DEMOGRAPHIC ANALYSIS OF THE JAMAICA BAY DIAMONDBACK TERRAPIN POPULATION: IMPLICATIONS FOR SURVIVAL IN AN URBAN HABITAT

A Final Report of the Tibor T. Polgar Fellowship Program

Alexandra K. Kanonik

Polgar Fellow

Masters in Biology Program
Hofstra University
Hempstead, NY 11549

Project Advisor:

Dr. Russell L. Burke
Department of Biology
Hofstra University
Hempstead, NY 11549

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ABSTRACT

Population studies can contribute essential information to the management of rare and endangered species. Such studies have been critical for understanding special life histories and for planning appropriate conservation and management methods for the special needs of 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 suffering declines.

This study examines the status of nesting diamondback terrapins (*Malaclemys terrapin*) in Jamaica Bay, New York, during the summer of 2009. Jamaica Bay is an 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 were collected on 383 female terrapins on the main nesting habitat on the island of Ruler's Bar Hassock. Seventy three per cent of these terrapins had been captured before. All captured female terrapins were reproductively mature and the majority of females sampled ranged from170-180 mm SPL. Data collected during 2009 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.

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INTRODUCTION

Diamondback terrapins (*Malaclemys terrapin)* are a unique species of turtle in the family Emydidae. They are the only members of this family that have a completely estuarine life history. The physiology and behavior of *M. terrapin* allows them to have a high tolerance to varying levels of salinity. Terrapins inhabit salt marshes and tidal creeks where they feed on mollusks, crabs and other crustaceans and invertebrates (Tucker et al. 1995). *M. terrapin* ranges from Cape Cod, Massachusetts to the Gulf Coast of Texas (Butler et al. 2006). Like many other Emydid turtles, *M. terrapin* are sexually dimorphic, as adult females are significantly larger than adult males.

Terrapins play an important ecological role in their habitat. Their presence in coastal ecosystems helps maintain nutrient and energy pathways. For example, during the nesting season female terrapins move nutrients and calories from water to land in the form of eggs. Terrapin eggs and emerging hatchlings are eaten by a variety of predators. Feinberg and Burke calculated that terrapin eggs containing 300,000 Kcal were eaten by raccoons on one small beach within their study site in Jamaica Bay in a single year (Feinberg and Burke 2003). Furthermore, the nutrients from eggs that are missed by vertebrate predators are often absorbed by plant roots for growth in an otherwise nutrient-poor environment (Stegmann et al. 1988; Feinberg and Burke 2003). In addition, terrapins have been shown to be among the species which regulate salt marsh invertebrate populations (Tucker et al. 1995). Terrapin predation reduces the abundance of periwinkles (*Littorina sp.*) (Levesque and Fauth 1999), which are known to be important grazers of salt marsh cordgrass (*Spartina alterniflora*) (Silliman and Bertness 2002).

The disappearance of diamondback terrapins is predicted to contribute to the decline of salt marsh habitat, mainly by allowing overgrazing of grasses that form a crucial part of this environment (Brennessel 2006).

Historically, *M. terrapin* have suffered significant declines as a result of human exploitation and habitat degradation. The former is attributed to the food trade in the early 1800s and the latter is attributed to the fact that terrapin habitats closely coincide with densely populated coastal areas and are therefore prone to human exploitation (Wood and Herlands 1997). For example, road mortality of female terrapins during the nesting season is a major problem in southern New Jersey where salt marsh nesting habitats are fragmented by highways (Wood and Herlands 1997). Meanwhile, in places like the Patuxent River in Chesapeake Bay and much of the rest of their range, terrapins suffer declines as a result of mortalities from accidental trapping in commercial and recreational crab pots (Roosenberg et al. 1997; Roosenberg and Green 2000; Cole and Helser 2001; Wood 1997; Hoyle and Gibbons 2000; Grosse et al. 2009; Guillory and Prejean 1998; Dorcas 2007).

In New York City, terrapins are threatened by habitat destruction. One notable example would be John F. Kennedy International airport where there are numerous cases each year of female terrapins appearing on the runways during the summer nesting season. The land for the airport was built by filling in existing tidal wetlands with dredged material from other portions of the bay, thus destroying a large part of the tidal marsh ecosystem (NYCDEP 2007). It is very likely that this area was once used as a nesting ground by Diamondback terrapins. Like other species of turtles, it is highly probable that female terrapins have nest site fidelity and will therefore return to their

place of hatching to nest, making them especially vulnerable to declines as a result of significant habitat changes (Klemens 2006).

In New York, there have been no real demographic studies on the *M. terrapin* populations occurring in the lower Hudson River and Long Island; therefore, the status of terrapins remains unclear for this region. Currently, terrapins are listed as an S3:Vulnerable species by the NY Natural Heritage Program, and are currently listed as a "Wildlife Species of Regional Conservation Concern" in the Northeastern United States (Therres 1999).

This study focused on one population of diamondback terrapins in Jamaica Bay, New York, which is the largest population in the state. Population studies have played an important role in turtle conservation. For example, studies of marine turtles have provided justification for their protection (Meylan and Donnelly 1999; Eckert 1993). Hellgren et al. (2000) estimated population sizes of Texas tortoises (*Gopherus berlandieri*), and studies by Bowen et al. (2004) of ornate box turtles (*Terrapene ornata*) provided insight into the factors that affected survival and recruitment rates within an urban habitat. Also, such studies on aquatic turtles have produced important information on population growth. These include Mitro (2003) who tested the effects of nest protection as an aid to population growth.

Jamaica Bay Wildlife Refuge (JBWR) is a 3704.9 ha estuarine wildlife refuge located at the southwestern corner of Long Island, New York in Jamaica Bay. The refuge is located in the boroughs of Queens and Brooklyn, and consists of one large island, Ruler's Bar Hassock (RBH, 520 ha), several smaller islands, and much of the coastline of Jamaica Bay. This area is part of the Hudson River Bight, and much of the

inflow to it comes from the Hudson River via Rockaway Inlet (Chant et al. 2008). JBWR is part of Gateway National Recreation Area (GNRA) which is a large federally-operated estuarine park managed by the National Park Service. JBWR is an ideal study site as *M. terrapin* are protected from commercial and recreational collection here and because JBWR has numerous suitable nesting habitats which allow easy access to female terrapins. Mark-recapture sampling of diamondback terrapins has been conducted at RBH since 1998.

