Plenary Talks

Keratin, Kids, and Kiawah Terrapins

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The longest ongoing study of diamondback terrapins (*Malaclemys terrapin*) anywhere began in the coastal salt marshes and tidal creeks bordering Kiawah Island more than three decades ago. A point of irony is that the first one was caught by a child as by-catch in a crab trap, a recreational practice later indicted as a cause of decline in the Kiawah terrapin populations. At the time, in the early 1980s, upon discovery that terrapins were abundant in the Kiawah River, a spontaneous response was to try to catch them. The next 22 terrapins were captured in a single seine haul of 15 minutes by three children and their dad in a tidal creek. Today, a dozen trained college students with seines and trammel nets can no longer repeat such a success rate in a full day. Such statements leave unanswered questions, including, why had herpetological studies conducted on the island beginning in the early 1970s not revealed the presence of terrapins? How did giant slider turtles in fresh waters and endangered loggerheads in the sea shift the focus away from the only turtle in the world endemic to the in-between brackish waters? Should the limitations of child labor laws be revisited so that more terrapins can be captured during the current sampling, or are other factors at play in explaining the status of terrapins in the Kiawah waters today?

The iconic diamondback terrapin: what have we learned and what do we need to know to ensure its survival?

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The diamondback terrapin is characterized by a long history of superlatives. It is one of only a very small number of turtles worldwide that routinely live at the brackish interface between fresh and salt water. Of the 58 species of turtles found in the United States, this is the only one we call a terrapin. The word “terrapin” originated in the early 17th century for denoting the diamondback terrapin, and was modified from the Virginia Algonquian word “torope.” Thus, Native Americans were the first to give this species a name, albeit not a Linnaean binomial, but it stuck. Today only a few US turtles have common names derived from Native American words. Roger Conant, one of America’s most famous herpetologists, added to the accolades by calling terrapins the “most celebrated of American turtles.” Because of their value as a gourmet food item in the early 1900s, they became one of the most economically important reptiles in the world. As wild stocks became depleted, the United States government initiated studies of captive propagation in the 1920s. The terrapin fad finally died out, around the time of Prohibition, and populations recovered from decades of exploitation, only to face a new suite of threats in the modern era. The terrapin is among the best-studied turtle species in the United States but research is apparently not enough to reverse observed population declines. I conclude by discussing lessons learned over almost 30 years of terrapin studies at nearby Kiawah Island, South Carolina.

Oral Presentations

***** Indicates the presenter

Investigating the Demographic Impacts of Ghost Traps on Diamond-Backed Terrapins (*Malaclemys terrapin*)

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Ghost traps include lost and abandoned blue crab (*Callinectes sapidus*) traps that passively capture terrapins. An estimated 25% of all crab traps become ghost traps, which can persist for years in coastal wetlands. Bycatch species die from anoxia, starvation, or predation within a trap. Any animal entering a ghost trap may become new bait until a trap is retrieved or disintegrates. My study estimates the number of ghost traps in the brackish sounds and intracoastal waterways along the Cape May Peninsula of New Jersey using side-scan sonar. I interpret salvaged skeletal elements from retrieved traps to estimate terrapin mortality rates. Minimum mortality and terrapin demographics can be inferred by applying paleontological techniques to disarticulated bones gleaned from ghost traps. Hyoplastra and hypoplastra are the bones most frequently retained in traps. Both have proven reliable for allometry, enabling reconstruction of shell dimensions in life. Fontanels also facilitate determination of demographic class. I assess the percentage of terrapin mortalities potentially avoided via bycatch reduction devices and identify locations of highest concern. By measuring several hundred complete skeletons in museum and university collections, I created a dataset for comparison to bones collected in the field. Regression models based on complete skeletons allow me to use isolated terrapin bones retrieved from traps to predict which populations are most vulnerable. Insights gained from these previously unpaired techniques lead me to coin the term "conservation osteology." These techniques, coupled with geo-referencing mortality hotspots, are powerful tools for understanding bycatch impacts.

Nesting Characteristics of the Ornate Diamondback Terrapin (*Malaclemys terrapin macrospilota)* in the Big Bend Region of Florida

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The diamondback terrapin (*Malaclemys terrapin*) occurs in brackish coastal regions ranging from Cape Cod, Massachusetts to southern Texas. Most of our understanding of this species' natural history is based on studies of populations along the Atlantic Coast. Few papers have been published on Gulf Coast terrapins and information related to nesting ecology is nearly absent. In Florida, the nesting season begins in early May and ends by late July. Nests laid early in the season must endure extreme tides, adverse weather conditions, and predation. We have studied the distribution of the ornate diamondback terrapin (*M. t. macrospilota*) in the Big Bend region of Florida since 2007, during which time we have also recorded nesting data. We recorded nesting dates, GPS locations, habitats, clutch sizes, and egg

measurements and weights. We located six intact terrapin nests that were found by following crawls on the sand. Additionally, two nesting females associated with two of these nests were captured, measured and weighed. Nests are typically located in sandy areas above the high tide mark and near coastal shrub vegetation. It is important to identify and map these nesting areas to insure consideration during habitat management and conservation efforts.

Texas diamondback terrapin (*Malaclemys terrapin littoralis*) in the Nueces Estuary, Texas

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To augment the limited information on Texas diamondback terrapins (*Malaclemys terrapin littoralis*) in Texas, terrapins were captured in crab traps during September-December 2010 at 13 stations within the Nueces Estuary, Texas. Three habitats were sampled within the estuary: tidal river, deltaic marsh, and oyster reef. Terrapins were marked and standard metrics were recorded. An overall catch per unit effort (CPUE) and M:F sex ratio were calculated. A population estimate was calculated using the POPAN model in Program MARK (6.1). Overall CPUE was 0.47 terrapins/trap/24 hours and 0.59, 0.19, and 0.0 for the oyster reef, tidal river, and deltaic marsh habitats, respectively. Sex ratio (M:F) was 1.5:1 among initial captures and 3.75:1 for recaptured terrapins. Average distance between capture and recapture was 0.4 km with a minimum and maximum distance of 0.0 km and 1.6 km, respectively. The population estimate was 438 terrapins. Minimal growth was observed in recaptured terrapins coupled with an average weight loss of 5.1%. Male dominated sex ratios are well documented in this species, and results from this study support those previous findings. Distances between initial captures and recaptures support previous research suggesting small home range and high site fidelity in this species. Minimal growth and observed weight loss was attributed to hypersaline conditions caused by severe drought. Slowed growth may result in delayed maturity in the Nueces Estuary terrapin population. Support for this study was provided by the Coastal Bend Bays and Estuaries Program and Center for Coastal Studies.

Conservation of the Diamondback Terrapin at the Northern Fringe

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We have conducted a number of studies and expanded our conservation efforts for diamondback terrapins on Cape Cod, MA. Using microsatellite markers, we have completed a population genetic study, which includes all 5 terrapin subgroups on Cape Cod: those that inhabit Wellfleet, Eastham. Orleans, Barnstable and Wareham/Marion. 4 of the subpopulations, all of which share the same embayment, are very similar from a genetic perspective. We have examined the correlation between female size, clutch size and size of hatchlings and have evidence that larger females produce larger clutches with larger offspring. We have examined nesting trends at one site for over 10 years and have

found that the onset of nesting is occurring earlier each year; almost 2 weeks earlier in 2012 compared to 2003. The onset of nesting correlates with warmer water temperatures in May of each year. Our conservation efforts have focused on creation of nesting habitat and protection of nests. Over the past 5 years, our turtle gardening and nest protection programs have been very successful; we have created a substantial increase in nesting habitat while dramatically decreasing depredation rates. As a result, we are observing a high level of recruitment. In partnership with the Cape Cod National Seashore, we are in our third year of nest monitoring in the Herring River Estuary, a site that is slated for the largest estuary restoration project in New England.

