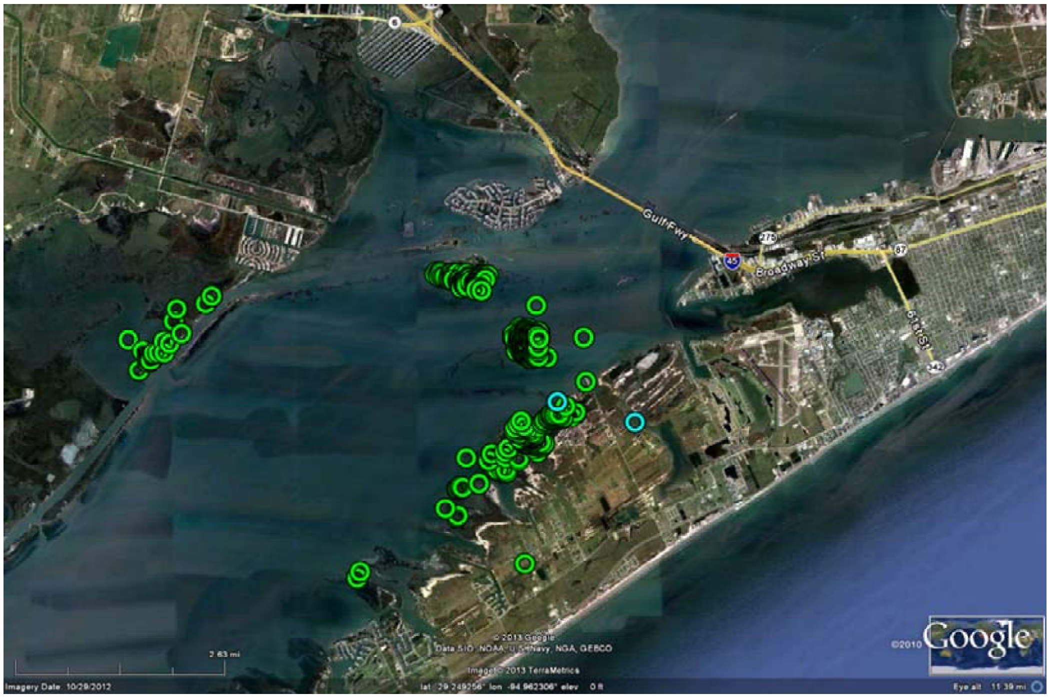

Figure 61. Spatial distribution of all captures on South Deer Island complex from March 2008 to December 2012.

Figure 62. Example of terrapin exhibiting high site fidelity (5-30 meters) and little movement over a period of weeks (in red).

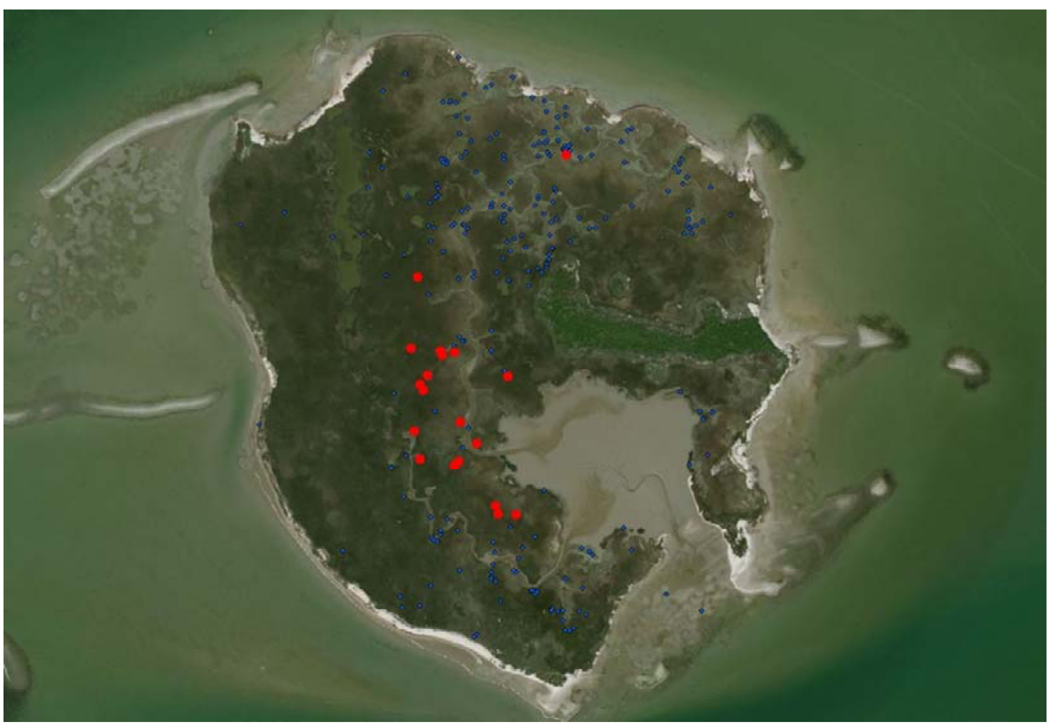

Figure 63. Example of terrapin exhibiting average site fidelity (100-200 meters) and moderate movement over a period of weeks (in red).

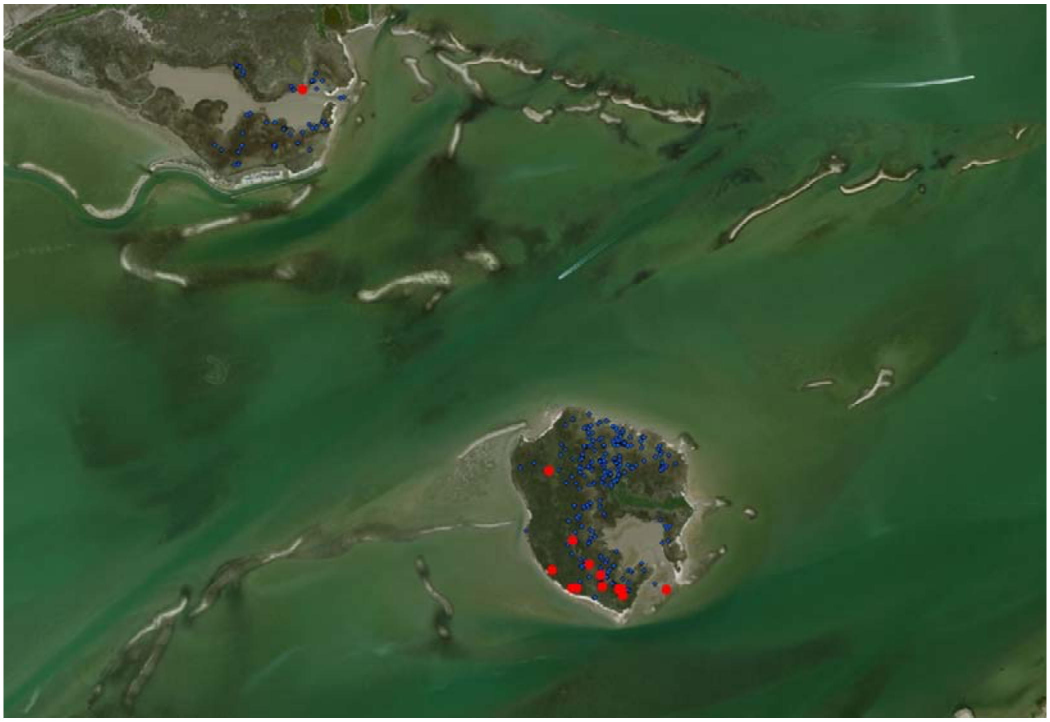

Figure 64. Example of terrapin exhibiting low site fidelity (100-200 meters) and moderate movement over a period of weeks (in red).

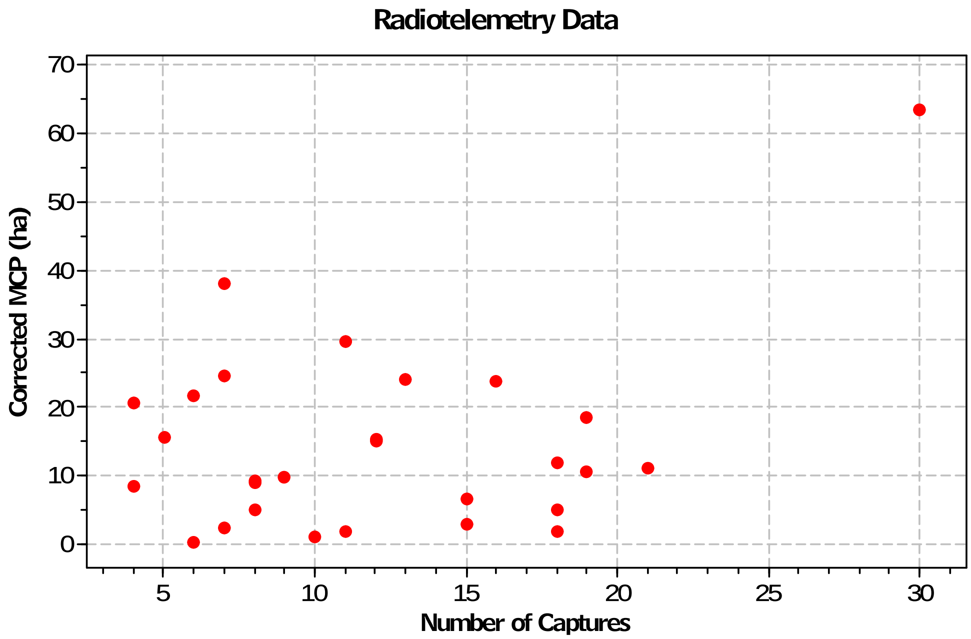

Figure 65. Estimate of terrapin home range (hectares) versus number of recaptures using data from 2008-2011 terrapin tagged with a radiotransmitter and using the minimum convex polygon method.

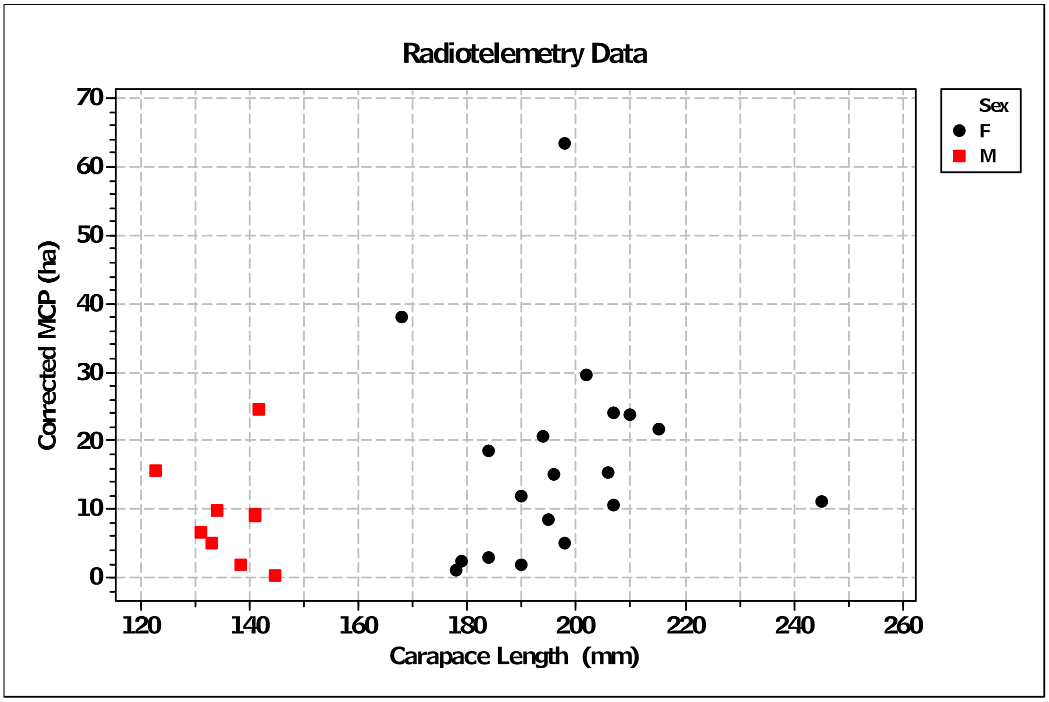

Figure 66. Estimate of terrapin home range (hectares) of terrapin by sex, using data from 2008-2011 terrapin affixed with radiotransmitters using the minimum convex polygon method.

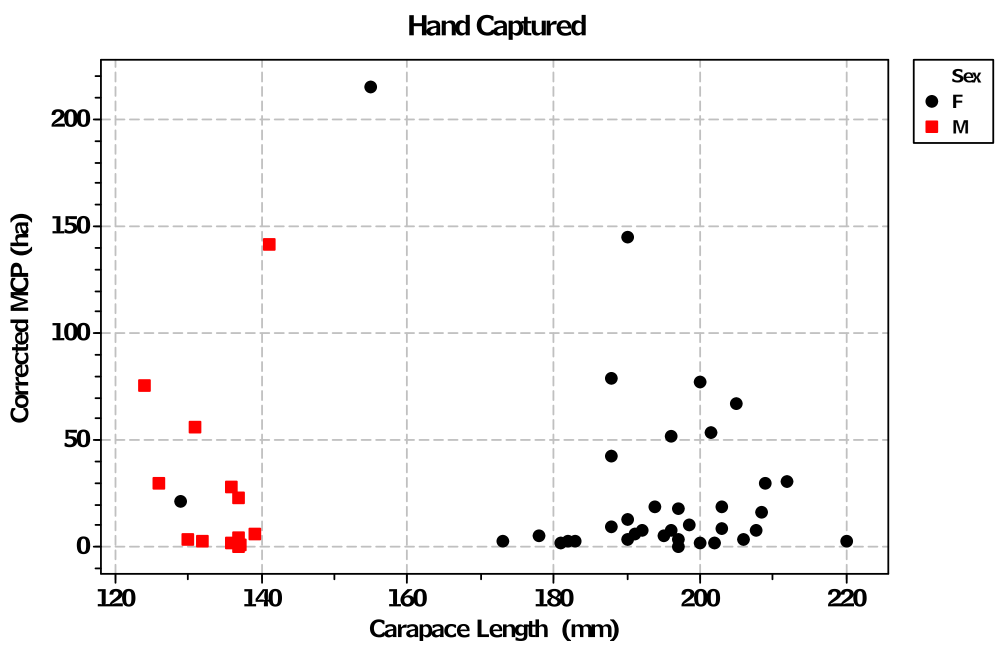

Figure 67. Comparison of terrapin home range (hectares) estimated from hand captured versus radio-tracked specimens using the minimum convex polygon method.

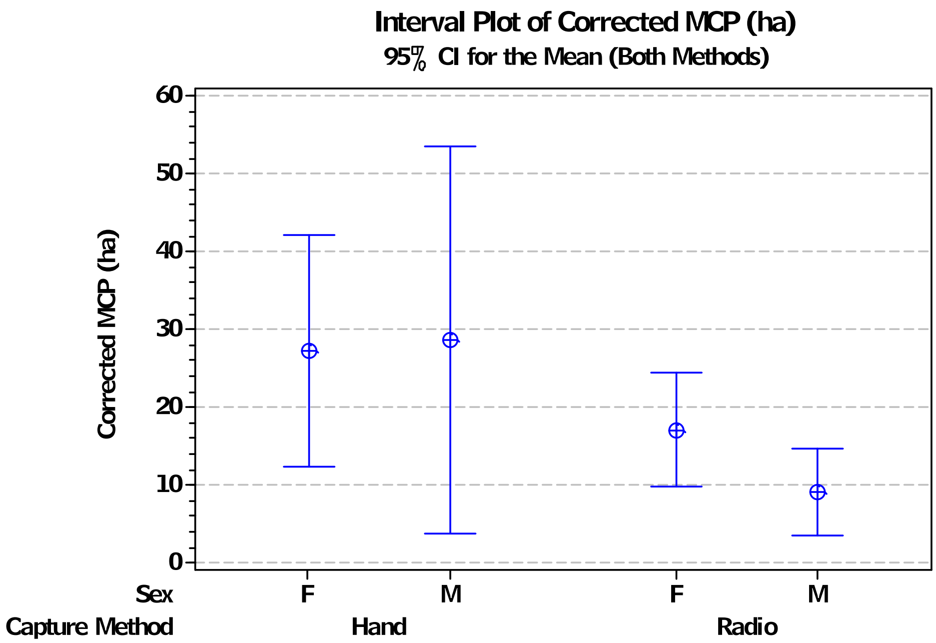

Figure 68. Comparison of average home range estimated by minimum convex polygons derived from hand captures versus radiotelemetry.

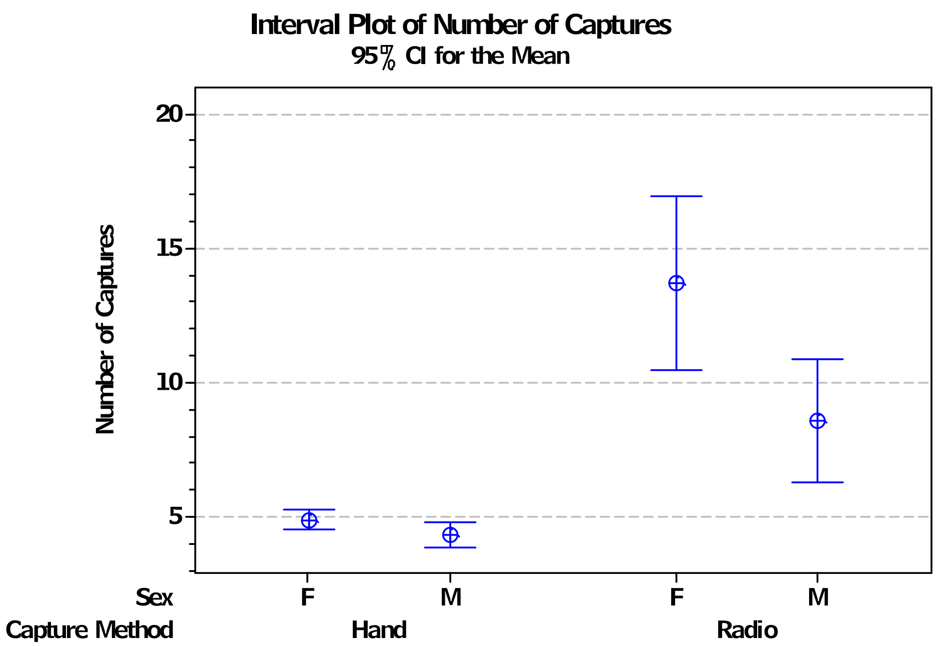

Figure 69. Comparison of number of recaptures using search and hand capture techniques versus radiotelemetry acquisition.

We also reviewed and provide pertinent recent results from her study (Clarkson 2012). She conducted her research during 15 sampling events on South Deer Island from February 2011 to September 2011 under the direction of the principal investigator. Based on her research she found distinct patterns in diel activity and habitat use by male and female terrapin on South Deer Island. Her sampling events consisted of a 24-hour observation period on South Deer Island during which radio-tagged terrapin were tracked every two hours and randomized transect land searches were conducted an hour before and after sunrise, noon, sunset, and midnight. This study was conducted in conjunction with our ongoing mark recapture study on South Deer Island, which influenced some of the sampling methodology. Based on her study she found that terrapin appear to be associated with areas containing 20-80% vegetative cover and are more likely to be found in areas containing high levels of vegetative cover during February (Figure 70)(Clarkson 2012). She also found that based on radiotelemetry results, terrapin appear to move further during daytime versus evening hours (Figure 71). Finally she also conducted limited acoustic telemetry studies during October 2010 -2011 using an array of receivers and 10 terrapin with acoustic tags around South Deer Island (Figure 72). She found that most terrapin were detected at a minimum 5-10 hours per month swimming.

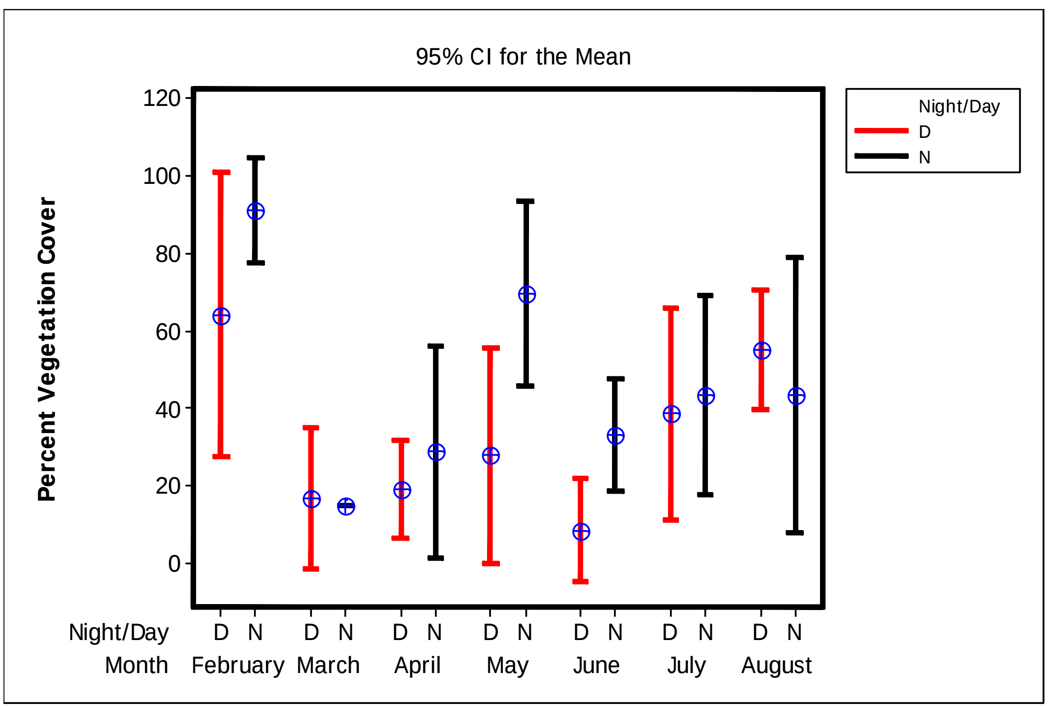

Figure 70. Seasonal utilization of vegetated areas based on radiotelemetry data collected during 24 hours surveys in 2011.

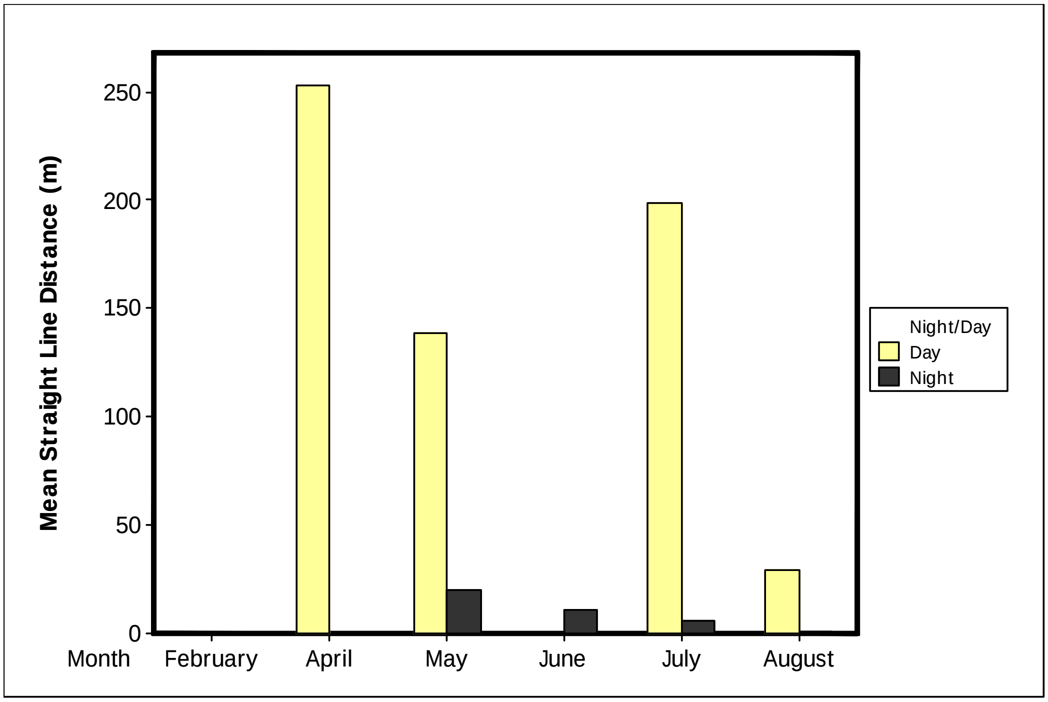

Figure 71. Mean of straight line distance travelled in each diel period, by month. Blank spaces do not indicate missing data but rather straight line movement of 0 meters. One-way ANOVA of radiotracked female terrapins showed significantly higher values of straight line distance travelled during the day versus during the night in April, August, and July ($p < 0.001$).

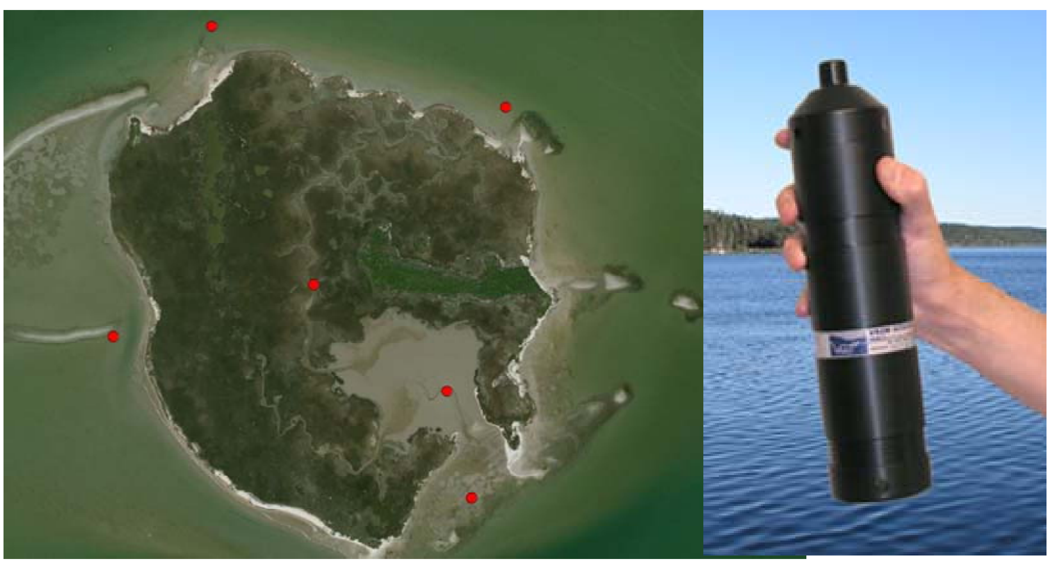

Figure 72. Array of VEMCO stationary acoustic receivers used to monitor in water movement of terrapin on South Deer Island during 2011.

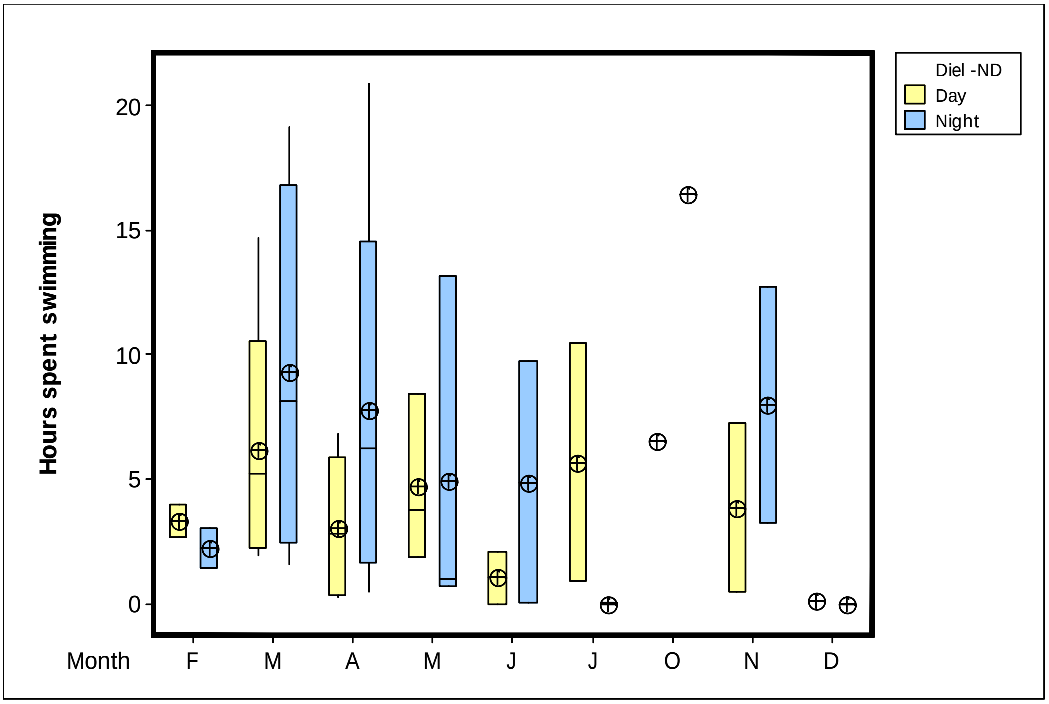

Figure 73. Boxplot of the mean and median total number of hours that each acoustically tagged female terrapin was detected by the stationary receivers between diurnal periods and month. Circle with crosshairs represents the mean of the data. One-way ANOVA failed to detect any significant difference in the number of hours that tagged females were detected by the acoustic receiver between diel periods and months (p=0.637).

Refinement and Development of Habitat Suitability Index

Adequate nesting habitats associated with estuarine marsh are critical to the Texas diamondback terrapin life cycle and population sustainability. The potential impact of rising sea level, due to global climate change, combined with increased urbanization will likely severely impact essential terrapin habitat. The Habitat Suitability Index (HSI), was designed for a wide variety of applications including conservation planning and evaluation of alternative impact scenarios. A HSI model for Atlantic coast terrapin subspecies was published in 1988, but currently there is no HSI model for the Gulf Coast terrapin subspecies. Therefore in order to assess potential impacts on terrapin habitat along the Gulf coast we will utilize data collected during this study to develop a HSI model for the Texas Diamondback Terrapin.

South Deer Island is a 0.3 km^2 island located 1.6 km north of Galveston Island in Galveston Bay. South Deer Island contains multiple waterways, and is dominated by cordgrass (Spartina spp.). The University of Houston-Clear Lake has been studying the terrapin population on South Deer Island since 2007. To date over 750 terrapin have been captured, tagged, and released in the coastal marshes in West Bay, Texas. Capture location and associated habitat type (vegetation community) were tabulated and used to estimate preferred terrapin habitat. Remote sensing color infra-red imagery was then used to extrapolate “potential” terrapin habitat beyond South Deer Island but within the Galveston Bay system. The current HSI that was developed for terrapin along the East Coast of the U.S. is being modified and adjusted for Gulf coast physical and topographic differences.

During our study we observed a geo-correlation between wetland habitats and terrapin distribution on South Deer Island. This relationship was used in conjunction with a remote sensing technique that utilizes three-band infrared imagery and a Maximum Likelihood Classification method, to classify terrapin foraging habitat (Figure 74 and 75). A sub-set of the imagery from South Deer Island was then used to create signatures for three categories of coastal wetland plant assemblages including Spartina spp., mixed marsh and upland marsh as well as two other habitat categories, dune/bare soil and standing water. The process included the use of the isodata clustering algorithm, which is used to create natural groupings of spatial cells based on spectral characteristics in multidimensional attribute space. The determined signatures were used as inputs into the Maximum Likelihood Classification function in the Spatial Analyst extension in ArcGIS. We will in the near future utilize this classification system to develop spatial models that we hope could predict the quality and occurrence of terrapin. The data generated from this research will help define the potential extent of terrapin populations in Texas and provide the information needed by managers to define the status of the population. Field validation tests using this HSI will be performed to determine its effectiveness and to recalibrate it as necessary. Once the predictive power of the HSI is validated it will be ready for use in planning for future habitat restoration and protection along the Texas coast.