The information collected from this study will help in understanding patterns of demographic changes within this population, provide an essential guide to the management of New York's largest terrapin population, and provide a comparison to other populations in the Northeast. This study has two aims, the first being to add as much information to existing data as possible by providing more recapture information on female terrapins. The second aim is to answer questions about the status of this population. The immediate questions are: "How many individuals are there?" and "What are the proportions of females within each age/size group?"

Further questions which can be answered through statistical modeling include: "Is the population suffering significant decline or growing?" and "Do changes in the demography of the population correspond temporally with habitat changes and marsh loss in JBWR?" Modeling will also help in determining whether management should be more productively aimed at protecting adults or hatchlings and if so, how many recruits will be required to sustain the population annually.

METHODS

Site Protocols:

In JBWR, standard mark-recapture sampling methods have been used during the summer nesting season since 1998 on the largest of the islands, Ruler's Bar Hassock (RBH). This island is divided by Cross Bay Boulevard into two areas, the East Pond trail and the West Pond trail. The main terrapin study area encircles the West Pond trail (Figure 1). In order to understand where female terrapins nest, the West Pond trail was further divided into zones according to numbered benches from 1-13 that are distributed along the gravel visitor trail. Distinct habitat types were characterized along the zones where terrapins were known to nest: dunes, beach, mixed grasslands, shrub lands, gravel trail, terrapin trail, and woodland habitats.

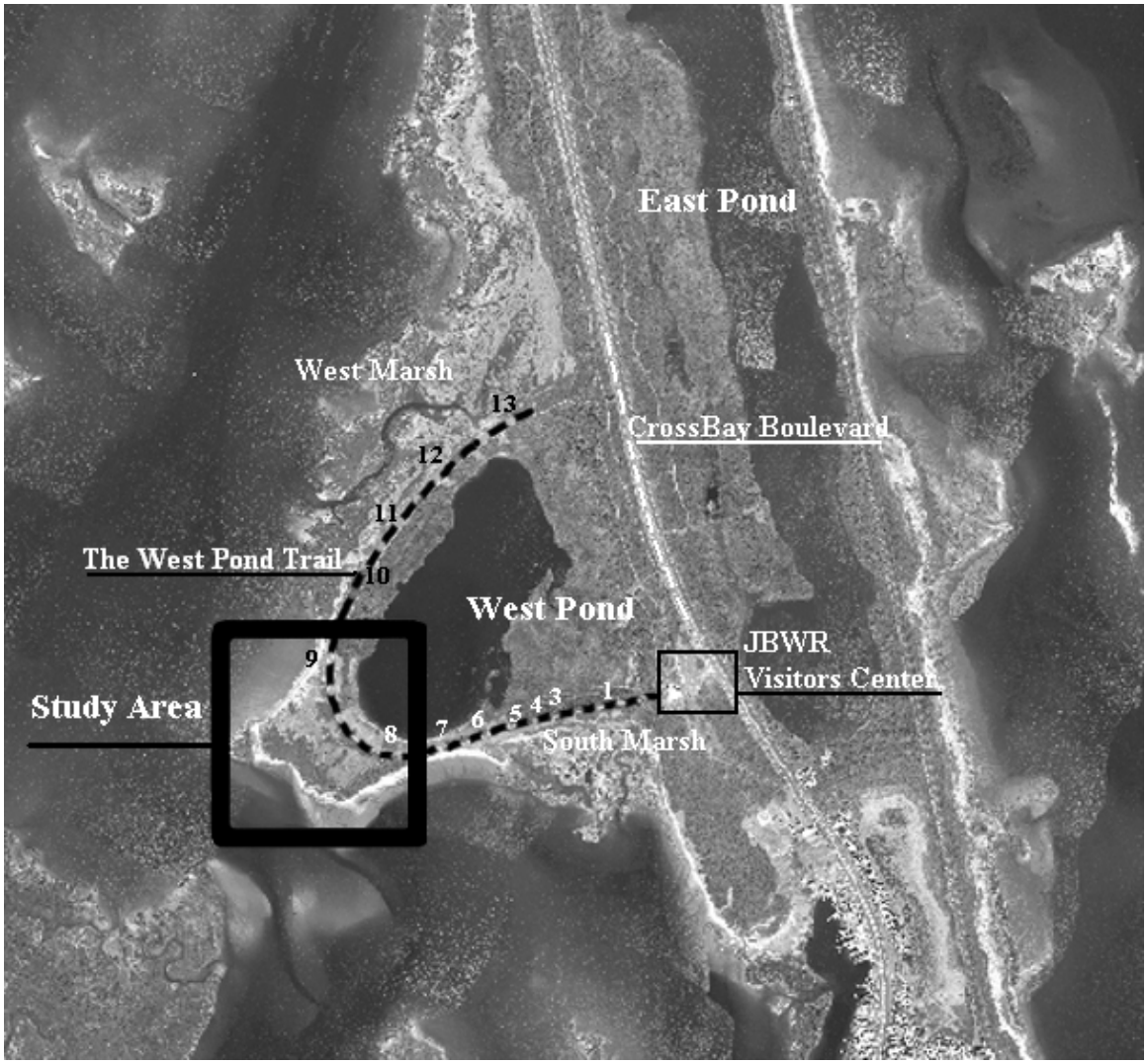

Figure 1. Map of Jamaica Bay. The main study area is on the largest island, Ruler's Bar Hassock. The area marked is the West Pond portion of this island.

Studies of this population were initiated in 1998 by Dr. Russell Burke and Jeremy Feinberg of Hofstra University. In JBWR, the nesting season for *M. terrapin* can begin in late May and finish in early August. Females may lay up to 2 clutches per season, with and average clutch size of 10.9 eggs, and nesting activity increases around periods of high tides (Feinberg and Burke 2003).