Survey techniques for diamondback terrapin (*Malaclemys terrapin*) populations in Florida

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Most reptile field guides describe the range of the diamondback terrapin as from Massachusetts to Texas, however throughout that range there are gaps where terrapins are absent. Gaps are sometimes due to habitat inconsistencies, both natural and anthropogenic. In order for state and federal agencies to manage terrapins and for researchers to study them, it is necessary to determine where terrapin populations occur. The Florida coastline represents about 20% of the species' entire range, and for much of it no terrapin records exist. Published studies of terrapins in Florida show them at Talbot Island in the northeast, Merritt Island on the central Atlantic Coast, the Florida Keys, and the Everglades. Recently we have worked in the Big Bend region recording population concentrations. It is often difficult to capture terrapins, but we realized that if what we need to know is where terrapin population "hotspots" are located, then it is not necessary to actually capture them. We use evidence in the form of depredated nests, terrapin remains, crawls, heads at the surface, and of course live terrapins or intact nests when we find them. This protocol allows us to cover more area and locate more of the hotspots. With that knowledge, subsequent researchers can perform population studies in the future. Our goal is to "connect the dots" of terrapin populations throughout Florida and we submit that our methods would be valuable rangewide.

Analysis of Diamondback Terrapin (*Malaclemys terrapin*) Hatchling Adaptations to Marine and Terrestrial Habitats

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The Diamondback terrapins (*Malaclemys terrapin*) are a threatened keystone turtle that inhabits salt marshes of the U.S. Atlantic Coast. Knowledge of the early life history, especially salinity tolerance and terrestrial overwintering, are vital to conservation efforts. Previous research has produced anecdotal evidence of hatchling terrestrial overwintering, occurring perhaps more frequently than any other

aquatic turtle. Terrapins and other emydid turtles have lachrymal glands used in osmotic regulation; however the ability of hatchlings to survive in various salinity environments is poorly understood. Immediately after hatching terrapin hatchlings were raised in six laboratory treatments of differing salinities (0.0, 1.0, 4.5, 9.0, 12.0, 18.0ppt) and others in a terrestrial habitat. Over the subsequent year hatchlings were tested for desiccation tolerance, salinity tolerance, and habitat preferences to detect ontogenetic changes. The hatchlings in moderately brackish water (4.5 and 9.0 ppt) experienced the greatest growth. Hatchlings in the terrestrial habitat had the lowest mortality, while those in the 0.0 ppt treatment were the highest. Both the desiccation and salinity tolerances were influenced by treatment; the terrestrial hatchlings being more desiccation-tolerant and the 18ppt hatchlings were more salinity-tolerant. The other treatments developed tolerance with age; however tolerance did not drastically increase overall for the hatchlings. Habitat preferences indicated a high affinity for terrestrial habitats across all treatments and a tendency for specimens from lower salinity treatment to prefer higher salinities and vice-versa. Our results suggest that terrapin hatchlings are physiologically flexible and can readily acclimate to a variety of diverse habitats.

Experiments with BRDs in Virginia tidal waters: An emerging consensus?

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The Virginia Marine Resources Commission regulates the Commonwealth's blue crab fishery but is hesitant to constrain crabbing beyond limits on the number of traps per person. As a result, by-catch reduction devices (BRDs) on commercial-style crab traps are not required for any person crabbing in Virginia tidal waters. We have completed three studies in the Chesapeake Bay estuary on crab catch and by-catch from commercial-style crab traps without BRDs and traps fitted with BRDs. Small BRDs (4.5 x 12 cm) were nearly 100% effective at excluding terrapins, but crab catch was depressed relative to the catch in traps without BRDs. Large BRDs (5 x 15.2 cm) tended to exclude most terrapins, even those whose shell dimensions were small enough to fit through the BRD gape. Further, crab catch was only slightly diminished in traps fitted with large BRDs, and legal crab size was unaffected. Traps without BRDs captured up to half of the estimated terrapin population in one creek system, demonstrating the localized negative impacts of crabbing on terrapins. Most recently, we have begun a study of BRDs on the oceanside of the eastern shore of Virginia, where despite commercial crabbing, terrapin populations still appear to be large. The effectiveness of BRDs at excluding terrapins and retaining crabs may vary by location, making the push for BRD regulations in Virginia that much more difficult.

Oral Presentations

Does crab trap mortality threaten adult females of Gulf Coast diamondback terrapin subspecies?

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Crab trap mortality has been widely touted as one of the major threats decimating numerous diamondback terrapin populations throughout the species' range. In addition to reducing overall population abundance, it is believed that crab trap mortality is a greater threat to adult males than the larger adult females because males never reach a size that limits their entry into crab traps. Research has even shown that, over time, this mortality has resulted in female-biased sex ratios in some populations. However, the average size of diamondback terrapins decreases with decreasing latitude; therefore, does crab trap mortality pose a significant threat to adult females of Gulf Coast subspecies? The width and height of commercial crab trap funnel openings were compared to shell morphology of adult female Mississippi diamondback terrapins (*Malaclemys terrapin pileata*) captured in salt marsh habitats and on nesting beaches in Alabama and Mississippi from 2006-2013. Approximately 90% of captured adult females would not be excluded from entering crab traps based on size, and thus would be susceptible to crab trap mortality. Moreover, a substantial amount of crabbing effort occurs in sampled areas that support relatively high terrapin nesting, further stressing the potentially underestimated threat crab trap mortality poses to diamondback terrapin females of smaller Gulf Coast subspecies.

Integrative conservation of diamondback terrapins (*Malaclemys terrapin*) on the Jekyll Island Causeway

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Conservation management of human-wildlife conflicts should be ecologically sustainable and socially acceptable. Roads are a pervasive anthropogenic threat to diamondback terrapins (*Malaclemys terrapin*) across the majority of their range. For example, 100-400 female terrapins are killed annually just on the 6-mile causeway to Jekyll Island, GA. Beginning in 2009, researchers at the University of Georgia and Georgia Sea Turtle Center collaborated to conduct a two-phase conservation initiative to reduce road effects on terrapin populations while also considering the attitudes of humans using the Jekyll Causeway. In Phase 1, we estimated rates of road mortality, as well as nest predation by raccoons, and these threats were predicted to cause modest to severe population declines. We identified that terrapin emergence on roads is temporally and spatially predictable, creating an opportunity for targeted management actions. In Phase 2, we surveyed Jekyll patrons in order to rank proposed management actions by overall public acceptability and identify conflicting attitudes among stakeholder groups. We

found strong support for actions that did not impact causeway aesthetics or speed limits. Patrons had highly conflicting, but mostly negative, attitudes toward strategies involving raccoon removal. We will use these findings to improve communication and buy-in among stakeholders. Beginning in 2013, we have deployed and are in the process of testing acceptable strategies, including flashing warning signage, short fencing, and roadside vegetation removal. If found effective, these management tools can be adapted to mitigate road threats throughout the terrapin's range, and for other at-risk wildlife.

Diet and foraging ecology of mangrove diamondback terrapins (*Malaclemys terrapin rhizophorarum*) in protected habitats of South Florida

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Diamondback terrapins (*Malaclemys terrapins*) are found in salt marshes and mangroves along the Atlantic and Gulf coasts from Massachusetts to Texas. Unique amongst turtles as the only estuarine species, they face many threats that impact coastal landscapes, including habitat loss, climate change, and pollution. These stressors could potentially affect the distribution and abundance of their prey species; thus it is important to understand their foraging ecology. Whereas previous diet studies have elucidated terrapins' role in temperate salt marsh food webs, food resources for subtropical mangrove terrapins have not been studied.

We are currently examining the role of this reptile predator in the subtropical mangrove food web. Specifically we are investigating how spatial and temporal variation influence terrapin diets by sampling terrapins and potential food items at sites within Everglades National Park and the Florida Keys National Wildlife Refuge. A secondary focus is to characterize long-term foraging ecology through stable isotope analysis. Incorporating stable isotope analysis of terrapin blood and scutes, along with their potential prey, will allow us to discern diet information over varying time scales. Thus far fecal samples have shown mangrove terrapins to be dietary generalists consuming prey such as crabs, snails, barnacles, and fish. Preliminary $\delta^{13}C$ analysis shows differences between terrapins' by site, and $\delta^{15}N$ analysis indicates males likely consume a variety of prey across trophic levels, while females appear more constant across individuals. This study will allow us to document how terrapins are potentially changing their resource use in a changing landscape.