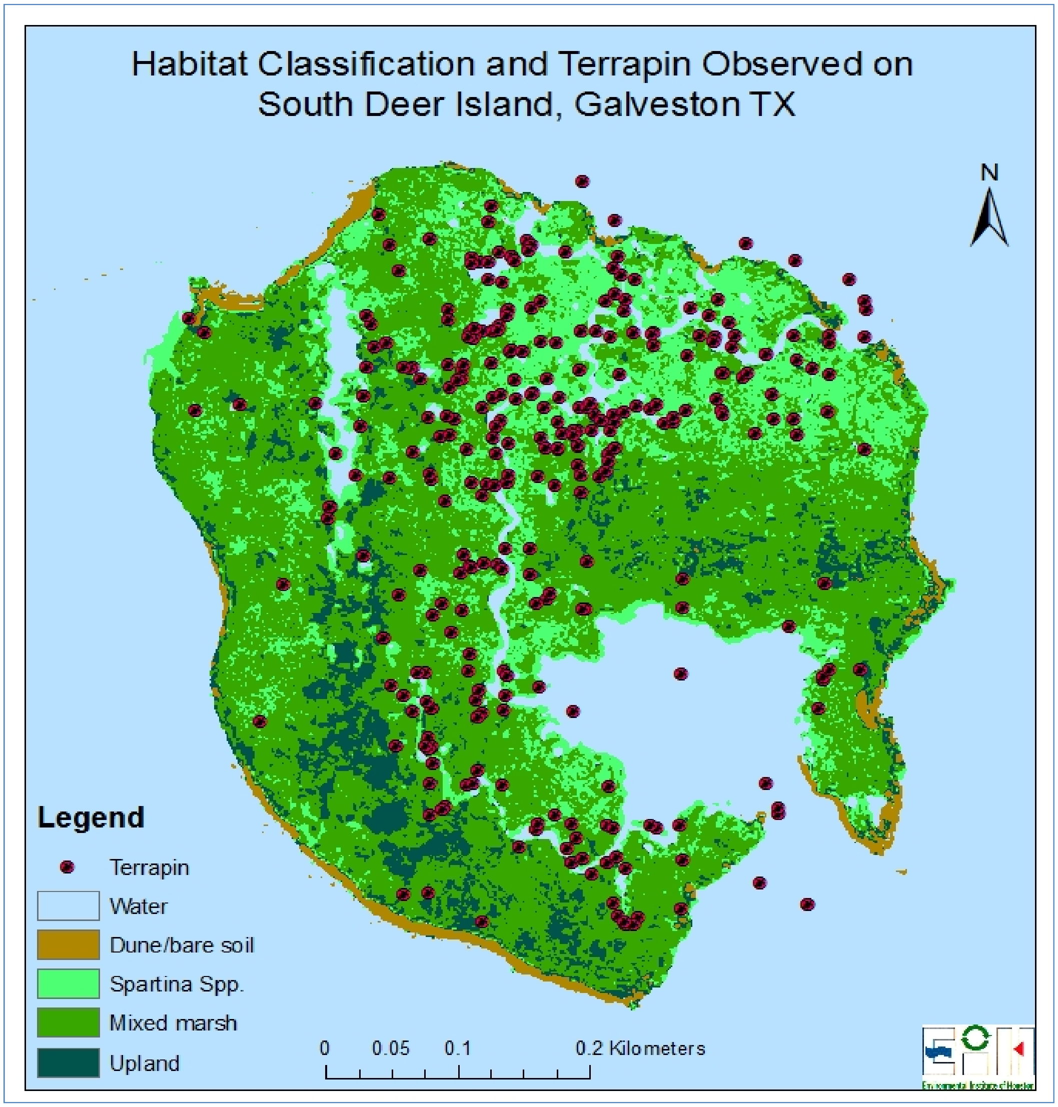

Figure 74. Habitat classification and terrapin captures on South Deer Island.

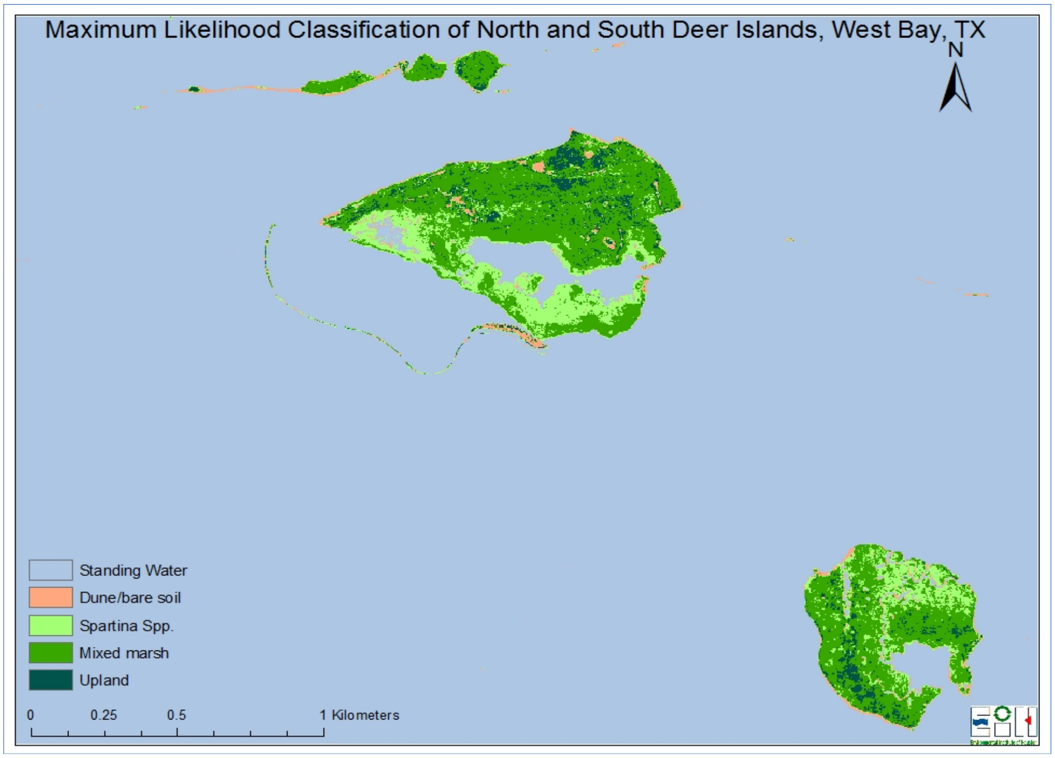

Figure 75. Maximum likelihood classification on North and South Deer Islands

Due in part to the lack of observations of nesting terrapin we will likely not be able to develop a definitive model based on any of the proposed metrics for the Gulf of Mexico or Texas Nesting Habitat Suitability model. Definitive evidence and documentation is needed before we can quantify the relationship of habitat variables and nesting and hatching success. Based on the very limited data collected by (Hogan 2003), it is very likely that the Atlantic model is totally inappropriate for large sections of Texas (Palmer and Cordes 1988). This is based on several observations including the presence of relatively large population of terrapin on South Deer Island, Aransas Bay, and Nueces Bay (Halbrook 2003; Haskett 2011; Koza 2006). These sites have a wide range of conditions but also contain shell hash islands that provide suitable elevation and isolation from predators. Future development of at HSI model for nesting or otherwise terrapin habitat in Texas should focus on these two attributes.

Future work for the GIS analysis of essential (e.g. nesting, foraging etc) terrapin habitats will also include the use of vegetation zoning, where different habitats can be found in different zones within the tidal frame – this requires high spatial topographical data (LIDAR data) and detailed tidal data and entails extensive ground-truthing. Future analysis may include the use of soft classification (fuzzy and/or linear mixture classifications) to reflect the mixed nature of these habitats.

Bycatch Study

Review of Literature on Effects of the Blue Crab Fishery on Terrapin Mortality

We conducted a thorough review of pertinent literature on the effects of the blue crab fishery on terrapin mortality in Texas. We did not find any literature on the effects of the Texas blue crab fishery on terrapin.

Review of Literature on BRD effectiveness and Blue Crab Catch Rates

We conducted a thorough review of pertinent literature on the effectiveness of BRD's and effects on blue crab catch rates in the commercial fishery. There does appear to be numerous articles that document the effectiveness of BRD's on reducing terrapin bycatch (Bishop 1983; Butler and Heinrich 2007; Coleman et al. 2011; Crowder et al. 2000; Cuevas et al. 2000; Dorcas et al. 2007; Grosse et al. 2011; Grosse et al. 2009; Guillory and Prejean 1998; Hart and Crowder 2011; Lukacovic et al. 2005; Mazzarella 1994; Morris et al. 2010; Morris et al. 2011; Rook et al. 2010; Roosenburg 2004; Roosenburg and Green 2000; Roosenburg et al. 1997; Wood 1997; Wood and Herlands 1995).

In the commercial blue crab trap fishery, circular 6.03 cm 'escape' rings are commonly used and have been found to minimize sublegal crab catches. Escape rings in crab traps are currently required in Florida, Louisiana, and Texas. These however are not effective at reducing bycatch of terrapin.

Incidental capture of diamondback terrapin (*Malaclemys terrapin*) in crab traps has been documented in Chesapeake Bay (Roosenburg et al. 1997), Georgia (Grosse et al. 2011) South Carolina (Bishop 1983; Dorcas et al. 2007), and Texas (Haskett 2011; Hogan 2003). The primary mechanism of mortality is through accidental drowning after capture, which is considered to be a major threat to terrapin populations ((Seigel and Gibbons 1995). However, multiple factors including pot design, distance from the shoreline, habitat, season, and overall terrapin capture rates will influence bycatch rates(Hart and Crowder 2011).

Bycatch reduction devices (BRDs) ranging in size from 4-5 cm (height) by 10-12 cm (width) have been found to be effective at reducing incidental catches of terrapin. Significant reductions in terrapin bycatch using BRDs in North Carolina have been reported (Hart and Crowder 2011). Similar reductions in terrapin bycatch have been reported in New Jersey and the Chesapeake Bay (Roosenburg and Green 2000; Wood 1997). BRD's have resulted in
a reported 73.2% reduction in terrapin bycatch in Florida (Butler and Heinrich 2004).
When BRDs where used in Virginia tidal marshes they were found to be highly effective in reducing the bycatch of terrapin and finfish. (Morris et al. 2011).
(Coleman et al. 2011)reported a 90% reduction in terrapin bycatch in traps deployed adjacent to Alabama salt marshes.

Studies of BRDs have shown varying effects on catch rates of blue crab. Some studies found little or no effect on legal blue crab catch rates or size of crabs caught and in some cases reported reductions in terrapin bycatch (Cuevas et al. 2000; Morris et al. 2010; Rook et al. 2010).

However, in some studies the investigators reported increases in legal-sized crab catch (Guillory and Prejean 1998), (Wood 1997). While only a very few studies reported reductions in legal-size crab catch rates (Hart and Crowder 2011).

Most recently testing of BRD's was conducted in Nueces Bay by (Baxter 2013). Their study was performed in the Nueces Estuary, TX from September 2012 through December 2012 and March 2013 through August 2013. Twenty four crab traps (12 experimental, 12 control) were used to capture Texas diamondback terrapins and blue crabs for three consecutive days each month that sampling occurred. The BRD used measured 1.75 in (4.5 cm) x 4.75 in (12 cm). This is identical to the large size BRD used during our study. Catch rates for Texas diamondback terrapins and blue crabs were compared between the two trap types.

Their results showed that the tested BRDs were highly effective in excluding Texas diamondback terrapins from crab traps (Baxter 2013). Twenty three diamondback terrapins were captured in control traps, whereas none were caught in traps equipped with BRDs. Overall, their control traps (n = 472) captured more blue crabs than experimental traps (n = 426). When sublegal crabs were excluded from the analysis, the control traps (n = 381) and experimental traps (n = 380) exhibited equivalent catch blue crab catch rates. For all captured blue crabs, there was no significant difference (p = .754) in mean carapace width between the two trap types. Mean carapace width was significantly different between trap types (p = .002) for blue crabs ≥127 mm. This significance is represented by a difference in mean carapace width of 4 mm between control and experimental traps. For larger blue crabs (≥152 mm) there was no significant difference (p = .514) in mean carapace width between control and experimental traps. Results of their study suggest that BRDs reduced bycatch rates of terrapin without substantially affecting the catch rates of legal crabs.

Review of the TPWD Derelict Blue Crab Trap Database

Each year since 2002, during the month of February the TPWD has sponsored a derelict blue crab trap pickup across the Texas coast (Morris 2003). Data is collected by volunteers on the presence of bycatch organisms. This database is maintained by Art Morriss of TPWD. All past data was provided to us to determine the rate of terrapin occurrence (both live and dead remains) in collected traps. It should be noted that this data source is biased by only providing information on recent bycatch of terrapin since older remains would mostly likely decompose rapidly or be scavenged. Based on our review of their database it appears that reported bycatch rates have been relatively low since 2005 (Table 5).

Table 5. Summary of terrapin bycatch associated with abandoned traps compiled by the annual TPWD abandoned crab trap removal program.

Diamond-backed terrapins observed during TPWD Abandoned Crab Trap Removal Program 2002-2013					
Year	Live	Dead	Total	Bay	Comments
2002	2		2	Sabine Lake	Observed in trap study
2003	1		1	Sabine Lake	Observed in trap study
2005		22	22	Gaveston Bay	Observed during trap removal - 20 found in 2 traps
2006		4	4	East Galveston Bay	Observed during trap removal - all found in 1 trap
2008		1	1	San Antonio Bay	Observed during trap removal
2009		1	1	Galveston Bay	Observed during trap removal
2011		1	1	Galveston Bay	Observed during trap removal
2013		1	1	Lavaca River	Observed during trap removal - Cason and Hartl

Specific documentation regarding the impacts of derelict crab traps was also provided by the USFWS staff of the Texas Chenier Plain Refuge Complex who participated in the TPWD statewide effort to remove abandoned crab traps from tidal waters(Valdez 2005). They reported an incident that was also documented in the TPWD database. They report that back in from February 18 to 27, 2005 eleven USFWS staff members and 9 volunteers from Anahuac NWR removed 265 traps from Galveston Bay waters, and that the Refuge Manager Bossert and a volunteer removed 23 traps from tidal waters on Texas Point NWR. During this period they discovered 20 dead Texas Diamondback terrapins in just three traps located in shallow tidal streams and flats connecting to East Bay just south of the Anahuac NWR. These traps were relatively close together, and another trap found in East Bay contained a single dead terrapin.

Field BRD Study Results: Physicochemical Data

Water temperature followed expected seasonal patterns (Figure 76). Significant differences in water temperature were detected between months and sites (Figure 77). The November Trinity Bay and March Greens Lake collections experienced the lowest water temperatures, while Greens Lake and Bolivar sites exhibited the highest values during the summer months.

Salinity ranged between 14 and 42 psu during the study period (Figure 78). The lowest and highest salinity values observed occurred at the Bolivar site in July and the Greens Lake site in April respectively. Significant differences in salinity were observed between collections with the lowest values occurring at Bolivar during July, and the highest values at South Dear during April and Greens Lake during April and May (Figure 79).

Secchi disk transparency ranged between 0.1 and 0.6 meters during the study period (Figure 80). The majority of the median readings ranged from 0.2 to 0.35, however the mean transparency level at the Greens Lake March collection was significantly higher than most other sites, with the exception of Bolivar June, Greens Lake March and April, and South Deer April collections (Figure 81). Trap deployment depths were examined between sites. Depth of deployment was generally shallowest at the South Deer site and collection periods, whereas the remaining sites showed considerable overlap (Figures 82 and 83).

Field BRD Study Results: Effects on Blue Crab Catch Rates

Overall median and mean catch rates of blue crabs did not vary much between traps lacking or possessing either small or large BRDs (Figure 84 and 85). Although there did appear to be a slight decline in catch rates with large and smaller BRD traps, this was not statistically significant. Due to possible interactions in gear, sites and seasonal patterns of blue crab catch rates we also examined trends in blue crab catch rates individually for each site.

Although median and mean catch rates of blue crabs varied seasonally at the Bolivar site there did not appear to be any statistical difference in catch rates between BRD treatment levels within monthly collections (Figure 86 and 87). Lowest catch rates occurred during April and June versus July and September 2012. This pattern in catch rates most likely reflects seasonal patterns in blue crab abundance and availability.

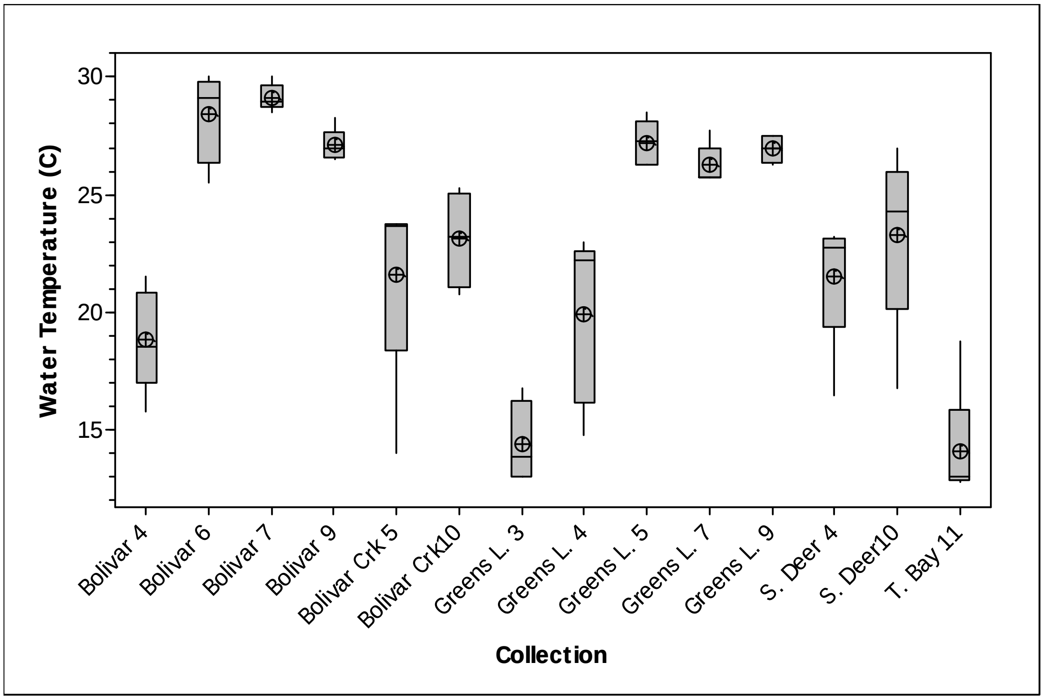

Figure 76. Boxplot of daily average water temperature recorded during at each bycatch sampling event at each site. ⊕ = mean value.

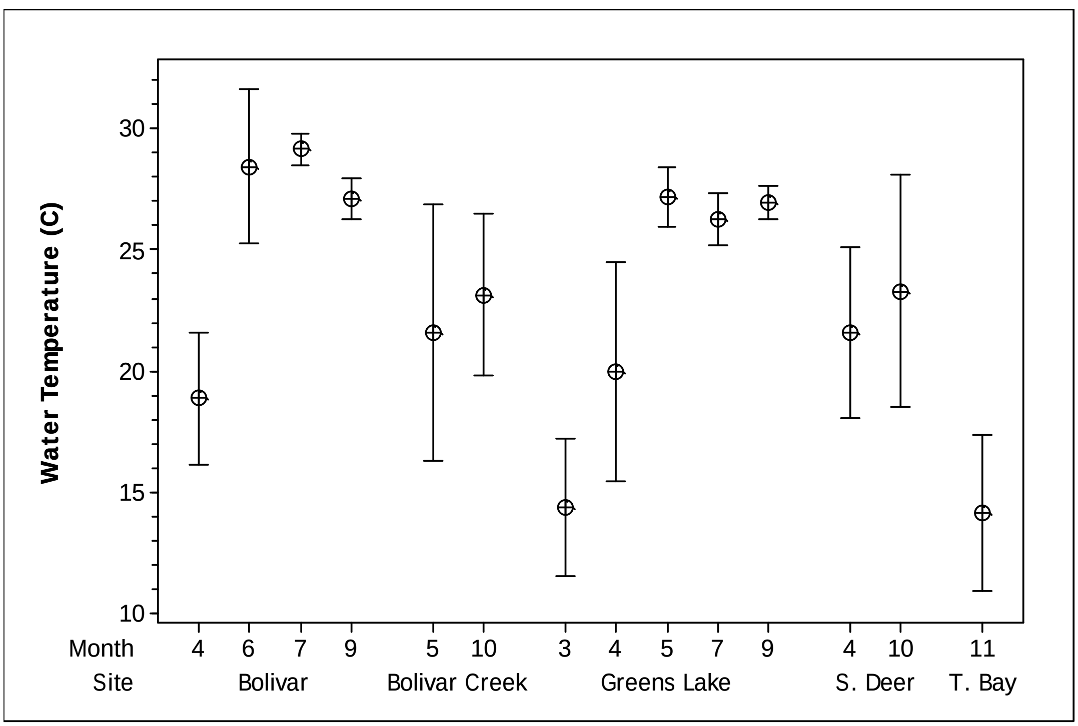

Figure 77. Confidence interval (95%) of the mean temperature for each collection (site and month). Collections with overlapping confidence intervals were not significantly different (ANOVA and Tukey's test $p < 0.05$).

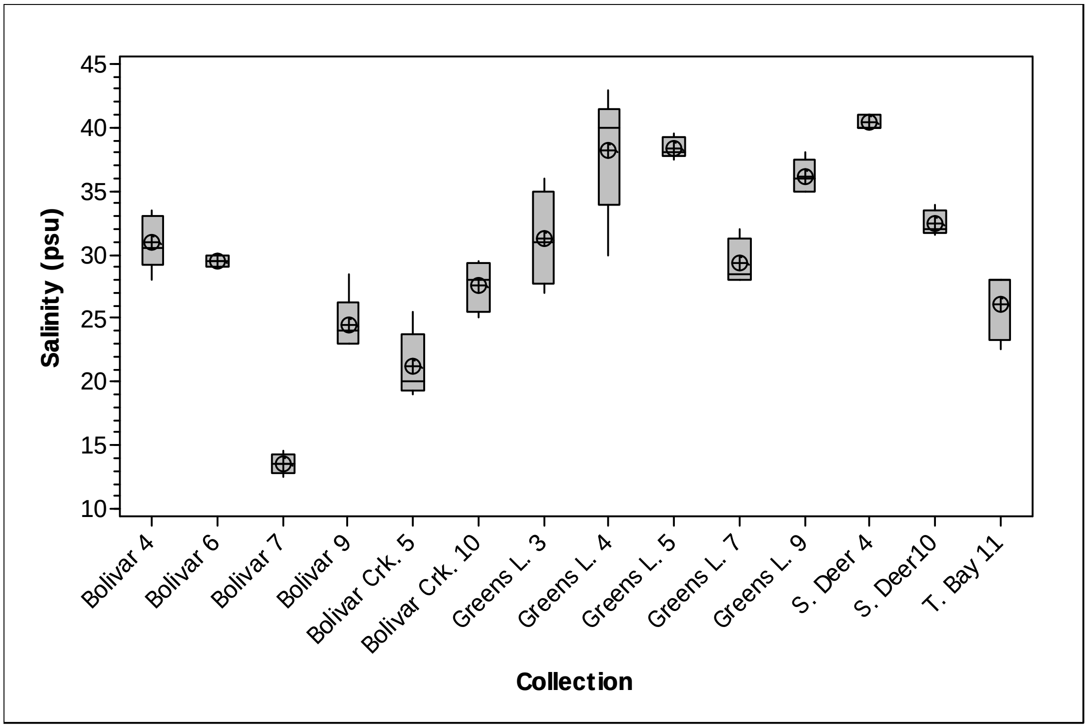

Figure 78. Boxplot of daily average salinity recorded at each bycatch sampling event at each site. ⊕ = mean value.

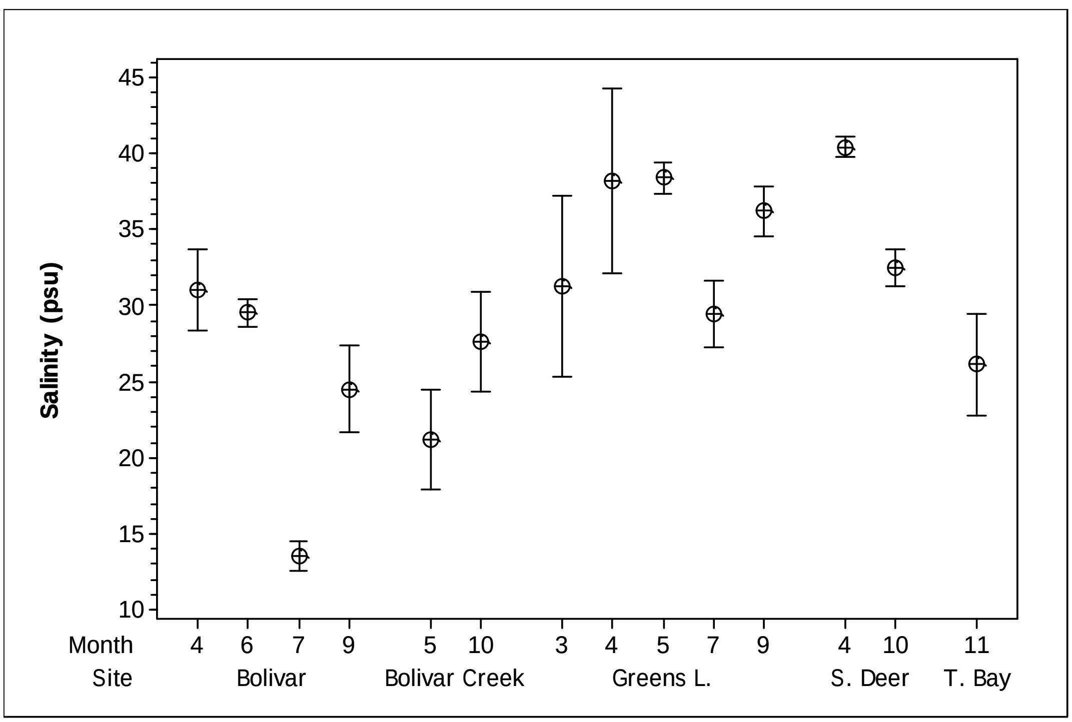

Figure 79. Confidence interval (95%) of mean salinity by collection (site and month). Collections with overlapping confidence intervals were not significantly different (ANOVA and Tukey's multiple range test $p < 0.05$).

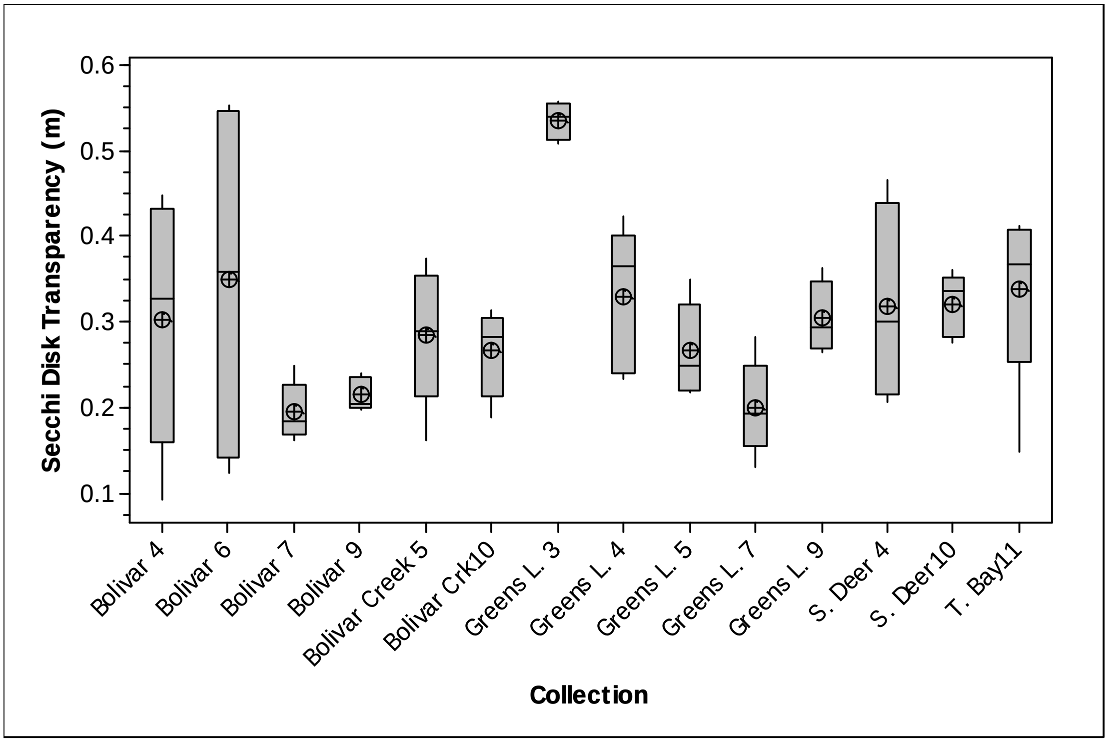

Figure 80. Boxplot of daily average Secchi disk transparency recorded during at each bycatch sampling event at each site. ⊕ = mean value.

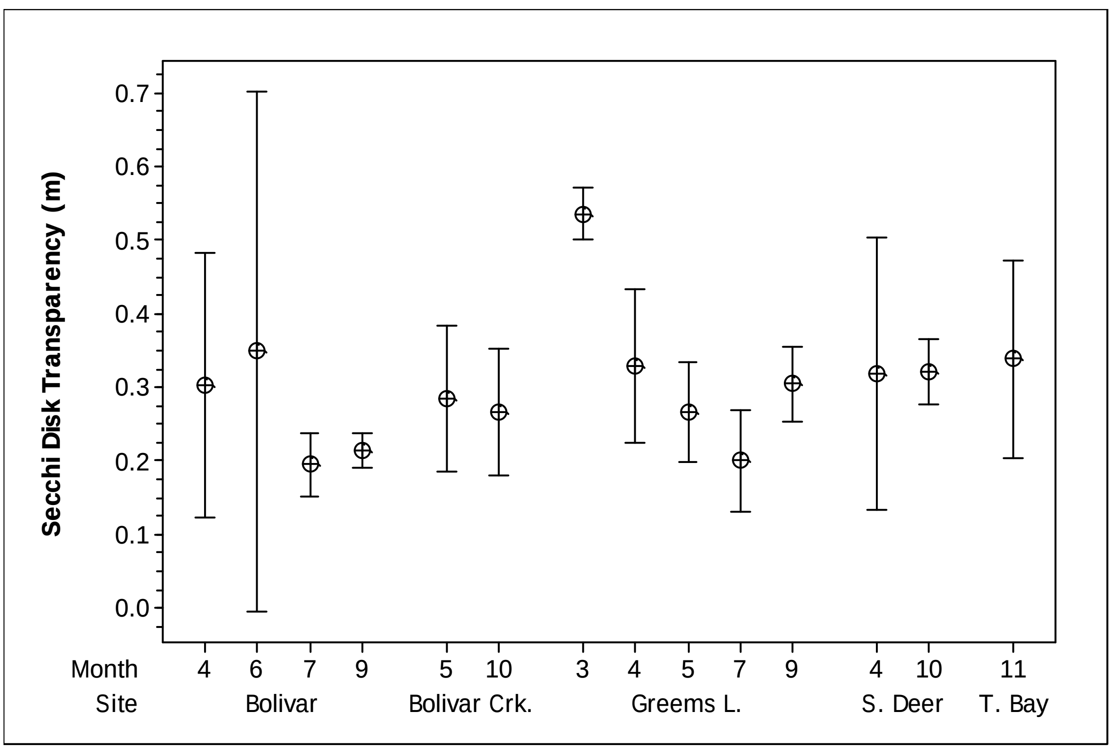

Figure 81. Confidence interval (95%) of the mean Secchi disk transparency by bycatch collection (site and month). In general collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$).