In the summer of 2009, nesting terrapin searches were conducted from June 1st – continuing until July 31st when there were no more sightings of terrapins making nesting attempts. The first nesting females were captured on June 6th and the last on July 28th. There were a total of 46 days where females were collected. A regular team of volunteers assisted with data collection and capturing terrapins on each sampling day. Typical field days began at 08:30 and concluded at 19:00. From morning to early evening, volunteers would watch for terrapins preparing to come onto the shore and would patrol the trails at regular intervals throughout the day for nesting terrapins. The nesting process takes about 20-25 minutes after a female finds suitable nesting substrate. Once a female terrapin was sighted on land, she was followed and hand captured after she finished nesting.

Sample Processing:

Once a female was captured she was taken back to the field station for data collection. Standard morphological data were taken on each female. Carapace and plastron measurements were recorded in millimeters. Straight carapace measurements were taken with calipers from the base of the nuchal scute to the base of the notch between the left and right 12th marginal scutes. Straight plastron measurements were taken from the base of the midline between the left and right gular scutes to the base of the midline between the left and right anal scutes.

Growth rings were measured on the carapace by counting the ridges following the first year of growth. More than one scute was counted in order to get a reliable estimate for the number of rings. Growth ring counts were only taken from terrapins that still retained clear ridges on their carapace.

Data on abnormalities in the field were recorded in illustrated form. Any noticeable morphological abnormalities or injuries on the carapace, plastron or on the body were drawn on the datasheet (Figure 2).

Each female was given two forms of permanent identification at first capture. A unique alphanumeric Passive Integrated Transponder (PIT) tag was injected into the body cavity of each captured terrapin, and a notch was cut into one of the marginal scutes of the carapace with a triangular file. Females that were caught already possessing either one or both forms of identification were considered recaptures. In addition, information on activity prior to capture, nesting habitat location, and the percentage of cloud cover during capture were recorded for each terrapin. Individuals were immediately released near the water's edge after all data were collected.

In 2009, some females were caught before they had oviposited in order to get the largest possible sample size of marked and unmarked females. Gravid females were marked with a paint spot after data collection in order to be more easily recognized the next time they were sighted. Females bearing these paint spots were left undisturbed when they later returned to nest.

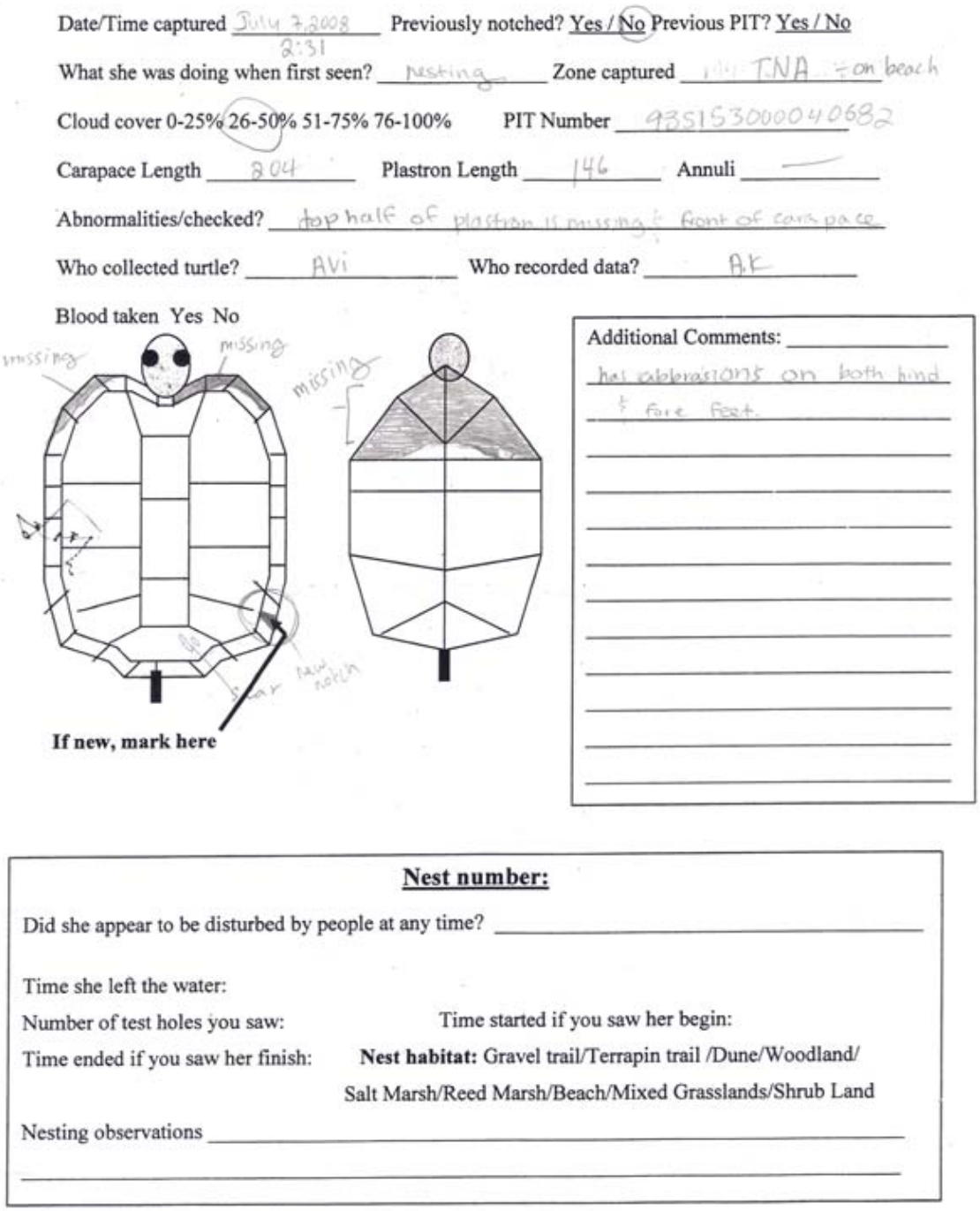

Figure 2. Data sheet illustrating the method of recording information on deformities and malformations found on female terrapins in JBWR.

RESULTS

During the 2009 nesting season, 383 individual females were captured. This is the highest number of turtles that have been captured during a single season of the JBWR studies (Table 1). Of these, 278 were recaptured turtles (initially marked in previous years) and 105 were newly marked individuals (never previously captured). Compared to previous years, the percentage of terrapins captured that have been previously captured had dramatically increased (Table 1). The percentage of terrapins captured that have been previously captured passed 50% in 2005; in 2009 the percentage of recaptured individuals was higher (72.6%) than that of newly captured terrapins (27.4%). The average sampling effort was 6-8 females captured on a given day for the duration of the season.

