

# Nest Predation and Ecology of Terrapins, *Malaclemys terrapin* *terrapin*, at the Jamaica Bay Wildlife Refuge

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**Abstract:** A study of diamondback terrapins (*Malaclemys terrapin*) was conducted at the Jamaica Bay Wildlife Refuge in 1998 and 1999. The study yielded detailed information on nesting ecology and predation. Terrapin nesting activity was detected on two islands in the refuge. Depredated terrapin nests were most numerous in mixed-grasslands and shrubland habitats yet densities were highest along a narrow sandy trail. I counted 1,319 and 1,840 depredated nests in 1998 and 1999, respectively, at the refuge. I also found the carcasses of 27 adult terrapins that were killed on land, apparently by raccoons. Female terrapins nested from 3 June to 23 July, and laid up to two clutches per season. Mean clutch size, estimated from a sample of whole eggs within nests, was 12 eggs. Nesting was observed from 9:30 a.m. to 9:15 p.m. Raccoons depredated 100% and 92.2% of terrapin nests monitored in 1998 and 1999, respectively. Only 5.2% of terrapin nests in the second year survived to produce hatchlings. Hatchling survivorship within these nests was 54%.

The diamondback terrapin (*Malaclemys terrapin*) inhabits coastal regions along the Atlantic and Gulf coasts of North America, from Cape Cod, Massachusetts, to Corpus Christi Bay, Texas (Ernst and Bury 1982). Because of their locally high population densities, active foraging style, and significant predatory impact, terrapins may constitute an important component of estuarine food webs (Hurd et al. 1979). However, it may not be possible to analyze the true ecological significance of terrapins accurately, due in part to the population declines that have occurred throughout much of their range for more than a century. In addition to the fact that terrapins of all size classes are prey for numerous predators (Ernst et al. 1994), human activities have had severe impacts on this species. In the late 19<sup>th</sup> and early 20<sup>th</sup> centuries, terrapins were prized for their meat and become the target of intense commercial harvesting. This led to the extirpation of many populations, especially those near cities (Ernst et al. 1994).

Long Island terrapins in particular were heavily exploited and nearly extirpated because of their convenient proximity to the New York City metropolitan area (Garber 1990, Marganoff 1970). After the collapse of the commercial terrapin industry during the Great Depression, harvesting pressures subsided and New York State subsequently enacted regulations to protect the species. In the decades that followed, many populations rebounded (Morreale 1992). As a result, terrapins were removed from the “Species of Special Concern” list in 2000, although they still receive protection as a “game species.”

Unfortunately, threats to terrapin populations still exist throughout their range. Harvesting and collection continue in certain areas and terrapins frequently drown as bycatch in crab traps (Cook 1989, Garber 1988, Wood 1997). The destruction and development of estuaries and upland nesting areas is also a problem facing some terrapin populations (Morreale 1992).

In urban regions such as Jamaica Bay, tide-borne debris may pose a threat to adult terrapins and hatchlings alike (Sadove et al. 1996). Additionally, terrapins are often injured or killed by automobiles when crossing roads to nest (Cook 1989, Wood and Herlands 1997). The release of commercial terrapins (as many as 100 at a time by people of certain ethnic and religious groups [Morreale 1992]) may also pose a threat. Because commercial terrapins usually come from southern states (Cook 1989, Garber 1988) and are kept in crowded conditions (pers. obs.), releasing them can introduce disease, affect population genetics, and skew sex ratios (since fish markets usually carry large adult females [Garber 1990]).

To date, no in-depth studies regarding terrapin predation or nesting ecology have been conducted in New York State. One of the largest and most robust populations in the state occurs in Jamaica Bay. Because of the

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large size and productivity of Jamaica Bay, Morreale (1992) estimated the bay to support thousands of terrapins. Cook (1989) conducted a basic study of terrapin nesting ecology at the Jamaica Bay Wildlife Refuge (JBWR), on the main island of the refuge, Ruler's Bar Hassock (RBH). He reported a 34-day nesting season. Female terrapins laid 11 to 18 eggs per nest (mean = 14.5;  $n = 8$ ), and mean incubation time was 81 days. Hatchling survivorship was 93% and nest predation was not observed. Cook (1989) attributed low predation and high success to the absence of predators, primarily raccoons (*Procyon lotor*), which were considered unable to colonize the dredge-spoil islands that comprise most of the refuge. Thus, JBWR's highly altered urban environment provided terrapins with atypically safe nesting conditions (R. Cook, National Park Service, pers. comm.).

Several years after Cook's study, raccoon sightings began to occur on RBH (in the early 1990s). The frequency of sightings increased steadily and by 1995 depredated terrapin nests were a common sight (R. Cook, National Park Service, pers. comm.). The rapid colonization likely resulted from the release of nuisance raccoons by local residents and animal trappers on Long Island (D. Riepe, National Park Service, pers. comm.). The main purpose of this study was to understand the effects of the recently established raccoon population on terrapin nesting ecology at JBWR, and to compare nesting and predation on RBH to other small isolated islands in the Refuge where terrapins may nest.