Oral Presentations

Understanding movement patterns and population structure of Diamondback terrapins in heavily urbanized ecosystems using mitochondrial DNA

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Many aspects of the long-term movement patterns of Diamondback terrapins (*Malaclemys terrapin*), both in terms of nest site fidelity of females and regional dispersal by both males and females, are poorly studied. Genetic data has the potential to unravel some of these patterns where direct observations of turtles are impossible or inconclusive. We have conducted a genetic study of terrapins in the New York/New Jersey area, specifically in Gateway National Recreation Area and the NJ Hackensack Meadowlands. Using a fragment of the mitochondrial D-loop and DNA samples from terrapins from Ruler's Bar Hassock and JoCo Marsh in Jamaica Bay, and Sawmill Wildlife Management Area in the NJ Meadowlands, we show that terrapins found in the Meadowlands are more closely related to each other than they are to terrapins in Jamaica Bay, though they do not appear to be completely isolated. This is the first time the genetics of the NJ Meadowlands terrapins have been examined and could shed light on the origin of this population, which is yet unknown. Adequate habitat for terrapins in the Meadowlands was probably rare prior to the 1950s. Given that terrapins live in habitats often subjected to intense anthropogenic impact, as evidenced by the terrapins in this study, an understanding of their movement patterns is critical to the development of sound management plans for this species.

Turtles in a different light: the underwater visual ecology and mating behavior in the diamondback terrapin

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Terrapin mating behavior has been explored through limited observations and genetic analyses, but what do we know about mate choice and selection? In closely related turtle species, courtship behavior involves tactile and visual communication. What is a terrapin looking for in a potential mate? Like birds and other reptiles, terrapins have tetrachromatic vision—they can perceive colors in the UV, blue, green, and red portions of the electromagnetic spectrum. This study has found, through the analysis of spectrophotometric data, that terrapins express conspicuous coloration and patterns on their skin, carapace, and plastron, in all four color channels. These colors and patterns may be used to assess the genetic quality of a potential mate. Phenotypic measurements show a strong correlation between colors expressed in the UV and red portions of the spectrum, suggesting that these colors are co-selected. Light availability in the water column attenuates to optimally highlight these correlated colors; ultraviolet light dominates at the water surface but attenuates quickly within 0.5 meters below the surface. This suggests

that mate selection should occur near the surface of the water column to allow the terrapin to optimally display UV coloration. Given that mating aggregations are observed to occur near the surface of the water column, this suggests that a visual signal may be an important factor in mate selection. Given also that males have been observed to arrive in advance to an aggregation site, terrapins may be performing lek behavior similar to that of birds, where vision dictates choice.

Potential Impact of the Blue Crab Fishery on Texas Diamondback Terrapin (*Malaclemys terrapin littoralis*)

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Very little information exists on the sources of mortality affecting the Texas Diamondback terrapin (*Malaclemys terrapin littoralis*). Although many factors have been proposed to contribute to terrapin mortality within Texas in recent history, including habitat loss and degradation, road and boat mortality, and mortality as bycatch in crab traps, few studies have provided evidence linking these factors to excessive mortality. Recently the Texas Parks and Wildlife Department (TPWD) has started reviewing available data on the blue crab (*Callinectes sapidus*) fishery to determine if the fishery represents a substantial risk to terrapin. Prior to this recent effort we had initiated a bycatch study to evaluate the risk of the current blue crab fishery to terrapin. 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 were low when compared to nearby high density areas. 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 due to shallow water and oyster reefs. The BRD's did negatively influence catch rates and sizes of blue crab at all sites. Although this study is ongoing our preliminary conclusion is that terrapin mortality from the blue crab fishery is probably limited to certain locations where 1) crabbers can actively fish in deeper navigable tidal creeks and 2) terrapin are found nearby in wetland habitat.

Osmotic and metabolic status of overwintering diamondback terrapins in North Carolina

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Estuarine ectothermic vertebrates are faced with highly variable, tidally-influenced conditions, and many aspects of their biology reflect their ability to withstand and respond to the challenges posed by this environment. Diamondback terrapins (*Malaclemys terrapin*) experience broad fluctuations in temperature, salinity, and freshwater and oxygen availability, particularly while overwintering in the

intertidal mud. The physiological adjustments necessary to maintain water and salt balance and the metabolic adjustments that accompany seasonal changes in activity have not been well-characterized for terrapins under field conditions. To investigate changes in osmotic and metabolic physiology of overwintering terrapins, we obtained repeat blood samples from 10 radio-tagged female terrapins maintained in an open-air fence enclosure in a North Carolina salt marsh. From November 2011 to April 2012 we measured monthly plasma concentrations of inorganic and organic osmolytes (Na^+, K^+, Cl^-, uric acid, urea), osmolality, glucose, and metabolic strategy indicators (lactate, total Ca^{2+}, and Mg^{2+}). We used a linear mixed model to assess the effects of month and environmental factors (mean carapace temperature, salinity, and total rainfall one week prior to blood sample) on terrapin blood chemistry, with terrapin mass and activity as covariates and terrapin individuals as random factors. Best fit models included carapace temperature and terrapin mass with high individual variability, suggesting there was no clear seasonal linear trend in osmotic status or shift in metabolic strategy in overwintering NC terrapins. This study provides unprecedented insight into the physiological strategies of terrapins exposed to natural environmental fluctuations and provides baseline blood composition data for diamondback terrapins.

Mangrove terrapins in the Florida Everglades

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Estimates of species-specific demographic parameters (i.e., survival rates, abundance, etc.) are necessary for population modeling efforts that are often used to assess endangerment. However, for many threatened species, such demographic parameters have not yet been estimated. Diamondback terrapins (*Malaclemys terrapin*) are distributed along the US coastline from Massachusetts to Texas in brackish water habitats. State-listed as at least a species of special concern in many states throughout its range, this long-lived, sexually dimorphic turtle is subject to both terrestrial and aquatic threats (i.e., roadkill, predation, and bycatch). Whereas ample morphological, behavioral, and reproductive information has been collected for terrapins living in temperate salt marsh habitats, comparatively little is known about mangrove terrapins. Analysis of a 12-year mark-recapture data set (N=607 marked individuals) on mangrove terrapins in Big Sable Creek, Everglades National Park revealed a 64% overall mean recapture rate and ~1:1 sex ratio (51% female/49% male) with 94% 'adult' animals in the sampled population. Consistent survival rates and abundance estimates suggest that this remote population of mangrove terrapins is stable, despite limited recruitment and limited nearby nesting habitat.

Oral Presentations

Using Spatial Models to Assess the Impacts of Landscape and Seascape Factors on the Distribution of Diamondback Terrapins

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Previous conservation research has focused more on identifying factors that influence distributions of terrestrial species than aquatic species, with practically no focus on species that occupy the aquatic-terrestrial ecotone. With more than 6,000 km of shoreline, Virginia's Chesapeake Bay provides an excellent opportunity to study how human modifications of this ecotone affect the distribution of the diamondback terrapin (*Malaclemys terrapin*). Terrapins are particularly susceptible to human modifications due to their reliance on both terrestrial and aquatic habitats. For example, modifications such as shoreline hardening alter foraging and nursery habitats and prevent female terrapins from accessing nesting grounds. Land-use change also increases the abundance of diamondback terrapin nest predators, such as raccoons and crows. Finally, crab pots are a significant source of incidental mortality in the small creeks that terrapins inhabit. Our goal was to assess the effects of these modifications on diamondback terrapin distribution in the bay. To accomplish this, ~170 locations around lower Chesapeake Bay were surveyed for presence of diamondback terrapins. Local and landscape-level characteristics were extracted from a Geographic Information System (GIS), then examined for any significant effect on terrapin distribution using occupancy modeling and information theoretic approaches. Both shoreline hardening and crab pots negatively affected terrapin occupancy, while the presence of marsh positively affected terrapin occupancy. Additionally, both crab pots and marsh showed landscape-level effects on terrapin occupancy while shoreline hardening had a local-level effect. These results support our hypothesis that anthropogenic development negatively affects diamondback terrapin distribution within Chesapeake Bay.