Year	Recapture	New	Total Number Captured	% Recapture
2001	0	11	11	0.0
2003	61	101	162	37.7
2004	91	96	187	48.7
2005	114	73	187	61.0
2006	24	24	48	50.0
2007	58	48	106	54.7
2008	97	56	153	63.4
2009	**278**	**105**	**383**	**72.6**

Table 1. Annual numbers of recaptured and newly marked female terrapins as part of the mark-recapture study on *M. terrapin* of the West Pond section of Jamaica Bay Wildlife Refuge, Queens, New York.

The number of new terrapins captured each year compared with the percentage of total captures each year that were recaptures strongly fit a logarithmic curve (R^2= 0.9562) with the equation y = 17.569Ln(x) - 43.597.

Using this equation, setting the value of Y to 100% to indicate 100% capture, and solving for X yields an estimate of 3498 adult female terrapins in this population, assuming that the population size has remained constant over the time measured (Figure 3).

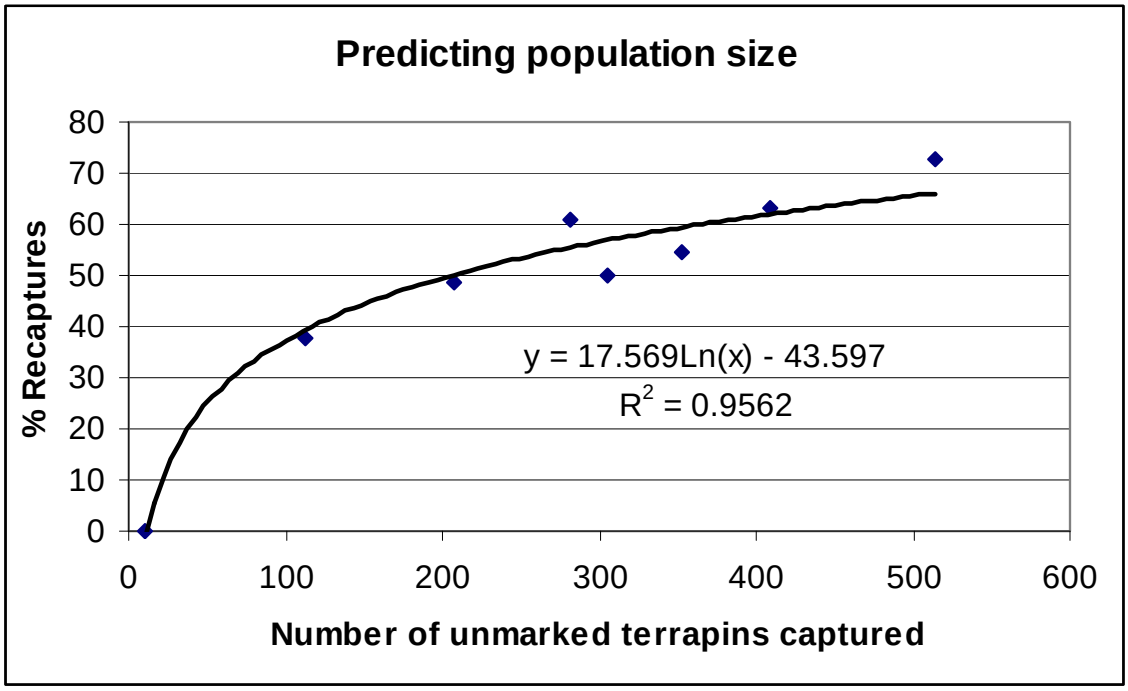

Figure 3. Estimate of the total number of female terrapins (3498 individuals) within the population in JBWR, Jamaica Bay, NY.

Looking at annual recapture information, the number of recapture events for each individually marked female terrapin in the JBWR population across the years was determined. Forty-two percent of terrapins were captured only once. However, two individuals were captured on six separate occasions (Figure 4).

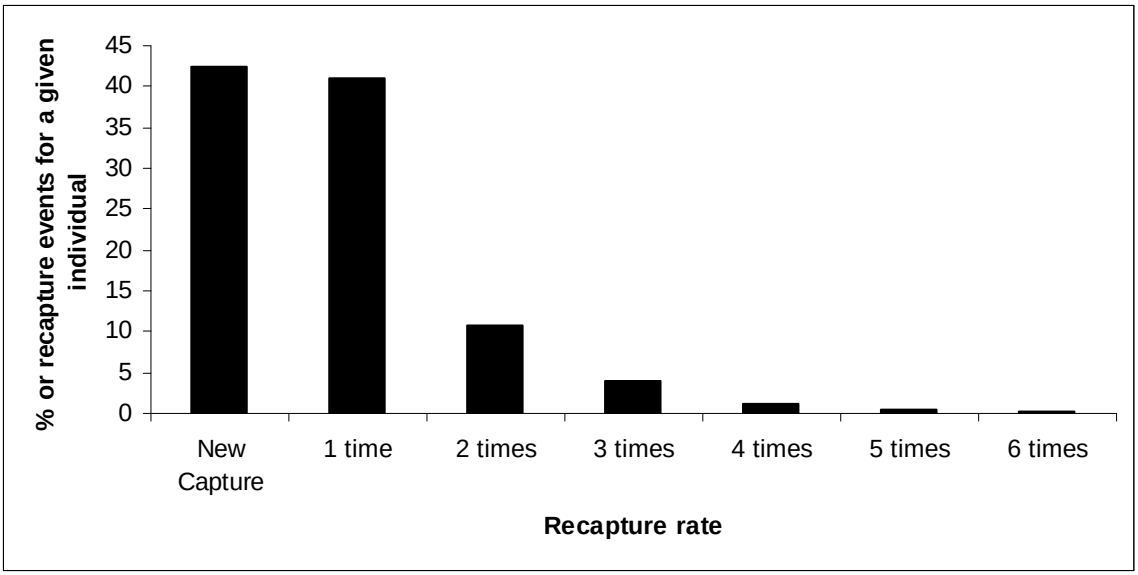

Figure 4. Frequency distribution for the number of recapture events for all individual female terrapin across the 2001-2009 sampling years (N=1237) in JBWR.

