FIELD REPORT

Marketing title
Diamondback Terrapins of Barnegat Bay

PI name
Dr. Harold Avery

Research site/ region
Lighthouse Center for Natural Resource Education, Waretown, New Jersey

Country
USA

Protected area status
Island Beach State Park, Edwin. B. Forsythe National Wildlife Refuge

17 Jan 2010

Report completed by
Hal Avery

Dear Earthwatch Volunteers,

The 2009 field season has come and gone and we are already in the stages of preparing for another successful field season. My co-principal investigators, graduate students, and staff want to thank all the Earthwatch groups that worked with us this summer. We had six amazing groups collecting valuable data on the diamondback terrapin populations in Barnegat Bay, while making new friendships and learning new life experiences. The hospitality of the Lighthouse Center for Natural Resource Education was wonderful as always and we are forever grateful to our "field mom" (Thanks Pat!) for keeping us well nourished with delicious and healthy foods. Thanks to our Earthwatch volunteers, we were fortunate to have collected much invaluable data on survival and reproduction of diamondback terrapins as well as their movements, responses to human impacts such as boat sounds, and samples from many individuals to understand their population genetics. Overall our 2009 volunteers helped us achieve the following:

-In the Northern portion of the Edwin B. Forsythe National Wildlife Refuge (north of Gunning River), we marked, measured, and collected blood samples from 251 new terrapins. We also recaptured13 terrapins that were originally captured in 2008, nine terrapins that were originally captured in 2007 and 33 that were originally captured in 2006.
-Amazingly, we recaptured one terrapin that was caught every year since the start of the project!
-In total, there were 442 terrapin captures in Forsythe, Spizzle Creek, and Great Bay.
-We completed trials on the behavioral response of 27 terrapins to the underwater sound of motorized boats that Lori Lester will be analyzing for her Ph.D. dissertation.

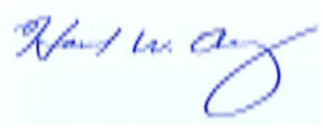
-We (safely!) completed open water boat harassment trials on 12 female terrapins divided into 3 size classes which Andy Harrison will be analyzing for his M.S. thesis.
-We outfitted several terrapins with sonic and radio transmitters for a pilot study on the nesting and hibernation behavior of several female terrapins. Late this fall, Jules, Lori, and Hal searched for the females and found them in the vicinity of Arnold's Pond. Julianne Winters will be analyzing these data as part of her Ph.D. research on habitat utilization by diamondback terrapins.
-We protected over 25 nests on Sedge Island which enabled us to mark and release several hundred terrapin hatchlings. John Wnek will use these data as part of his Ph.D. dissertation.
-During the end of the last expedition of the season, we marked and released a successful clutch of hatchlings that incubated near the Lighthouse Center Dock.

Thanks to all the help from Earthwatch volunteers from 2006-2009, we have been able to make our first scientific estimate of the terrapin population size at the North Forsythe trapping location (750 ha) this year. After four extremely successful years of turtle trapping in North Forsythe we have captured, marked, and released 1,283 individuals. We estimate that there are 2,614 terrapins (minimum of 1686 – maximum of 3542) in the North Forsythe population. Estimates of populations sizes in subsequent years will enable us to determine population trends (i.e., are populations increasing or decreasing?) in the Forsythe Refuge. Similar population estimates will soon be forthcoming for other study sites. We have also determined that the adult population of diamondback terrapins is female biased, with nearly two females to every one male. Initially, female biased sex ratios may positively affect the population, since females are responsible for producing clutches of eggs. However, we need to investigate why there are fewer males than females. We look forward to many more years of resea~~w~~rch so we can determine whether the population is in decline and in need of further protection from crab pots, boaters, and habitat destruction.

In the last year, my Ph.D. students Emily Basile, Claire Coleman and John Wnek have submitted a total of five manuscripts for publication in peer reviewed journals, based on the data we have collected in the last four years of terrapin research. They can't thank you enough for all your hard work and dedication and we can't wait to share the publications with you. I also have several new students who will begin new projects in 2010 and of course Jules, Lori, and Abby will continue their research projects that were initiated in 2009.

From my co-PIs Walt Bien, Ed Standora, and Jim Spotila along with my graduate students, interns, and myself, I would like to thank each of you for your amazing contribution to our project. Without you, none of these important achievements would be possible. The insights that we gain on how human impacts affect wild terrapins will have an invaluable impact on the future survival of the diamondback terrapin at Barnegat Bay and elsewhere.

Best wishes~~,~~ and we hope that you will stay in touch!



SECTION ONE

Top highlight for the past field season

After four highly successful years of turtle trapping we have our first scientifically credible estimate population size in the northern area of Forsythe National Wildlife Refuge. At North Forsythe we have captured, marked, and released 1,283 individuals and we estimate the population size of terrapins to be 2,614 terrapins (minimum=1686 and maximum=3542). We are in the process of also determining the population sizes of terrapins at other locations in Barnegat Bay in relation to human impacts. With these estimates we will be able to discover long-term population trends of terrapins in Barnegat Bay. Without these estimates and trends further protection of the terrapin in New Jersey and elsewhere is unlikely.

Non-technical overview of results

Our 2009 field research findings have allowed us to determine how specific human impacts affect terrapin populations and behavior. Although our population size estimates may seem large, our research findings demonstrate how humans are impacting terrapins. Use of crab pots, motorized boats, loss of saltmarsh habitat, and deposition of dredge sediment are increasing deaths and injury rates, and reducing dispersal rates and hatching success. With our emerging research findings we will enhance the effectiveness of conservation plans for the terrapin in Barnegat Bay.

SECTION TWO

1. REPORTING ON RESEARCH OBJECTIVES

Objective 1

The population status of diamondback terrapins in Barnegat Bay is currently unknown and the State of New Jersey lists the terrapin as a species of special concern. Thus, in order to provide accurate and appropriate protection we aim to establish the population status of the diamondback terrapin. Specifically, we aim to determine vital population statistics such as population sizes, population size structure, population age structure, sex ratios, immigration and emigration rates, and birth and death rates.