Factors Causing Deviation from Optimal Egg Size Theory in the Diamondback Terrapin (*Malaclemys terrapin*)

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When investing energy in reproduction, organisms face tradeoffs between what number and size of offspring will optimize fitness. Optimal egg size (OES) theory predicts that a relatively constant OES should be selected, while any increase in resources allocated to reproduction should increase clutch size. Variations on this theory predict that egg size should be optimized, but not necessarily constant across a population, as optimality is contingent on maternal phenotypes and recent environmental conditions. We examined the relationships among body size variables (pelvic aperture width, caudal gap height, and

plastron length), maternal body condition, clutch size, and egg width of *Malaclemys terrapin* from separate populations at Kiawah Island and Edisto Island, SC. We found that terrapins do not fit traditional OES theory. Both populations exhibited greater variation in egg size among clutches than within (ANCOVA; Kiawah: $F = 26.845$, $df = 25$, $p < 0.001$; Edisto: $F = 12.14609$, $df = 20$, $p < 0.001$), suggesting an absence of optimization. We found that egg size appeared to be constrained in Kiawah terrapins but not in the Edisto population and that maternal body condition explained over half the variation in mean egg width in Kiawah terrapins ($F_{2,16} = 8.489$, $p < 0.001$, $R^2 = 0.514$) but not in terrapins from Edisto Island ($F_{2,19} = 2.694$, $p = 0.093$, $R^2=0.221$). This study demonstrates how factors not incorporated into traditional OES theory which result in deviation from the model's definition of optimization can contribute to a more complete understanding of optimizing reproductive output.

The Value of Head-Count Surveys to Collect Baseline Data On The Diamondback Terrapin (*Malaclemys terrapin*) of The Cape Romain National Wildlife Refuge

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Rapid declines and demographic fluctuations in populations of Diamondback Terrapin (*Malaclemys terrapin*) have been reported by multiple studies throughout the species' range. Despite the growing concern for this species future, only a small number of *M. terrapin* populations have been studied. Collecting data on previously undocumented populations of *M. terrapin* aids in the justification and creation of specific management strategies and initiatives for their protection. Visual head-count surveys of *M. terrapin* were conducted from April through November 2011 in various areas of the Cape Romain National Wildlife Refuge in Awendaw, South Carolina in order to collect baseline data on relative *M. terrapin* abundance. The head-count data were statistically analyzed in order to evaluate factors that may influence *M. terrapin* activity patterns and distribution across different habitat types within the refuge. The results of this analysis suggest that month, creek size, and distance to suitable nesting habitat had the most significant influence on *M. terrapin* abundance, while the interaction between creek size and month, the interaction between creek size and distance to suitable nesting habitat, lunar phase, and the interaction between lunar phase and tidal stage also had significant influence on *M. terrapin* abundance and therefore, may all be factors used by *M. terrapin* for habitat selection within the refuge. Furthermore, the methodology developed for this study contributes to the establishment of a standardized protocol which can be used in future studies of *M. terrapin* abundance, allowing for the accurate comparison of populations over time and in different areas.

Oral Presentations

Medical and surgical management of traumatic injuries occurring in free ranging chelonians and integrating education into rehabilitation programs

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Traumatic injuries occurring from automobiles, boat propellers, and predators are the most common reason for chelonians to be presented to the Georgia Sea Turtle Center (GSTC). Innovative wound care techniques have been developed for these injuries. Attention must be paid to emergency care, development of a prognosis, diagnostic testing and supportive care for turtles presenting with significant wounds. Principles of wound care that are utilized on other species should be followed. Topical placement of bone cement with antibiotics and doxirobe gel (Pharmacia & Upjohn Company, Kalamazoo, MI 49001, USA), honey, honey comb, Medi-honey (Derma Sciences from New Zealand, Toronto, Ontario MIS 3S4), a variety of silver based products, and a borate based biological glass (Rediheal, Avalon Medical, Stillwater, MN 55082 USA) have proven useful in managing these wounds. In areas that are difficult to bandage, suture loops and umbilical tape can be used to keep medication and packing material in place. A modified Vacuum Assisted Wound care protocol has been successfully used for some wounds. Stabilization of shell fractures has been performed with a variety of techniques including zip ties, bra hooks and more traditional screws and wire repair. Automobile related morbidity and mortality is significantly affecting terrestrial and aquatic turtle populations throughout their range. Over a half a million people have had the opportunity to learn about chelonians though the interactive educational exhibits and programs at the Georgia Sea Turtle Center (GSTC) since its opening 6 years ago.

Is Head-starting the Turtle Conservation Panacea that Everyone Wants it to Be?

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We evaluate a ten year demographic data set from a population in which large numbers of both naturally released hatchlings and headstarted individuals have been marked and released. We ask three fundamental questions concerning headstarts from our population. First, do they continue to grow at the accelerated rate after release? Second, do headstart females become reproductively active at an earlier age than their wild counterparts? Finally, is the survivorship of headstarts more similar to individuals their age or their size? Our data suggest that naturally released hatchlings' growth quickly catches that of headstarts and as a consequence we did not observe a difference in minimum age of first reproduction between our two groups. Furthermore, the recapture rates (survivorship) of headstarts is more similar to that of their age counterparts than their size counterparts suggesting that the much anticipated increase in survival due to larger body size does not occur. Our findings suggest that headstarting although doing no harm, does not appear to provide the demographic "boost" of its intended purpose for terrapin

populations. Thus conservation strategies for terrapins in areas of existing populations may achieve greater gains by predator control, restoring habitat, and protecting existing individuals. To this end, headstarting may provide an excellent tool for education and outreach that identifies and promotes effective conservation strategies for terrapins.

Distribution and abundance of diamondback terrapins in southwestern Louisiana

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Throughout the diamondback terrapin's range, Louisiana likely holds the most available habitat of any other state for the species (approximately 6500 km^2 of brackish/saline marshes), yet little is known about terrapin distribution and abundance throughout coastal Louisiana. Most terrapin records have come from the southeastern coastal marshes, while few are known from southwestern Louisiana; for the latter, the most recent specimen or published records date back to the 1970s. Therefore, we wanted to determine if (1) terrapin populations persist in historical collection localities and (2) determine if terrapin populations are present in new coastal marsh localities of southwestern Louisiana. We sampled for diamondback terrapins during 2011-2013 and targeted marshes near historical collection localities, as well as other apparently suitable brackish and saline marshes. We used unbaited fyke nets with 7.6 and 15.2 m leads to capture terrapins, as well as manually searching tidal ponds by airboat. Terrapins were captured at almost all sites, with terrapin abundance varying considerably across sites. Several sample sites would be classified as having "locally abundant" and demographically stable terrapin populations; at other sites we collected a smaller number of individuals with unknown population viability. In summation, all sites with terrapin captures represent either (1) a new locality for terrapins or (2) the first record in over 40 years for that locality. Terrapin sampling in southwestern Louisiana will continue in these locations to further delineate population densities and terrapin life history.

Between the Bay and a Hard Place:The Stress Response of Nesting Diamondback Terrapins due to Bulkheading in Barnegat Bay, NJ.