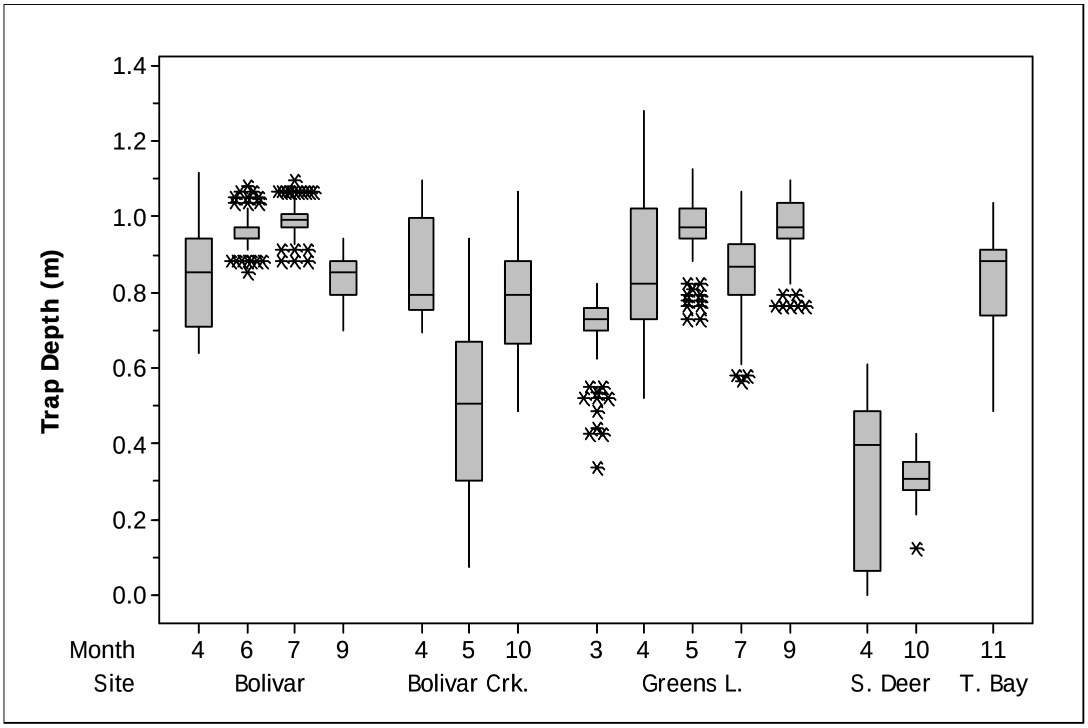

Figure 82. Boxplot of trap depth recorded during at each bycatch sampling event at each site.

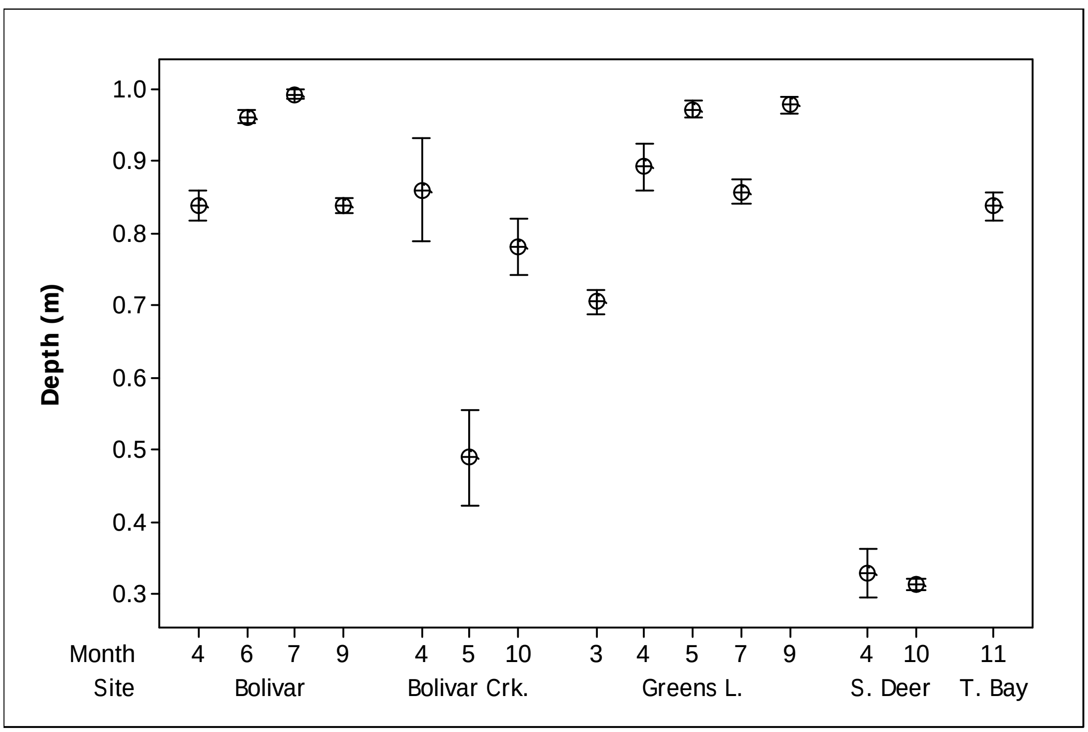

Figure 83. Confidence interval (95%) of the mean trap depth calculated for bycatch sampling events at each site and month.

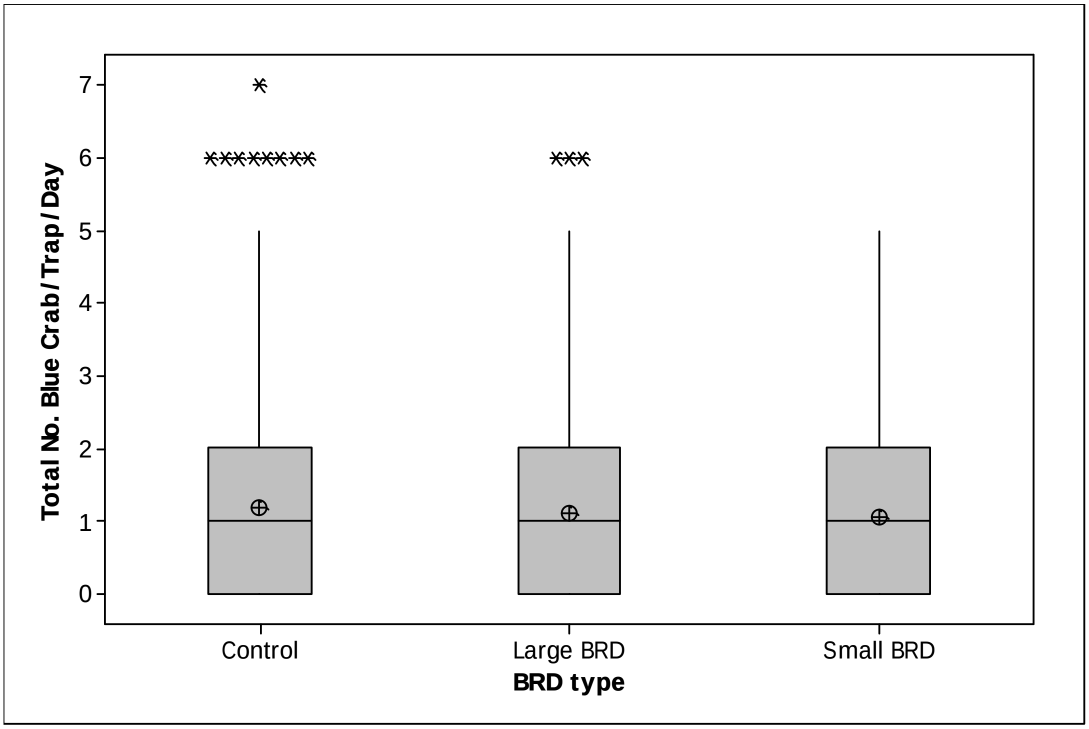

Figure 84. Boxplot of blue crab catch rates in experimental traps equipped with and without small and large BRDs during the study period. ⊕ = mean value.

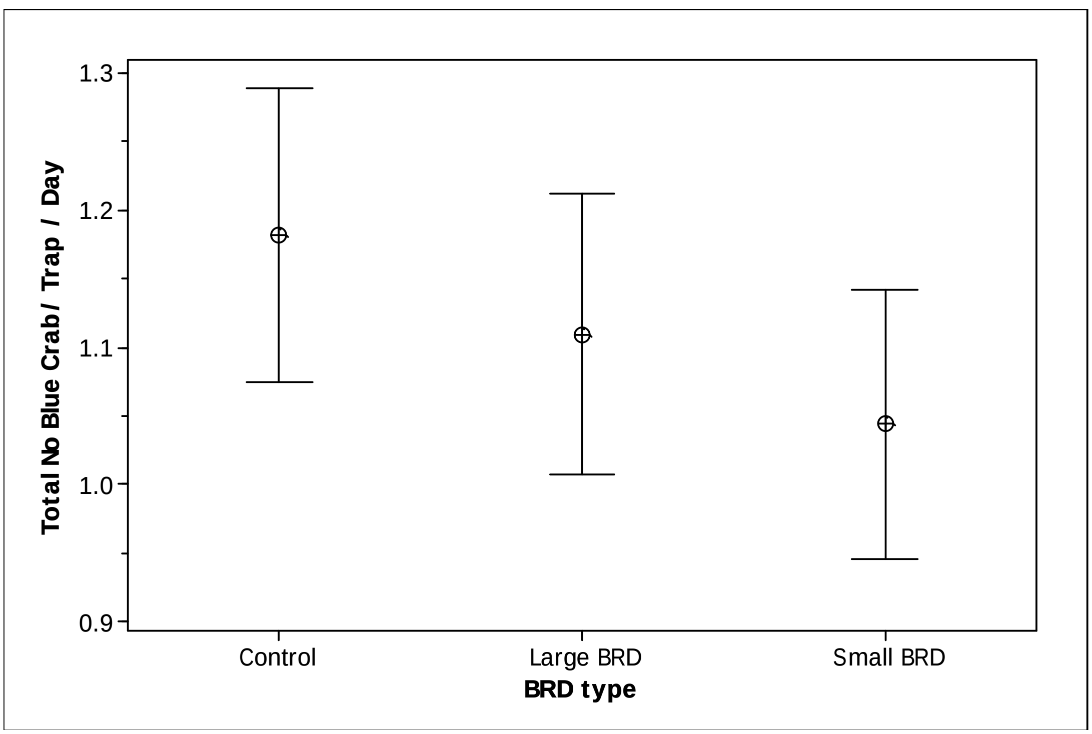

Figure 85. Confidence interval (95%) of the mean salinity by bycatch collection (site and month). Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$).

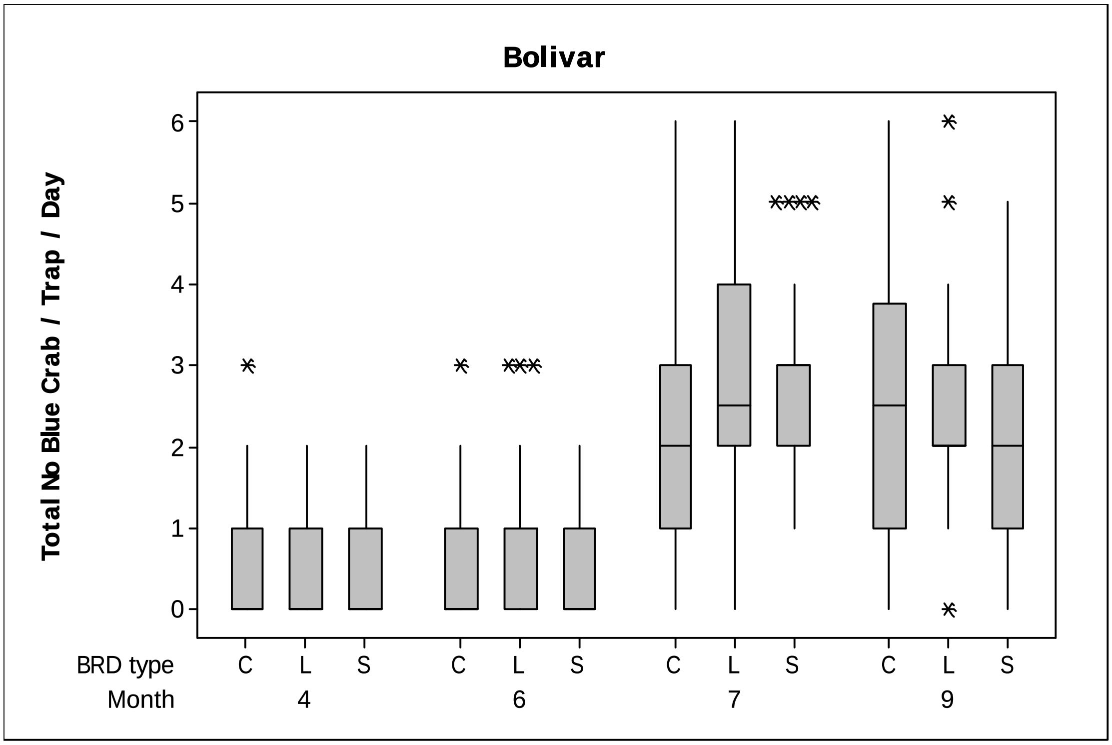

Figure 86. Boxplot of blue crab daily trap catch rates observed at the Bolivar site (C = control; L = large BRD; S = small BRD).

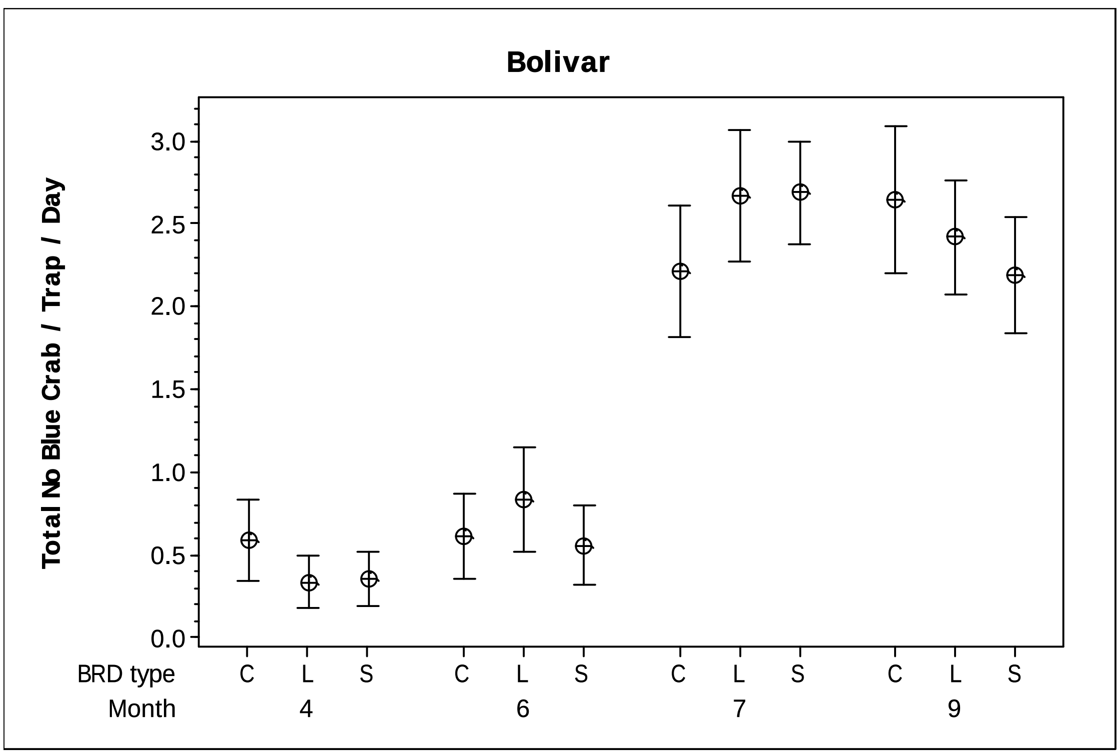

Figure 87. Confidence interval (95%) of the mean blue crab daily trap catch rates at the Bolivar site (C = control; L= large BRD; S = small BRD). Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$).

Similar to the Bolivar site, median and mean catch rates of blue crabs varied seasonally at the Bolivar Creek (Figure 88 and 89). Statistically significant ($p < 0.01$) highest mean catch rates occurred across all BRD types during October trapping. There was no consistent statistical difference between BRD treatment levels. This pattern in catch rates most likely reflects seasonal patterns in blue crab abundance and availability.

Blue crab catch rates at the Greens Lake site varied statistically between months and BRD treatment types (Figure 90 and 91). Average catch rates (0.9653 crabs/traps/day) in control traps were significantly higher than traps with small BRDs (0.6597 crabs/traps/day) (Tukeys test $p<0.05$). Monthly highest catch rates occurred during July at all sites, and September catch rates were significantly higher than March levels (Tukeys test <0.05).

Median and mean catch rates of blue crabs varied seasonally at the South Deer site (Figure 92 and 93). Statistically significant ($p < 0.05$) highest mean catch rates occurred across all BRD types during October trapping. There was no consistent statistically significant difference between BRD treatment levels. Blue crab catch rates at South Deer most likely reflect seasonal patterns in blue crab abundance and activity.

BRD testing was conducted only once during the study period at the Trinity site. Unlike the other sites we used otherwise standard unaltered commercial crab traps versus the modified traps containing the escape chamber used at other sites. During November we failed to document any statistically significant difference between BRD treatment levels (Figure 94 and 95). Blue crab catch rates at the Trinity site were generally low (1 crab/trap/day).

Field Study Results: BRD Effects on Captured Blue Crab Size

We also evaluated the influence of BRD size on captured blue crab sizes. Crabs that are legally harvestable size (>127 mm CW) were tallied and compared between traps similar to overall catch rates reported earlier. In addition, we report the sizes of crabs captured. Overall the size of blue captured in traps without BRDs yielded significantly larger crabs (ANOVA and Tukeys multiple range test; $p<0.01$) (Figure 96 and 97). The majority of crabs captured by all methods were however larger than the legal harvestable size. A total of 73% of the crabs harvested in traps with no BRDs were above the legal harvestable length of 127 mm (Figure 98 and 99). In contrast, only 63% of the crabs captured in the traps with BRDs (either size) were above the size limit. This represents a 10% decline in the number legally captured crabs. In summary, it appears that both BRDs reduced the average size of captured crabs and resulted in a higher proportion of under sized crabs that cannot be legally harvested.

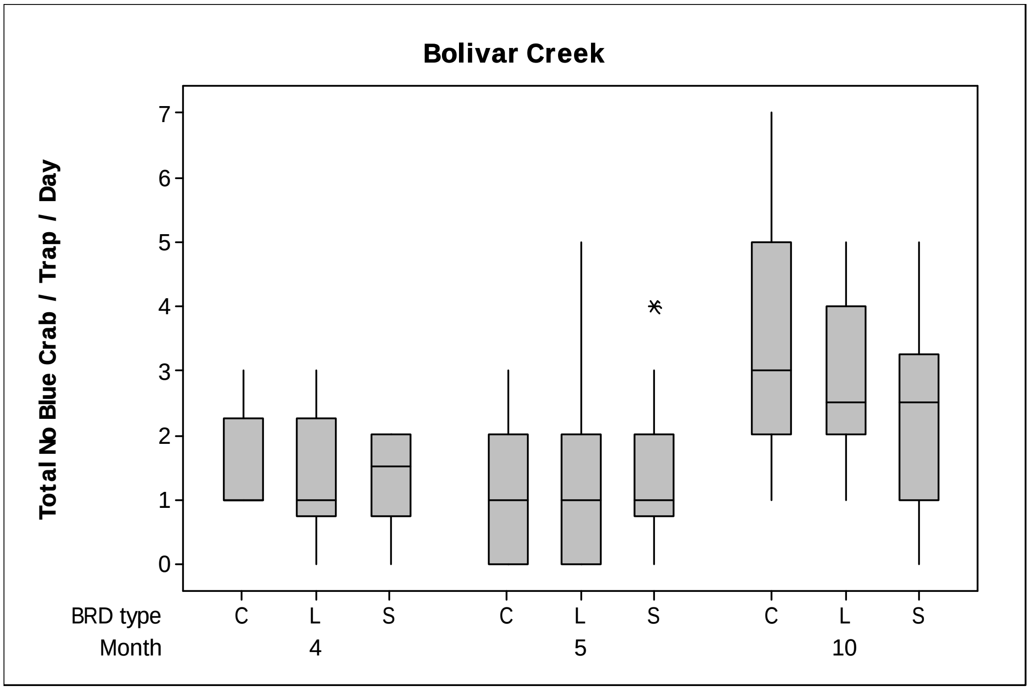

Figure 88. Boxplot of blue crab daily trap catch rates observed at the Bolivar Creek site (C = control; L = large BRD; S = small BRD).

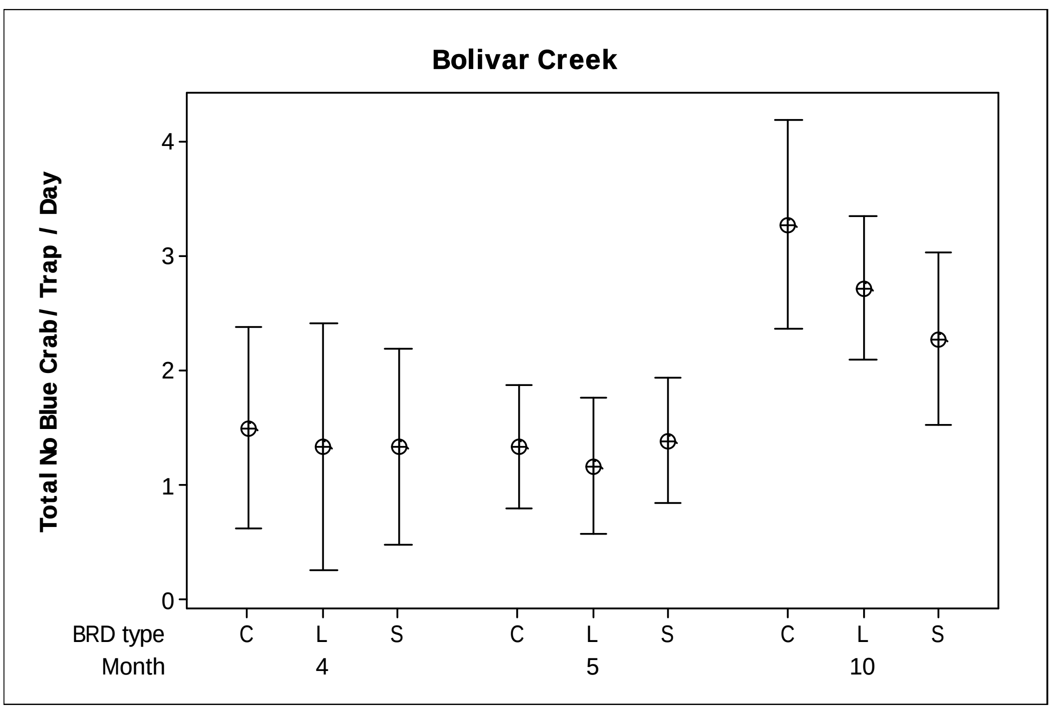

Figure 89. Confidence interval (95%) of the mean blue crab daily trap catch rates at the Bolivar Creek site (C = control; L= large BRD; S = small BRD). Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$).

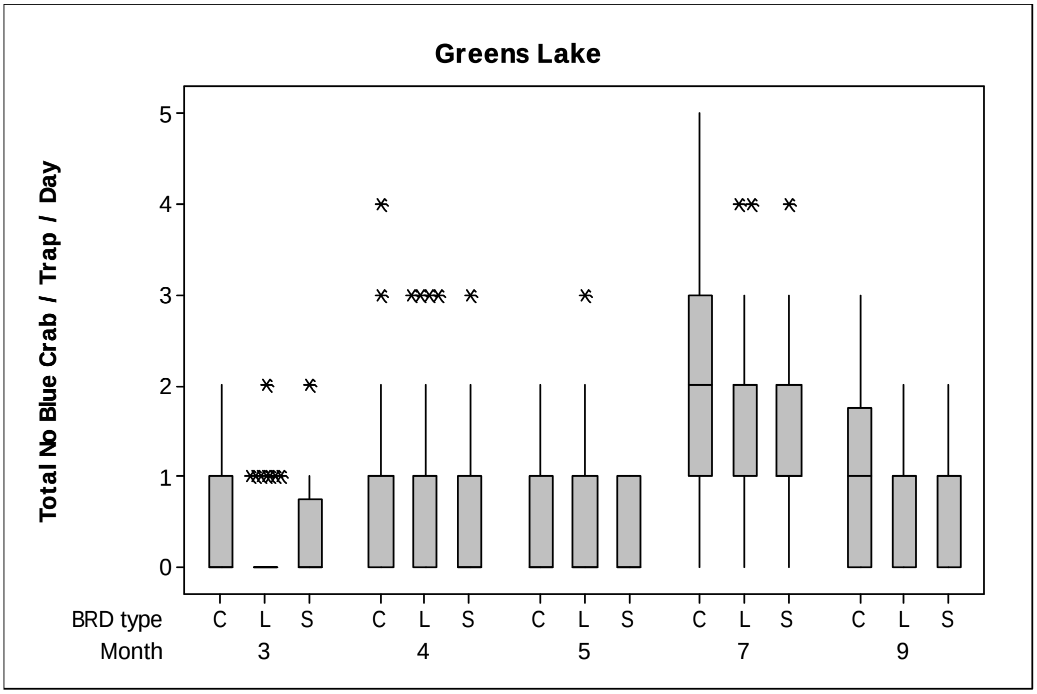

Figure 90. Boxplot of blue crab daily trap catch rates observed at the Greens Lake site (C = control; L = large BRD; S = small BRD).

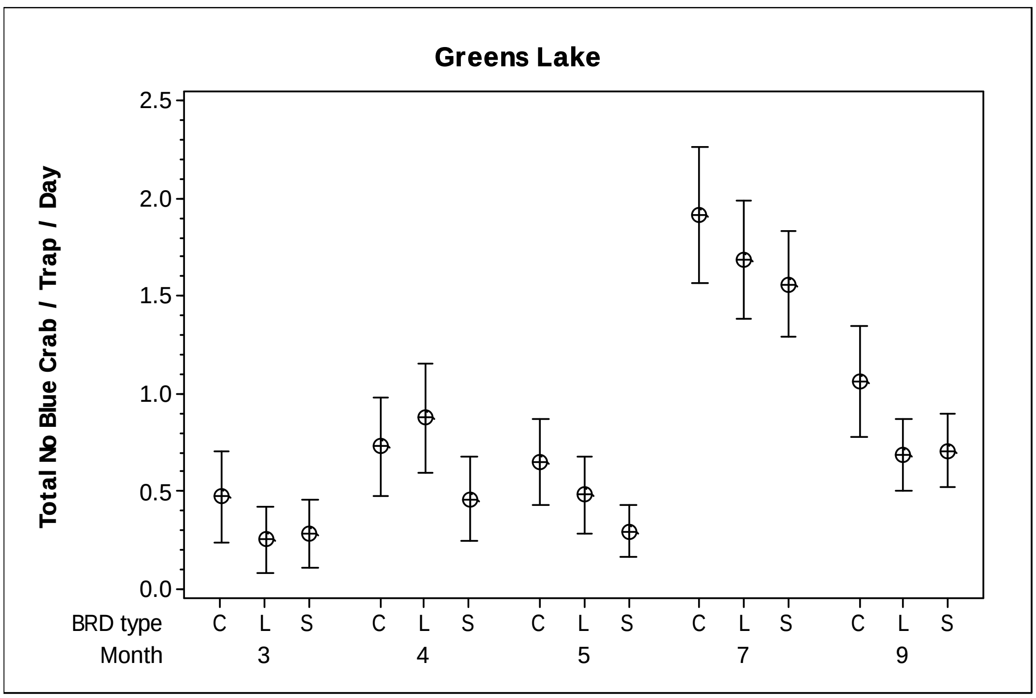

Figure 91. Confidence interval (95%) of the mean blue crab daily trap catch rates at the Greens Lake site (C = control; L= large BRD; S = small BRD).). Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test p < 0.05).

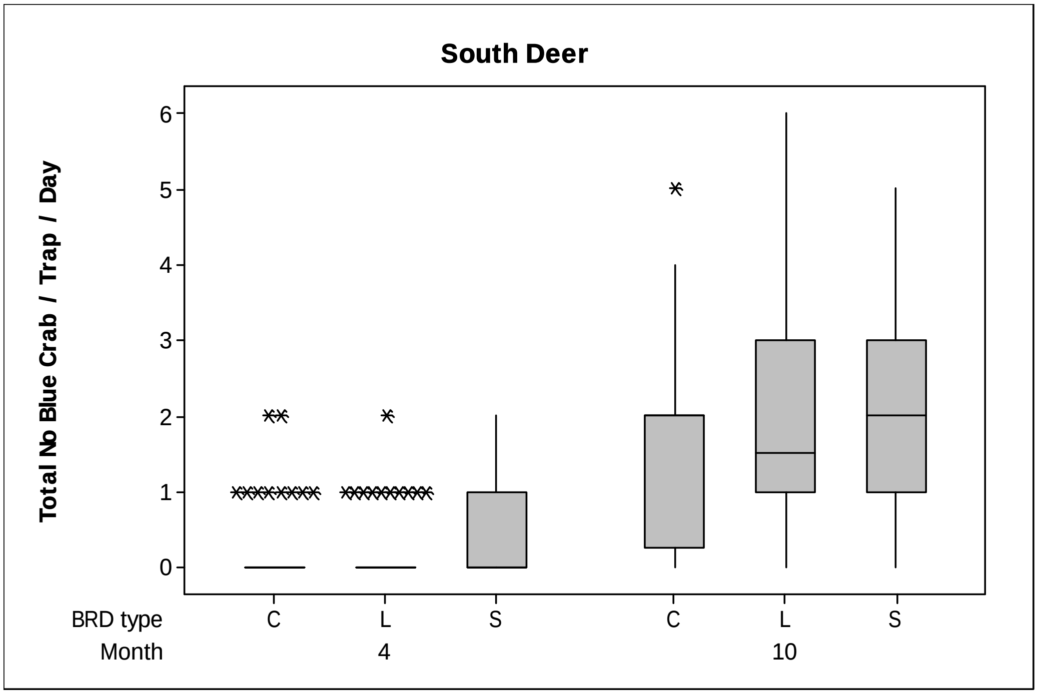

Figure 92. Boxplot of blue crab daily trap catch rates observed at the South Deer site (C = control; L = large BRD; S = small BRD).