Progress against objective

From 2006-2009, we conducted an intensive population study of diamondback terrapins (Malaclemys terrapin) in Barnegat Bay, New Jersey. In the Forsythe National Wildlife Refuge we have captured 1282 individual terrapins and through repeated trapping have determined that the overall sex ratio of captures was female biased with 1.8 females : 1.0 males. This ratio is significantly different from 1:1 ($x2 = 104.5$, $df = 1$, $P < 0.001$). Mature females comprise 72% of the females sampled in the population. Maturity was determined from straight carapace length (SCL) measurements of >140 mm SCL. We used a Jolly-Seber open population model to estimate population size, after carefully examining capture data for and ensuring that there were no violations of the underlying assumptions of mark-recapture analysis with goodness-of-fit tests in the program RELEASE. We estimated that 2614 (1686 – 3542; 95% confidence interval) terrapins (> 90 mm SCL) inhabited the northern 750 ha of the Barnegat division of the Edwin B. Forsythe National Wildlife Refuge. We are preparing findings on population age structure and rates of immigration, emigration, birth, and death. Our population estimates suggest that the population is sufficiently large enough to avoid genetic and environmental stochasticity. Because we capture few small juveniles (< 90 mm SCL), we have unreliable estimates on population recruitment rates. To aid future efforts to estimate age-specific

mortality, we have marked and released over 500 hatchlings with the objective of recapturing them in future field seasons to determine survival rates and recruitment rates, as well as to augment the terrapin population at Barnegat Bay NJ.

We are analyzing data collected from 2006 to 2009 and the results will be published in the peer reviewed scientific journal Copeia and other appropriate scientific journals. The results will also be written as part of the Ph.D. dissertation of Claire (Coleman) Sheridan of Drexel University. We will continue to collect population demography data for the duration of this research project.

Mean and maximum dispersal distance of diamondback terrapins in Barnegat Bay, NJ that were recaptured in subsequent years, as measured by direct dispersal methods. Data is categorized by sex and maturity.

	N	Mean Distance/ Year (m/yr)	SE ± 1	Maximum Distance (m/yr)
Juvenile Females	19	275	75	953
Mature Females	38	418	68	1984
Juvenile Males	39	149	37	942
Mature Males	25	86	27	388

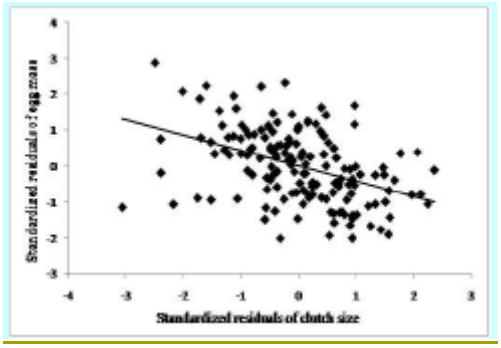
Dispersal distances of juvenile, male and female terrapins with Northern Forsythe in Barnegat Bay, NJ.

Objective 2

To determine the reproductive output and hatching success of nests in Barnegat Bay terrapins.

Progress against objective

From 2006 to 2009 the research team collected data from several nesting populations of the diamondback terrapin in Barnegat Bay, New Jersey, to evaluate reproductive output and hatching success of nests. The field sites include Island Beach State Park (IBSP), the Edwin B. Forsythe National Wildlife Refuge (EBFNWR), and the Great Bay Wildlife Management Area (GBWMA). Adult females were captured by hand on nesting areas or trapped using hoop or fyke nets during the reproductive seasons of 2006-2008. The reproductive status of female turtles was determined by palpation. X-radiographs were taken from most gravid females. Some females were induced to oviposit via interperotineal injection with 10-30 IU/kg Oxytocin (Ewert & Legler 1978) as they were part of another study (see objective 4). Other females naturally laid eggs in nests. All nests were protected with predator excluder cages. Mesh size of predator excluder cages prevented emerging hatchlings from escaping. Upon emergence, clutch success was recorded as the total number of hatchlings alive after emergence of at least one hatchling divided by the total number of eggs incubated. We found that egg mass varied little within clutches. Mean clutch size varied within sites and between the years of study (ranging from 10.5-13.5). Clutch size, egg mass, egg width, and clutch mass increased significantly with female carapace length. Hatching success (78-84% over the three years) was not related to female size or any clutch or egg size measurement. The primary failures in hatching success were attributed to penetration by roots and predation by insects. We found a significant negative trade-off between clutch size and egg mass, after standardizing for female size. In the context of reproductive characteristics of the terrapin across the species range, our data suggests that clutch size increases with latitude and that egg mass, egg width, and egg length decrease with latitude.



Trade-off in clutch size and egg mass in M. terrapin.

These results have been submitted for publication to the journal Oikos. The title of the publication is "Constraints on egg size, optimal egg size theory, and latitudinal reproductive variation in the Diamondback terrapin (*Malaclemys terrapin*)." The results will also be a component of the Ph.D. dissertation of Claire (Coleman) Sheridan of Drexel University. We will continue to collect data on reproductive output and hatching success in future field seasons so we can better understand and predict how environmental heterogeneity and human impacts affect the reproductive success of diamondback terrapins.

Objective 3

To determine if sex-biased dispersal occurs in the diamondback terrapin, if natal philopatry occurs in the diamondback terrapin, and to compare indirect and direct methods of measuring dispersal. Furthermore, to use landscape genetics analysis to determine the effects of landscape features (natural and anthropogenic) on diamondback terrapin effective dispersal.