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Barnegat Bay Estuary exhibits the highest development rate of any Mid-Atlantic estuary. In fact, bulkheading has increased 30% over the past thirty years along these shorelines, severely limiting the aquatic-terrestrial interface for wildlife. The diamondback terrapin (*Malaclemys terrapin*) requires the upland habitat that is blocked by bulkheading for annual nesting. To determine the effect of bulkheading on this threatened species' nesting behavior we measured terrapin stress levels in relation to artificial

bulkheading. Stress was quantified through measures of corticosterone and testosterone levels in relation to bulkheading exposure. Blood samples were drawn immediately upon capture from 91 nesting terrapins at both experimentally bulkheaded and adjacent reference beaches. Corticosterone and testosterone analyses show no significant increase due to bulkheading, suggesting that barriers do not elicit a stress response in nesting terrapins. Plasma profiles of acute corticosterone showed a significant climb, although secretion in terrapins encountering bulkheading did not approach peak hormone levels. Testosterone significantly dropped over the course of the reproductive season, while corticosterone stayed consistent throughout. These endocrinological data represent the first documentation of reproductive and stress hormone secretion levels in nesting diamondback terrapins, exhibiting levels comparable to those of other Chelonians. We propose that our endocrinological records can be applied towards better understanding how human development can physiologically affect wildlife. With the increasing rate of bulkheading construction in Barnegat Bay, this study acts as a novel approach to guiding shoreline development within America's estuaries.

Assessing the nesting ecology of diamondback terrapins at Barnegat Bay, New Jersey after Hurricane Sandy

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Hurricane Sandy made landfall in New Jersey on October 29, 2012, causing extensive damage along the coastline with an unprecedented storm surge. Salt marsh habitats within Barnegat Bay, New Jersey experienced significant flooding and erosion. Some shoreline habitats that serve as diamondback terrapin nesting sites were also inundated with flood water. At one nesting area, North Sedge Island, adjacent to Barnegat Inlet, the storm surge eroded a 10 cm surface layer of sandy soil from the highest area on the Island. This summer, we are comparing the number of returning nesting females at North Sedge Island (post-storm) to our long-term nesting data. We hypothesize that there will not be a significant reduction in the recapture rate of females on the Island. However, hatching success may be lower as a result of increased level of salt remaining in the soil after the Island was inundated with flood water. Results of this study will provide insight into changes in the nesting ecology of terrapins in response to a major storm event. This will enable us to provide management recommendations for maintaining terrapin nesting habitat in areas susceptible to storm surge during severe storm events which are predicted to become more frequent and severe in coming years in the Mid-Atlantic region.

Oral Presentations

Carnage on the causeways: twenty-two years of diamondback terrapin (*Malaclemys terrapin*) road kills on southern New Jersey coastal roads

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In 1989 a long-term diamondback terrapin conservation program was jointly initiated by Stockton College and The Wetlands Institute. One of the components of this program has been documenting terrapin road kills during the annual nesting season on roads crossing or adjacent to coastal salt marshes. We report here some of the results of our efforts to date. Between 1989 and 2012, we patrolled a 64-kilometer transect along the Atlantic coast of the southern New Jersey's Cape May Peninsula five times daily – at midnight, 5 AM, 8 AM, 11 AM, and 2 PM. Road kills were tabulated, live terrapins were moved from traffic lanes and placed out of harm's way at the sides of roads, and injured terrapins were given veterinary attention. During this period of time, hundreds of volunteers drove nearly 400,000 transect kilometers (the equivalent of driving around Earth's circumference nearly ten times!). So far, 11, 893 dead terrapins have been documented within the transect. Among our findings are: 1. diamondback terrapins nest both during the day and at night in equal numbers; 2. there are two (and sometimes three) peaks of nesting activity during every nesting season; 3. the nesting season has been starting increasingly early over the course of the past twenty-two years; 4. the onset of the nesting season appears to be correlated with increased water temperature; and 5. road kill numbers appear to fluctuate in eight-year cycles.

Poster Presentations

Validation of trammel netting as a means for monitoring population trends for diamondback terrapins (*Malaclemys terrapin*) in the Charleston Harbor estuary.

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Spatial distribution and diel activity patterns dictate the interaction potential of any species, which has substantial management implications for both the mitigation of anthropogenic mortality sources as well as the design of monitoring surveys. Since 1994, the South Carolina Department of Natural Resources has recorded incidental capture of diamondback terrapins (*Malaclemys terrapin*) in an estuarine finfish survey that samples with 600' trammel nets set along the marsh edge in large order water bodies. In 2013 we received a State Wildlife Grant to use acoustic telemetry to test the null hypothesis of no difference in the frequency of occurrence of diamondback terrapins at trammel net study sites in the Ashley River vs. adjacent small-order creek habitats. Automated receivers were deployed at 12 fixed locations in river (7) and creek (5) habitats near Duck Island, South Carolina to continuously record (when submerged) the presence of acoustically-tagged terrapins. Fixed location data were complemented by mobile searches using a boat-based receiver-hydrophone system. During April and May 2013, 75 diamondback terrapins were captured by trammel net sets and trawling (15' otter trawl). Acoustic transmitters (Vemco, V9-2H, 368 d battery) were epoxied to the carapace of 12 female (15.8 to 20.0 cm SCL) and 6 male (12.4 to 13.2 cm SCL) terrapins; based on results of a transmitter-retention study conducted at the South Carolina Aquarium, we only attached transmitters to males >300 g. Preliminary data (~27k detections) through May 2013 demonstrate extensive mixing of terrapins between large order river habitats and small order tidal creeks.

Assessing the nesting ecology of diamondback terrapins at Barnegat Bay, New Jersey

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Mortality of diamondback terrapins can occur as a result of extreme weather events, predation, or as a result of human interactions like road mortality and drowning in crab pots. Severe storms such as hurricanes and nor'easters that occur across the terrapin range could also alter habitat. This study will assess the nesting ecology of terrapins after an unprecedented stochastic event, Hurricane Sandy, at Barnegat Bay, New Jersey. By identifying nesting female terrapins, we will be able to compare their reproductive output after the storm to previous seasons. By using individually marked female terrapins, we will be able to assess changes in average clutch size, average egg mass and the number of returning females to the nest site at North Sedge Island. Although this study may not determine the factors that could lead to the changes in reproductive output, the data will provide insight into post-storm assessment of terrapin populations. The results of this study may be used by wildlife managers to better develop strategies that will help with the long-term recovery of terrapin populations at Barnegat Bay.

Poster Presentations

The Natural History of the Parasitic Trematode *Pleurogonius malaclemys* in Diamondback Terrapins *Malaclemys terrapin*

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Hunter (1961, 1967) described a parasitic trematode (*Pleurogonius malaclemys*), whose definitive final host is the diamondback terrapin (*Malaclemys terrapin*). The diamondback terrapin is found in brackish waters of the eastern and southern coasts of the United States. Hunter showed that the eastern mud snail (*Ilyanassa obsoleta*), an abundant terrapin prey species, is an intermediate host for *P. malaclemys*. Byers et al. (2011) further showed that the frequency of *P. malaclemys* cysts on mud snails can be an accurate indirect measure of terrapin abundance. Our studies censusing *P. malaclemys* cysts on mud snails in Jamaica Bay (JB), NY and Great South Bay, NY have confirmed that the trematode occurs further north than previously reported, that the trematode cysts infect snails year round but that snail infection frequencies vary dramatically by season. Therefore value of *P. malaclemys* cyst frequency on mud snails as a measure of terrapin abundance may be ascertained locally and seasonally. We also found that juvenile terrapins can be infected by *P. malaclemys* under laboratory conditions, but that many of the consumed cysts do not result in adult trematodes in the gut. We also measured the prevalence and intensity of *P. malaclemys* infections in wild adult terrapins, and conducted field and laboratory studies of the lifecycle of *P. malaclemys* infection on terrapins. *P. malaclemys* is capable of encysting on other biological substrates, particularly those found to be a part of terrapin diets, and this could account for the high infection loads in wild terrapins.