The terrapins in this study are all sexually mature as they were captured while making nesting attempts. Measurements of SPL (straight plastron length) for all females across the years were analyzed to determine which size/age groups existed within the population . Females within the SPL 170-180 mm size range were the dominant group for all years (Figure 5).

The minimum size of reproductive females across all sampling years ranged from 80-162 mm, the average SPL was 146.2 millimeters (Table 3). For the 2009 nesting season, the minimum size of captured female terrapins was 153 mm (Table 2).

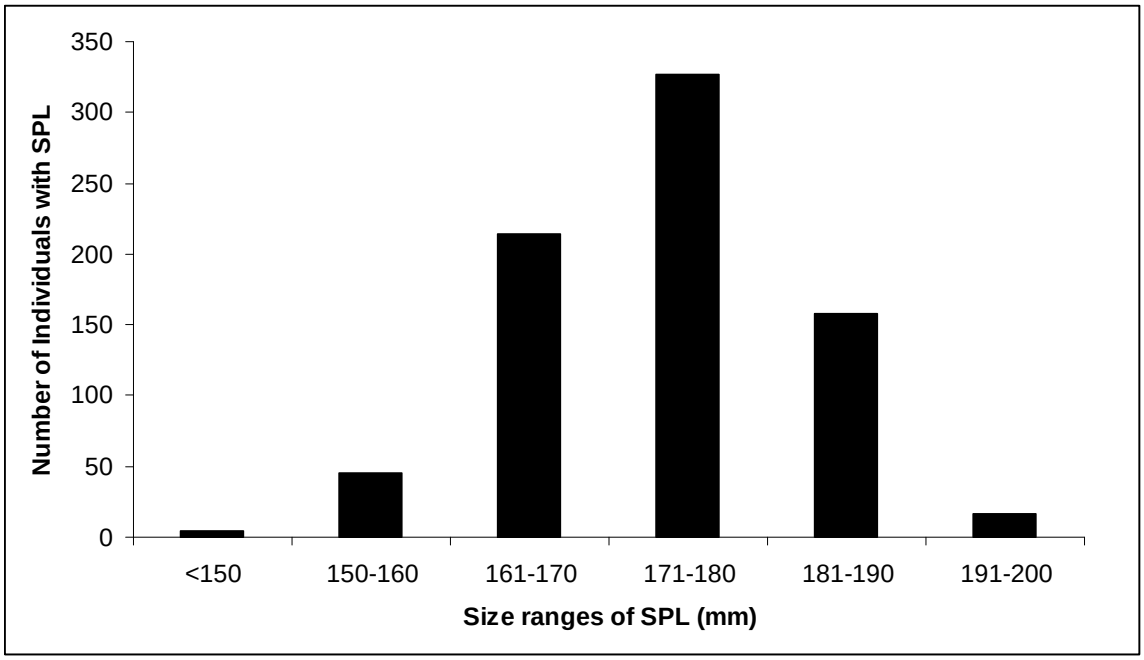

Figure 5. Size range frequency distribution from the sampling years 2001-2009 illustrating the size as measured through straight plastron length (SPL) of female Diamondback Terrapins in the West Pond section of Jamaica Bay Wildlife Refuge, Queens, New York.

Growth ring data has been recorded intermittently through the study. Using the available data, it was determined that in 66% of females growth rings could not be counted due to wear (Figure 6). The most growth rings that have been recorded in any turtle in any year were 12, the fewest were 4 rings. From the growth ring data that was available, a relationship between the number of growth rings and the years between captures for recaptured females could not be determined. As a result, it is not possible to calculate the age at first reproduction, the relationship between SPL and growth rings, or whether growth rings are added annually.

Year	SPL (mm)
2001	162
2003	158
2004	156
2005	80
2006	156
2007	159
2008	146
2009	**153**

Table 2. Absolute minimum measured annual SPL of female terrapins of the West Pond section of Jamaica Bay Wildlife Refuge, Queens, New York.

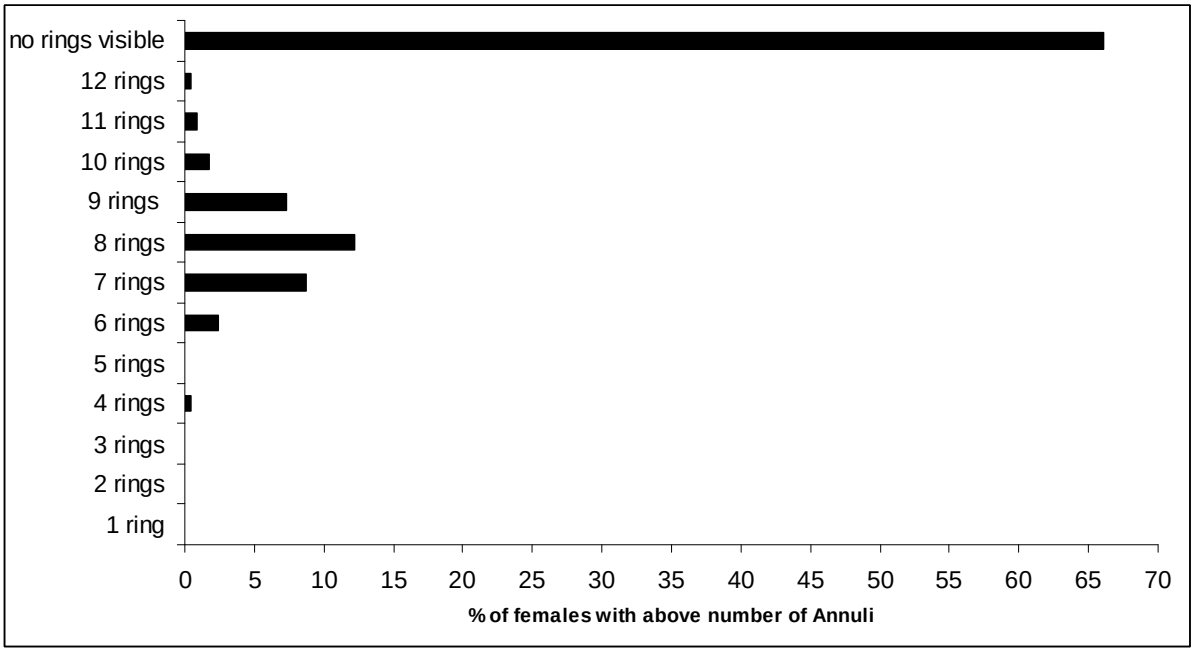

Figure 6. Growth ring frequency distribution from years 2001-2009 for female Diamondback Terrapins. This chart displays the percentage of females with the given number of annuli that could be counted any given year. N=468.