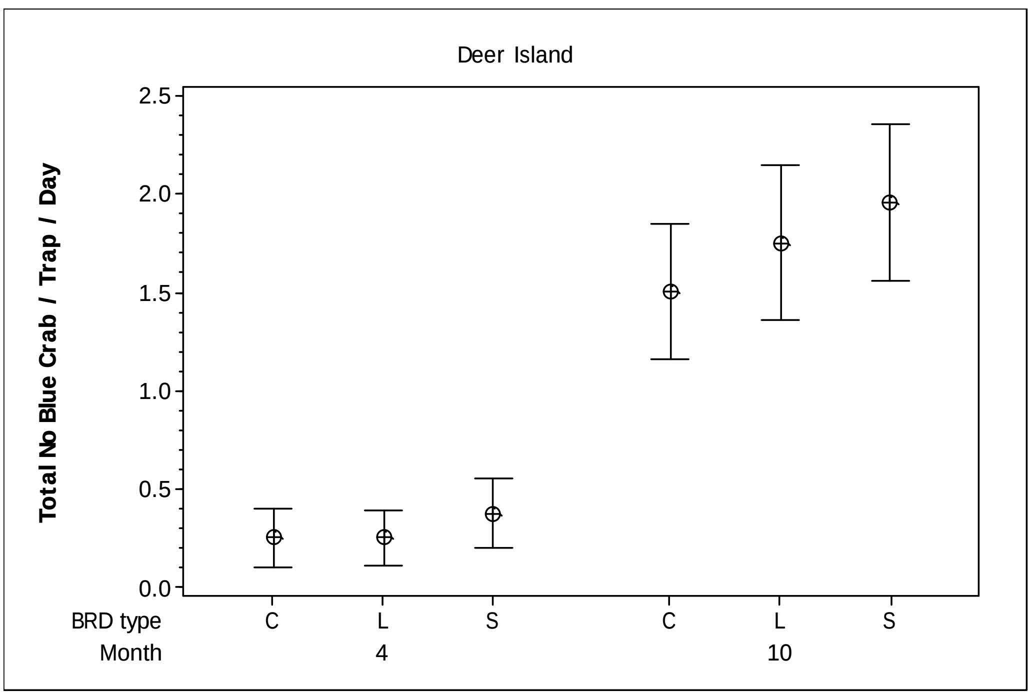

Figure 93. Confidence interval (95%) of the mean blue crab daily trap catch rates at the Deer Park site (C = control; L= large BRD; S = small BRD). Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$).

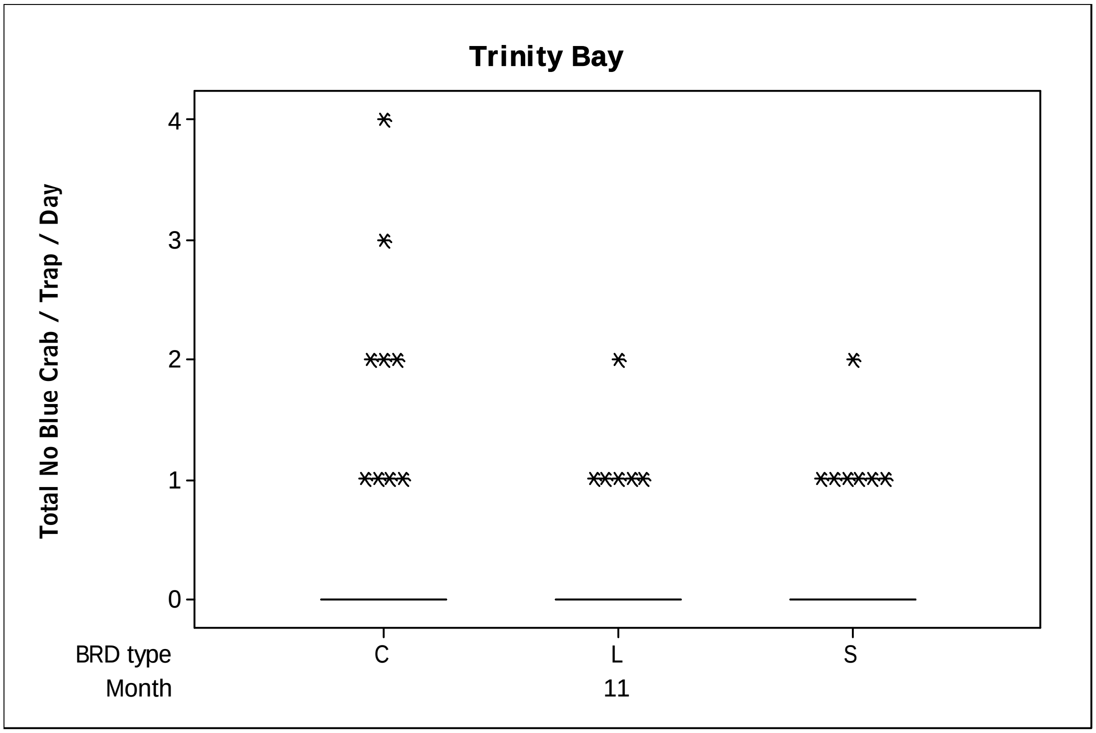

Figure 94. Boxplot of blue crab daily trap catch rates observed at the Trinity Bay site (C = control; L = large BRD; S = small BRD).

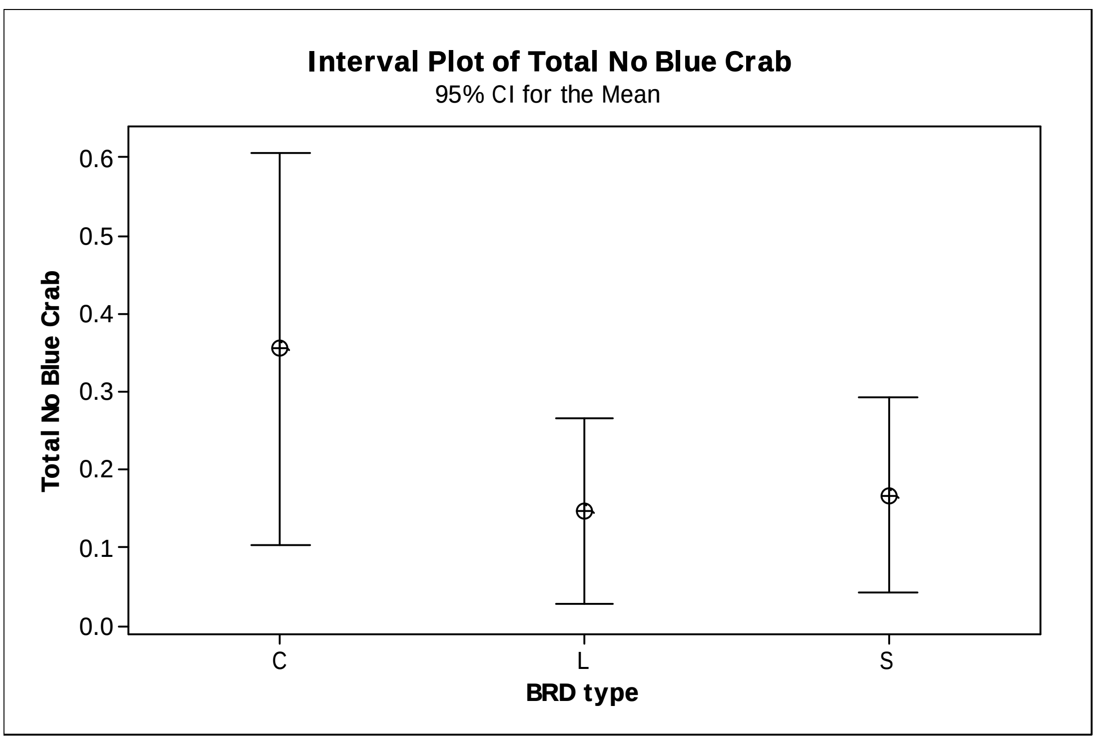

Figure 95. Confidence interval (95%) of the mean blue crab daily trap catch rates at the Trinity Bay site (C = control; L= large BRD; S = small BRD).. Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$).

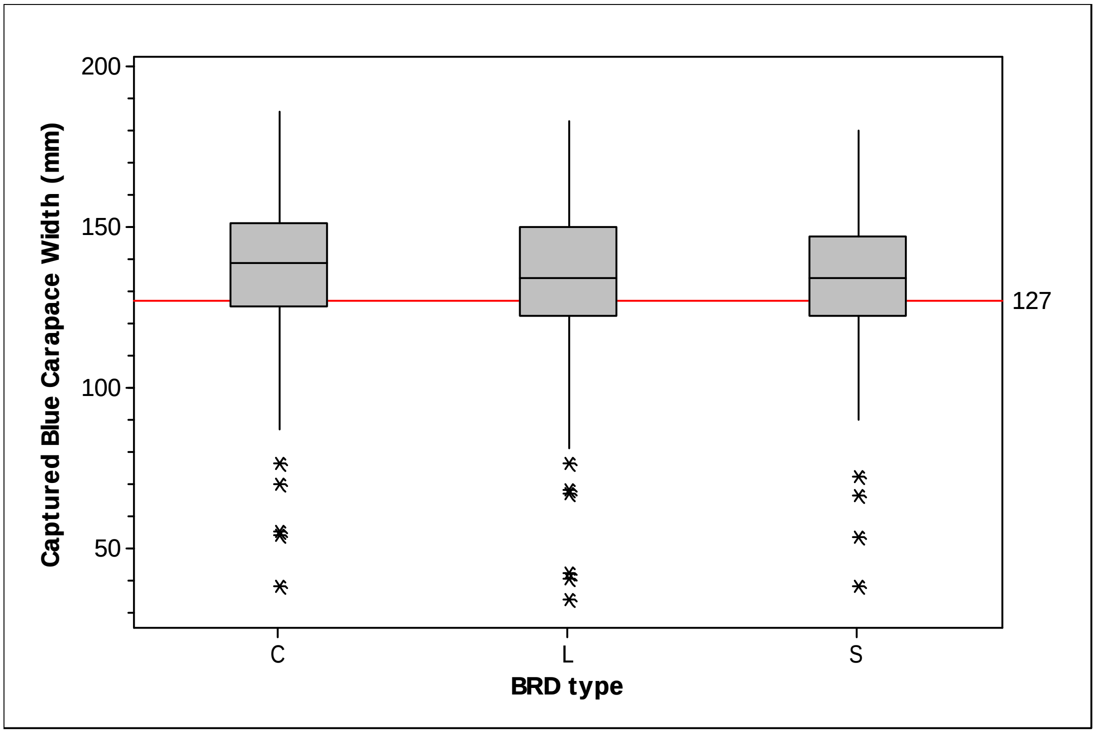

Figure 96. Boxplot of blue crab carapace width collected with three levels of BRD installed (C = control; L = large BRD; S = small BRD) from all sites. The Texas commercial legal minimum size limit for blue crabs is shown on the figure.

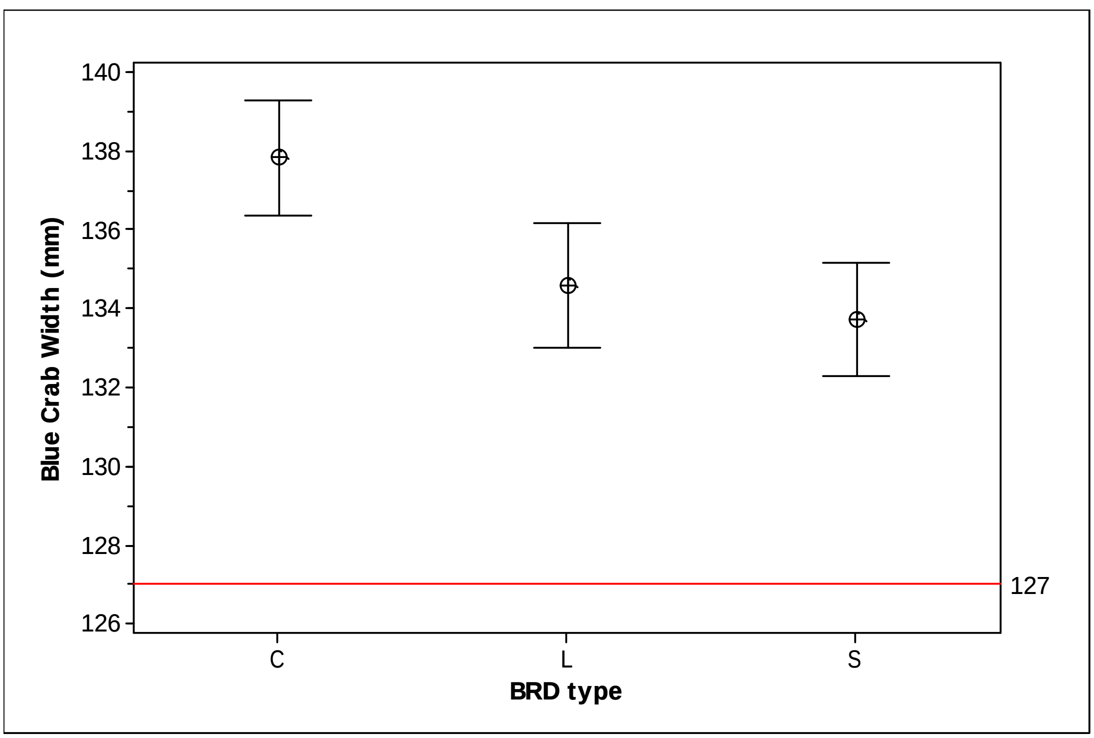

Figure 97. Confidence interval (95%) of the mean blue crab size. Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$). (C = control; L = large BRD; S = small BRD)

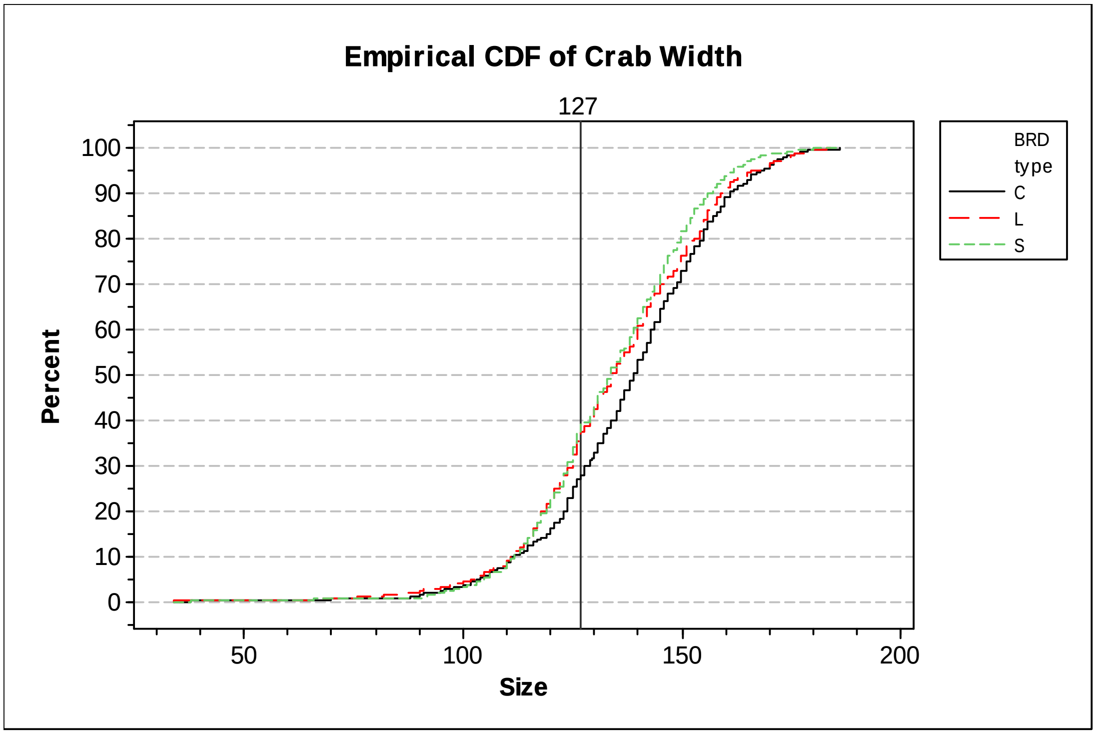

Figure 98. Empirical cumulative distribution of blue crab size versus BRD utilized in experimental traps during the study period. Legal harvest size for blue crab depicted at 127 mm CW. (C = control; L = large BRD; S = small BRD)

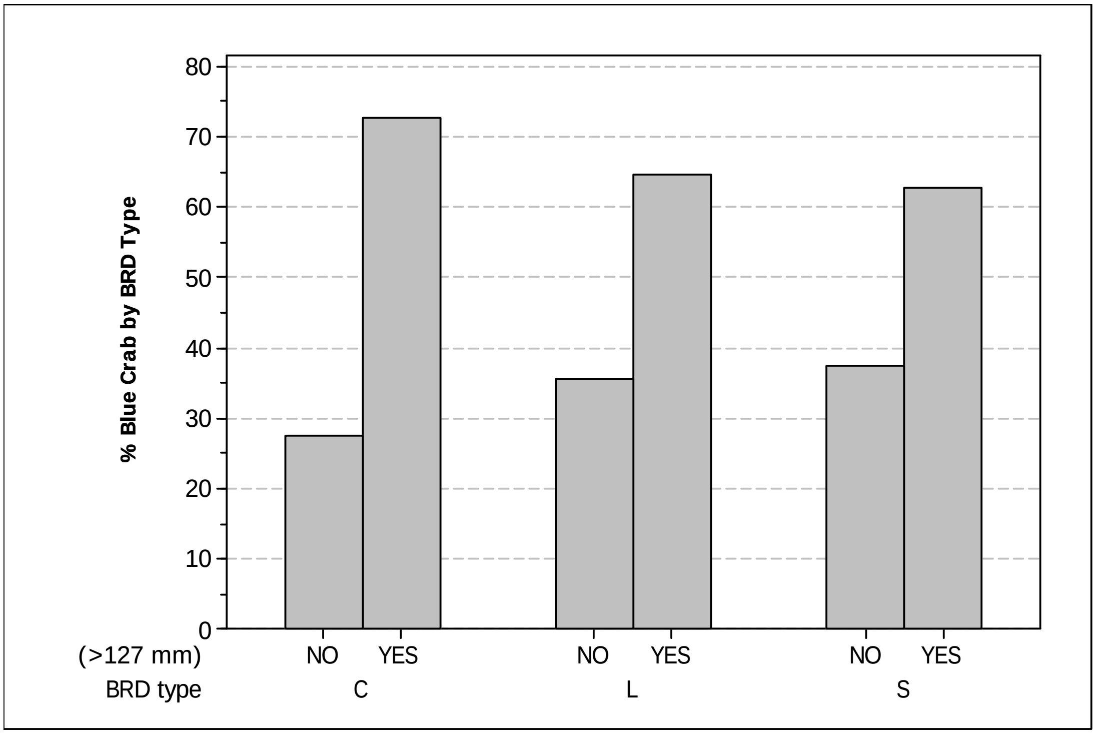

Figure 99. Percentage of crab above and below the legal size limit by BRD type. Data is pooled from all sites. (C = control; L = large BRD; S = small BRD)

Field Study Results: BRD Effects on Numbers of Terrapin Captured

A total of 36 terrapin were captured during 1782 individual daily trap events throughout the study period (Figure 100). Some of these were captured more than one time resulting in 45 total occurrences. Unless noted, we removed subsequent captures from our analysis of catch data. The majority of terrapin were captured at the Deer Park site during April 2012 (Figure 101). Terrapin were seldom captured at the Bolivar Creek and never captured at any of the other sites including Greens Lake and Bolivar where terrapin have been observed in the past. Terrapin were never captured in traps equipped with the small BRD. We examined patterns in terrapin capture rates at sites known to have terrapin which included the Bolivar Peninsula, Deer Island and Greens Lake. Analysis of this subset of data revealed statistically significant ($p < 0.05$) difference in catch rates between sites and BRD type and interactions between both factors (Figure 102). In general the highest mean daily catch rates occurred at the Deer Island site (0.11 terrapin / trap / day) and were significantly higher when compared to all other sites. Overall control traps yielded the highest statistically significant (0.08 terrapin/trap/day) catch rates. However, since there was significant interaction between sites and trap types we analyzed trends in catch rates by “collections”, which was a combined classification variable defined as site and BRD groupings (e.g. Deer Island Control, Deer Island Small BRD, and Deer Island Large BRD). When reanalyzed using collections as the classification variable, we found that only the South Deer Island control sites exhibited significantly ($p < 0.05$) higher (0.3021 terrapin/trap/day) catch rates. As previously mentioned terrapin were not captured in traps equipped with the small BRD.

Field Study Results: BRD Effects on Size of Terrapin Captured

We measured the size selectivity of BRD equipped pots by comparison of several morphometric measures including carapace length, width, depth, and approximate surface area and body volume. We included data from recaptures of terrapin as well (n=45). Since terrapin were not captured in any cages where small BRD were utilized our comparisons are limited to comparisons of traps without a BRD and those with the large style BRD. A t-test was used to test differences in terrapin size between trap BRD treatment levels using pooled Deer Island and Bolivar Creek terrapin captures. Carapace length of terrapins captured in traps without a BRD, were significantly ($p < 0.05$) larger than those in traps with a large BRD (means size 135.5 vs. 126.3 mm) (Figure 104). Similarly, although barely insignificant ($p = 0.054$) carapace width of terrapins captured in traps without a BRD exhibited higher mean sizes (mean size 97.43 vs. 93.38) in comparison to traps equipped with a large BRD (Figure 105). Carapace depth of terrapins captured in traps without a BRD, were significantly ($p < 0.01$) larger than those in traps with a large BRD (means depth 50.57 vs. 48.25 mm)(Figure 106). Both estimated volume and surface are of terrapin were significantly ($p < 0.01$) larger in specimens captured in traps without a BRD versus those with a large BRD (Figure 107 and 108). These results support the hypothesis that BRD use does reduce the capture of larger terrapin.

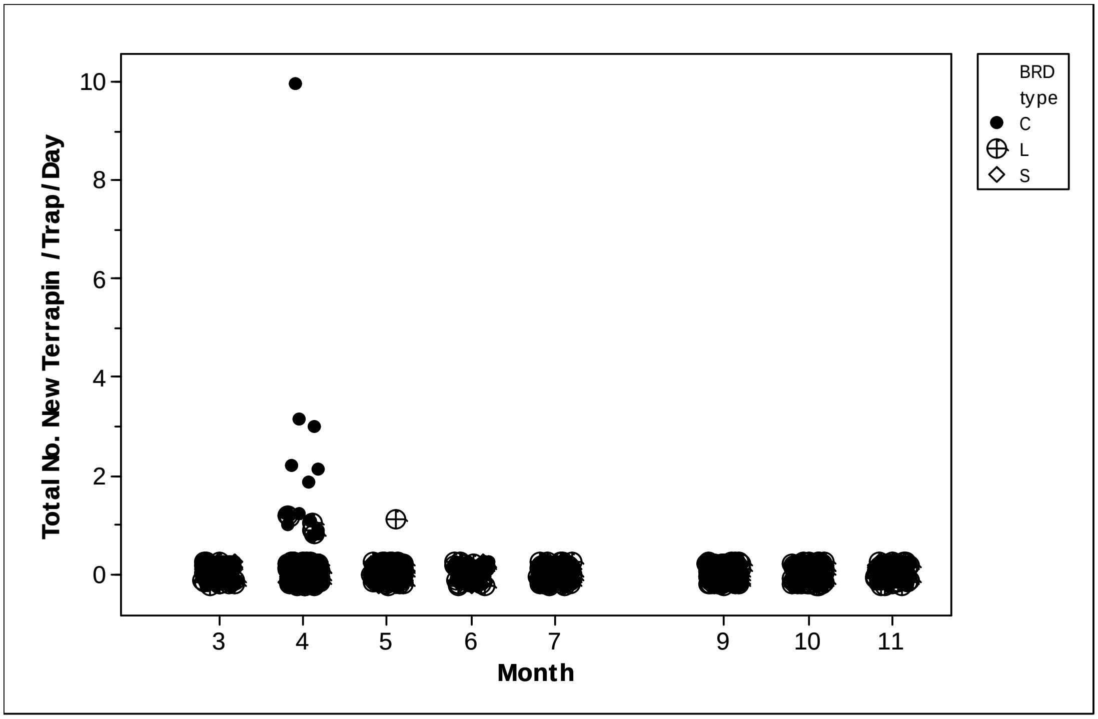

Figure 100. Total number of new terrapin captures (unique individuals/trap/day) captured by month and BRD type at all sites combined (C = control; L=large BRD; S = small BRD).

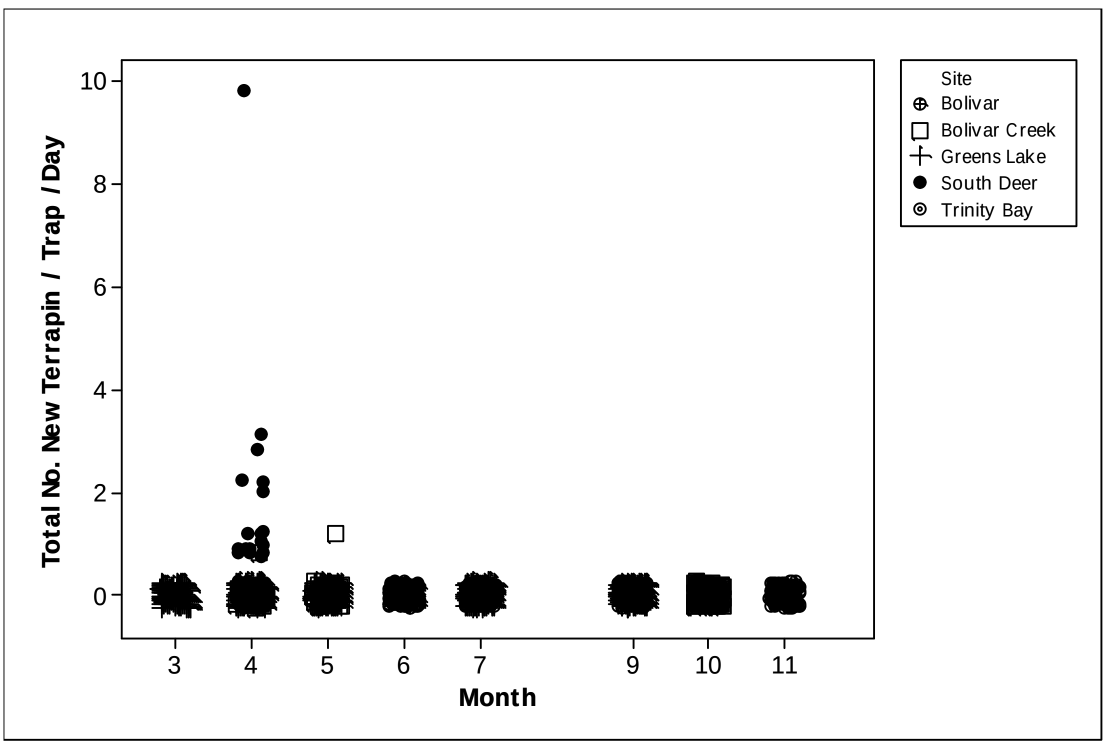

Figure 101. Total number of new terrapin captures (unique individuals/trap/day) captured by month and site.

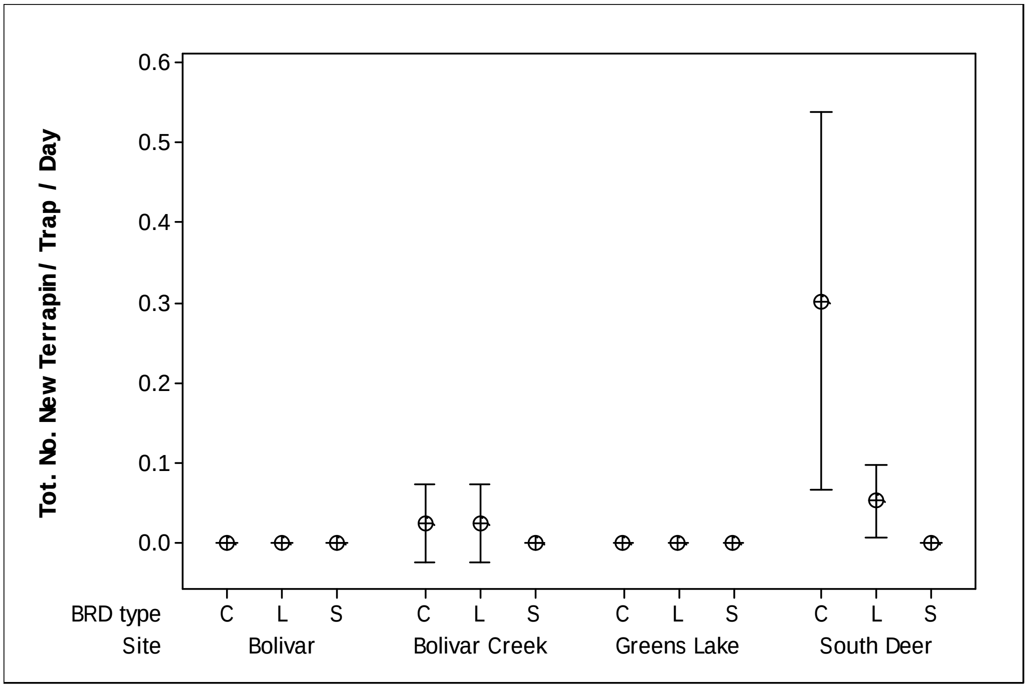

Figure 102. Confidence interval (95%) of the mean terrapin daily catches rates by site and trap type. Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$). (C = control; L = large BRD; S = small BRD).

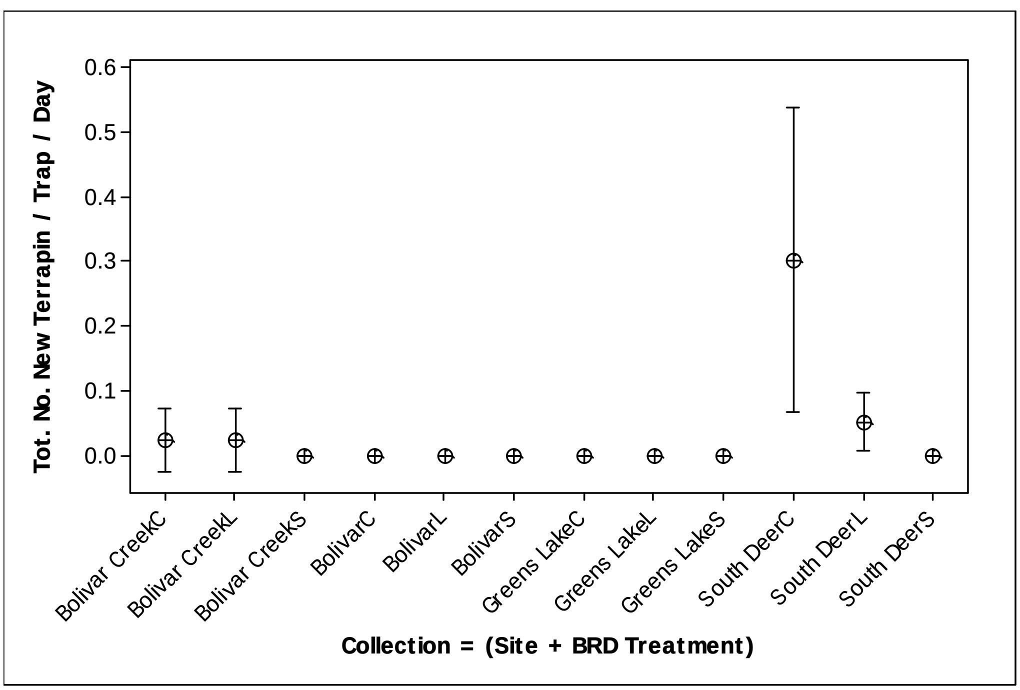

Figure 103. Confidence interval (95%) of the mean terrapin daily catch rates collection (site + trap type = C, L, S). Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$). (C = control; L = large BRD; S = small BRD).