Progress against objective

Nesting ecology and population studies indicate that diamondback terrapins exhibit nest site fidelity and high habitat fidelity. However, genetic studies indicate high levels of gene flow. Because dispersal affects the genetics and population dynamics of a species, we used six highly polymorphic microsatellite DNA markers to investigate sex-biased dispersal and natal philopatry of diamondback terrapins in Barnegat Bay, NJ. We compared results of spatial autocorrelation analysis, assignment methods, and Wright's FST estimators to dispersal measured via capture-mark-recapture analysis. Capture-mark-recapture analysis indicated that all individuals have relatively small dispersal distances (<2 km), with mature females dispersing greater distances than males, both immature and mature, but not further than immature females. Mean assignment indices and spatial autocorrelation analyses indicated that mature males exhibited sex-biased dispersal and mature females exhibited natal philopatry to nesting beaches. Sensitivity of assignment methods and Wright's FST estimators indicated that approximately 10% of the population per generation dispersed, with 80-100% of dispersers being males of greater than 4.4 years of age. Thus, we conclude that some males disperse away from their natal area before establishing small home ranges. We also developed landscape genetic models, to determine how landscape features (i.e., shoreline development, water depth, roads, bulkheading, and emergent or shoreline saltmarsh habitat) affect gene flow in the diamondback terrapin. Our landscape models clearly show that terrapins do not disperse in straight-line routes or follow shorelines to move from one location to another, nor do they use aquatic habitat for dispersal. Instead, the spatial genetic variation in terrapins is explained by a model where terrapins primarily disperse through estuarine emergent wetland (i.e., shoreline saltmarsh habitat). From these results we can conclude that adult males primarily disperse through estuarine emergent wetland and are primarily responsible for gene flow in terrapin populations. Because gene flow in necessary to maintain genetic variability and long-term viability of species, we conclude that preservation of estuarine emergent wetland in Barnegat Bay is essential to maintaining gene flow in terrapin

populations. In addition, because nesting females are philopatric to natal beaches, we conclude that terrapin nesting beaches in Barnegat Bay must be identified and protected from further degradation and development to ensure future population recruitment and viability.

Landscape model depicting the likely paths of terrapin movement in Barnegat Bay based on gene flow between populations

We are in the final stages of editing and reviewing prepared manuscripts for publication for Objective 3. One paper has been submitted to the Journal of Molecular Ecology, titled "Sex-biased dispersal and natal philopatry in the diamondback terrapin, Malaclemys terrapin" and is currently in review. Another publication, "Landscape Genetic Structure of Diamondback Terrapins (*Malaclemys terrapin*) in a Fragmented Estuary System", is being prepared for submission and will be submitted within a month to PLOS (Public Library of Science) Biology for publication. The results will also be written as part of the Ph.D. dissertation of Claire (Coleman) Sheridan of Drexel University. We will continue to collect additional data for refining our landscape genetic models in upcoming field seasons.

Objective 4

The objectives of our study on the mating system of the terrapin were (1) to determine the proportion of clutches with multiple paternity at four nesting locations within Barnegat Bay, New Jersey and one nesting location within the Chesapeake Bay, Maryland, (2) to compare female size, clutch size, egg size, hatchling size, and hatching success between clutches with single and multiple paternity, (3) to determine if sperm storage and re-mating occurs within and between nesting seasons, (4) to test the hypothesis that males and females move to mating aggregations outside of their home ranges and (5) to test the hypothesis that multiple paternity is correlated with population sex ratios.

Progress against objective

We used nuclear microsatellite markers to compare frequencies of multiple paternities within five nesting locations of the diamondback terrapin (*Malaclemys terrapin*). Using six highly polymorphic microsatellite markers, we determined if multiple paternity existed in 23 to 46 clutches of terrapins from five nesting locations. We found that the frequency of multiple paternities differed significantly among locations, ranging from 12.5 to 45.7%. Clutches with multiple paternities did not differ from clutches with single paternity with respect to female size, clutch size, egg size, hatchling size, or hatching success, suggesting that multiple paternities may not provide initial benefits to offspring survivorship. Male and females mated within their home ranges and thus mating events are not responsible for the high levels of gene flow documented in this species. Frequency of multiple paternities exhibited a significant non-linear correlation with population sex ratio. Our research also confirms that sperm storage occurs both within and between seasons in female diamondback terrapins. The usage of stored sperm may play a role in the frequency of multiple paternities.

This objective is in the final stages of editing and review for publication. The paper being prepared for submission to the Journal of Molecular Ecology is titled, "Inter-population variation of multiple paternity in the diamondback terrapin (*Malaclemys terrapin*)". The results will also be written as part of the Ph.D. dissertation of Claire (Coleman) Sheridan of Drexel University.

Objective 5

Determine the effects of soil characteristics and thermal environment on embryo mortality and hatchling success in terrapin nests.

Progress against objective

Terrestrial habitats are critical to the survival and reproductive success of aquatic turtles because they are used for nesting. In estuarine ecosystems, diamondback terrapins are potentially adversely affected by development, dredging, invasive vegetation and pollution, among other factors. Because natural nesting areas have been fragmented or destroyed, terrapins may use roadsides and dredge islands (i.e., artificial islands made of dredged sediments) for nesting. Terrapins in Barnegat Bay Estuary, New Jersey, use a mosaic of natural and degraded terrestrial ecosystems for nesting. Marshes are often filled with sediments dredged from the bay floor and are used as nest sites by terrapins. During the 2006-2008 field seasons (June – September), terrapin nests were monitored at North Sedge Island which was filled with dredge material over 80 years ago and is a popular nesting area for terrapins. We constructed three experimental plots composed of sand, loamy-sand and dredge soil, to determine whether hatching success of terrapin eggs differed due to the soil substrate they incubated in. Terrapin nests in the loamy-sand plot had the highest percentage of hatching success in both 2006 (56.1%) and 2007 (85.3%). In contrast, nests in soil freshly dredged from the bay produced no hatchlings in 2006 and 2008. Nests in aged dredge soil had a hatching success of 59.4% in 2007 and 49.1% in 2008. Our findings suggest that although nesting female terrapins may use terrestrial areas with freshly dredged soil, the dredge soil may significantly reduce or prohibit hatching success of terrapin nests. These findings suggest that viability of terrapin populations may be compromised in areas where dredged soil is deposited and where terrapins nest. In the 2009 nesting season, we continued to incubate additional nests in the different soil types. We have submitted a manuscript for publication to Journal of Integrative Zoology which is currently still in review. These findings are also being prepared for use in John Wnek's Ph.D. dissertation.