Data on bodily injuries and abnormalities have been recorded fairly consistently in this study; with more detailed information available in the 2009 sampling year than in previous years. The most common shell abnormalities for the terrapins of JBWR occurred on the posterior of the carapace around the 5th vertebral scute. Extra scutes around the area of and on the 5th vertebral were by far the most common morphological abnormality. Some interesting abnormalities on females included missing sections from the carapace or plastron and missing limbs which may be attributed to either predation or anthropogenic factors.

Diamondback terrapins can deposit 1-2 clutches per season. Nesting activity at JBWR peaks 2-3 times each season, and as a result, instances of capture tend to increase during those periods (Feinberg and Burke 2003). There were two distinct peaks in nesting activity for this year: one on June 19 and the second on July 12 (Figure 7).

The most individuals captured on any given day were 30 on 06/19. On this day there were two periods of high tides during daylight hours, which may have attributed to the high number of captures since nesting activity corresponds to high tides (Feinberg and Burke 2003).

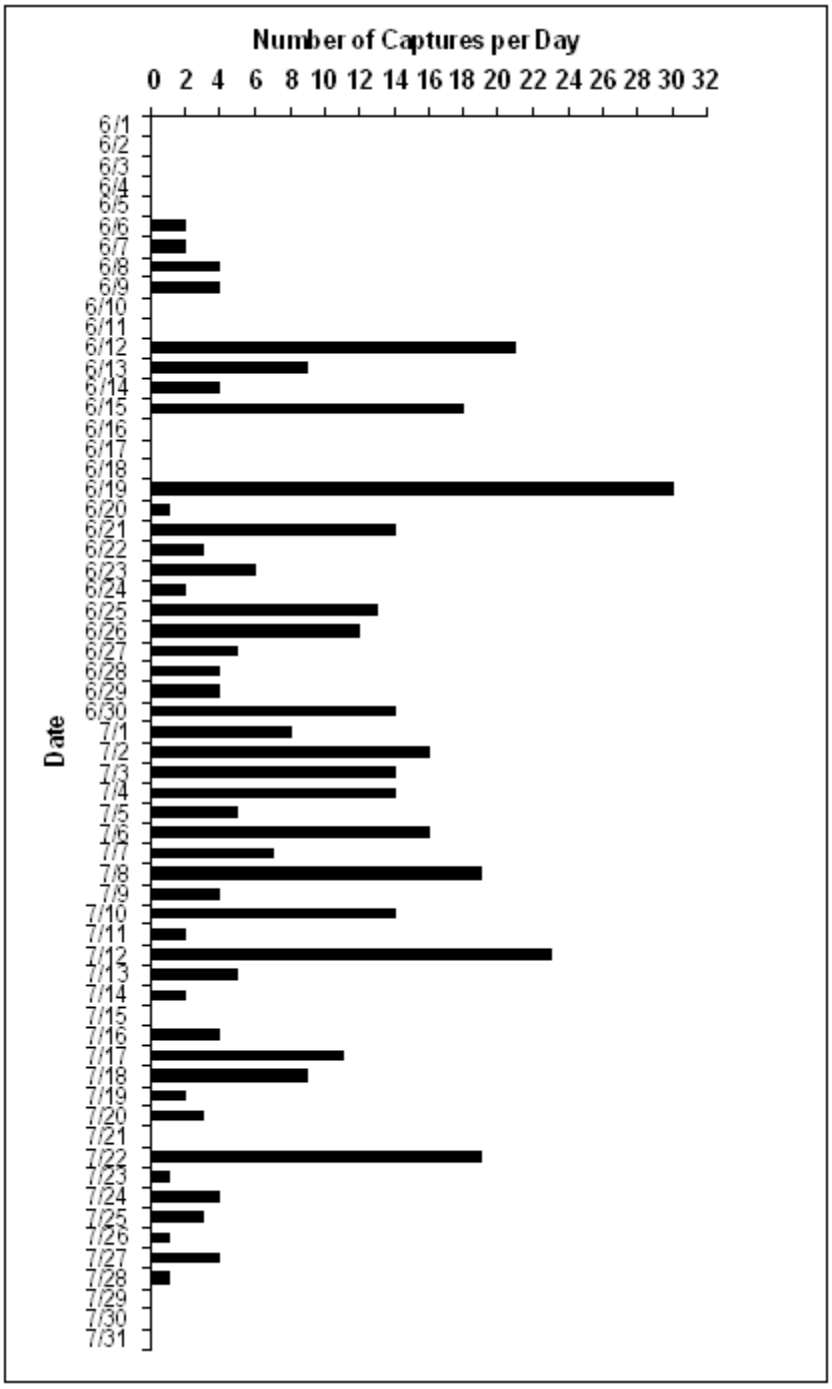

Figure 7. Total number of female terrapins captured on a given day during the 2009 summer nesting season in JBWR, Jamaica Bay, NY.