Table 6. Results of ANOVA and Tukey's multiple range test for catch rates versus combined BRD trap type and sites (= collection).

```
Source          DF        SS      MS     F      P
Collection 2    11    8.2772  0.7525  9.07  0.000
Error         1626  134.9315  0.0830
Total         1637  143.2088

S = 0.2881   R-Sq = 5.78%   R-Sq(adj) = 5.14%


                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level              N    Mean   StDev  -------+---------+---------+---------+--
Bolivar CreekC    42  0.0238  0.1543    (------*------)
Bolivar CreekL    42  0.0238  0.1543    (------*------)
Bolivar CreekS    42  0.0000  0.0000  (------*------)
BolivarC         180  0.0000  0.0000     (---*---)
BolivarL         180  0.0000  0.0000     (---*---)
BolivarS         180  0.0000  0.0000     (---*---)
Greens LakeC     228  0.0000  0.0000      (--*--)
Greens LakeL     228  0.0000  0.0000      (--*--)
Greens LakeS     228  0.0000  0.0000      (--*--)
South DeerC       96  0.3021  1.1618                           (----*----)
South DeerL       96  0.0521  0.2234         (---*----)
South DeerS       96  0.0000  0.0000    (----*----)
                                      -------+---------+---------+---------+--
                                           0.00      0.12      0.24      0.36


Grouping Information Using Tukey Method

Collection 2       N    Mean  Grouping
South DeerC       96  0.3021  A
South DeerL       96  0.0521    B
Bolivar CreekL    42  0.0238    B
Bolivar CreekC    42  0.0238    B
South DeerS       96  0.0000    B
Greens LakeS     228  0.0000    B
Greens LakeL     228  0.0000    B
Greens LakeC     228  0.0000    B
BolivarS         180  0.0000    B
BolivarL         180  0.0000    B
BolivarC         180  0.0000    B
Bolivar CreekS    42  0.0000    B

Means that do not share a letter are significantly different.
```

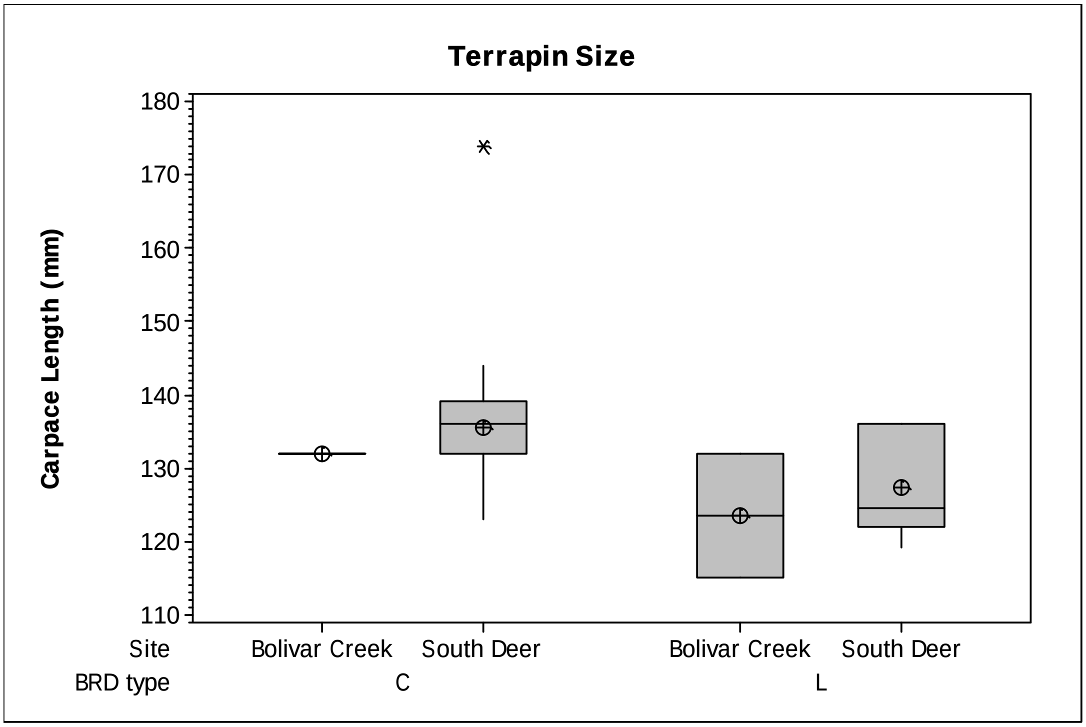

Figure 104. Boxplot of terrapin carapace length of specimens collected at two levels of BRD use (C = control; L = large BRD) from Bolivar Creek and South Deer sites. ⊕ = mean value.

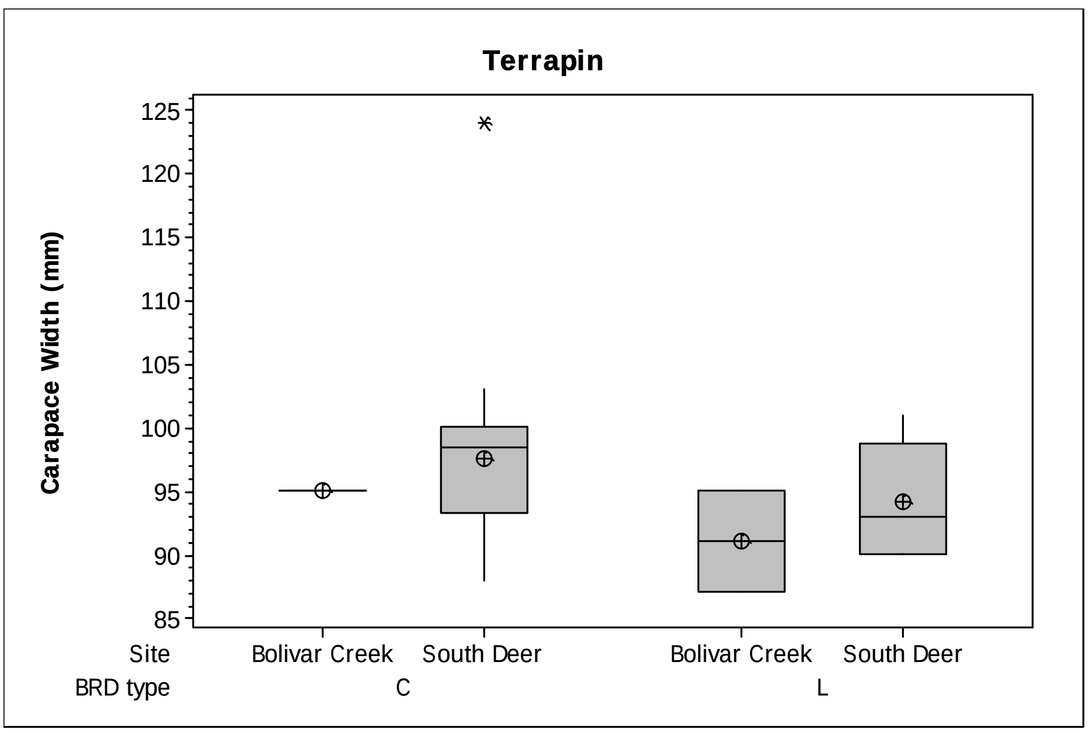

Figure 105. Boxplot of terrapin carapace width of specimens collected at two levels of BRD use (C = control; L = large BRD) from Bolivar Creek and South Deer sites. ⊕ = mean value.

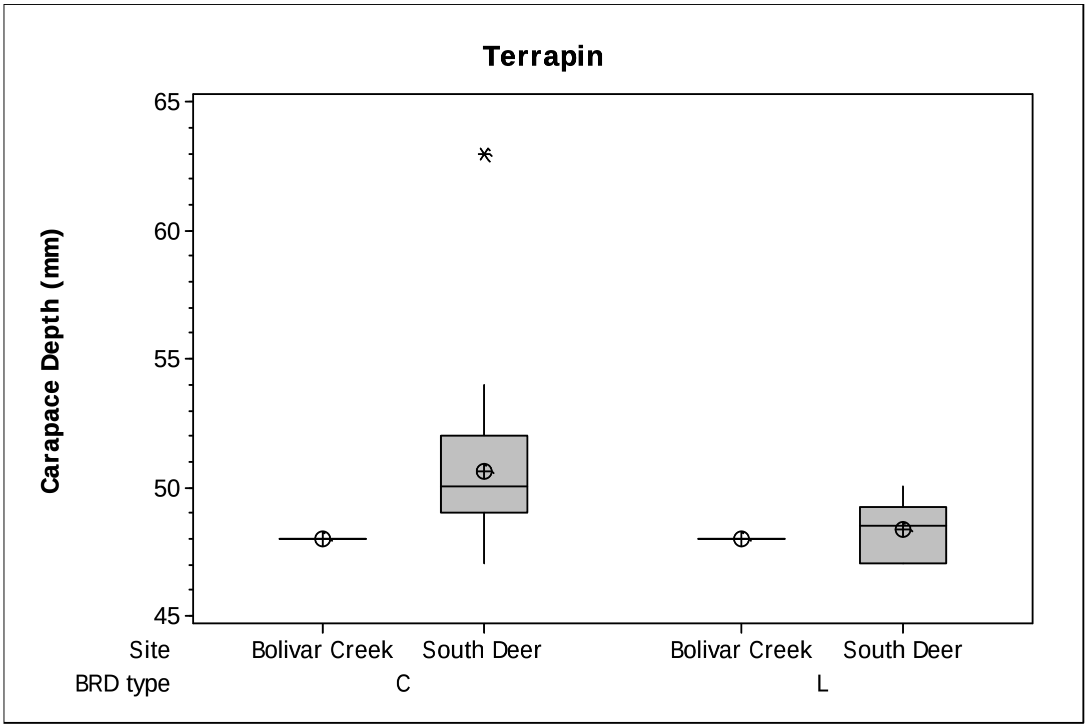

Figure 106. Boxplot of terrapin carapace depth of specimens collected at two levels of BRD use (C = control; L = large BRD) from Bolivar Creek and South Deer sites. ⊕ = mean value.

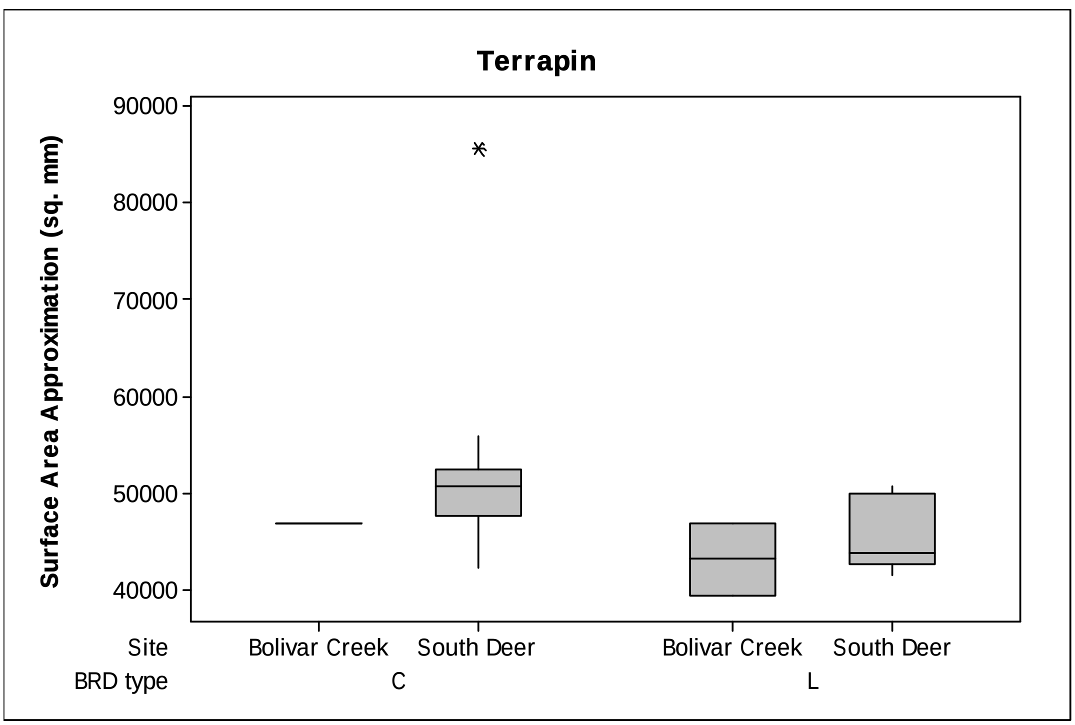

Figure 107. Boxplot of terrapin body surface area estimated from length, width and depth measurements from specimens collected at two levels of BRD use (C = control; L = large BRD) from Bolivar Creek and South Deer sites. ⊕ = mean value.

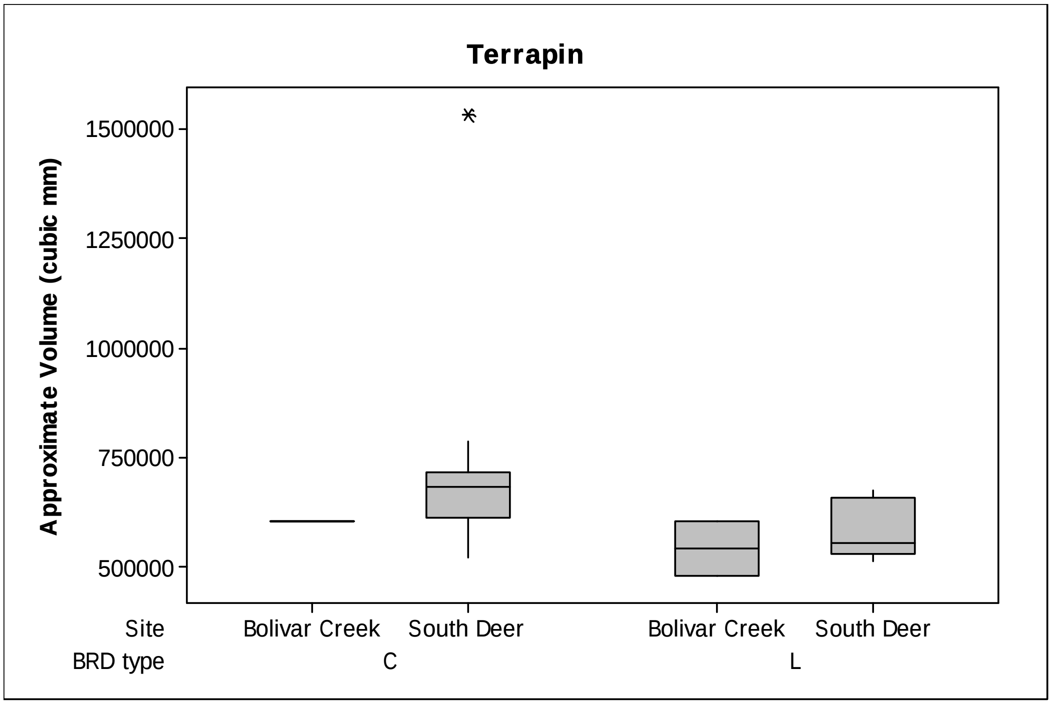

Figure 108. Boxplot of terrapin body volume estimated from length, width and depth measurements from specimens collected at two levels of BRD use (C = control; L = large BRD) from Bolivar Creek and South Deer sites. ⊕ = mean value.

During this study only one large (174 mm CL) female terrapin was captured in a control trap at the Deer Island site (Figure 104 and Figure 105). The pattern in size data observed during this study suggests that the use of BRDs results in selectivity towards smaller size terrapin and therefore would reduce the capture of larger females.

Field Study Results: Non-terrapin Bycatch Rates

We also examined differences in non-terrapin bycatch rates based on the type of BRD used across all sites. Bycatch rates were generally higher in traps lacking a BRD device (Figure 110 and 111). Results of two-away ANOVA with interaction terms indicated that non-terrrapin bycatch rates were significantly ($p<0.01$) higher in traps equipped without a BRD and at the Greens Lake site (Figure 112 and Table 7). However we also detected a significant interaction in bycatch rates between BRD design and sites ($p <0.05$). When considered together the non-terrapin bycatch rates observed in pooled Greens Lake Control collections were significantly higher than all other sites except the Bolivar Creek collections (Figure 112 and 109).

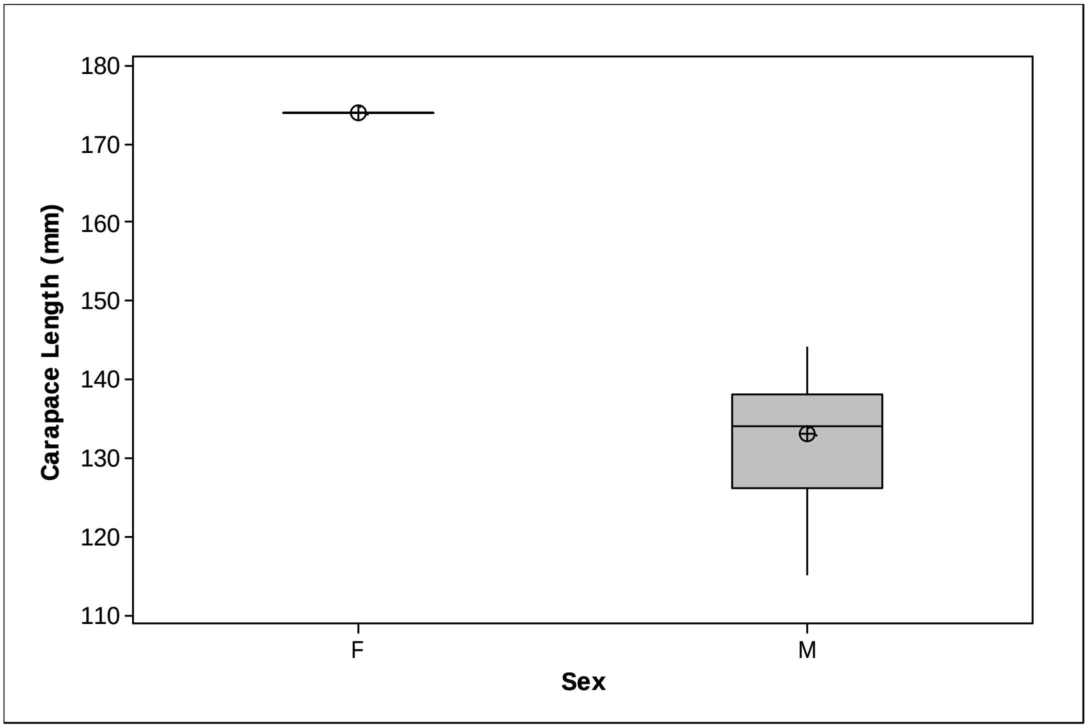

Figure 109. Boxplot of terrapin carapace length by gender from Bolivar Creek and South Deer sites. ⊕ = mean value.

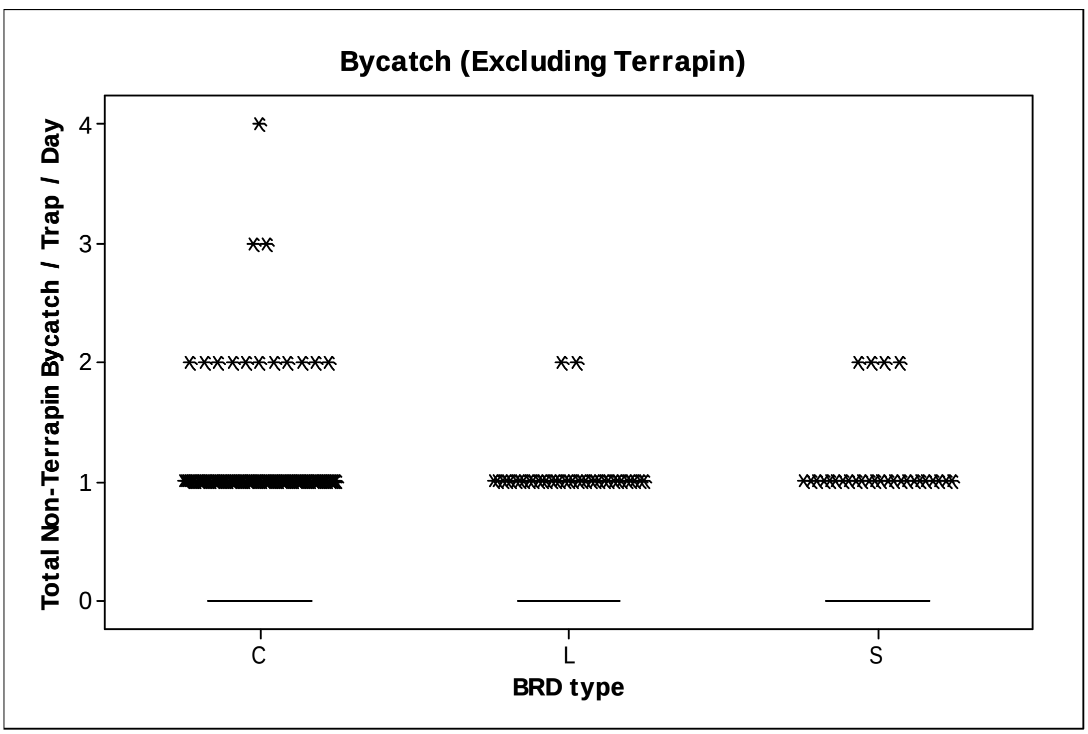

Figure 110. Boxplot of total non-terrapin bycatch rates observed in traps equipped with different types of BRD (C = control; L = large BRD) from Bolivar Creek and South Deer sites.

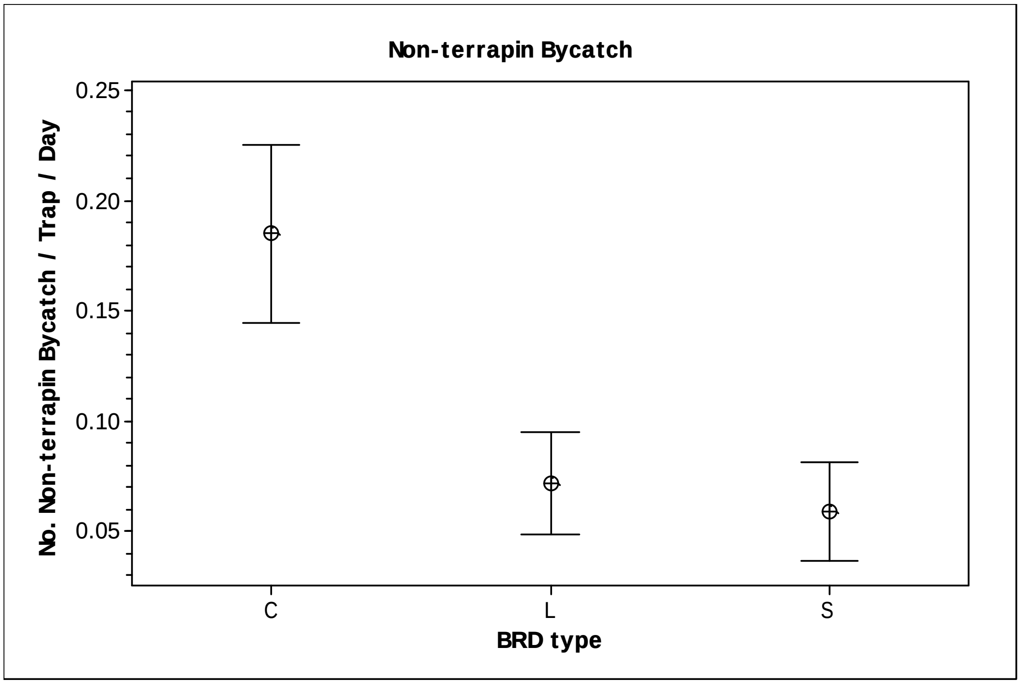

Figure 111. The 95% confidence interval of mean non-terrapin bycatch rates observed in traps equipped with various BRD devices across all sites. BRD types with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$). (C = control; L = large BRD; S = small BRD).

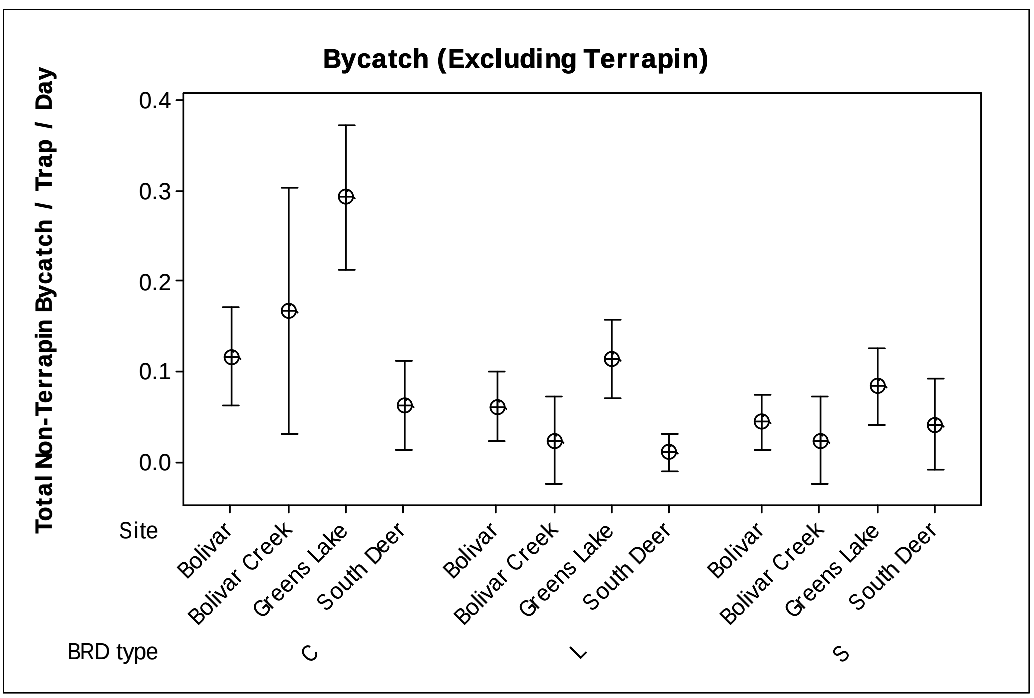

Figure 112. The 95% confidence interval of mean non-terrapin bycatch rates observed in traps equipped with various BRD devices at each site. Collections with overlapping confidence intervals are not significantly different (ANOVA and Tukey's test $p < 0.05$). (C = control; L = large BRD; S = small BRD).

Table 7. Results of ANOVA and Tukey's multiple range test of non-terrapin bycatch rates by BRD trap type and sites.

```
Factor    Type   Levels  Values
Site      fixed       5  Bolivar, Bolivar Creek, Greens Lake, South
Deer,
                         Trinity Bay
BRD type  fixed       3  C, L, S

Analysis of Variance for Total Other Bycatch wo DT, using Adjusted SS
for Tests
Source           DF    Seq SS    Adj SS  Adj MS      F      P
Site              4    5.0765    5.0598  1.2649  10.95  0.000
BRD type          2    5.4309    2.7804  1.3902  12.03  0.000
Site*BRD type     8    1.8480    1.8480  0.2310   2.00  0.043
Error          1768  204.2717  204.2717  0.1155
Total          1782  216.6270
S = 0.339909   R-Sq = 5.70%   R-Sq(adj) = 4.96%

Grouping Information Using Tukey Method and 95.0% Confidence
Site             N     Mean  Grouping
Greens Lake    685  0.16331  A
Bolivar        540  0.07407    B
Bolivar Creek  126  0.07143    B
South Deer     288  0.03819    B
Trinity Bay    144  0.02778    B

Grouping Information Using Tukey Method and 95.0% Confidence

BRD
type    N     Mean  Grouping
C     595  0.14435  A
L     594  0.04187    B
S     594  0.03865    B

Means that do not share a letter are significantly different.
```

Table 8. Results of ANOVA and Tukey's multiple range test of non-terrapin bycatch rates by collections (pooled combined BRD trap type and sites).

```
One-way ANOVA: Total Other Bycatch wo DT versus Collection

Source        DF       SS     MS     F      P
Collection    14   12.355  0.883  7.64  0.000
Error       1768  204.272  0.116
Total       1782  216.627

S = 0.3399   R-Sq = 5.70%   R-Sq(adj) = 4.96%


                                     Individual 95% CIs For Mean Based on
                                     Pooled StDev
Level              N    Mean   StDev  --------+---------+---------+---------+-
Bolivar CreekC    42  0.1667  0.4371               (--------*-------)
Bolivar CreekL    42  0.0238  0.1543   (--------*--------)
Bolivar CreekS    42  0.0238  0.1543   (--------*--------)
BolivarC         180  0.1167  0.3703                (---*---)
BolivarL         180  0.0611  0.2624           (---*---)
BolivarS         180  0.0444  0.2067          (---*---)
Greens LakeC     229  0.2926  0.6120                               (--*---)
Greens LakeL     228  0.1140  0.3321                (---*--)
Greens LakeS     228  0.0833  0.3212             (---*---)
South DeerC       96  0.0625  0.2433          (----*-----)
South DeerL       96  0.0104  0.1021     (-----*-----)
South DeerS       96  0.0417  0.2478        (----*-----)
Trinity BayC      48  0.0833  0.2793         (-------*-------)
Trinity BayL      48  0.0000  0.0000  (-------*-------)
Trinity BayS      48  0.0000  0.0000  (-------*-------)
                                     --------+---------+---------+---------+-
                                           0.00      0.12      0.24      0.36
Pooled StDev = 0.3399

Grouping Information Using Tukey Method

Collection         N    Mean  Grouping
Greens LakeC     229  0.2926  A
Bolivar CreekC    42  0.1667  A B
BolivarC         180  0.1167    B
Greens LakeL     228  0.1140    B
Trinity BayC      48  0.0833    B
Greens LakeS     228  0.0833    B
South DeerC       96  0.0625    B
BolivarL         180  0.0611    B
BolivarS         180  0.0444    B
South DeerS       96  0.0417    B
Bolivar CreekS    42  0.0238    B
Bolivar CreekL    42  0.0238    B
South DeerL       96  0.0104    B
Trinity BayS      48  0.0000    B
Trinity BayL      48  0.0000    B

Means that do not share a letter are significantly different.
```

Analysis of Blue Crab Fishery Dependent and Independent Data

We attempted to attain landings and effort statistics from the TWPD fishery dependent database.

1) Commercial crabbing trip tickets
2) Historical commercial landings
3) Incidental intercept creel surveys of commercial crabbers
4) TPWD Fishery Independent Sampling.

Ms. Paige Campbell formerly with TPWD assisted us with our request for commercial blue crab trip ticket data. She stated that the TPWD initiated the current self reporting blue crab trip ticket program in 2007. We were provided access to data up to 2011. Unfortunately little information on effort was provided with TPWD trip ticket data. Therefore we indirectly evaluated the effort and landings from their historical landings.

Historical commercial blue crab landings provided by TPWD peaked during 1980s, but has declined since then (Figure 113). In general landings of blue crab have generally been highest in the San Antonio Bay system (Figure 114). Data extracted from the GDAR blue crab stock assessment report suggests that catch rates of blue crab began to increase rapidly during the early 1960's while the number of commercial crab licenses did not begin to increase until the mid-1980's (Figure 115 - 117). The large reduction in number of licenses fisherman reflects changes in the Texas license program which was enacted by legislation in 1997 that incorporates limited entry and crab license buyback programs to reduce effort (VanderKooy 2013). However, CPUE has also decline. The most likely explanation involves the higher number of inactive fisherman who may be holding on to their license in speculation of rising prices.
Creel survey data summarized by major bay systems suggests that average reported trip length was generally much lower as one moved toward the Lower Laguna Madre (Figure 118 and 119). This suggests that commercial blue crab fisherman along the upper coast most likely stay on the water longer either running additional traps or checking them more frequently.

Recorded terrapin captures by the TPWD fishery independent monitoring program has occurred sporadically (Figure 120 to 124). From 1975 through 2012, TPWD collected 69,756 bag seines, made 25,210 gill net sets, and collected 48,720 bay trawl samples. The lowest numbers of terrapin ever captured by this program were in Sabine Lake. There are no records of terrapin being collected from the Lower and Upper Laguna Madre, Baffin Bay, East Matagorda Bay, and Trinity Bay. Interestingly refuge biologists and blue crab fishermen have observed or captured numerous terrapin in the East Matagorda Bay region. We failed to detect any spatial or temporal trend in terrapin sizes (Figure 127 and 128). Corpus Christi, San Antonio and Matagorda Bay yielded similar number of terrapin. Terrapin were most frequently captured by TPWD in water temperatures between 20 and 32 ºC and over a wide salinity range (2 to 42 psu)(Figure 125). Catch rates have fluctuated with the highest number of captures occurring in 2003 and no catches occurring in 1988, 1991, 1997, and 2011 (Figure 126). These data suggest terrapin have a wide salinity tolerance range. However the upper limit of their distribution appears to be 43 psu. This may explain their absence in the Laguna Madre.