Assessment of the Impact of Bycatch Reduction Devices on Diamondback Terrapin and Blue Crab Catch

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The diamondback terrapin (*Malaclemys terrapin*) is listed as a species of special concern in North Carolina by the N.C. Wildlife Resources Commission. One of the prominent threats facing the diamondback terrapin is drowning in recreational and commercial crab pots. Excluder devices have been shown to reduce terrapin mortality, but these devices face opposition from the fishing industry due to fears that they will decrease target species catch. The primary goal of our study was to examine the ability of bycatch reduction devices (BRDs) to exclude terrapins from crab pots without causing a reduction in blue crab catch. The distribution and abundance of terrapins in southeastern NC waters is lacking, therefore, a secondary goal was to assess the feasibility of using modified crab pots to document diamondback terrapin presence. Forty standard commercial crab traps were modified with a four-foot tall chimney and strategically positioned in marsh areas of Bogue Sound, NC. Two dimensions of BRDs were addressed, a 2 in x 6 in and a 1.5 in x 6 in BRD. Over the course of this study, 4,688 blue crabs and 6 terrapins were captured. No terrapins were caught in pots fitted with a BRD. Preliminary results show low terrapin captures and no significant difference between the total number of crabs

caught in pots with BRDs versus control pots (P= 0.705; t= -0.397). The overall outcome of this project will aid in future management plans for the diamondback terrapin by providing information on optimal BRD configurations and terrapin distribution.

Using Geographic Information System Technology to Spatially Analyze the Environmental Conditions affecting Nesting Site Selection of the *Malaclemys terrapin*

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Diamondback terrapins (*Malaclemys terrapin*) is an estuarine species that has one of the greatest geographic distributions for a single species of turtle; yet, populations of this species are in the decline. Terrapins are being exposed to habitat destruction from developing coastal zones, decreased nesting territory due to flooding and fragmentation, increased predation upon nests and drowning in commercial crab traps. Raising sea levels make flooding more prominent in coastal areas where Diamondback terrapins nest and is an increasingly serious problem for terrapin populations. A population of Diamondback terrapins was observed during the nesting season of 2012 at a known nesting location on a manmade trail at the Wetlands Institute located in Stone Harbor, NJ. Nesting locations were georeferenced using Global Positioning System technology (GPS). Groundwater monitoring wells were installed along the trail in close proximity to terrapin nesting sites and water levels were collected during storm events and tidal cycles. These data were compared to elevation data to determine flooding within nest cavities. Nesting trends were also spatially analyzed using Geographic Information Systems (GIS) to determine if terrapins chose nesting sites which were at a higher elevation and therefore away from flooding. Our results suggest that nests sites were selectively constructed in areas less prone to flooding.

Possible Effects of Higher Salinity on the Texas Diamondback Terrapin Size

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The Diamondback Terrapin (*Malaclemys terrapin*) has the ability to survive in a variety of salinities. It is difficult for many species of reptiles to survive in hyper saline conditions, but terrapin are able to survive in full strength salt water for an extended period of time. They survive hyper saline conditions through a variety of physiological and behavioral adaptions. Their salt gland is used to excrete excess salt. Past observations have documented terrapin drinking fresh rain water and from the top most fresh layer of the water column. The end of the terrapin's range occurs at the southwestern coast of Texas within the Laguna Madre. This waterbody is hypersaline with salinities often approaching 40 psu or greater. However, one of the last locations where terrapin is located is in the Corpus Christi/Nueces Bay estuary. The Corpus Christi Bay system has limited fresh water inflow, and thus has hyper saline conditions often occur. We hypothesized that salinity gradients may represent strong selective pressure that may manifest itself in morphology, behavior and physiology. As a preliminary comparison we

obtained morphological data on the Texas Diamondback terrapin (*M.terrapin littoralis*) from the Corpus Christi Bay system and compared it to Galveston Bay populations which are found in the eastern part of the state where rainfall is plentiful and salinities are normally much lower. We compared length to width ratios to see if hyper saline conditions affect terrapin morphology. We initially hypothesized that Galveston Bay terrapin would be larger (defined as length to width ratio) than Corpus Christi specimens due to the higher energy needed to survive and osmoregulate under hyper saline conditions. Results of our analyses are presented and the influence of local hydrology is discussed.

Crabbing Alters Diamondback Terrapin Population Size Structure and Growth Rates

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Human activities have been characterized as the greatest contemporary selective pressure affecting other species. In coastal ecosystems, commercial fisheries act as a major source of predation for both target and non-target species. For example, the diamondback terrapin, *Malaclemys terrapin,* is frequent by-catch in commercial and recreational crab traps. Crab traps act as gape-limited predators, predominantly killing smaller terrapins (juveniles and males). Evidence of this is seen throughout the literature examining the effects of crab traps on terrapin population abundance, age and body size. However, until recently, there have been no published studies of whether crabbing activities are altering terrapin growth rates. We captured and measured body size and age of terrapins in 22 tidal creeks along the Georgia coast that varied in the level of commercial crabbing activity in an effort to elucidate how crab pots affect age-specific size in terrapin populations. From 1301 terrapins examined, we found no difference in mean estimated terrapin age between creeks without crabbing and those with high crabbing activity; however, we did observe that terrapins were larger in high crabbing creeks. This result is consistent with other studies; however, unlike those studies that imply the increase in terrapin size is the result of higher survival among larger, adult females, our growth rate data suggest that larger age-specific size may be related to faster growth among terrapins from high crabbing creeks. We provide both ecological and evolutionary processes that could lead to increased growth rates among terrapins in creeks with high crabbing activity. We propose the possibility that crab pots, acting as gape limited predators have facilitated an evolutionary shift in terrapin growth rates and that this shift may have come at an unknown cost to terrapin performance.

Poster Presentations

The Effects of Nest Site Selection on Diamondback Terrapin Sex Ratios in Coastal Georgia

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Vehicle-induced mortality is a major threat impacting diamondback terrapin populations throughout their range, however, this mortality consists of primarily adults. While adult mortality may present the largest threat to terrapin populations, road-associated threats impacting demographics of terrapin eggs and hatchlings may exacerbate declines. Our objectives were to determine the effects of nest site selection on hatchling sex ratios on the Jekyll Island Causeway, GA. Gravid female diamondback terrapins were captured while crossing the road and injected with either oxytocin or a combination of oxytocin and prostaglandin to induce oviposition. Eggs were collected and distributed along the causeway in artificial nests with an I-button temperature logger in one of three habitats: Open, hedge rows or nesting mounds. As expected, nest temperatures were highest on top of the nesting mounds and coolest under the hedgerows. As a result, incubation time was more rapid for nests on the nesting mounds and in the open habitat and consisted of all female hatchlings. In contrast, the nests under the hedgerows were significantly cooler and resulted in 85% of hatchlings being male. Direct mortality of diamondback terrapins due to vehicular mortality has been well documented in the literature. While this direct mortality can have detrimental impacts on terrapin populations, the indirect effects associated with roadside nesting habitats, such as subsidized predators and variations in incubation temperatures, may also impact diamondback terrapin recruitment and population sustainability, and should be closely evaluated when small scale management decisions in areas of high nesting density are being made.

Population trends of Diamondback Terrapins in Jamaica Bay Wildlife refuge

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Population studies can contribute essential information to the management of rare and endangered species. These studies are critical for understanding unique life history strategies and for planning appropriate conservation initiatives for individual species. This is especially true for turtles, due to the fact that they are exceptionally long-lived. Diamondback terrapins (*Malaclemys terrapin*) are medium-sized turtles that occur in estuarine habitats along the North American east coast from Cape Cod, Massachusetts to the Gulf Coast of Texas (Butler et al. 2006). Information on the status of diamondback terrapins is patchy throughout their range and many isolated populations may be quietly suffering declines. This study examines the status of nesting *M. terrapin* in Jamaica Bay, New York by looking at twelve years of mark-recapture data. Jamaica Bay is a 3704.9 ha urban estuary located on the eastern edge of the Hudson River Bight, where studies on terrapin nesting ecology have been ongoing since

1998. Between the months of June and July, data are collected on an average of 200 female terrapins on the main nesting habitat on the island of Ruler's Bar Hassock. Seventy eight per cent of these terrapins had been previously captured. All captured female terrapins were reproductively mature and the majority of females sampled ranged from170-180 mm SPL. Data collected during 2012 were compared with data from previous years. This is the first study of this kind for this population, where demographic data were analyzed in order to understand the structure and status of M. terrapin in Jamaica Bay.