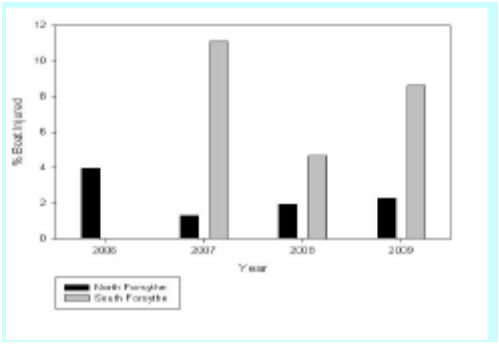
Objective 6

To determine the impact of boats on terrapins by measuring the rate of boat injuries.

Progress against objective

Terrapins are commonly exposed to motor boats in Barnegat Bay and this may result in injury to the turtles due to boat strikes. An injury is considered to be caused by a boat propeller only if there is major damage to the carapace or plastron that cannot be accounted for by any other explanation (i.e., propeller marks are obvious). Therefore, it is possible that some of the other injuries found on terrapins are also due to boat strikes. It may also be the case that boat propeller strikes kill terrapins on impact and these terrapins may not be found. Thus our boat injury estimates are likely low. In North Forsythe, 1 - 4% of terrapins captured in the past four years have been injured by a boat whereas in South Forsythe 5-11% of terrapins had boat injuries.

These data findings are still being analyzed as part of Lori Lester's Ph.D. dissertation.



Percent of Boat Injured Terrapins in Forsythe Refuge.

Objective 7

The main objective is to determine the effects of anthropogenic sound (i.e., boat engine noise) on the behavior of diamondback terrapins.

Progress against objective

Twenty terrapins have been exposed to an underwater sound of an approaching motorized Lowe Boat (23.0 km/hr) and seven terrapins have been exposed to the sound of an approaching Parker Boat (53.4 km/hr). The terrapins responded to the playback recordings of boat engine noise by increasing swimming speed away from the speaker, lifting their heads out of the water, digging into the substrate at the bottom of the ditch, or continuing to swim past the speaker. A mixed effects model for nested data is currently being designed to determine if the behavioral responses differed significantly before, during, and after sound exposure. Field experiments will continue during the 2010 field season to increase sample sizes. This research will be presented at the Second International Conference on "The Effects of Noise on Aquatic Life" in Cork, Ireland in August 2010. This research will also be compiled into a dissertation, "The Effects of Anthropogenic Sound on the Northern Diamondback Terrapin" as an environmental science Ph.D. thesis of Lori Lester of Drexel University. An estimated five papers (in-air audiogram, in-water audiogram, behavioral study, ambient sound analysis, and boat injury rates) will be published as a result of this research in journals such as Bioacoustics, Journal of the Acoustical Society of America, or Marine Ecology Progress Series.

These data findings are also being analyzed as part of Lori Lester's Ph.D. dissertation.

Objective 8

To determine the behavioral responses in the Northern Diamondback Terrapin (*Malaclemys terrapin terrapin* Schoepff, 1793) to boat traffic. Baseline turtle behavior was compared to behavior under treatment conditions involving exposure to a boat. The turtle's behavior was determined each second using an accelerometer and a temperature and depth data logger. Behavioral responses were analyzed to determine significant differences in mean surface time, total surface time, depth, angle of ascent/descent, rate of ascent/descent, banking angles, and dive profiles in relation to size class (small, medium, large). These data can lead to implications involving the disruption of terrapin daily activities in response to boat traffic, which could affect growth and development, impacting the population.

Progress against objective

Twelve female terrapins were divided into three size classes. Each turtle was outfitted with a radio transmitter, sonic transmitter, accelerometer (Hobo Pendant-G), and temperature and depth data logger (StarOddi). Terrapins were assigned to a two-group simple randomization designed experiment. On the first day, the turtle was released at the point of capture and

passively followed by paddled-boat for six-hours (the amount of memory the data loggers contain at a one-second sampling rate). The turtle was then recaptured and brought back to the lab for data removal. The following day, the turtle was released at the site of capture where the turtle was then passively pursued for two-hours, subjected to harassment for two-hours, and passively pursued for two-hours to determine recovery time. Harassment was defined as piloting the boat to within three-meters of the turtle every 15 minutes. The turtle was recaptured, brought back to the lab for the data to be downloaded and removal of equipment, and then released the following day at the point of capture. Data was analyzed using JMP-Up software with an alpha of 0.05.

Data are currently being analyzed and will be part of Andy Harrison's M.A. thesis at Buffalo State College.

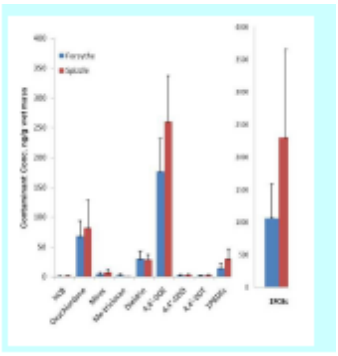
Objective 9

To determine the organic contamination of Barnegat Bay, NJ by utilizing a model estuarine reptile species, the diamondback terrapin. Concentration levels as well as contamination patterns will be reported in terrapin tissues, a terrapin prey item (the blue mussel Mytilus edulus) and nesting sediments throughout the Bay. An experiment focusing on a contaminant class of emerging concern, polybrominated diphenyl ethers, will determine the risk or transfer of PBDEs from nesting sediments to developing terrapins embryos. Data collected will also be used to form a risk assessment using organohalogen concentrations and a few measured health parameters with in the terrapins.