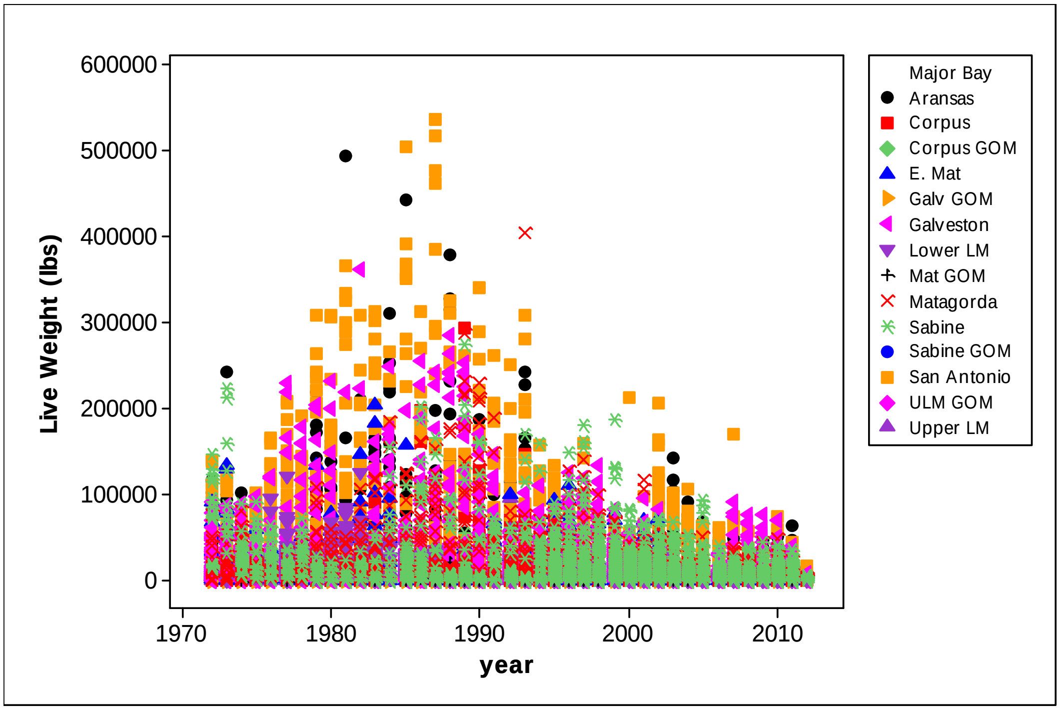

Figure 113. Historical landings of blue crab in Texas by Year and Major Bay from 1972 to 2011.

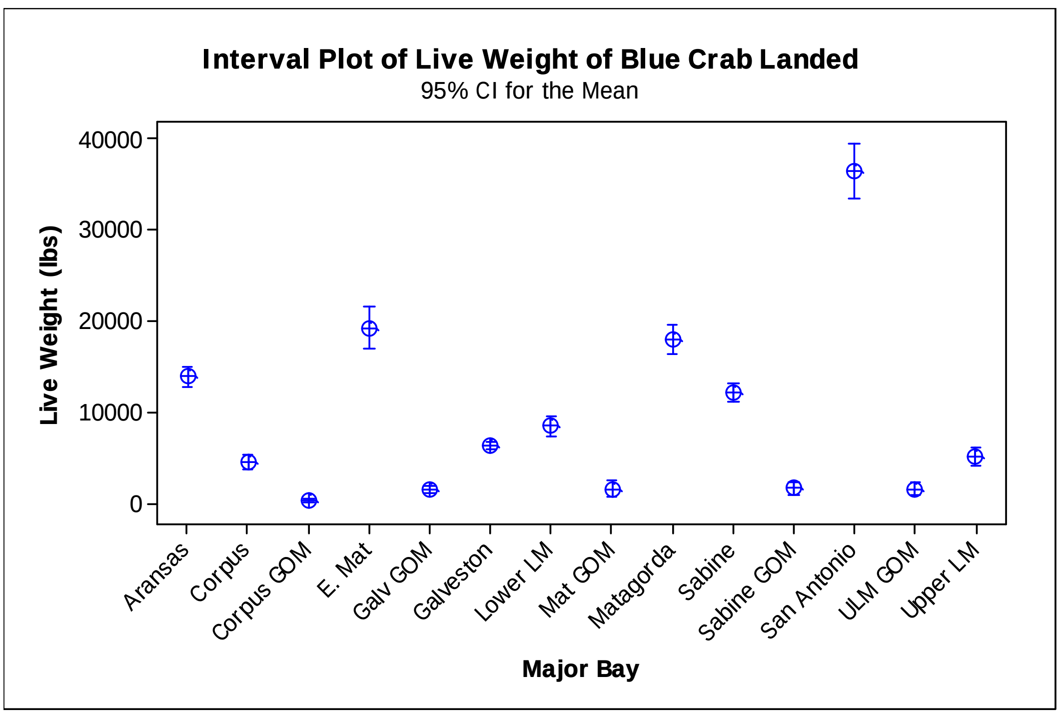

Figure 114. Comparison of overall mean landings of blue crab by major bay systems and adjacent Gulf of Mexico waters from 1972 to 2011.

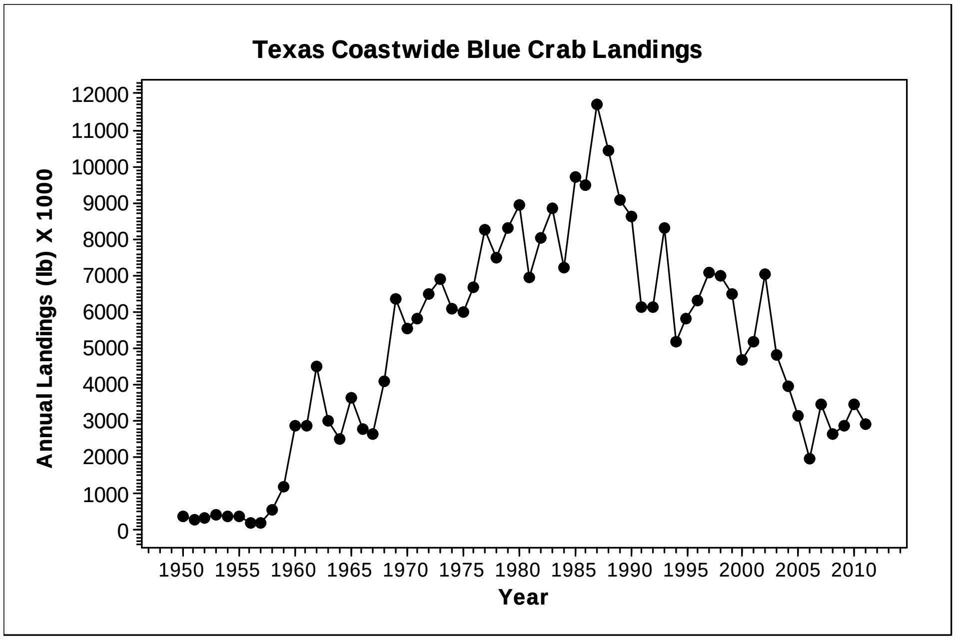

Figure 115. Trends in Texas coast wide landings of blue crab by the commercial fishery. Source: (VanderKooy 2013).

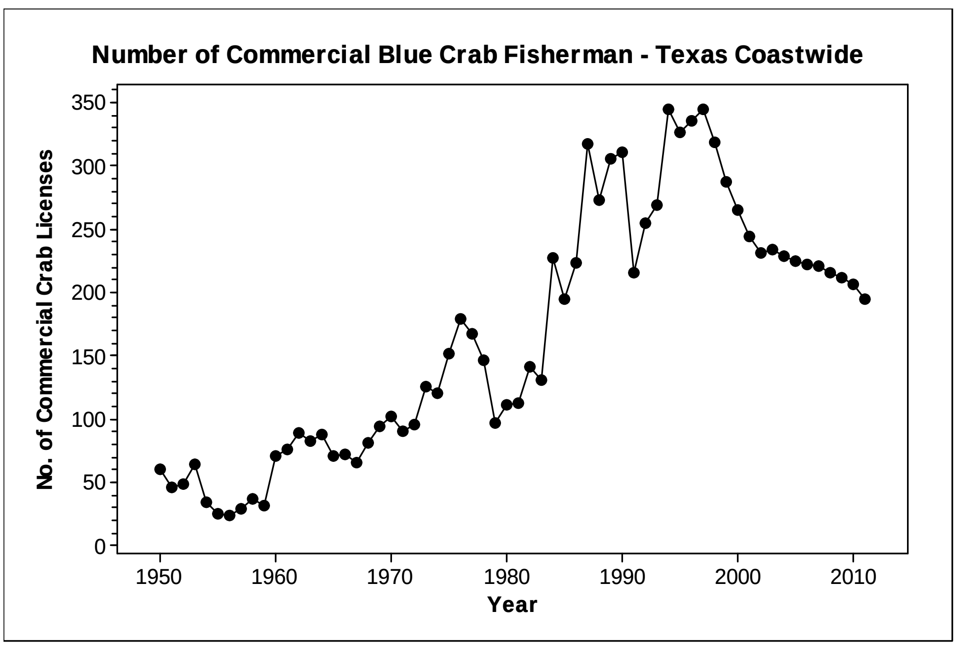

Figure 116. Number of commercial blue crab fisherman in Texas. Source: (VanderKooy 2013).

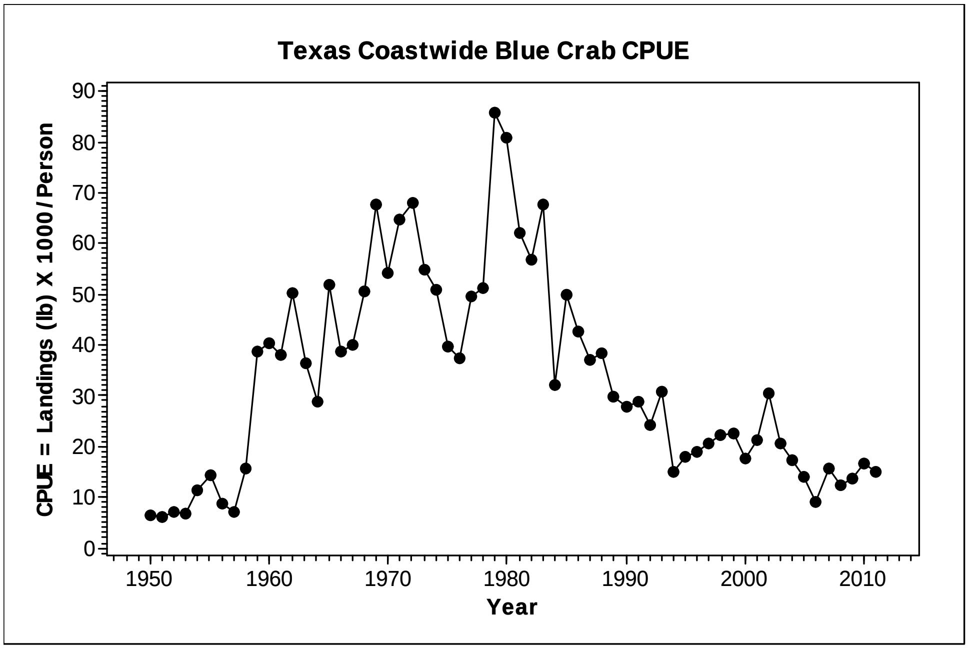

Figure 117. Trends in Texas coast wide annual CPUE of blue crab by the commercial fishery. Source: (VanderKooy 2013).

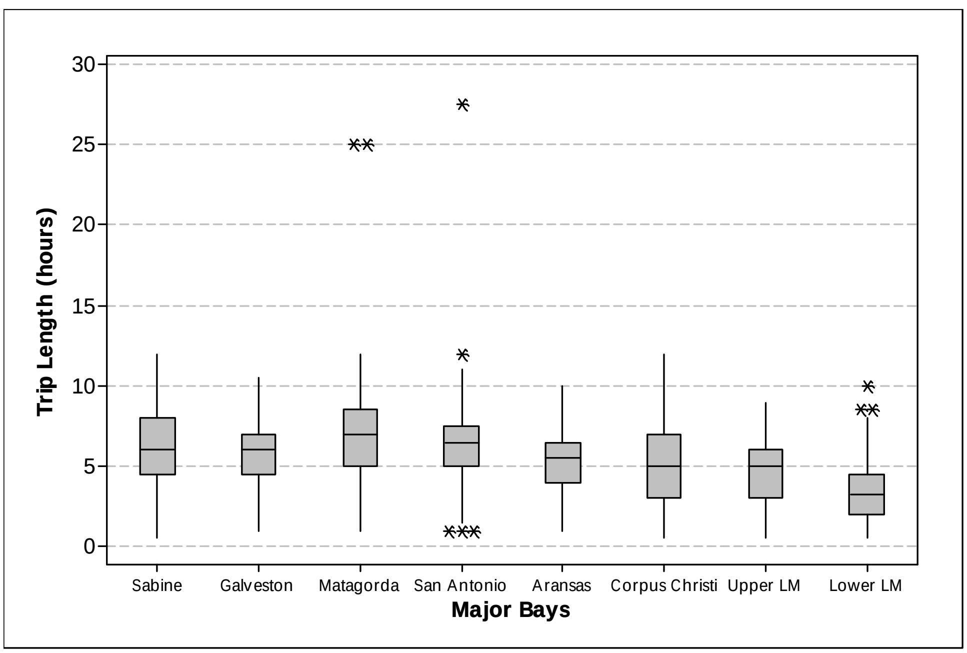

Figure 118. Reported trip length by blue crab fisherman at boat ramp creel surveys. Period of record:2000 to 2011.

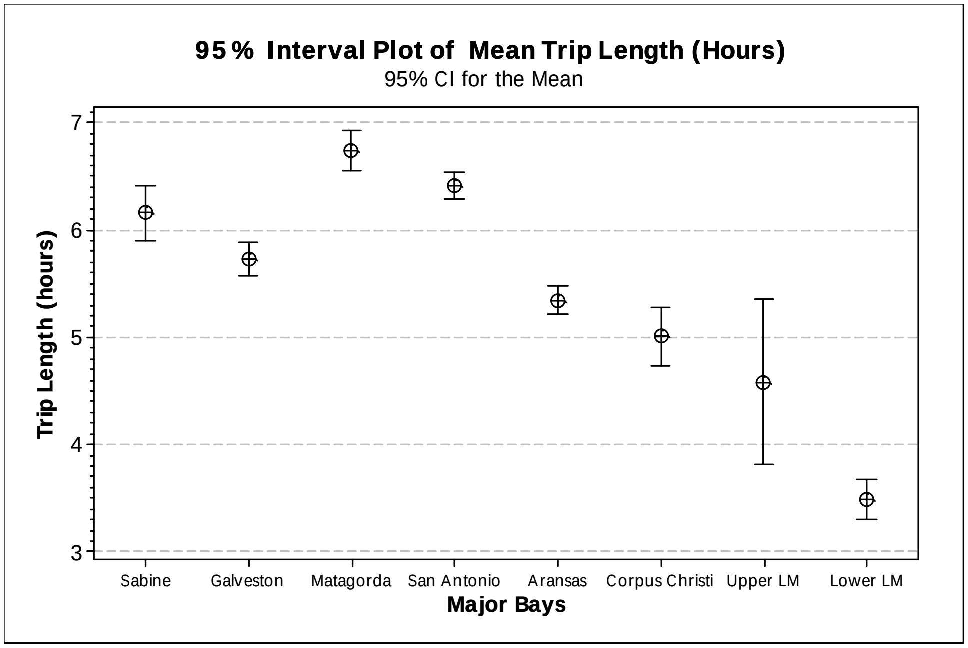

Figure 119. Average and 95% confidence intervals of the mean reported trip length by blue crab fisherman at boat ramp creel surveys. Data from 2000 to 2011.

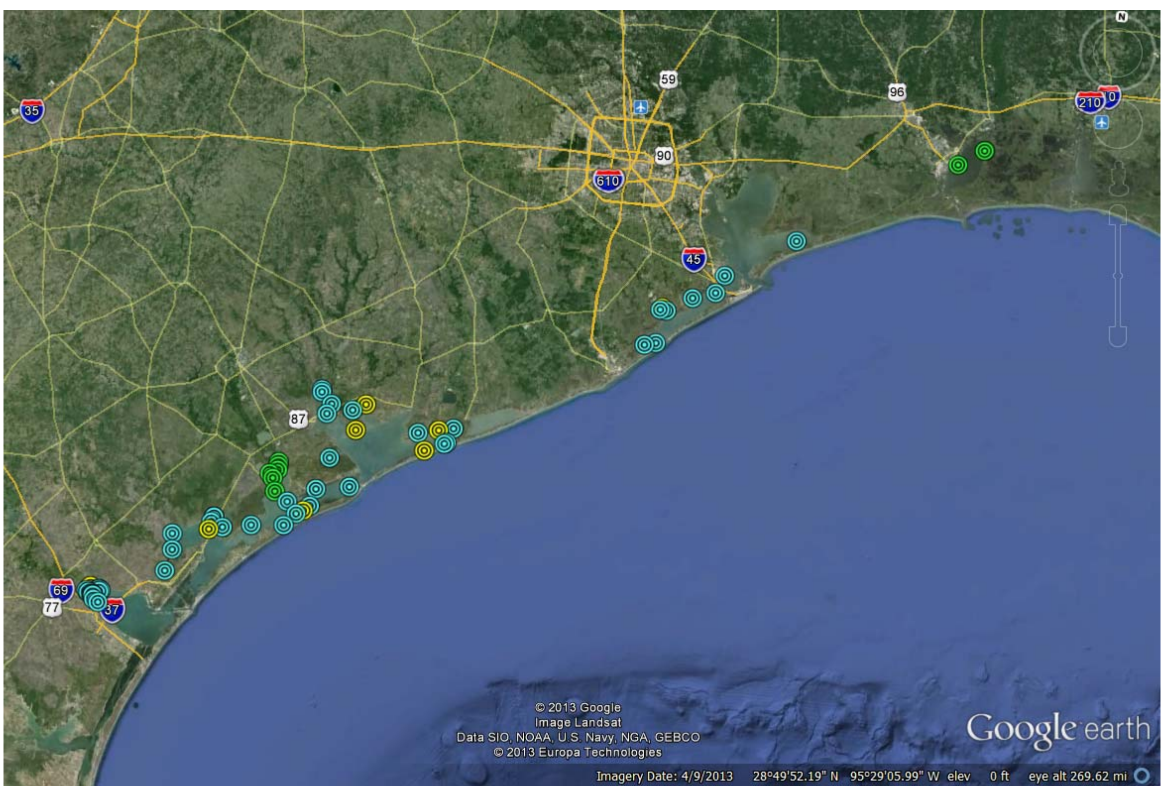

Figure 120. Distribution of historical terrapin captures by TPWD fishery independent monitoring from 1977 to 2013. Color code: blue = gill net; yellow = bag seine; green = trawl.

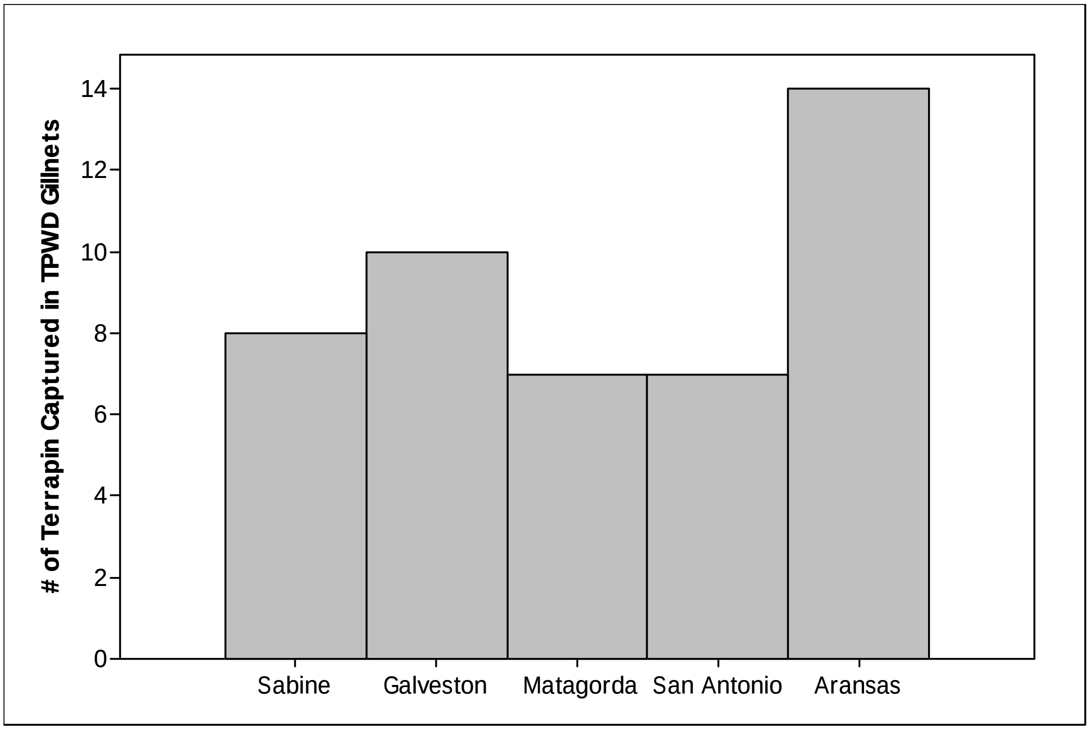

Figure 121. Total number of diamondback terrapin captured in TPWD gillnets monitoring by major bay system from 1976 through 2013.

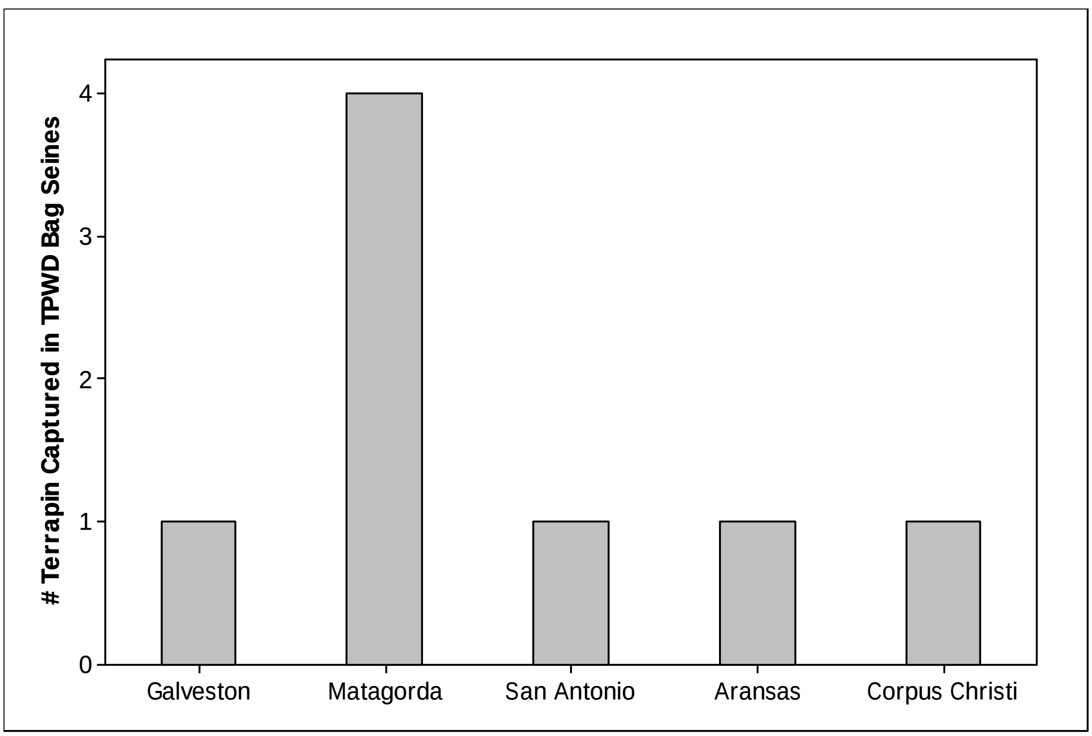

Figure 122. Total number of diamondback terrapin captured in TPWD bag seine monitoring by major bay system from 1977 through 2013.

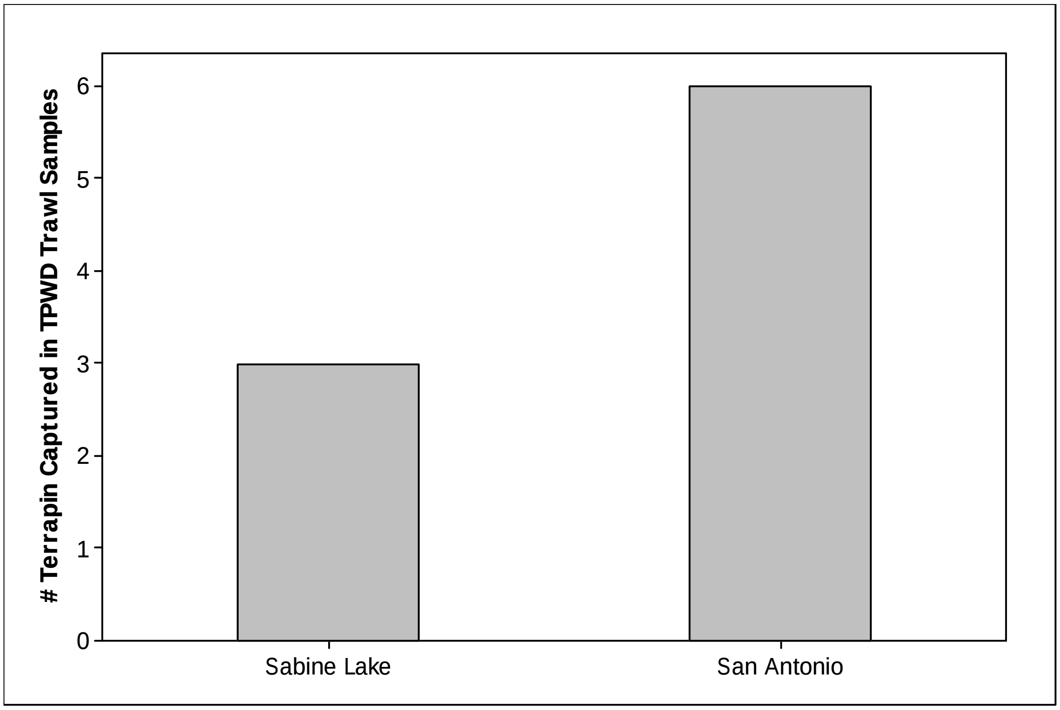

Figure 123. Total number of diamondback terrapin captured in TPWD bay trawl monitoring by major bay system from 1985 through 2013.

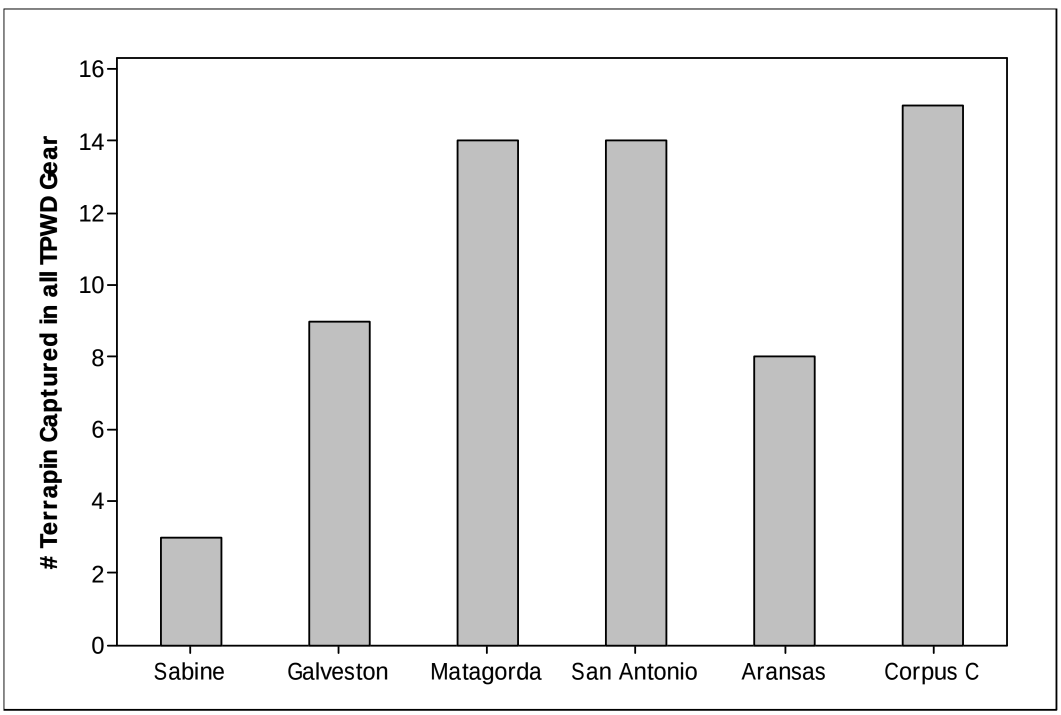

Figure 124. Total number of diamondback terrapin captured in all TPWD monitoring gear by major bay system from 1977 through 2013.

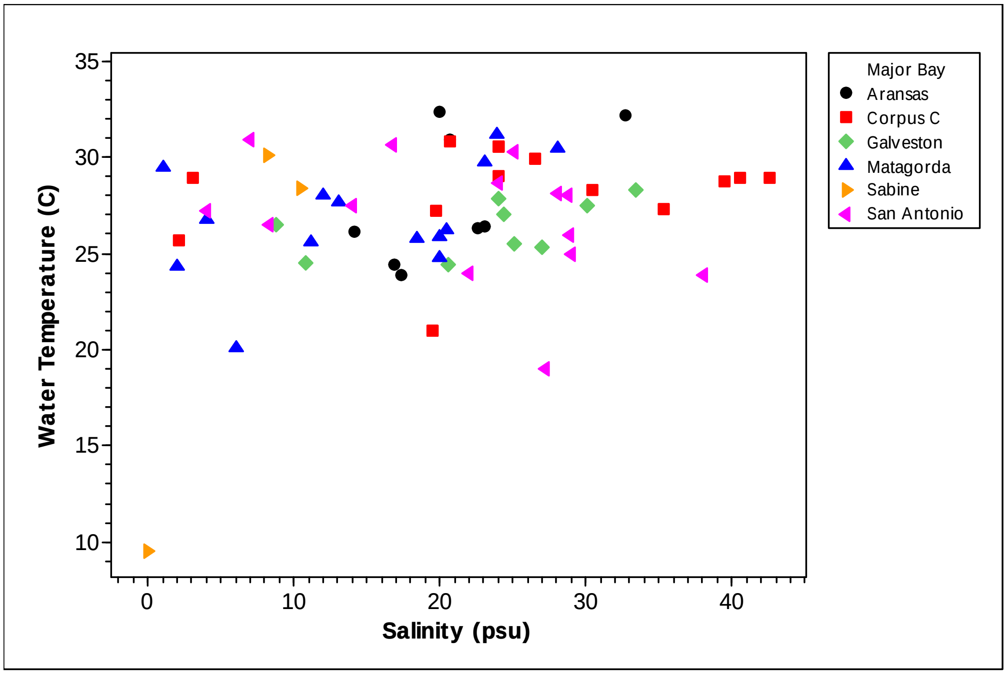

Figure 125. Distribution of TPWD monitoring program terrapin captures by salinity and water temperature in each major bay system.