A Two-year analysis of terrapin road mortality along route 175 in Chincoteague, VA

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In some populations, road mortality may be a significant factor that influences the status of terrapin populations. Therefore, it is important to document the extent of road mortality among populations to determine its influence on population viability. In this study we investigated the pervasiveness of *Malaclemys terrapin* vehicular mortality observed during 2012 & 2013 nesting season in Chincoteague, VA. Route 175, the only causeway allowing access to traffic onto Chincoteague Island, is surrounded by salt marsh and is likely an important nesting site for terrapins residing in the surrounding area given its higher elevation and proximity to the marsh. Mortalities were observed by driving the length of the causeway twice daily during the active seasons to scan for dead terrapins. When sighted, the GPS coordinates of a dead terrapin were recorded along with gender, reproductive status, morphometrics, and basic meteorological data. In most cases, a scute fragment and bone sample were also collected for age analysis. In 2012 a total of 89 terrapins were killed along this causeway. As expected, mortality was heavily female biased. The peak mortality in the 2012 season occurred during the last week of May; However, during the 2013 season there appeared to be some delay in peak mortality, with very few terrapins killed during the month of May. Preliminary analyses suggest that the delay in peak mortality during the 2013 season was likely a result of cooler weather patterns.

The role of bait and bycatch reduction device orientation on blue crab and diamondback terrapin catch

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Diamondback terrapins (*Malaclemys terrapin*) have experienced declines throughout their range, and mortality in crab pots is increasingly considered to be the chief conservation concern. To minimize the risk of terrapins entering crab traps, researchers have suggested the use of by-catch reduction devices (BRDs) that reduce the size of crab trap openings excluding terrapins from entering crab traps. Despite these recommendations, few studies have observed terrapin interactions with BRDs and the effectiveness of these devices to prevent entry into crab traps. The objective of our study was to determine the relative effectiveness of BRDs and bait on blue crab and male terrapin behavior around

crab traps and overall capture abundance. We observed terrapin behavior when crab traps were baited with a variety of commonly used baits and with vertical and horizontal installation of BRDs. Overall, terrapins investigated the crab trap more frequently when baited with fish and were captured more frequently when BRDs were not installed on the trap. Understanding these interactions will better allow us to recommend regulations to prevent the continued decline of terrapin populations due to blue crab fisheries while maintaining or improving the blue crab catch.

Survey of the distribution of the Carolina diamondback terrapin (*Malaclemys terrapin centrata*) in the Guana, Tolomato, Matanzas National Estuarine Research Reserve

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In order to know more about a species, it must be determined where their habitats are. Diamondback terrapin (*Malaclemys terrapin*) population studies in Florida have found terrapin life in the northeast and central Atlantic areas, the Keys, the Everglades, Tampa Bay, St. Martins Keys, and Big Bend regions. However, records have shown that there is no evidence of diamondback terrapin (*M. t. centrata*) in our area of Jacksonville to Daytona Beach, FL even though it seems to be prime habitat for terrapins. Our goal is to survey the area included within the Guana, Tolomato, Matanzas National Estuarine Research Reserve (GTMNERR), which includes the Guana, Tolomato, and Matanzas rivers, their shorelines and small landmasses within the rivers. Even though the city of St. Augustine Beach is also in this area, the GTMNERR excludes the city because of human development. Consequently, we have collected sighting records from some local aquatic managers, and one of us (JAB) previously recorded terrapins in some creeks within the study area. In order to accomplish our goal, we will search all shorelines, including St. Augustine, for traces of terrapins including live terrapins, terrapin remains, crawls, raided nests and intact nests. In the surrounding tidal creeks, we will search for heads when terrapins' surface for air. This is part of a larger effort to survey the entire eastern coast of Florida for diamondback terrapin populations so there are accurate records of terrapin life in this area of Florida.

Diets differences within a single bay: Diamondback Terrapins Diets in Eastern and Central Jamaica Bay, New York

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Diamondback terrapins, *Malaclemys terrapin*, inhabit salt marshes and tidal creeks of the Atlantic and Gulf Coasts of North America. Terrapins are keystone predators in estuarine ecosystems, and thus conservation of this species is critical to the maintenance of natural nutrient and energy pathways. Long term diet analysis of terrapins in Jamaica Bay (New York) show that unlike southern terrapins, Jamaica Bay terrapins do not feed mostly on snails (*Littorina*). Instead, Jamaica Bay terrapins show dramatic

inter-annual diet changes among a variety of prey. Between 2008 and 2011, prey species consumed by central JB terrapins switched from a diet consisting of mostly gem clams (*Gemma gemma)*, ribbed mussels (*Geukensia demissa)* and crabs (various sp.) to large amounts of vegetation (leaves, stems, sea lettuce (*Ulva)*, and aquatic grasses). Jamaica Bay appears to be different in some ways from less-urbanized terrapin study sites; nesting areas are well separated from the remaining relatively large marsh fragments and the JB marsh system is smaller and more fragmented than where terrapins have been studied elsewhere. Starting in 2009 there have been increasing numbers of terrapins nesting at nearby John F. Kennedy Airport (eastern JB); this population appears to be distinct from that in central JB. The surge of terrapins in eastern JB may be due to the relatively good health of JoCo Marsh, adjacent to JFK airport. This study will assess diet differences between eastern and central terrapins using fecal analysis. Our preliminary results show marked dietary differences between the two adjacent populations.

Mercury Concentrations in Diamondback Terrapins (*Malaclemys terrapin*) from Coastal South Carolina

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Mercury contamination of aquatic environments is a global concern and is considered a serious threat to wildlife and human health. In recent years, the diamondback terrapin (*Malaclemys terrapin*) has been proposed as an indicator species of mercury contamination in estuarine ecosystems. In this study, we measured total mercury (THg) concentrations in terrapin blood from two South Carolina barrier islands (Kiawah and Edisto Islands) to examine the influence of location, sex, body size, and age on circulating mercury concentrations in these animals. All terrapins sampled (n = 59) contained detectable THg, and the overall mean THg concentration (37.1 ng/g) was similar to that previously observed in terrapins from other localities in coastal South Carolina. THg concentrations did not differ statistically between Kiawah and Edisto Islands, nor between males and females at Kiawah. However, at Edisto THg concentrations were significantly higher in females than males. THg was positively correlated with body size (carapace length, body mass) in females from both sites but not in males. At Kiawah, THg was positively correlated with age in females, but negatively correlated with age in males. Higher THg in females compared to males is likely the result of sexual dimorphism; females are significantly larger than males and consequently exhibit a higher dietary intake while feeding on larger and potentially more contaminated prey items. Likewise, inter-sex differences in THg accumulation with age may reflect sex-specific differences in certain life history traits influencing exposure (e.g., microhabitat use, diet) or in the toxicodynamics or toxicokinetics of mercury in terrapins.

Poster Presentations

The status of the diamondback terrapin in the salt marshes of Alabama

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The biology and conservation status of diamondback terrapins in the salt marshes of Alabama was studied over the past nine years. A variety of sampling methods were utilized including depredated nest surveys, drift fences on nesting beaches with bucket traps, modified crab traps, in-water "head" surveys, and radio-tracking of adult females. The results indicate that, overall, the diamondback terrapin population in Alabama has declined drastically over the past century, and is currently represented by small aggregations of terrapins in a variety of location. The largest aggregation that has been identified is located in Cedar Point Marsh. This location has an associated nesting beach with the highest amount of nesting identified for any location in Alabama. The Cedar Point Marsh aggregation appears to be comprised of approximately 400 terrapins (juvenile through adult stages), with an estimate of approximately 53 adult females utilizing the nesting beach. Radio-tracking studies indicate that many of these adult females may reside in this marsh after nesting season, although the nesting beach is also utilized by females from nearby marshes. Our studies indicate that the primary threats that limit the recovery of the terrapin population in Alabama are crab trap-induced mortality and depredation of nests by raccoons. We are currently evaluating a terrapin headstart program as a potential means of decreasing nest depredation and enhancing the conservation status of the Cedar Point Marsh aggregation.