DISCUSSION

Historically, the Diamondback terrapin population in JBWR has been coping with a variety of stresses. Currently, JBWR wetlands are at 1% of their pre-1700 coverage (NYCDEP 2007). The New York State Department of Environmental Conservation (NYSDEC) estimates that since 1924, a total of approximately 566.6 ha of tidal salt marsh have been lost from the islands of JB. Since then, the rate of marsh loss has accelerated from 0.4% to 3.0% per year which calculates to 133.5 ha annually (NYCDEP 2007). A possible explanation for the loss of these wetlands may be attributed to extensive dredging and filling operations which have occurred in the JB system since the early 1900s. These operations have removed and extended existing shorelines, caused erosion, increased salinity levels, and have alternated the flow patterns of sediment and fresh/salt water (NYCDEP 2007). An alternate explanation for such rapid losses can be attributed to sea level rise as a result of global warming, which has caused tidal inundation of existing wetland habitat (NYCDEP 2007). In addition to habitat losses the overall water quality of the entire JB system has deteriorated over the years as a result of industrial and urban development along the coast. Aside from the above environmental stresses, depredation has had a prominent and more direct impact on the Diamondback terrapin population. In Jamaica Bay Wildlife Refuge terrapin eggs experience very high (93%-100%) predation rates by raccoons (*Procyon lotor*) (Feinberg and Burke 2003; Burke unpub. data). Raccoons are not native to the Ruler's Bar Hassock, rather they were introduced there in the 1980s (Ner and Burke 2008).

Due to the unusually cold spring and the unusually heavy levels of rainfall in summer 2009, the nesting season in JBWR began late and finished later as compared to previous years. The mean average temperatures for spring were: 5°C in March, 11.6°C in April, and 16.13°C in May. The mean average temperatures during the summer nesting season were 20°C for June and 23.3°C for July, the average precipitation during these months was 0.13 inches. Despite this, the percentage of recaptured individuals was higher than previous years (73%), probably due to the intensive sampling effort. All females that had been captured were reproductively mature. The recapture rate for individual female terrapins has varied from only two recapture events to as many as six recapture events throughout the years. This may indicate that a higher sampling effort will be needed in the following years of this study in order to see if this rate increases with a larger sampling size.

Information on the size/age groups among the terrapins in JBWF illustrates a definite pattern of the size groups that are seen and captured each year. Females in the 171-180 mm SPL size class are the most common. These are the average sized mature females that are likely to be older than six years of age. Females in the 150-160 mm or smaller group and females with plastron sizes greater than 191 mm appear to be the least common. Very few individuals from both of these size groups are captured each year. This demonstrates that smaller adults and older more mature females are poorly represented within this population. This may be due to the variable sampling effort throughout the years that this study has been conducted. It may also be implying that something is happening to terrapins within these age groups in Jamaica Bay.

It is often assumed that growth rings on turtles are annual, and therefore make it possible to determine age. For this study, the age of females could potentially be inferred from growth ring counts on the carapace. For example, it is generally assumed that females with 6 distinguishable growth rings are possibly 6 years of age, the approximate age of first reproduction; whereas female terrapins that have 8 growth rings are thought to be 8 years old or older. Females with rings worn down altogether, are most likely older than 12 years of age. However, there is not enough data in this study as of yet to determine whether rings are indeed deposited annually. It is possible that growth ring counts for recaptured females have not been recorded consistently over the years; in the future it would be helpful to have data from more individuals over multiple years.

Information on injuries, deformities or malformations on terrapins in JBWR has been collected in order to more accurately track individual females. These records could also be applied to calculating rates of female survivorship throughout the years. In a study of injury rates of adult terrapins in South Carolina, Cecala et al. (2008) reported that injuries reduced survivorship of individuals. Injuries have not been correlated with survivorship rates in the Jamaica Bay population as of yet, but some interesting observations can still be made. In the JBWR population of female diamondback terrapins, the most common abnormality has been the growth of extra scutes on or near the 5^{th} vertebral carapace scute. It is still unclear why this kind of anomaly may occur. It is possible that these extra scutes form either during development within the egg or as a result of bites or injuries that were sustained when these terrapins were hatchlings. If this is true, then it suggests that despite the high rate of predation in Jamaica Bay by raccoons, some hatchlings will still survive to reproductive maturity. This would be logical since

predation tends to be higher for turtles in their juvenile stages as compared to when they are adults (Klemens 2006). The fact that mature females were sometimes found with missing limbs or missing portions of their carapace may further support this idea.

A full analysis of population estimates, demographic changes and survivorship rates of female terrapins in JBWR using statistical modeling has not been implemented in this study as of yet. Various methods have been used in past research (Avissar 2006; Bowen et al. 2004; Gibbons et al. 2001; Gibbs and Shriver 2002; Hart and McIvor 2008; Hellgren et al. 2000; Hoyle and Gibbons 2000; McDonald and Amstrup 2001; Mitro 2003; Wood 1997). Two different modeling software packages will be used for this study: program MARK (White and Burnham 1999) and program R (Gentleman 2008). In the past, program MARK has been the most common software used to model wildlife populations. However, MARK has several limitations for which program R can readily compensate. As an example, program MARK can easily generate population estimates of recaptured animals using a Cormack-Jolly-Seber (CJS) model, but MARK doesn't handle multiple covariates at one time well. This leads to lower confidence intervals on estimates on a population of individuals. It is important to take covariates into account because knowing what variables affect the structure of a population helps to better depict biological reality. Program R has a simpler user-interface and is more flexible with inputting covariates into an analysis (J. Gibbs, SUNY-ESF, pers. comm.). An additional year of study of the terrapin population at JBWR is planned, and the data collected for the 2010 field season will be incorporated into analyses using both program MARK and R.

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REFERENCES

Avissar, N. G. 2006. Changes in population structure of diamondback terrapins (*Malaclemys terrapin terrapin*) in a previously studied creek in southern New Jersey. Chelonian Conservation and Biology 5:154-159.

Bowen, K.D., P.L. Colbert and J.J. Frederic. 2004. Survival and recruitment in a human-impacted population of ornate box turtles, *Terrapene ornata*, with recommendations for conservation and management. Journal of Herpetology 38:562-568.

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

Butler, J. A., G.L. Heinrich, and R.A. Seigel. 2006. Third workshop on the ecology, status and conservation of diamondback terrapins (*Malaclemys terrapin*): Results and recommendations. Chelonian Conservation and Biology 5:331-334.

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

Chant, R.J., J. Wilkin, W. Zhang, B-J Choi, E. Hunter, R. Castelo, S. Glenn, J. Jerisa, O. Schofield, R. Houghton, J. Kohut, T. K. Frazer, and M.A. Moline. 2008. Dispersal of the Hudson River Plume in the New York Bight. Oceanography 21:149-161.