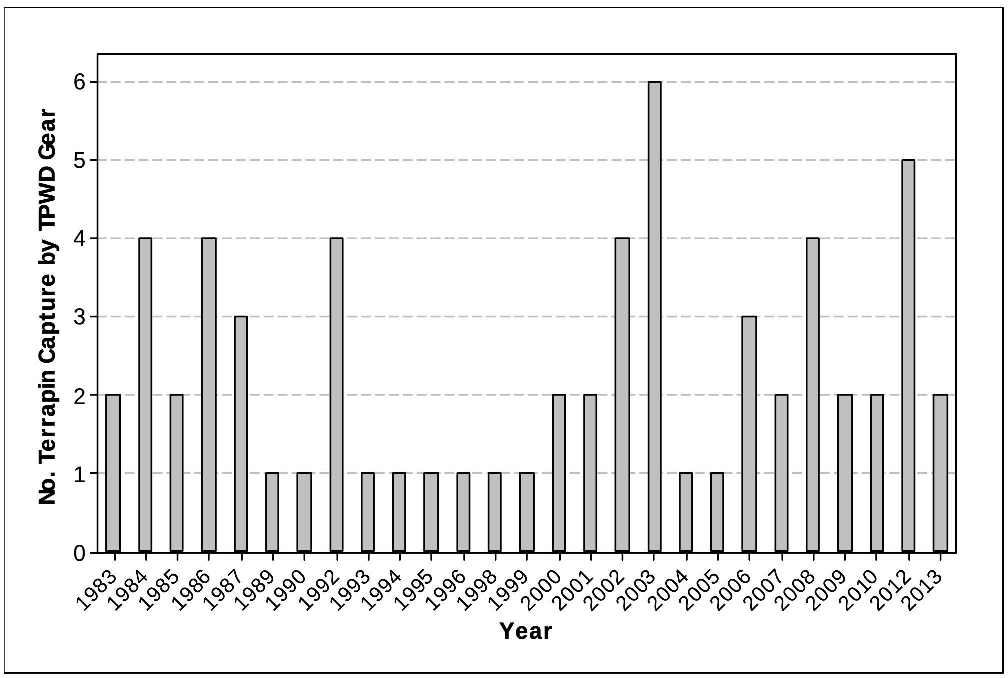

Figure 126. Annual captures of terrapin by TPWD fishery independent monitoring program.

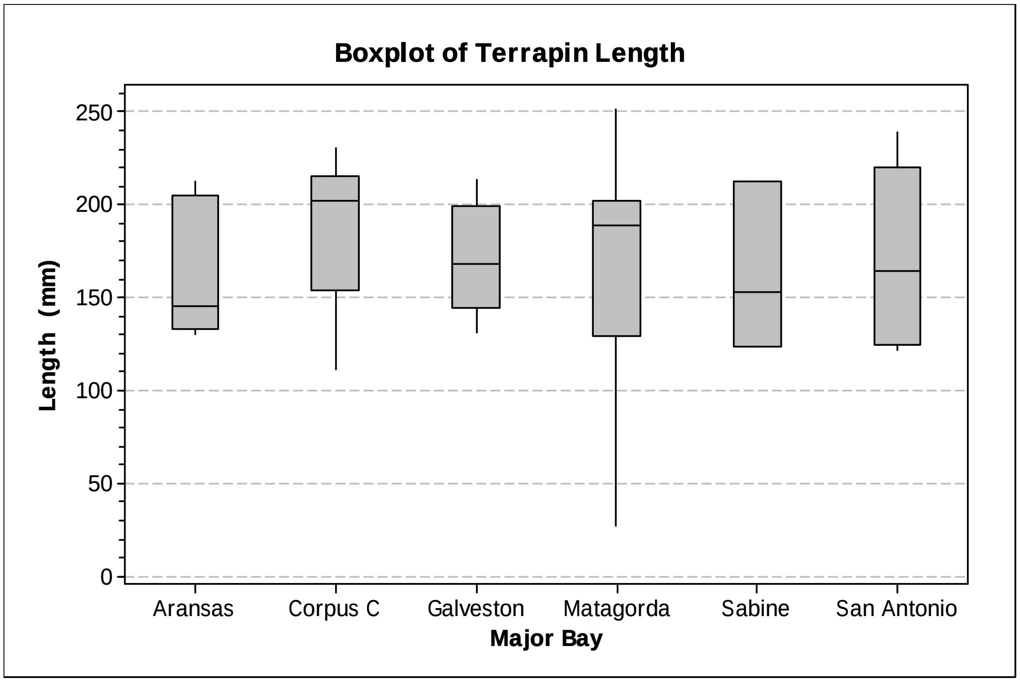

Figure 127. Size distribution of terrapin captured by bay systems. Data obtained from TPWD fisheries independent monitoring during 1977 to 2013.

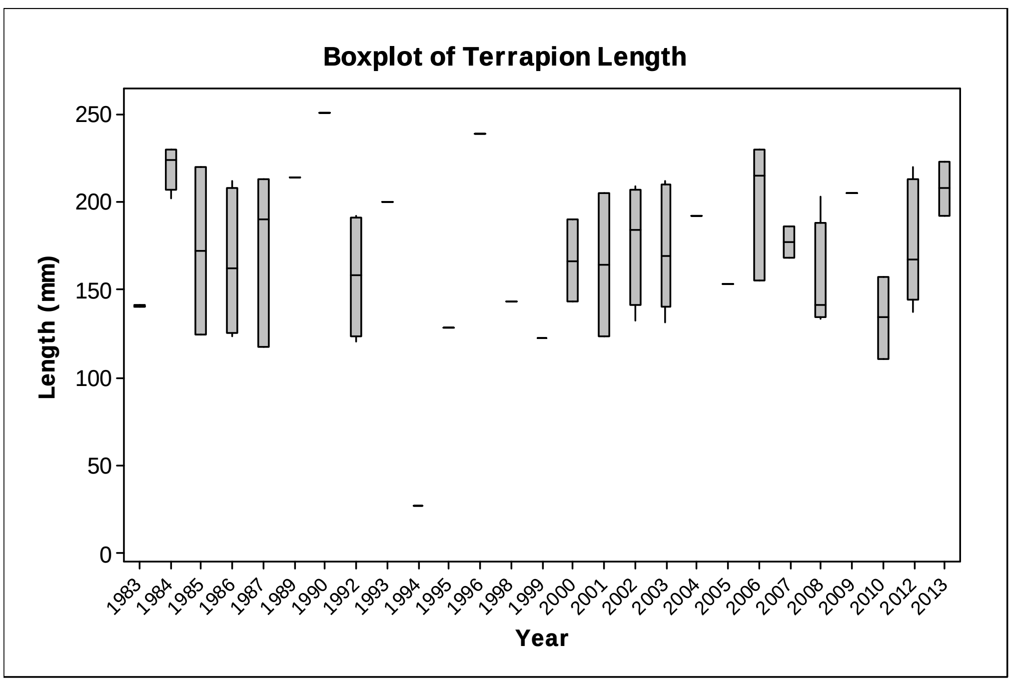

Figure 128. Size distribution of terrapin captured in all bay systems based on TPWD fisheries independent monitoring data collected from 1977 to 2013.

Field Study Results: Survey of Blue Crab Fisherman

The Texas Parks and Wildlife Department (TPWD) provided us with a list of the current residential crab fishermen licenses. The 2011-12 TPWD database contained a total of 177 commercial crabbing licenses. Some individuals had more than one license. The distribution of licensees by county is depicted in (Figure 129 and 130). The majority (41%) of licensees were listed as residing in counties near Galveston Bay. This included Chambers (17%), Chambers (17%), Galveston (14%) and Harris (6%). Approximately 6%, 9%, 9% and 11% of licensed crab fishermen are listed as being from counties to Sabine Lake, Matagorda Bay, San Antonio Bay and Aransas Bays respectively. This includes Jefferson, Calhoun and Aransas counties primarily.

We also estimated the number of licenses by bay system. Licensees from counties were assigned to adjacent major bay systems. Since licensees from Calhoun County could utilize either the San Antonio or Matagorda Bay, we created a combined category for both of these bay systems. Finally, we assigned the inland counties to the closest major bay system. Utilizing this classification we found that the majority (n=75; 42%) of licensees occurred in the Galveston Bay system (Figure 131 and 132). The Matagorda-San Antonio and Aransas Bay systems were the second and third highest bay systems in terms of licensees (n = 24 and 20). These bay systems represent 19 and 11% of all the licenses respectively. If these were apportioned equally to the existing 10 licensees in Matagorda Bay and the 8 licensees in San Antonio Bay, then each system would have 20 and 18 licensees respectively.

We also pooled the major bays into upper (Sabine Lake and Galveston Bay), middle (E. Matagorda, Matagorda and San Antonio Bays) and lower (Aransas, Corpus Christi, Baffin Bays and the Upper Laguna Madre). Based on this classification, the highest number (n=90) and percentage (50%) of licensees were found along the upper coast (Figure 133 and 134). The lowest number (n = 33) and percentage (31.1%) of licensees occurred along the lower coast.

Out of the original list of 178 licensees in the TPWD database we were only able to locate 121 valid addresses These 121 Texas commercial blue crab license holders were sent questionnaires. We also attempted to contact licensees who had current phone numbers who did not response to the mail questionnaire and/or to gather additional information. Out of the 121 surveys only 40 crab fishermen (33.1%) responded. Two respondents did not complete the survey completely. Mail responses accounted for 17 (45.6%) of all respondents. Phone interviews accounted for 23 (58.9%) of the remaining responses. The majority of the respondents had over 10 years of experience (Table 9). Almost 50% of the respondents had over 20 years of experience. The San Bernard River and Corpus Christi Bay respondents were the least experienced fishermen. Two respondents also target stone crabs. We examined the spatial distribution and experience of respondents to the survey. The majority of experienced (>10 years experience) blue crab fishermen were found within the Galveston and Aransas Bay systems (Table 10). Two individuals from San Antonio Bay and an unreported bay system reported the least amount of experience (< 1 year). Almost 50% of the respondents had over 20 years of experience. The San Bernard River and Corpus Christi Bay respondents were the least experienced fishermen. Two respondents also target stone crabs.

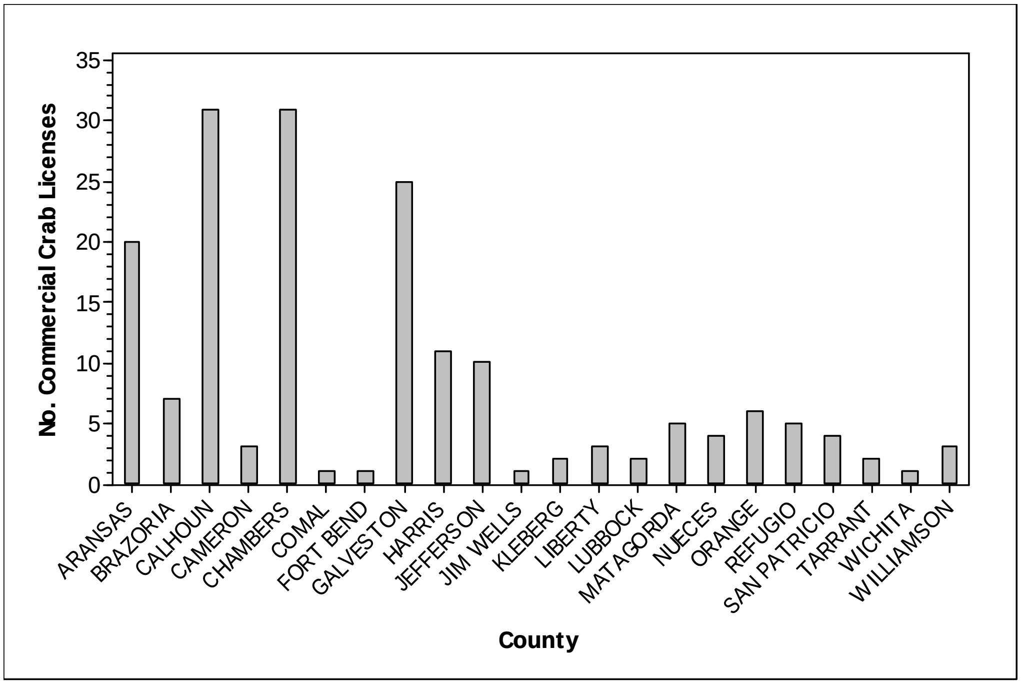

Figure 129. Number of commercial blue crab licensees by county during 2011-2012. Data provided by TPWD.

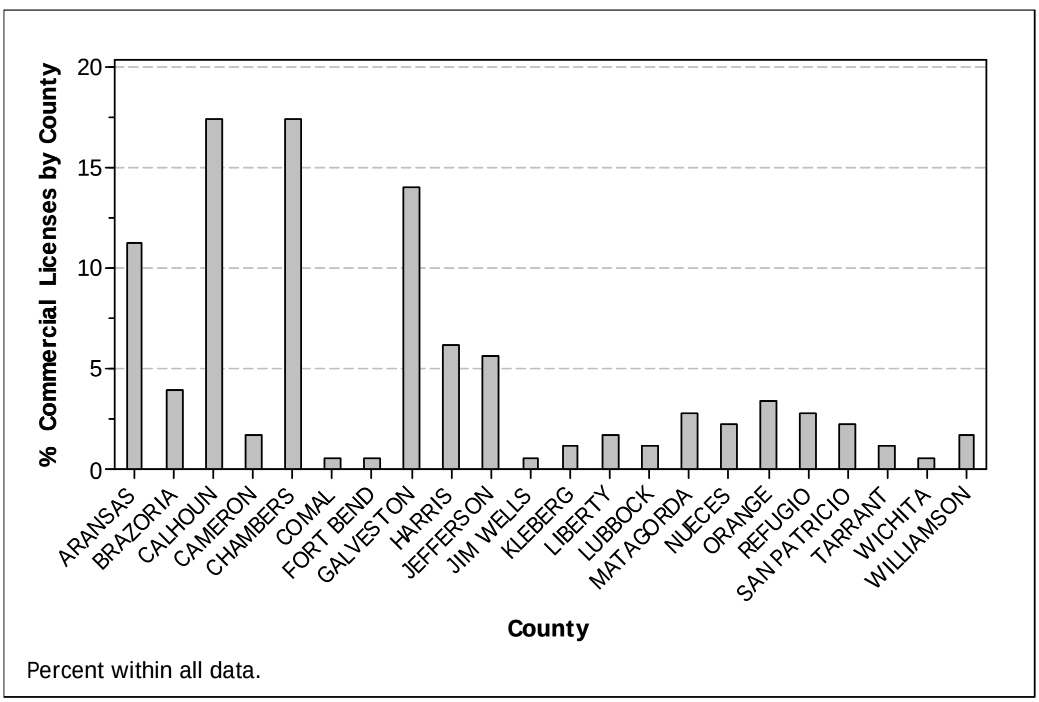

Figure 130. Percentage of commercial blue crab licensees by county during 2011-12. Data provided by TPWD.

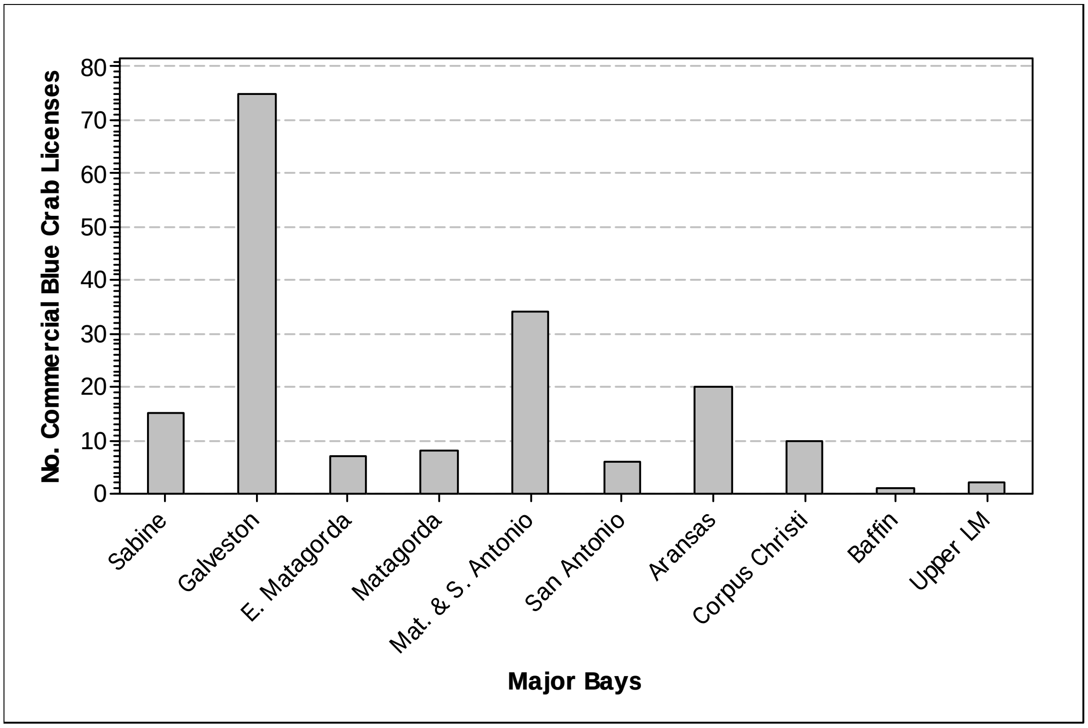

Figure 131. Distribution of licensed blue crab fishermen by major bay system as inferred from county of license. For non-coastal counties the closest bay system was used.

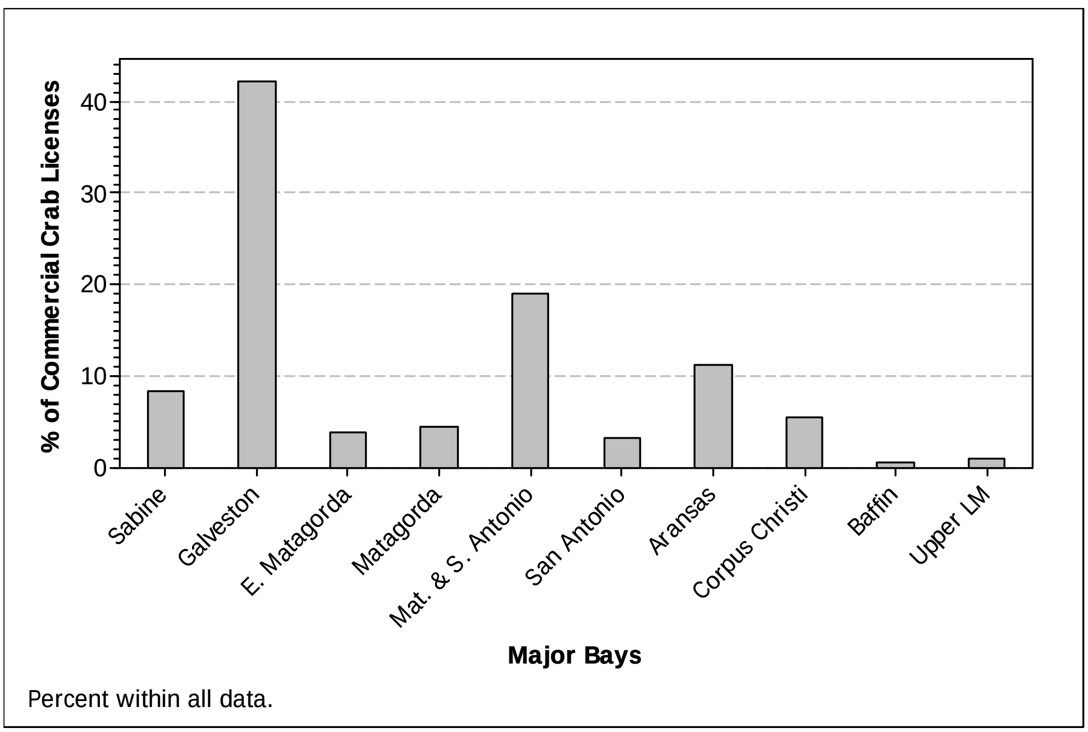

Figure 132. Percentage of licensed blue crab fishermen by major bay system as inferred from county of license. For non-coastal counties the closest bay system was used.

Figure 133. Distribution of commercial crab licenses along Texas coastal regions. (Upper - Sabine to Christmas Bay; Middle - from points west of Christmas Bay to San Antonio Bay; Lower – from points west of San Antonio Bay to Lower Laguna Madre).

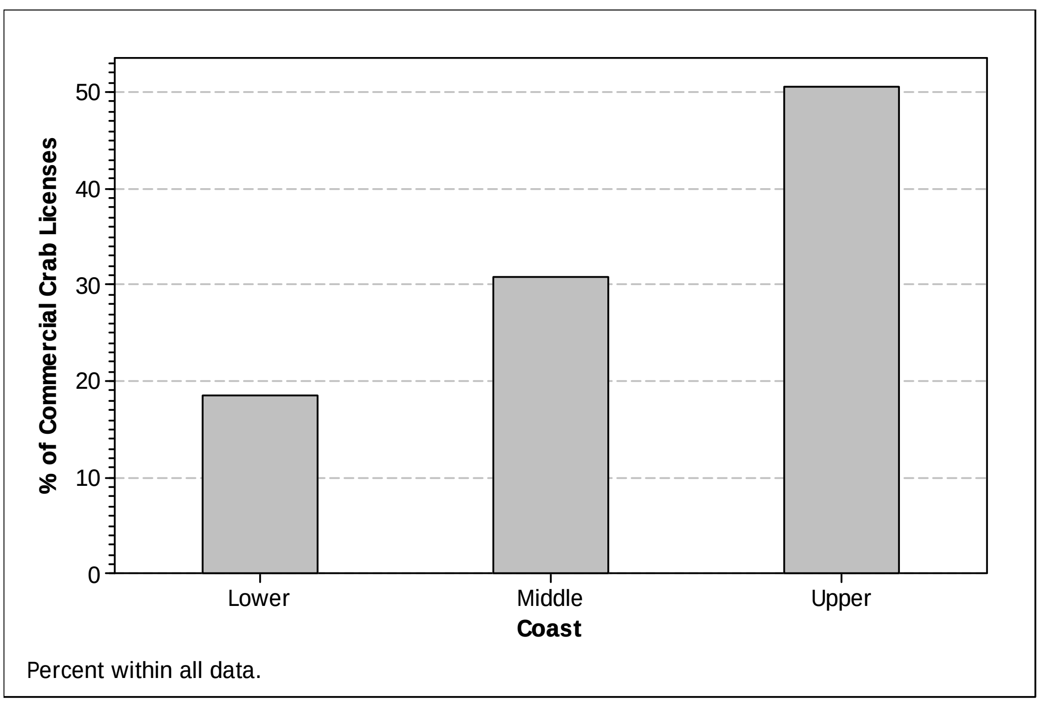

Figure 134. Percentage of commercial crab licenses along Texas coastal regions. (Upper - Sabine to Christmas Bay; Middle - from points west of Christmas Bay to San Antonio Bay; Lower – from points west of San Antonio Bay to Lower Laguna Madre).

Table 9. Self reported experience level of crabbers possessing commercial and both (commercial and recreational) licenses.

Experience	Both	Commercial	Total
less than 1 year	1	1	2
1-5 years	2	7	9
5-10 years	1	3	4
10-20 years	0	6	6
over 20 years	4	15	19
Total	8	32	40

Table 10. Self reported experience level of crabbers possessing commercial and both (commercial and recreational) licenses by major bay system.

	Years Experience					
Major Bay	**< 1 year**	**1-5 years**	**5-10 years**	**10-20 years**	**> 20 years**	**Total**
Sabine Lake			2		2	4
Sabine Lake and Galveston Bay		1			1	2
Sabine Lake, Galveston, Matagorda, Corpus Christi, and Lower Laguna Madre				1		1
Galveston		3		3	7	13
San Bernard River		1				1
E. Matagorda				1		1
Matagorda	1					1
San Antonio			1		3	4
Aransas		1			1	2
Aransas and Copano		1	1		2	4
Aransas and Corpus Christi					1	1
Corpus Christi		2				2
Upper Laguna Madre and Baffin Bay				1		1
Lower Laguna Madre					1	1
No Reply	1				1	2
Total	**2**	**9**	**4**	**6**	**19**	**40**

A total of 16 out of 38 (42%) respondents who answered the question claimed they have never captured a terrapin in their crab pots (Table 11). The majority (15 out of 38; 39%) of responses were obtained from crab fishermen who work wholly or partially within the Galveston Bay system. Within individuals who work this system 9 out of 20 respondents (45%) claimed that they had never captured a terrapin. Other bay systems yielding a high number of responses included the Aransas Bay area. A total of 7 respondents claim they commercially fish for crabs in the Aransas Bay system. Several of the respondents crabbing the Aransas Bay indicated they had never captured a terrapin. The remaining respondents crabbing in this bay system reported low (<5 terrapin) career bycatch totals. Two respondents (5% of the total respondents) who fish the lower San Bernard River and East Matagorda area claimed that they had captured more than 100 terrapin over their career (Table 11). Some respondents claimed to have captured terrapin in the Lower Laguna Madre which is interesting since terrapin have not been reported in the past south of Baffin Bay. Therefore it is more likely these respondents had captured another species of turtle. If however this is true, this would represent a range extension for this species.

In contrast to career landings, a total of 28 out of 38 respondents (74%) reported that they did not capture any terrapin during 2011 (Table 12). As previously noted most responses were obtained from crab fishermen who work wholly or partially in the Galveston Bay system. A total of 9 out of 18 (50%) individuals who fish for blue crab in Galveston Bay and answered this question claimed that they did not capture any terrapin during 2011. As previously mentioned some respondents claimed to have captured terrapin in the Lower Laguna Madre. Since this is outside the reported range of this species it is more likely these respondents had captured another species.

To insure that we were comparing comparable units of bycatch and fishing effort we further attempted to characterize both sampling gear and effort. Based on the results of our survey, crab fisherman reported that the most common (84%) gear used was the 4-opening square crab pot (Table 13). Only one crab fisherman who targeted the East Matagorda system exclusively used another type of gear.

The number of days per week that crab pots were deployed in each bay system was reported by commercial blue crab fisherman (Table 14). The majority (70%) of crab fisherman reported deploying crab pots 6-7 days per week. A large percentage (84%) of crab fisherman deployed 100-200 traps per day on fishing days (Table 15). One crabber claimed they had 3 permits and therefore had routinely deployed 300 to 600 traps per day. Commercial crab fishermen reported that most crab pot deployment was conducted in open bays and tidal creeks (Table 16). Only one crab fisherman in Galveston Bay reported fishing exclusively in tidal creeks or rivers. Forty-five percent of the crab fishermen reported deploying pots in open areas exclusively. The majority of these crab fishermen worked in Galveston Bay and the Aransas Bay areas.

Table 11. Distribution of total terrapin bycatch reported by blue crab fisherman over their career by major bay systems.

	Categories of Reported Number of Terrapin Captured Over Career							
Major Bays where Crab Pots Deployed	**0**	**< 5**	**5-10**	**11-50**	**51-100**	**>100**	**No Reply**	**Total**
Sabine Lake			1	1	1		1	4
Sabine Lake and Galveston	2							2
Sabine Lake, Galveston, Matagorda, Corpus Christi, Lower Laguna Madre		1						1
Galveston	7	3	1	1			1	13
San Bernard River						1		1
E. Matagorda						1		1
Matagorda	1							1
San Antonio	1			2			1	4
Aransas	1	1						
Aransas and Copano	2	2						4
Aransas and Corpus Christi		1						1
Corpus Christi	1			1				2
Upper Laguna Madre and Baffin Bay	1							1
Lower Laguna Madre				1				1
No Reply							2	2
Total	**16**	**8**	**2**	**6**	**1**	**2**	**5**	**40**

Table 12. Distribution of total terrapin bycatch reported by blue crab fisherman during 2011 in each major bay system.

	Categories of Reported Number of Terrapin Captured during 2011					
Major Bays where Crab Pots Deployed	**0**	**< 5**	**5-10**	**11 - 50**	**No Reply**	**Total**
Sabine Lake	2		1		1	4
Sabine Lake and Galveston	2					2
Sabine Lake, Galveston, Matagorda, Corpus Christi, Lower Laguna Madre	1					1
Galveston	11	1			1	13
San Bernard River			1			1
E. Matagorda				1		1
Matagorda	1					1
San Antonio	2	2				4
Aransas	2					2
Aransas and Copano	4					4
Aransas and Corpus Christi	1					1
Corpus Christi	1	1				2
Upper Laguna Madre and Baffin Bay	1					1
Lower Laguna Madre			1			1
No Reply					2	2
Total	**28**	**4**	**3**	**1**	**4**	**40**

Table 13. Type of crab pots used in each bay system as reported by commercial blue crab fisherman.

	Crab Pot Type					
Major Bays	4-opening square pot	3-eyed square pot	4-opening square pot and 3- eyed square pot	4-opening square pot and 2-eyed half pot	No Response	Total
Sabine Lake	3	1				4
Sabine Lake and Galveston	2					2
Sabine Lake, Galveston, Matagorda, Corpus Christi and Lower Laguna Madre	1					1
Galveston	10		3			13
San Bernard River	1					1
E. Matagorda		1				1
Matagorda	1					1
San Antonio	4					4
Aransas	1			1		2
Aransas and Copano	4					4
Aransas and Corpus Christi	1					1
Corpus Christi	2					2
Upper Laguna Madre and Baffin Bay	1					1
Lower Laguna Madre	1					1
No Reply	1				1	2
Total	**33**	**2**	**3**	**1**	**1**	**40**

Table 14. Number of days per week that crab pots were deployed in each bay system as reported by commercial blue crab fisherman.

	Number of Days Crab Pots Deployed per Week								
Major Bays	< 2 days	> 2 days	2-3 days	2-3 days or 4-5 days	2-3 days or 6-7 days	4-5 days	6-7 days	No Reply	Total
Sabine Lake							3	1	4
Sabine Lake and Galveston Bay						1	1		2
Sabine, Galveston, Matagorda, Corpus Christi, and Lower Laguna Madre							1		1
Galveston	2	1		1			9		13
San Bernard River							1		1
E. Matagorda							1		1
Matagorda			1						1
San Antonio			1				3		4
Aransas						1	1		2
Aransas and Copano							4		4
Aransas and Corpus Christi					1				1
Corpus Christi	1						1		2
Upper Laguna Madre and Baffin Bay							1		1
Lower Laguna Madre						1			1
No Reply								2	2
Grand Total	**3**	**1**	**2**	**1**	**1**	**3**	**26**	**3**	**40**

Table 15. Number of crab pots deployed per day of active fishing in each bay system as reported by commercial blue crab fisherman.

	Number of Crab Pots Deployed on a Daily Basis					
Major Bays	**< 20**	**50-100**	**100-200**	**300-600**	**No Reply**	**Total**
Sabine Lake			2	1	1	4
Sabine Lake and Galveston Bay		1	1			2
Sabine Lake, Galveston, Matagorda, Corpus Christi, and Lower Laguna Madre			1			1
Galveston		2	11			13
San Bernard River			1			1
E. Matagorda			1			1
Matagorda			1			1
San Antonio			4			4
Aransas			2			2
Aransas and Copano			4			4
Aransas and Corpus Christi			1			1
Corpus Christi	1	1				2
Upper Laguna Madre and Baffin Bay			1			1
Lower Laguna Madre			1			1
No Reply					2	2
Total	**1**	**4**	**31**	**1**	**3**	**40**

Table 16. Deployment location of crab pots within each bay as reported by commercial blue crab fisherman.

	Water Body Type				
Major Bays	**Tidal creeks and rivers**	**Open Bay**	**Tidal Creeks, Rivers and Open Bay**	**No Reply**	**Total**
Sabine Lake		2	2		4
Sabine Lake and Galveston Bay			2		2
Sabine Lake, Galveston, Matagorda, Corpus Christi, and Lower Laguna Madre			1		1
Galveston	1	7	5		13
San Bernard River			1		1
E. Matagorda			1		1
Matagorda		1			1
San Antonio		3	1		4
Aransas		1	1		2
Aransas and Copano			4		4
Aransas and Corpus Christi		1			1
Corpus Christi		1	1		2
Upper Laguna Madre and Baffin Bay		1			1
Lower Laguna Madre			1		1
No Reply				2	2
Total	**1**	**17**	**20**	**2**	**40**

Since one of the major mechanisms by which terrapin drown is extended (> 45 minutes) submersion, we attempted to characterize the most common practices used by commercial crab fishermen in regards to the frequency of crab pot retrieval and inspection. Crab fishermen reported that they often check their traps more than once a day, but none reported checking intervals of less than 4-6 hours (Table 17).