Progress against objective

In this study, fat biopsies and plasma samples were collected from live male and female terrapins from two sites within Barnegat Bay, New Jersey. A deceased gravid female terrapin was also necropsied and her whole blood, fat, liver, ovary, follicle and full clutch of 11 eggs were collected. A pooled sample of blue mussels (Mytilus edulus), representing a terrapin food item was also analyzed. The collected samples were analyzed at the Hollings Marine Laboratory in Charleston, SC through collaboration with the National Institute of Standards and Technology. All samples were analyzed for the presence of polybrominated diphenyl ethers (PBDEs), a class of brominated flame retardants that is persistent in the environment and has been reported to cause endocrine disruption and delayed neurobehavioral development. Multivariate Analysis of Variance (MANOVAs) indicated that terrapins from the most northern site, Spizzle Creek, had higher mean concentrations of PBDEs than Forsythe Refuge for all tissue types. Differences were also observed between males and females with males having higher concentrations in fat and females in plasma. PBDE patterns in the terrapin tissue show an atypical profile compared to findings of most all other wildlife and human monitoring studies. The PBDE congener pattern was dominated by PBDEs 153 and 100 instead of PBDE 47 and 99, which has been documented in only a few other turtle species. The normal pattern measured in the mussel prey suggests that the terrapin has efficient metabolism or elimination of PBDE 47 and possibly PBDE 99.

These findings have been written and have been submitted as a manuscript for publication in the Journal of Environmental Toxicology and Chemistry. This research will also be part of Ms. Emily Basile's Ph.D. dissertation from Drexel University.



Organohalogen contaminant concentrations in terrapin fat from two sites with in Barnegat Bay, NJ.

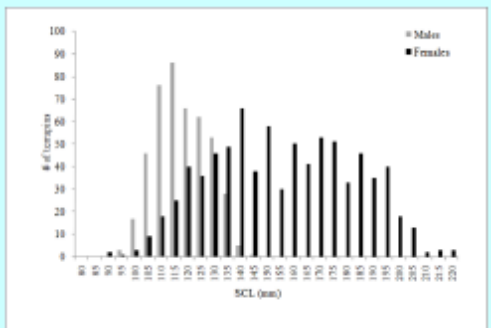
Objective 10

The main aim of this objective is to analyze the home range and thermal ecology of the diamondback terrapin using radio-telemetry. Knowledge of terrapins' habitat use and behavior will allow for more informed management decisions in terrapin conservation.

Progress against objective

Knowledge of terrapin movements and behavioral patterns is requisite for understanding the habitat requirements of terrapins and for constructing a comprehensive management strategy for the diamondback terrapin. We analyzed the home range movements and thermal ecology of terrapins in Barnegat Bay. Twenty terrapins were fitted with radio transmitters and temperature data loggers, and were located twice a week, on average, using GPS. Mean selected temperatures of male and female terrapins were measured. Terrapin temperatures will be compared to environmental temperature data to determine behavioral patterns in response to environmental conditions. Location and movement data are being analyzed using GIS software, and home range sizes will be determined using three models; the minimum convex polygon, 95% Jennrich-Turner ellipse, and 95% kernel method. Home range sizes will be compared between male and female terrapins and between summer months. Our findings show that females move greater distances than males, and often occupy deeper water in open water and in saltmarshes. Findings to date indicate that female terrapins have greater home range sizes, travel greater distances, and have lower mean body temperatures than males.

This work is currently being analyzed and will formally presented in the Masters of Science thesis of Jacqueline Walters from Buffalo State College. Jacqueline will also be publishing this research in a peer-reviewed ecology journal. The research was presented in 2008 at Buffalo State College (citation below).
Walters, J.R., E.A. Standora, H.W. Avery, and W.A. Mix. A biotelemetric study of the thermal ecology, behavior, and home range movements of diamondback terrapins (Malaclemys terrapin) in Barnegat Bay, New Jersey. Poster session presented at: The Tenth Annual Student Research and Creativity Celebration. Buffalo State College. April 26, 2008. Buffalo, NY.



Size Class Distribution of Male and Female Diamondback Terrapins in Barnegat Bay

Objective 11

The main aim of this objective was to determine the feasibility of using submersible underwater receivers (SURs) to remotely track free-ranging terrapins throughout Barnegat Bay.

Progress against objective

In 2009 we initiated use of submersible underwater receivers (SURs) set in arrays throughout areas of Barnegat Bay where we have previously marked and studied terrapins. This allows us to determine the movements of individual terrapins between seasons and years over great distances. By placing SUR units within close enough proximity to each other (based on reception range), and in linear arrays, we can determine the direction of terrapin movements over time. Large female terrapins were outfitted with sonic transmitters (Sonotronics Inc., IBT-96-5, 40kHz), which then send signals to SURs when within range. Sonic transmitter frequency, date, and time of signal reception are all logged remotely for each terrapin that comes within range. These data we will allow us to determine the movements of individual turtles in monitored areas.

From June 19 to September 1, 2009, one gravid female terrapin was monitored near The Lighthouse Center for Environmental Education. After being tagged with radio and sonic transmitters, this terrapin (BCOPX) was tracked using SUR units and active telemetry. Two SURs were placed in an array to record movement in and out of the canal where the female was originally captured. Between June 20, 2009 and July 5, 2009 SUR units indicated four occurrences of BCOPX within the Lighthouse Center canal. Each occurrence varies in time and duration, but all may be indicative of major nesting periods. Two periods of SUR data reception were complimented with radio receptions, suggesting BCOPX was close to the surface and/or nesting in the area at that time. After July 5, this female did not return to the Lighthouse Center Canal, indicating that this site is only used by BCOPX during the nesting season. One SUR unit continued to monitor the canal until September 1, and collected no receptions. These data suggest that BCOPX, and perhaps other gravid females in the Bay, utilize unique habitats for nesting, and these are likely different than those used during other activities such as foraging or hibernation. By remotely recording data use to determine home ranges and movements of gravid females, this research will be fundamentally important to understanding the habitat requirements and other life history parameters of diamondback terrapins in Barnegat Bay, NJ.