Cole, R.V. and T.E. Helser. 2001. Effect of three bycatch reduction devices on diamondback terrapin *Malaclemys terrapin* capture and blue crab *Callinectes sapidus* harvest in Delaware Bay. North American Journal of Fisheries Management 21:825–833.

Dorcas, M. E., J. D. Wilson and J. W. Gibbons. 2007. Crab trapping causes population decline and demographic changes in diamondback terrapin over two decades. Biological Conservation 137:334-340.

Eckert, K.L. 1993. The Biology and Population Status of Marine Turtles in the North Pacific Ocean. NOAA Technical Memorandum NMFS-SWFSC-186.

Feinberg, J.A and R.L. Burke. 2003. Nesting ecology of diamondback terrapins (*Malaclemys terrapin*) at Gateway National Recreational Area. Journal of Herpetology 37:517-526.

Gentleman, R. 2008. R Programming for Bioinformatics. Computer Science & Data Analysis. Chapman & Hall/CRC, Florida.

Gibbons, J. W., J. E. Lovich, A. D. Tucker, N. N. Fitzsimmons and J. L. Greene. 2001. Demographic and ecological factors affecting conservation and management of diamondback terrapins (*Malaclemys terrapin*) in South Carolina. Chelonian Conservation and Biology 4:66-74.

Gibbs, J.P and W.G. Shriver. 2002. Estimating the Effects of Road Mortality on Turtle Populations. Conservation Biology 16: 1647-1652.

Grosse, A. M., J. D. van Dijk, K. L. Holcomb, and J. C. Maerz. 2009. Diamondback terrapin mortality in crab pots in a Georgia tidal marsh. Chelonian Conservation and Biology. 8:98-100.

Guillory, V. and P Prejean. 1998. Effect of a terrapin excluder device on blue crab, *Callinectes sapidus*, trap catches. Marine Fisheries 60:38-40.

Hart, K.M and C.C. McIvor. 2008. Demography and Ecology of Mangrove Diamondback Terrapins in a Wilderness Area of Everglades National Park, Florida, USA. The American Society of Ichthyologists and Herpetologists. DOI: 10.1643/CE-06-161.

Hellgren, E.C., Kazmaier, R.T., D.C. Ruthven III and D.R. Synatzske. 2000. Variation in Tortoise Life History: Demography of *Gopherus Berlandieri*. Ecology 81: 1297-1310.

Hoyle, M.E and J.W. Gibbons. 2000. Use of a Marked Population of Diamondback Terrapins (*Malaclemys terrapin*) to Determine Impacts of Recreational Crab Pots. Chelonian Conservation and Biology 3:735-737.

Klemens, W. M. 2006. Turtle Conservation. Smithsonian Institution. USA 211-215pp, 216pp.

Levesque, E.M. and J.E. Fauth. 1999. Effect of diamondback terrapin *Malaclemys terrapin* on the size and density of salt water periwinkle, *Littorina irrorata*. Paper presented at the Annual Meeting of the American Society of Ichthyologists and Herpetologists, June 24-30, The Pennsylvania State University, State College, PA**.**

NYCDEP2007. Jamaica Bay Watershed Protection Plan Volume I-Regional Profile. New York City Department of Environmental Protection. New York City. New York City Department of Environmental Protection website. http://www.nyc.gov/html/dep/html/dep_projects/jamaica_bay.shtml (accessed March 30, 2010).

McDonald, T.L and S.C. Amstrup. 2001. Estimation of Population Size Using Open Capture-Recapture Models. Journal of Agricultural, Biological, and Environmental Statistics 6:206-220.

Meylan, A.B. and M. Donnelly. 1999. Status justification for listing the hawksbill turtle (*Eretmochelys imbricata*) as critically endangered on the 1996 IUCN Red List of Threatened Animals. Chelonian Conservation and Biology 3:200-224.

Mitro, M. G. 2003. Demography and viability analysis of a diamondback terrapin population. Canadian Journal of Zoology 81:716-726.

Ner, S, and R.L. Burke. 2008. Direct and indirect effects of urbanization on Diamondback terrapins of New York City: Distribution and predation of terrapin nests in a human-modified estuary. pp. 107-117 *in* J.C. Mitchell, R.E. Jung, and B. Bartholomew (eds.), Urban Herpetology. Herpetological Conservation Vol. 3, Society for the Study of Amphibians and Reptiles.

Roosenburg, W. M., W. Cresko, M. Modesitte, and M. B. Robbins. 1997. Diamondback terrapin (*Malaclemys terrapin*) mortality in crab pots. Conservation Biology 5:1166-1172.

Roosenburg, W. M. and J. P. Green. 2000. Impact of a bycatch reduction device on diamondback terrapin and blue crab capture in crab pots. Ecological Applications 10:882-889.

Silliman, B.R. and M.D. Bertness. 2002. A Trophic Cascade Regulates Salt Marsh Primary Production. Proceedings of the National Academy of Sciences (USA) 99:10500-10505.

Stegmann, E. W., R. B. Primark, and G. S. Ellmore. 1988. Absorption of nutrient exudates from terrapin eggs by roots of *Ammophila breviligulata*. Canadian Journal of Botany 66:714–718.

Therres, G.D. 1999. Wildlife species of conservation concern in the Northeastern United States. Northeast Wildlife 54: 93-100.

Tucker, A. D., N. N. Fitzsimmons, J. W. Gibbons. 1995. Resource partitioning by the estuarine turtle *Malaclemys terrapin*: trophic, spatial and temporal foraging constraints. Herpetologica 51:167-181.

White, G.C. and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46 Supplement, 120-138.

Wood, R. C. 1997. The impact of commercial crab traps on northern diamondback terrapins, *Malaclemys terrapin terrapin*. Pp. 21-27 *in* J. Van Abbema (Ed.), Proceedings: Conservation, Restoration, and Management of Tortoises and Turtles--An International Conference. New York Turtle and Tortoise Society, New York, USA.

Wood, R. C. and R. Herlands. 1997. Turtles and tires: the impact of road kills on northern diamondback terrapin, *Malaclemys terrapin terrapin*, populations on the Cape May peninsula, southern New Jersey. pp. 46-53 *in* J. Van Abbema (Ed.), Proceedings: Conservation,Restoration, and Management of Tortoises and Turtles--An International Conference. New York Turtle and Tortoise Society, New York.