Our final analysis consisted of developing a weekly and annual standard index of crabbing effort to compare to reported annual terrapin bycatch levels. We developed and report the trap-day/week measure which is computed as:

*# Trap-Days/Week = (Median reported number of days traps are deployed weekly) * (Median Number of traps deployed each day)*

This was also converted into an annual rate by the following formula.

*# Trap/Days/Year = (52 weeks) * (#Trap-Days/Week)*

To minimize errors associated with assigning effort or catch to the wrong bay system we utilized coastal zones for calculation of effort. In order to estimate the overall "most likely" effort expended on an annual basis by the commercial blue crab fishery we took the average number of trap/days/week and trap/days/year by coastal zone and multiplied these by a correction factor for non-respondents who did had a valid contact address but did not participate in the survey. Then, an adjustment factor was calculated (number of possible licenses per coastal zone with current valid address which we attempted to survey)/(number of licenses reporting per coastal zone). As an upper case or maximum estimate of effort we used the total number of licenses within the TPWD database (i.e. number of all listed licenses by bay system/number of respondents by coastal zone) to calculate effort as well. Results of these analyzes are presented in (Table 18).

The results of estimated blue crab fishing effort clearly illustrates that the majority of effort is concentrated along the upper Texas coast (Galveston Bay and Sabine Lake). Under both scenarios used, the effort in this zone was at least twice as much as the other individual coastal zones. These crude estimates represent an initial attempt to quantify the relative risk by coastal zones to diamondback terrapin. The higher amount of commercial blue crab trapping in the upper coast would, all other things being equal, pose a greater threat to diamondback terrapin.

Table 17. Frequency of crab pot monitoring reported by commercial blue crab fisherman.

		Frequency of Crab Pot Monitoring			
Major Bays	**>1/day**	**1/day**	**1/2 days**	**No Reply**	**Total**
Sabine Lake	1	2		1	4
Sabine Lake and Galveston Bay	1	1			2
Sabine Lake, Galveston, Matagorda, Corpus Christi, and Lower Laguna Madre	1				1
Galveston	9	4			13
San Bernard River			1		1
E. Matagorda	1				1
Matagorda		1			1
San Antonio	3	1			4
Aransas	2				2
Aransas and Copano	4				4
Aransas and Corpus Christi	1				1
Corpus Christi	2				2
Upper Laguna Madre and Baffin Bay	1				1
Lower Laguna Madre		1			1
No Reply				2	2
Total	**26**	**10**	**1**	**3**	**40**

Table 18. Estimated amount of blue crab fishing effort by coastal zone based on 2011-2012 TPWD commercial blue crab license data. The number of licenses, not licensees was used for calculation of total effort.

Category	Lower Coast	Middle Coast	Upper Coast	Total
Licenses Surveyed	24	36	65	125
No Response	9	27	44	80
Responded	15	9	21	45
Total Number of Licenses in Database	41	47	89	177
Correction Factor = Licenses Surveyed/Responded	1.60	4.00	3.10	
Maximum Corrrection Factor = Licenses Surveyed/Total No. Licenses in Database	2.73	5.22	4.24	
Average Trap Days per Week	773	804	867	
Average of Trap Days Per Year	40,181	41,786	45,067	
Corrected Total Trap Day/Week = Avg. Trap Days/Week * Correction Factor * Licenses Surveyed	18,545	28,929	56,333	
Corrected Total Trap Day/Year = Avg. Trap Days/Year * Correction Factor * Licenses Surveyed	964,340	1,504,286	2,929,333	
Maximum Trap Day/Week = Avg. Trap Days/Week * Correction Factor * Total No. of Licenses in Database	31,681	37,768	77,133	
MaximumTrap Day/Yr = Avg. Trap Days/Year * Correction Factor * Total No. of Licenses in Database	1,647,414	1,963,929	4,010,933	

Field Study Results: Informal Comments by Crab Fisherman

Various blue crab fishermen who responded to our survey provided additional comments regarding their experience in regards to terrapin bycatch. The more informative comments have been quoted and/or are summarized below.

<u>Respondent #1 – East Matagorda Bay Area</u>

He stated that sometimes, he will go 3 -4 years without catching any terrapin. Some years he may catch 1 or 2 and some years may catch 100 terrapin. They are very area specific and he catches the most in early spring. He caught a lot of terrapin in Jones creek and Cedar bayou. He claims he caught about 50 terrapin in one day around Wolf Island at the mouth of the Brazos and San Bernard. He said that people do not really eat the turtles, so most of the crabbers throw them back, but that the alligators “eat the hell out of them."He expressed concern over offering information on turtles at first because he thinks they will impose TED regulations on their traps. However, he said he's thinking about getting out of the business in a few years, so he's more than willing to take us out, show us where the turtles are, and tell us anything we want to know. He gave personal number and said call any time we want to go out.

<u>Respondent #2 – Sabine Lake</u>

Said he doesn’t catch many turtles because the water is really salty.

<u>Respondent #3 – East Bay, Galveston Bay</u>

Very concerned over offering information on turtles and bycatch because he distrusts scientific surveys because they always "lead to trouble" and he does not want to lose his job. Said he used to see a lot of turtles when he as "a kid" but never catches them anymore.

<u>Respondent #4 – Trinity Bay, Galveston Bay</u>

Says he never catches turtles.

<u>Respondent #5 – Sabine Lake and Galveston Bay</u>

Said he got the mailed survey but didn't send it back because "you try to help somebody out and they take the information and hurt you with it making you put BRDs on your traps." Now, he doesn't care anymore because he wants to get out of it.

<u>Respondent #6 – Copano and Aransas Bay</u>

Depending on opening size, your might catch a turtle but why would you want to? Can’t sell turtles! Also, don't know of any turtles in our waters.

Respondent #7 – Mission and Hynes, San Antonio Bay

Crab traps are in water year round except 2 weeks out of the year. Very seldom catch a turtle.

Respondent #8 – Trinity Bay

Never caught a turtle and has not noticed trend but has not been crabbing very long.

Respondent #9 – Sabine Lake

Said that he gets very little bycatch in his traps because he uses BRD's that he constructed himself. He said that he measured the larger crabs with calipers to figure out how wide he should make his BRDs. Every now and then, he said he'll get some redfish and flounder. Said that his BRD's have reduced his bycatch by about 95% but have had no effect on the amount of harvestable blue crab he gets.

His grand dad was a fur trapper and raised him. Together, they farmed terrapin back when it was legal. He said that Sabine Lake used to be full of terrapin and now you see very few. They sold terrapin in Louisiana and shipped them in bulk mostly up north packed in seaweed. He'd also catch terrapin putting bait in minnow traps because he found that terrapin were more attracted to the bait when it was floating vs. sitting on the bottom.

Said Old River Cove (between Port Arthur and Bridge City), which is that big finger off the lake, is where there are a lot of terrapin and a nice nesting beach. He said that he caught 2 redfish this year with terrapin hatchlings in the gut content. He said most of the turtles can be found on the back side of the Lower Natchez Refuge along the grassy shorelines.

Said he used to catch terrapin off his dock by lowering an 8' X 10' Pipe-frame butterfly net off the dock when the tide was going in or out and caught quite a few of them.

Respondent #10

"Turtle business is a bunch of "?!%", what is more important, a turtle or a man making a living". Worried BRD will hurt catch.

Field Study: Ride along observer program

We had limited success in arranging ride along trips with commercial fishermen. We were however able to take a couple of trips with Mr. Spencer Aplin, on October 17, 2012 and June 19, 2013. His mother, Sylvia Aplin is the actual permit holder. He has been captain of his crab boat for over 17 years now. He fishes for crabs in the vicinity of Jones Creek, San Bernard River and associated bays in Brazoria County. He typically launches his boat at Riversend Rd. (CR 441B near the mouth of the San Bernard River and Intercoastal Waterway (ICWW). According to Mr. Aplin commercial blue crab fishing is his primary income source. EIH research assistant, Sybil Glenos, met Mr. Aplin and his crew at 8:00 AM on Wednesday, October 17, 2012 during the first trip. Spencer's crew consisted of 2 young men. Their vessel was covered with a large working deck (Figure 135). Our observations are based on the first half of the day with them as they did their 1st "run". They did a 2nd run after lunch. Spencer said that his family holds 4 permits, but 1 of them he does not use. He has a total of 537 traps set in the San Bernard Refuge. While I was on board with them, we checked about 250 traps and collected just over 500 lbs. of harvestable-sized blue crabs. They stored the crabs in large bins, which held approximately 100 lbs. each. All bycatch in the traps were returned to the water. The only bycatch that was harmed was an eel that was stuck in the bait cage and severely injured (Figure 136). The eel was left in the trap to serve as bait for crabs . Overall, Ms. Glenos did not observe much bycatch considering the number of traps that were handled. Other bycatch included 2 oyster toadfish, 2 large stone crabs and a few undersized ones, a mangrove snapper, 2 southern flounder, a pinfish, and several Sheepshead. Sheepshead was the most commonly observed bycatch.

On June 19, 2013, research assistants Rachel George and Bryan Alleman met Mr. Aplin and his deckhands, Lloyd and Taylor, at his boat parked at the end of River End Road. Mr. Aplin was having mechanical issues with the steering on his boat and he told us he was not comfortable going into the shallower areas such as Cedar Lakes and Cow Trap Lake. Mr. Aplin used four-hole square crab pots which he uses and checks every other day. The process of checking crab pots started with Mr. Aplin grabbing the traps with a gaff hook. Then, either Lloyd or Taylor pulled up the traps, shook the crabs out of the traps into a box, re-baited the traps, and finally returned the traps to the subsequent pots spot. The final trap was moved from its original spot to a new spot further up in the line. Mr. Aplin's crew checked 126 crab pots along Jones Bayou and later 65 traps along the San Bernard River from these traps they filled 5 and a half boxes with blue crabs (one box held about 100 pounds). They were unable to check about 200 traps due to his steering problem.

There was very little bycatch observed in Mr. Aplin's traps, and no terrapin were captured or observed. Bycatch was composed of stone crab, sea catfish, spadefish, Sheepshead, and Atlantic croaker. About 15 (7.8%) out of 191 traps contained bycatch that day. All bycatch was released. Mr. Aplin did not keep the stone crab claws because he said the meat sticks to the claw when you freeze it.

Figure 135. Photograph of Spencer Aplin's commercial crab boat were we observed commercial crab fishing activity on October 17, 2012 and June 19, 2013.

Figure 136. Shrimp eel bycatch observed during blue crab fishing ride along on October 17, 2012.

Mr. Aplin stated that he has noticed a few trends in the terrapin populations in San Bernard Area. He said in previous years there were very few terrapin in the area but recently there has been more terrapin around. He said he only finds terrapin in San Bernard area for a short period. He theorizes that the terrapin move away from the San Bernard area due to high salinity and/or prey unavailability. When terrapin are around, he reported catching 20 terrapin in one traps near left fork in Cow Traps Lake. He showed us areas where he has found terrapin either basking or in his traps (Figure 137).

Figure 137. Location where terrapin have been sighted during past crab fishing trips by Mr. Aplin in the East Matagorda Bay Area.

DISCUSSION

Based on the result of this study we can make several conclusions about the life history of terrapin in Texas and the relative risks of bycatch mortality associated with the commercial blue crab fishery of Texas. Based on information obtained from crabbers, past information surveys, TPWD fishery independent surveys and ongoing work by our institution and others it appears that several areas appear to be most likely to contain high numbers of terrapin. This includes the Nueces and Aransas Bay systems, upper portions of the Matagorda Bay system, the East Matagorda Bay system and interconnecting waterways and tidal streams, and the West Bay-Deer Island complex.

Although we have not investigated all of these sites thoroughly it appears they all provide several habitat features Diamondback Terrapin apparently may prefer. This includes relative isolation from predators, shallow water that prevents large numbers of boaters including crabbing boats from penetrating, a sufficient network of intertidal marsh and tidal creeks and shell hash beaches of sufficient elevation to provide suitable nesting habitat. Each of these sites may not provide all of these features but they all seem to provide most of them. For example the East Matagorda complex is very shallow and difficult to navigate such that large expanses of it remain largely ignored by recreational and commercial fisherman. The Deer Island complex also provides a formidable barrier to most boaters via a large expanse of intertidal oyster reef with very few channel markers. In addition, it has had a long history of being predator free (at least coyotes and raccoons). The Nueces Bay area provides numerous isolated shell hash islands and relative shallow reefs for foraging by terrapin. The protection of these habitats and education of boaters and fisherman should help increase awareness for conservation of this species. Another feature that helps reduce terrapin mortality and disturbance from man is their general cryptic and cautious behavior.

Our ongoing research has identified several habitat features that may provide suitable nesting and foraging habitat. We continue to work on development of this tool and the incorporation of these variables into predictive spatial models. Populations inhabiting the South Deer Island complex appear to fluctuate primarily due to limited movement between the islands and mainland. The sex ratios appear to be fairly stable at approximately 50%. Our telemetry and mark recapture studies have documented a range of site fidelity and inherent variability in individual movement. Terrapin home range estimates varied based on how data was collected using telemetry or manual searches. Our best estimates range between 2 and 30 ha.

During our study of the population status and demographics of the Deer Island terrapin we captured and/or attained past data on a total of 876 terrapin consisting of 431 unique individuals. The highest capture rates occurred during 2011 when this study supplemented our past population monitoring efforts. Time series estimates of population size at South Deer Island based on Jolly Seber mark recapture models were highly variable with relatively large confidence intervals. The average point estimate of the population size ranged between 0 and 850. The overall median estimate for the four year period between 2008 and 2013 was 258 terrapin for a 29 ha island or 10 terrapin/ha.

Females on South Deer Island between the ages of 3 and 7 appear to exhibit a mean growth rate of 10 mm per year. Male terrapin appear to grow much faster at an earlier age and then experience erratic but slow rates possibly not more than 1 or 2 mm per year up to the age 8. As stated this suggests that more energy is placed in males growing faster and becoming sexually mature. In contrast the slower growing female, in terms of percentage of total maximum size, is more likely due to the higher metabolic costs associated with egg production. Based on examination of histograms of pseduocohorts we predict that males between the ages of 4 and 9 may experience an annual mortality rate of 20-22%. It was more difficult to estimate survival in females since it appears that the population was dominated by older age 8 females with few younger cohorts during the study period. Estimated annual survival rates based on the "pseudocohort" of age 8 to 12 females ranged between 80 and 85%. Based on the age distribution of the female, recruitment of younger individuals has been poor in recent years. Another explanation is that smaller younger females may more difficult to locate and capture or that they are utilizing different habitats where we are not surveying. This pattern needs to be investigated more closely since poor recruitment of younger females may eventually lead to a population bottleneck were a large percentage of each generation is being produced by a small minority of older and larger females.

The combination of physical isolation, suitable habitat and abundant prey has led to the relatively high population levels observed at the South Deer Island complex. The lack of boat access to commercial fisherman and most recreational vessels, the apparent lack of terrestrial predators and the beneficial protection they share by inhabiting the island with federally protected colonial waterbirds has no doubt led to the establishment of this series of island populations that links South Deer Island, North Deer Island, Greens Lake and Galveston Island. We will continue to monitor and study this unique population into the future as funding allows.

The possible impact of the commercial blue crab fishery on terrapin survival and population viability is difficult to predict. However, the general downward trend in the blue crab fishery in terms of landings and possibly effort may have led to increased survival of terrapin due to less bycatch. Unfortunately due to the paucity of long-term historical data on the blue crab fishery and bycatch it is not possible to conclusively prove this. We found that terrapin bycatch rates in our experimental gear were low at many locations despite the historical occurrence and collection of terrapin at these sites. These sites represent areas where blue crab fishing effort has been observed but terrapin populations are low in comparison to nearby higher density areas (based on other studies – not presented). In contrast we found elevated bycatch rates in our experimental gear in areas where terrapin are abundant but observed commercial blue crab fishing effort is low. This low level of commercial blue crab fishing effort is directly due to navigational hazards associated with shallow water and numerous oyster reefs. In contrast, the areas with the highest risk to terrapin from bycatch mortality would be the deeper more accessible tidal creeks and channels crab fisherman can safely drive their vessels and where blue crab catch rates most likely higher. In these areas terrapin bycatch rates would like be much higher.

During our studies of Galveston Bay we have attempted to monitor areas the fit this description and we have found consistently that they possess lower numbers of terrapin. This may be due to several factors including more accessibility to natural predators, less nesting beaches and perhaps elevated bycatch mortality. In summary, it is difficult to determine if bycatch from the commercial blue crab fishery is a serious risk since the interaction with habitat and trends in the fishery also influence the likelihood that terrapin will be exposed to this type of risk. The highest risk from bycatch mortality would be from accessible areas (e.g. open water, deeper tidal creeks) which allows high blue crab fishing effort, that are located adjacent to suitable terrapin habitat. In addition, terrapin are often very active during the spring months during mating so this would potentially expose them to crab pots as well.

The effects of BRDs on terrapin bycatch rates were difficult to assess. Throughout the study a total of 1913 blue crab and 175 other species of bycatch were captured. However only 45 individual terrapin were captured. In addition, no terrapin were ever captured in an open bay traps during this study. Although few terrapin were captured none were ever collected by traps equipped with small BRD. The only large female terrapin captured during the study was collected in a control trap. Overall median and mean catch rates of blue crabs did not vary much between crab pots lacking or possessing either small or large BRDs. Although it did appear that catch rates of blue crab declined in pots with large and smaller BRDs, this was not statistically significant. However, the size of blue crabs captured in traps without BRDs yielded significantly larger crabs. The majority of crabs captured by crab pots with and without BRDs were however of legal harvestable size. A total of 73% of the crabs harvested in traps with no BRDs were above the legal harvestable length of 127 mm. In contrast, only 63% of the crabs captured in the traps with BRDs (either size) were above the size limit. This represents a 10% decline in the number legally captured crabs. In summary, it appears that both BRDs reduced the average size of captured crabs and resulted in a higher proportion of under sized crabs that cannot be legally harvested.

These results suggest that requiring BRDs in commercial crab traps in tidal creeks in Texas would directly reduce bycatch mortality of terrapin, but it would also impact the catch of legal size blue crabs. However, since terrapin were not captured in open bay habitats during this study, where the majority of the commercial blue crab fishing effort occurs, it is unclear whether the requirement to add BRDs would make a significant impact on terrapin bycatch mortality. The blue crab fishery supports one of the largest commercial fisheries in Texas, surpassed only by shrimp and oysters in annual landings. The overall impacts of potential BRD regulations on the Texas commercial blue crab fishermen and terrapin bycatch should be carefully considered by management professionals.

Appendix 1. Final Crab Fisherman Survey Cover Letter, Mail Survey Form and Phone Interview Protocol

Environmental Institute of Houston

December 19, 2013

«AddressBlock»

«GreetingLine»

You have received this letter because you are a licensed commercial crab permit holder registered in the state of Texas. The University of Houston-Clear Lake and the Environmental Institute of Houston (EIH) are conducting a study on the catch and bycatch rates of the Texas blue crab fishery. Your expertise is needed to help with this research.

Please find enclosed a short, one page (front and back), and interview form. Please complete this form and return to EIH using the enclosed return addressed envelope. Also enclosed, for your records, is an Informed Informational document describing the study; and the Principal Investigator's contact information should you have any questions regarding the interview form or the study.

Thank you for your time and contribution to this research study.

Respectfully,

Jenny Oakley

Environmental Scientist
Environmental Institute of Houston

(281) 283-3950
Oakley@uhcl.edu

TEXAS BLUE CRAB FISHERMEN SURVEY

Date:___________________ Contact Name (***Optional***): _________________________________

Contact Phone (***Optional***): ______________ Email (***Optional***):________________________________

\- -

1. Do you crab commercially or recreationally? (*circle one*)
   a. **Commercially** **b. Recreationally** **c. Both**

2. How many years have you been crabbing? (*circle one in each column*)

Commercially: (*circle one*)	**Recreationally:** (*circle one*)
a. **Less than 1 year**	a. **Less than 1 year**
b. **1-5 years**	b. **1-5 years**
c. **5-10 years**	c. **5-10 years**
d. **10-20 years**	d. **10-20 years**
e. **over 20 years**	e. **over 20 years**
f. **Not applicable**- recreational only	f. **Not applicable**- commercial only

3. What kind of crab do you primarily target? (*circle one*)
   a. **Blue Crab** **b. Stone Crab** **c. other (*specify*):**____________________________

4. What type of crab trap do you fish with? (*circle all that apply*)
   a. **4-Opening Square** **b. 2-Opening Rectangle** **c. Circular** **d. Hoop Trap** **e. Other:**___________




5. Where do you primarily obtain your traps? (Circle one)
   a. **I make my own traps** **b. Purchase from a manufacturer, Name:** _________________________________

6. Where do you primarily deploy your traps? (Circle all that apply)
   a. **tidal creeks/rivers** **b. open bays** **c. both** **d. other (specify):** __________________________

7. Please circle the major bay system in which you deploy crab traps. * Specify minor bays in the blanks provided below:

Sabine Lake	Galveston Bay	Matagorda Bay	San Antonio Bay	Aransas Bay	Corpus Christi Bay	Upper Laguna Madre	Lower Laguna Madre

8. What type of bait do you primarily use in your traps? (*circle all that apply*)
   a. **Menhaden (poagie, shad)** **b. Mullet** **c. Catfish** **d. other (*specify*):______________**

9. On average, how many days a *week* are your traps deployed? (*circle one*)
   a. **Less than 2 days/week** **b. 2-3 days/week** **c. 4-5 days/week** **d. 6-7 days/week**

10. On average, how many traps do you deploy at any one time? (*circle one*)
    a. **Less than 20** **b. 20-50** **c. 50-100** **d. 100-200**

11. On average, how frequently do you check or retrieve your traps? (*circle one*)
    a. **Every 2-3 hours** **b. Every 4-6 hours** **c. Only once a day**

12. What type of bycatch* do you *regularly* find in your traps? (*circle all that apply*)
    a. **Undersized crabs** **b. fish** **c. turtles** **d. other (specify): ____________________**

13. How many turtles would you estimate you caught in 2011? (*circle one*)
    a. **Zero** **b. Less than 5** **c. 5-10** **d. 11-50** **e. 51-100** **f. over 100**

14. How many turtles would you estimate you have caught throughout your career? (*circle one*)
    a. **Zero** **b. Less than 5** **c. 5-10** **d. 11-50** **e. 51-100** **f. over 100**

15. Throughout your career, have you noticed a trend in your annual catch of harvestable Blue Crab? (*circle one*)
    a. **Increase** **b. Decrease** **c. No Difference**

16. Throughout your career, have you noticed a trend in the number of turtle bycatch? (*circle one*)
    a. **Increase** **b. Decrease** **c. No Difference**

***Bycatch = animals other than legal size crabs.**

Please feel free to include below any additional comments or details that you feel could benefit this study:

Thank you for your time and cooperation!

Please return this completed form to EIH, 2700 Bay Area Blvd, Box 540, Houston TX 77058 using the enclosed return envelope.

Bycatch Study: EIH Interview Protocol

Interview Protocol for Blue Crab Bycatch Study
Before the phone call interview try to pre-fill out the info on the top of the interview sheet:

Interviewer Name: your name at the top left corner of the survey form.
Date:
Contact Name:
Contact Phone #:
Contact E-mail:
Type of Interview: over-phone, in-person, etc.
If you call and get no answer, leave the following message:

I am _______________ with the University of Houston-Clear Lake and we are conducting a study on the catch and by-catch rates of the Texas blue crab fishery. To more accurately assess the blue crab fishery, your expertise is needed by participating in a brief survey. Please call 281-283-3950 at your earliest convenience to complete the survey. If we have not heard from you in one week we will attempt to contact you again. Thank you for your time and assistance.

Record the date/time and your initials of every call attempt at the bottom of the interview form… if you leave a message please note. If they do not have an answering machine, or you left a message with someone else please note that.

Follow the general format and instructions below:

I am ___*your name*___ with the University of Houston-Clear Lake and we are conducting a study on the catch and by-catch rates of the Texas blue crab fishery. To more accurately assess the blue crab fishery, your expertise is needed by participating in a brief survey. The survey should take approximately 5 minutes. Your input will be kept completely confidential and will be used for educational purposes only.

Would you be willing to participate in a brief survey regarding blue crab fishing?

If yes continue, if no simply thank them for their time and document the attempt.
If they agree to take the survey:

Great! Thank you. The survey is mostly multiple choices, so I will offer you responses to choose from. To conduct this survey in a timely manner, I will ask that you answer each question and then once we have completed all of the questions, you will have all the time you need at the end to offer any additional information that you would like to provide. All information we ask of you is optional, so should you decide that you do not wish to continue or wish to skip a particular question, just let me know.

Do you have any questions before we begin?

If no questions:

Ok. Let's begin the survey now.

Proceed to question # 1:

Question #1:

Do you crab commercially, recreationally, or both?

If response to question #1 is commercial only or recreational only, proceed to appropriate question #2. If response is both, ask both questions for #2.

If response is <u>commercial,</u>

<u>Question #2:</u>

How many years have you been crabbing commercially?

A) Less than 1 year
B) 1-5 years
C) 5-10 years
D) 10-20 years
E) Over 20 years

If response is <u>recreational,</u>

<u>Question # 2:</u>

How many years have you been crabbing recreationally?

A) Less than 1 year
B) 1-5 years
C) 5-10 years
D) 10-20 years
E) Over 20 years

<u>Question #3:</u>

What kind of crab do you primarily target?

A) Blue crab
B) Stone crab
C) Other: ______________________

If response to Question #3 is "other," ask to specify and record.

<u>Question #4:</u>

What type of crab trap do you fish with?

A) 4-opening square trap
B) 2-opening rectangle trap
C) Circular trap
D) Hoop trap
E) Other: _________________

If response to Question #4 is "other," ask to specify and record. Only describe the traps if they ask.

<u>Question #5:</u>

Where do you primarily obtain your traps? Do you:

A) Construct your own

B) Purchase traps from a manufacturer; Name of manufacturer: ___________

If response to Question #5 is "manufacturer," ask to specify the name of the manufacturer.

Question # 6:

Where do you primarily deploy your traps?

A) Tidal creeks and rivers
B) Open Bays
C) Both tidal creeks and open bays
D) Other: ________________

If response to Question #6 is "other," ask to specify and record.

Question # 7:

In which major bay system do you deploy your traps?
(Sabine, Galveston, Matagorda, San Antonio, Aransas, Corpus Christi, Upper Laguna Madre, Lower Laguna Madre)

____

Record response, and then ask:

Could you specify the minor bays in which you deploy your traps?

____

Record response.

Question #8:

What type of bait do you primarily use in your traps?

A) Menhaden, poagie, and/or shad
B) Mullet
C) Catfish
D) Other: _____________

If response to Question #8 is "other," ask to specify and record.

Question #9:

On average, how many days a week are your traps deployed?

A) Less than 2 days/week
B) 2-3 days/week
C) 4-5 days/week
D) 6-7 days/week

Question #10:

On average, how many traps do you deploy at any one time?

A) Less than 20
B) 20-50
C) 50-100
D) 100-200

Question #11:

On average, how frequently do you check or retrieve your traps?

A) Every 2-3 hours
B) Every 4-6 hours
C) Only once a day

Question #12:

What type of bycatch do you regularly find in your traps?

A) Undersized crabs
B) Fish
C) Turtles
D) Other: ___________

If response to Question #12 is "other," ask to specify and record.

Question # 13:

How many turtles would you estimate you caught in 2011?

A) Zero
B) Less than 5
C) 5-10
D) 11-50
E) 51-100
F) Over 100

Question #14:

How many turtles would you estimate you have caught throughout your career?

A) Zero
B) Less than 5
C) 5-10
D) 11-50
E) 51-100
F) Over 100

Question #15:

Throughout your career, what type of trend have you observed in your annual catch of harvestable Blue Crab?

A) Increase
B) Decrease
C) No difference

Question # 16:

Throughout your career, what type of trend have you observed in the amount of annual turtle bycatch?

A) Increase
B) Decrease
C) No difference

That concludes the survey. Are there any additional comments or details that you wish to provide that you feel might also benefit this study?

Record additional comments:

____

____

____

____

____

Thank you so much for your participation! If you would like any more information regarding this study please feel free to contact Jenny Oakley at the University of Houston-Clear Lake. The number she can be reached is (281) 283-3950.

If the interview is in person, please leave the interviewee with a copy of the UH-CL Informed Information Document (Attached)

Informed-Informational Document about Research

You are being asked to participate in the research project described below. Your participation in this study is entirely voluntary and you may refuse to participate, or you may decide to stop your participation at any time. Should you refuse to participate in the study or should you withdraw your consent and stop participation in the study, your decision will involve no penalty or loss of benefits to which you may be otherwise entitled. You are being asked to read the information below carefully, and ask questions about anything you don't understand before deciding whether or not to participate.

Title: Crab Trap By-catch Study

Principal Investigator(s): George Guillen, Ph.D., University of Houston-Clear Lake
Email: Guillen@uhcl.edu; Phone: (281) 283-3950
Student Investigator(s): Sybil Glenos, Bryan Alleman, Abby Marlow, Emma Clarkson

PURPOSE OF THE STUDY

The purpose of this research is to study Blue Crab and bycatch catch rates in Galveston Bay, TX

PROCEDURES

The research procedures are as follows: We will be conducting surveys from commercial and recreational crab fishermen inquiring of their experiences in the crabbing profession regarding both crab catch and bycatch.

EXPECTED DURATION

The total anticipated time commitment will be approximately 5 to 10 minute.

RISKS OF PARTICIPATION

There are no anticipated risks associated with participation in this project.

BENEFITS TO THE SUBJECT

There is no direct benefit received from your participation in this study, but your participation will help the investigator(s) better understand catch and bycatch rates from commercial and recreational crabbing along the Texas Coast.

CONFIDENTIALITY OF RECORDS

Every effort will be made to maintain the confidentiality of your study records. The data collected from the study will be used for educational and publication purposes, however, you will not be identified by name. For federal audit purposes, the participant's documentation for this research project will be maintained and safeguarded by the Principal Investigator, Dr. George Guillen, for a minimum of three years after completion of the study. After that time, the participant's documentation may be destroyed.

FINANCIAL COMPENSATION

There is no financial compensation to be offered for participation in the study.

INVESTIGATOR'S RIGHT TO WITHDRAW PARTICIPANT

The investigator has the right to withdraw you from this study at any time.

CONTACT INFORMATION FOR QUESTIONS OR PROBLEMS

The investigator has offered to answer all your questions. If you have additional questions during the course of this study about the research or any related concern, you may contact the Principal Investigator, George Guillen, Ph.D., at phone number (281) 283-3950 or by email at Guillen@uhcl.edu.

You have agreed to waive your signature on this form. Your voluntary participation is indicated by completing and returning the survey form (attached), and you may cease your participation at any time. Such participation does not release the investigator(s), institution(s), sponsor(s) or granting agency(ies) from their professional and ethical responsibility to you.

THE UNIVERSITY OF HOUSTON-CLEAR LAKE (UHCL) COMMITTEE FOR PROTECTION OF HUMAN SUBJECTS HAS REVIEWED AND APPROVED THIS PROJECT. ANY QUESTIONS REGARDING YOUR RIGHTS AS A RESEARCH SUBJECT MAY BE ADDRESSED TO THE UHCL COMMITTEE FOR THE PROTECTION OF HUMAN SUBJECTS (281-283-3015). ALL RESEARCH PROJECTS THAT ARE CARRIED OUT BY INVESTIGATORS AT UHCL ARE GOVERNED BY REQUIREMENTS OF THE UNIVERSITY AND THE FEDERAL GOVERNMENT. (FEDERALWIDE ASSURANCE # FWA00004068)

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