A second gravid female (BHKQX), was monitored from June 21 to July 20, 2009 in Forsythe National Wildlife Refuge and showed similar nesting behavior to BCOPX. Four SUR units were arranged in an array from the point of capture to a presumed nesting site (Conklin Island) to determine movement within this range during the nesting season. Three long-term receptions were recorded over this time period, with an occurrence on June 23rd at the Conklin Island nesting site. The SUR units recorded no receptions of BHKQX after this date. Twice in July this terrapin was found in proximity to her capture site through active radio telemetry. Until July

27th BHKQX was not found to be present in Osprey Cove. Again, these data are indicative of a terrapin using specialized habitats for nesting, and conclusive records of an individual traveling from a point of capture to the area where she may nest. The presence/absence data collected through active and sonic telemetry are valuable indicators of gravid female habitat use during nesting season in Barnegat Bay, NJ.

A final preliminary study utilizing the SUR array is currently underway to measure adult female habitat use during seasons other than nesting. Five receivers were positioned in Arnold's Pond (E 18 569078 N 4399037) to localize movements of three adult females within this area on August 1, 2009. The three terrapins were captured and released at the same time and location. Data continues to be recorded by this SUR array, and will likely continue until early June 2010. Information collected during this study may indicate movement of individuals in relation to one another, and help us understand if terrapins captured together maintain similar home ranges. To this date, it has been surprising how localized each terrapin has been to the Arnold's Pond area, having recorded the majority of presences being in the central cove area, versus the entrance/exits. Data on these individuals will also indicate movements during winter brumination periods, and if the areas used in late summer are similar to those during the winter. SUR data from August to June will provide information for a descriptive comparison of adult female habitat use and behavior between the nesting season (early June – mid July) and non-nesting periods (August – late May).

Data from this feasibility study, allow us to address what information can be determined regarding terrapin behavior when utilizing SUR units in Barnegat Bay and include:

1. Presence or absence of an individual in a 150m radius of a SUR unit
2. Movement between sites
3. Directionality of individual movement
4. Time of day and date of presence or absence at site (may be related to temperature or tides)
5. Daily, weekly, monthly, and annual site fidelity
6. Movement of one individual relative to other tagged individuals (i.e. clustering behaviors, avoidance, group migrations)
7. Relative time spent in a specific range of sites
8. Time of activity and inactivity of individuals or groups
9. With overlap in SUR radii – very accurate location of an individual, +/- 10m

The results of this study will contribute to the research design for the dissertation of Julianne Winters of Drexel University. Winters is a second year Ph.D. student interested in studying how bulkheading, climate change, boating, and human occupation in Barnegat Bay Estuary, New Jersey, impact the nesting behaviors of diamondback terrapins. Winters will utilize both sonic and radio telemetry for measurements of aquatic and terrestrial spatial habitat utilization of free-ranging reproductive females. Winters will determine the nesting behavior of individuals under various conditions: (1) nest site closure via bulkheading, (2) modeling predicted sea level rise due to climate change, and (3) exposure to boating activity and human presence. The data collected will be critical in determining the direct and indirect effects of anthropogenic impacts to terrapins in areas of known high terrapin densities. The findings will aid in management decisions regarding both aquatic (e.g., boat) and land (e.g., beach) uses in relation to ensuring the viability of wildlife resources within the Barnegat Bay Estuary.

2. PARTNERSHIPS

Several partnerships have contributed to the success of our project and include the following organisations and contributions:

1. Natural Resource Education Foundation (NERF) staff and board members have contributed to our success by allowing us to utilize their field station and dormitories (Objectives 1-9). Our terrapin hatchery is also located on this site.
2. MATES academy high school students have supported us with invaluable field assistance each summer. We have trained 2-3 high school interns each summer in various field techniques (Objectives 1-9).
3. Rutgers University Marine Field Station (RUMFS) staff, students, and interns at RUMFS have contributed greatly to the success of the collection of nesting females along Great Bay Boulevard (Objective 4). The staff have also provided invaluable advice on the using of sonic transmitters and the recording of boat noises (Objective 7 and 8).
4. The staff at the Hollings Marine Laboratory in Charleston, SC through collaboration with the National Institute of Standards and Technology (NIST) have contributed in both time and resources to analysis of contaminants in fat, blood, and other tissue samples for Objective 9.
5. The University of Ohio and the Poplar Island Restoration Site in Maryland through the collaboration of Willem Roosenburg provided us with tissue samples for an analysis of paternity at a location outside of Barnegat Bay (Objective 4).
6. Kim Scribner at the University of Michigan-Contributed to the landscape genetics analysis (Objective 3).
7. Arthur Popper at the University of Maryland-Contributed to the anthropogenic sound analysis (Objective 7).
8. Catherine Carr, Jakob Christensen-Dalsgaard, and Darlene Ketten of the Marine Biological Station and the Woods Hole Oceanographic Institute in Woods Hole, MA assisted with the completion of In-Air hearing tests on diamondback terrapins (Objective 7).
9. Borough of Island Heights and Barnegat Township provided access for our project to use of their public boat ramps free of charge (Objective 1-9).
10. Chris Claus at Cattus Island County Park- Provided access to trap terrapins at Cattus Island County Park (Objective 3).
11. Robin Scott from Ray Scott's Dock provided access to collect tissue and blood samples in Margate, NJ (Objective 3).

3. PROJECT DEVELOPMENT

We occasionally remove objectives based upon their completion by graduate students and we occasionally add new objectives based upon the matriculation of new graduate students. The changes in these objectives do not alter the core research goal of assessing the population status and impact of humans on terrapins in Barnegat Bay nor do they drastically change the field experiences of volunteers. Additional objectives for the 2010 field season will be included in our research renewal proposal.