Effects of Environmental Temperature Variation on Body Temperatures and Habitat Use in Free-Ranging Diamondback Terrapins (*Malaclemys terrapin*)

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Environmental temperatures (T_e's) strongly influence the body temperatures (T_b's) of ectotherms. During behavioral thermoregulation, ectotherms typically select microhabitats with a T_e closest to their preferred T_b. Diamondback terrapins (*Malaclemys terrapin*) are emydid turtles inhabiting salt marsh environments, where T_e's change both seasonally and daily in response to tides and other environmental factors. In this study, we use carapace-mounted microdataloggers to gather hourly T_b's from free-ranging terrapins at Kiawah Island, South Carolina over the course of twelve months (Oct. 2007-08) to determine the effects of location, gender, month, and tide level on terrapin T_b and to determine the

effects of month and gender on terrapin basking frequency. Simultaneous measurements of T_b and T_e (i.e., mud and water temperatures) also allowed us to make inferences regarding terrapin microhabitat use. We found that neither location nor gender had a biologically significant effect on T_b. As expected, average T_b was significantly different in different months. Additionally, tidal level had no significant effect on average T_b. Basking events occurred significantly more in males than in females. Both genders basked most frequently in spring, specifically in April. Occasional basking events were detected during both fall and in summer, and basking during winter was rare. During November, December, January, February, March, and June T_e of the shallow mud was the best predictor of T_b. During April, May, July, August, September, and October T_e of the water was the best predictor of T_b. At no time did T_e of the deep mud predict T_b. Our research documents monthly variation in microhabitat use, differences in basking behaviors between genders, and contributes to a fuller understanding of *M. terrapin* thermal biology.

Evaluation of Diamondback Terrapin (*Malaclemys terrapin*) throughout Coastal Louisiana

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Louisiana Department of Wildlife and Fisheries (LDWF) is currently implementing a multi-year (2012-14) project evaluating Diamondback terrapin distribution and abundance with specific emphasis placed on the State's eastern and central coastline. *NOTE: Please see our collaborator's (Dr. Will Selman) research efforts within southwestern Louisiana*. These efforts encompass two principal endpoints: 1.) Evaluation of adult and sub-adult populations and 2.) Delineation and evaluation of terrapin nesting beaches and reproductive productivity. Current efforts (2013) highlight significant progress in securing land access agreements with the State's principal private and public coastal land owners, completion of initial spring and fall adult and sub-adult terrapin sampling within select sites (n=16) and evaluation of both new and established terrapin nesting beaches.

Poster Presentations

Sexual dimorphism and feeding ecology of diamondback terrapins (*Malaclemys terrapin*)

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Many species of turtles, including the diamondback terrapin (*Malaclemys terrapin*), exhibit sexual dimorphism in body size, possibly enabling the sexes to exploit different resources and reduce intraspecific competition. Female terrapins not only have larger body sizes but also disproportionately larger heads and jaws relative to males. To better understand the connection between skull morphology and terrapin feeding ecology we measured in-lever to out-lever ratios of the jaw (a measure of mechanical advantage) of 27 male and 33 female terrapin skulls to evaluate biomechanics of the trophic apparatus. Additionally, we measured prey handling times by feeding fiddler crabs (*Uca pugnax*), a natural prey item, and using 24 terrapins in the laboratory. Our results indicate that although females have disproportionately larger heads than males, they have similar in:out lever ratios, suggesting that adductor muscle mass is more important in determining bite force than in:out lever ratios. Females also had considerably reduced prey handling times relative to males, suggesting that adductor muscle mass may be more important in determining bite force than in:out lever ratios. Understanding factors affecting terrapin feeding ecology can shed light on the potential roles male and female terrapins play as top-down predators that regulate grazing of periwinkle snails (*Littorina irrorata*) on marsh grass (*Spartina alterniflora*).

Creek-specific variation in survivorship and recruitment of *Malaclemys terrapin* over three decades

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Diamondback terrapins (*Malaclemys terrapin*) are a species of conservation concern and throughout their range populations have experienced noticeable declines. Mark-recapture studies have been conducted at Kiawah Island, SC since 1983. During the early 1990's populations began to decline. Anthropogenic habitat modification, such as the construction of docks, roads, and housing developments as well as activities such as crab-trapping likely play a role in this decline: however, evaluation of spatial and temporal variation in survivorship and recruitment is necessary to fully understand factors causing the decline and its impacts on the population. Our objectives were to test three hypotheses related to

survivorship and recruitment in terrapins: 1) population decline as a result of crab-trapping will cause a decline in male survivorship over time while female survivorship remains relatively constant; 2) population decline due to road mortality will result in a decline in female survivorship and constant male survivorship; and 3) increased nest depredation, as a result of increased suburbanization, will lead to low recruitment and relatively constant overall adult survivorship. Using program MARK, survivorship was estimated using open-population models and recruitment was estimated using Pradel models. Creek-specific models were used to illustrate survivorship and recruitment trends. In all creeks sampled, annual survivorship did not differ between males and females and estimates were low (i.e., average annual estimates were 84.8%) and in some cases declining. Recruitment rates were also low, with an average recruitment rate of 8.0%. Combined, low survivorship and recruitment rates may lead to extirpations of terrapins on Kiawah Island.

The diamondback terrapin education kit for formal and informal educators

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Diamondback terrapins are model indicators of the health of marsh systems within estuaries across their range. Along the coast are the most densely human-populated areas in the United States with increasing development pressure degrading salt marsh, thus estuarine health overall. Awareness through education is an important aspect in protecting estuarine habitats. By using terrapins, the message about the importance of salt marsh habitats can reach a wider audience. There is information about terrapin biology, ecology and conservation available through agencies, internet sites, and the Diamondback Terrapin Working Group (DTWG). The goal of this project is to develop a collection of terrapin education materials that could be used by educators in both formal and informal settings. The collection (called the "kit") contains a PowerPoint presentation and script about the biology, ecology and conservation of terrapins, learning activities developed by members of the DTWG, and information about salt marsh habitat and estuarine environments. National core content standards are included for applicable lessons. To determine the effectiveness of the education kit, a survey about terrapins will be administered prior to using the kit, and a similar survey will be administered after the kit is used. If the "kit" is successful, an electronic version of this kit will be made available.

Poster Presentations

Devising Integrated Conservation Planning Tools: Using Wildlife Behavior, Engineering, and Public Awareness to Reduce Conflicts of Diamondback Terrapins (*Malaclemys terrapin*) and Roads.

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The vast majority of turtle species worldwide have been negatively impacted by anthropogenic disturbance in the form of habitat fragmentation, development, commercial and recreational harvest, and road mortality. The diamondback terrapin (*Malaclemys terrapin*), North America's only estuarine turtle, inhabits the brackish waters of coastal salt marshes. In Georgia, the species is currently listed as a "Species of Concern." A multi-year VHF telemetry study of *M. terrapin* movement behaviors and spatial ecology on Jekyll Island as it relates to habitat structure and human land use is vital to increase an understanding of how both human and *M. terrapin* behaviors and habitat use conflicts can be managed in order to reduce the rapid annual loss of *M. terrapin* females, thereby increasing recruitment and ensuring the long-term survival of these barrier island populations. This study will provide timely information to both transportation planners and environmental engineers who are currently challenged with road designs through sensitive marsh habitats and in mitigating impacts on wildlife that are attracted to roadside habitats. A detailed understanding of *M. terrapin* spatial ecology in habitat fragmented by roads will enable these decision-makers to construct needed avenues of transportation while simultaneously limiting negative impacts upon wildlife. Outreach and education will allow dissemination of information through stakeholder involvement that will in turn facilitate adaptive management of human behaviors and the landscape. This poster presents preliminary results of radio tracking and overall project scope of graduate thesis work after one season of data collection.