4. DISSEMINATION

Printed
(Earthwatch acknowledged)
Title: Among population variation in multiple paternity in the diamondback terrapin (Malaclemys terrapin)
Stage: In Review
Authors: C. M. Sheridan, W. M. Roosenburg, W.F. Bien, J.R. Spotila, and H.W. Avery

Title: Among Sex-biased dispersal and natal philopatry in the diamondback terrapin (Malaclemys terrapin)
Stage: In Review
Authors: C. M. Sheridan, K. Scribner, W.F. Bien, J.R. Spotila, and H.W. Avery

Title : Organohalogen contaminant concentrations in diamondback terrapins from Barnegat Bay, New Jersey

Stage: In Review.
Authors: Emily R. Basile , Harold W. Avery, Walter F. Bien, and Jennifer M. Keller.

Title : Effects of nest substrate and shading on the development and survivorship of diamondback terrapin embryos (Malaclemys terrapin).
Stage: In Review.
Authors: J.P. Wnek, W.F. Bien and H.W. Avery.

Title : Constraints on egg size, optimal egg size theory, and latitudinal reproductive variation in the Diamondback terrapin (Malaclemys terrapin)
Stage: In prep
Authors: C. M. Sheridan, J. Wnek, W.F. Bien, J.R. Spotila, and H.W. Avery

Title: Landscape genetic structure of diamondback terrapins (Malaclemys terrapin) in a fragmented estuary system
Stage: In prep
Authors: C. M. Sheridan, K. Scribner, W.F. Bien, J.R. Spotila, and H.W. Avery

Digital

http://terrapinstationnj.blogspot.com/- Earthwatch acknowledged

Mass Media

News Articles
Rising, Gerry. Buffalo State takes a slow but intense look at turtles. The Buffalo News. July 19, 2009. http://www.acsu.buffalo.edu/~insrisg/nature/nw09/0719TurtleResearch.htm - Earthwatch acknowledged
Teacher joins turtle study project. Dailyrecord.com November 25, 2009. - Earthwatch acknowledged
Study Shows Terrapins Can Hear. The Beacon. July 2009 - Earthwatch acknowledged
Studying the diamondback terrapin. Photo gallery in Asbury Park Press. July 2009. http://www.app.com/apps/pbcs.dll/gallery?Avis=B3&Dato=20090724&Kategori=MULTIMEDIA02&Lopenr=907240802&Ref=PH - Earthwatch acknowledged
DeAngelis, Martin. Terrapin-rescue project in Margate bumps up survival odds. Press of Atlantic City. August 6, 2009
DIAMOND TERRAPIN: OUR BAY NEIGHBOR . Spring/ Summer 2009. ALLIANCE FOR A LIVING OCEAN. http://www.livingocean.org/spring2009newsletter.pdf
Marino, Suzanne. Rescued turtles are released to their habitat. Shorenewstoday.com. Aug, 12, 2009. http://www.shorenewstoday.com/news.php?id=3616

Invited Lectures- Earthwatch acknowledged
Y.A.L.E. School Cherry Hill, NJ (A school providing programs for students with Asperger's syndrome, specific learning disabilities, emotional/behavioral disabilities, and/or multiple disabilities.)
Title: Diamondback terrapins of New Jersey-Biology and Human Impact, 45 min presentation directed towards 9-12 graders in the special education program with live turtles and demonstration of field equipment. Students were currently finishing up an Environmental Science session in their Biology classes.
Author: Claire Coleman

Y.A.L.E. School Cherry Hill, NJ (A school providing programs for students with Asperger's syndrome, specific learning disabilities, emotional/behavioral disabilities, and/or multiple disabilities.)
Title: Diamondback terrapins of New Jersey-Biology and Human Impact,

A 45 min presentation directed towards 1-4th graders in the special education program, with live turtles and demonstration of field equipment. Students spent the week before reading about turtles for the Read Across America program. The school picked the theme “Yertle the Turtle” by Dr. Suess. After the lecture some students toured the hallways with me to show bulletin boards that they designed to demonstrate their knowledge of turtles.
Author: Claire Coleman

Posters - Earthwatch acknowledged
Conference: The College of Arts and Science Research Day, Drexel University and Drexel University Research Day 2009
Date: April 6, 2009 and April 23, 2009
Title: The Mating System and Dispersal of the Diamondback Terrapin in Relation to Habitat Fragmentation in the Barnegat Bay Estuary New Jersey
Authors: C. M. Coleman, H.W. Avery, and J.R. Spotila
Award: Honorable Mention in the Graduate Division of Biological and Biomedical Research

Meetings and Conferences

Conference: The College of Arts and Science Research Day, Drexel University and Drexel University Research Day 2009
Date: April 6, 2009 and April 23, 2009
Title: The effects of substrate type on the hatching success of diamondback terrapins (Malaclemys terrapin) at Barnegat Bay, New Jersey
Authors: J. Wnek and H.W. Avery

Conference: The College of Arts and Science Research Day, Drexel University and Drexel University Research Day 2009
Date: April 6, 2009 and April 23, 2009
Title: Effects of Anthropogenic Sound on the Behavior of the Northern Diamondback Terrapin (Malaclemys terrapin terrapin)
Authors: Lester, L. A., Avery, H. W., Spotila, J. R., Standora, E. A. and W. F. Bien

Conference: The College of Arts and Science Research Day, Drexel University and Drexel University Research Day 2009
Date: April 6, 2009 and April 23, 2009
Title: Utilization of Passive Sonic Telemetry as Indicators of Movement and Nesting of the Northern Diamondback Terrapin (Malaclemys terrapin terrapin)
Authors: J. Winters, H.W. Avery, and J.R. Spotila
Award: First Place- Graduate Studies: Biological & Biomedical Research

Conference: The College of Arts and Science Research Day, Drexel University and Drexel University Research Day 2009
Date: April 6, 2009 and April 23, 2009
Title: Unique Polybrominated diphenyl ether (PBDE) pattern in Diamondback Terrapins of Barnegat Bay, New Jersey
Authors: E.R. Basile, H.W. Avery, J. M. Keller, W.F. Bien and J.R. Spotila

Conference: The College of Arts and Science Research Day, Drexel University and Drexel University Research Day 2009
Date: April 6, 2009 and April 23, 2009
Title: Importance of Morphological Variation to the Conservation of the Northern Diamondback Terrapins (Malaclemys terrapin terrapin) in New Jersey
Authors: A. Dominy, H.W. Avery

Symposium Talks- Earthwatch acknowledged

Conference: Atlantic Estuarine Research Society Spring 2009 Meeting (March 5-7) in Ocean City, Maryland
Date: March 5-7, 2009
Meeting Theme: Clash of the Populations: Emerging Challenges for Coastal Lagoons
Session Title: Living Resources
Title: Habitat Fragmentation in Barnegat Bay Estuary: Mating System and Dispersal of the Diamondback Terrapin
Authors: C. M. Coleman, H.W. Avery, and J.R. Spotila

Conference: Evolution 2009: Joint annual meeting of the Society for the Study of Evolution, the Society of Systemic Biologists, and the American Society of Naturalists
Date: June 12-16, 2009
Session Title: Management and Conservation
Title: Dispersal of the Diamondback Terrapin in Relation to Habitat Fragmentation in the Barnegat Bay Estuary, New Jersey
Authors: C. M. Coleman, H.W. Avery, and J.R. Spotila

Conference: SETAC North America 30th Annual Meeting (New Orleans, LA)
Date: November 19-23, 2009
Title: Unique Polybrominated diphenyl ether (PBDE) pattern in Diamondback Terrapins of Barnegat Bay, New Jersey
Authors: E.R. Basile, H.W. Avery, J. M. Keller, W.F. Bien and J.R. Spotila

5. CAPACITY DEVELOPMENT AND EDUCATION

We are successfully educating and training four Ph.D. candidates, two Ph.D. students, and two thesis Master's students, all of which study the diamondback terrapin for their dissertation research under Dr. Avery. We have also successfully trained and educated two Master's students (non-thesis) and three high school students (MATES academy and other).
Lori Lester-Ph.D. candidate
Claire Sheridan (Coleman)- Ph.D. candidate
Emily Basile- Ph.D. candidate
John Wnek- Ph.D. candidate
Julianne Winters- Ph.D. student
Abby Dominy- Ph.D. student
Andrew Harrison - Master's (thesis) student
Jacqueline Walters - Master's (thesis) student
Lori Pester-Master's (non-thesis) student
Rachael Rutherford- Master's (non-thesis) student

6.1 CONTRIBUTIONS TO INTERNATIONAL CONVENTIONS, AGENDAS, POLICIES, MANAGEMENT PLANS

Dr. Avery presented research findings as a plenary invited speaker at the International Society of Integrative Zoology in Beijing, China, in June2009 as part of a symposium on the implications of global climate change on wildlife. His presentation was influential in re-shaping the management plans of estuaries world-wide. These changes to estuarine management plans are in the process of being considered for implementation in affected areas of the world.

6.2 CONTRIBUTIONS TO LOCAL, NATIONAL AND REGIONAL CONVENTIONS, AGENDAS, POLICIES, MANAGEMENT PLANS

We presented our research at the 2009 meeting of the Mid-Altantic Diamondback Terrapin Working Group (MADTWG) in Stone Harbor, New Jersey. We also plan to present our research at the 5th National Symposium on the Ecology, Status, and Conservation of the

Diamondback Terrapin in 2010. Both meetings contribute to the development of statewide and regional management plans to determine protection actions needed for the diamondback terrapin.

7. ACTIONS OR ACTIVITIES THAT ENHANCE NATURAL AND SOCIAL CAPITAL

Land/Water Management: Throughout the region of southern New Jersey crab pots that are for sale in a myriad of hardware stores, sporting good outlets, and recreational retail stores are now being outfitted with turtle excluder devices (TEDs) prior to being sold, based on our research and the efforts of Mr. John Wnek, Ph.D. candidate who works on this Earthwatch project. Through outreach to the Margate and Waretown (NJ) communities regarding our research, we have educated and exposed over 8,000 citizens to our research findings and have increased their environmental awareness to issues related to diamondback terrapin conservation.

8. LONG TERM IMPACT OF PROJECT

Taxa of conservation significance enhanced, restored or maintained

One of the major goals of the Earthwatch sponsored research on the diamondback terrapins of Barnegat Bay NJ is to determine whether the conservation status of the diamondback terrapin as a "Species of Special Concern" in New Jersey is appropriate protection status or not for the future viability of terrapin populations within the state. We are collecting the baseline data of population sizes, mortality rates, and reproductive rates that are necessary to determine whether populations are increasing or decreasing, and whether the diamondback terrapin populations in Barnegat Bay, NJ will be viable in the short- and long-term.

Habitats enhanced, restored or maintained

We are working with the U.S. Fish and Wildlife Service in Forsythe National Wildlife Refuge to enhance the saltmarsh habitat for the diamondback terrapin and other wildlife. We are preparing a report to the U.S. Fish and Wildlife Service that documents the elevated rates of boat injuries incurred by diamondback terrapins in relation to use of personal watercraft and other motorized watercraft in the Refuge. Habitat enhancement will be in the form of reducing the anthropogenic risks of mortality in the Refuge. This will be accomplished by changing the regulations of watercraft use (e.g., speed regulations, areas off limits to use, etc.) based on our population research of the diamondback terrapin in relation to current motorized watercraft use.

Ecosystem services enhanced, restored or maintained

Provisioning - Our research includes the removal of ghost traps (i.e. crab traps that have broken away from floats and kill wildlife because they are lost) from areas of Barnegat Bay. This habitat improvement directly increases the survivorship and harvest of blue crabs that would otherwise drown and be lost in submerged traps. Blue crabs are harvested for food in Barnegat Bay by the human population. This action also benefits the diamondback terrapin populations by reducing drowning mortality in submerged traps.