## Study Area

The Jamaica Bay Wildlife Refuge is managed by the National Park Service and encompasses 7,821 ha of land and water in Jamaica Bay (Fig. 1). Its land area comprises scattered marsh islands as well as five additional upland islands. All but one of the upland islands was created by fill dredged from the bay in the early part of the 20<sup>th</sup> century (Black 1981). Ruler's Bar Hassock is the largest island in the refuge and the only one connected to mainland Long Island by a bridge.

## Materials and Methods

*Identifying Terrapin Nesting Islands*—The four isolated islands, Little Egg Island, Canarsie Pol, Ruffle Bar, and Subway Island were surveyed for terrapin nesting activity in 1998. Each island was surveyed at least once between 25 July and 7 August. Pedestrian transects were conducted, with the aid of several volunteers, to survey all land areas

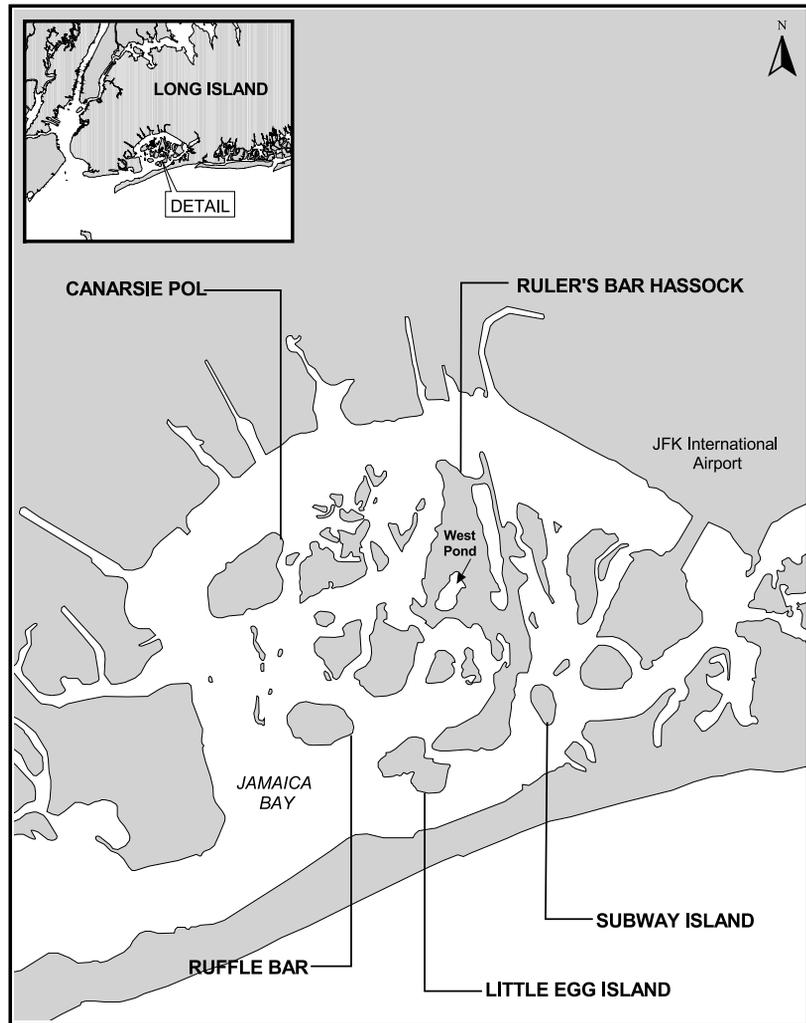


Fig. 1. Map of Jamaica Bay Wildlife Refuge with inset of New York Metropolitan region and Hudson River Bight

within 250 m of the shoreline. We walked transects 2 to 3 m apart, in unison, searching for indications of nesting activity such as: nesting turtles, depredated nests, turtle eggshell fragments, dead female terrapins in upland regions, hatchlings, false nests, and tracks leading inland from the water.

*Terrapin Predation and Ecology*—In 1998 and 1999, I surveyed and counted all depredated nests and dead adult terrapins on RBH and any other island found to host nesting terrapins. Pedestrian surveys were conducted in the same manner as the nesting activity surveys (see above). Carcasses of adult terrapins were collected and inspected for cause of death. Sex was recorded as “unknown” when carcasses with carapace lengths less than 140 mm were found near the shore, and severe decomposition had occurred. Nesting habitat on RBH (including 3,180 m of shoreline and 22 ha of upland habitat) was surveyed daily from 1 June to 31 July. Because the other islands were difficult to access, predation counts could only be conducted on a single day each year, in August. Fortunately, the small size of these islands made this possible.

I used the 1998 depredated nest count data to design Geographical Information System (GIS) maps showing the distribution of depredated nests throughout RBH. I subdivided the principal nesting areas into polygons so the data could be spatially analyzed. All polygons were delineated arbitrarily, and their sizes varied. The habitat types and physical characteristics were generally consistent within polygons but varied substantially between polygons.

The GIS maps were designed in two different formats. One format presents “count data” which are the actual number of depredated nests recorded in each polygon. The second format presents normalized “density data” which are the mean number of depredated nests per square meter, in each polygon. This was done to eliminate the bias associated with comparisons between polygons of varying size. The GIS maps were designed using ESRI ArcView software (version 3.2), and data were collected in the field using Trimble GPS equipment.

Another element of this study involved locating and monitoring freshly oviposited terrapin nests for mortality and survivorship rates. In 1998, freshly laid nests were located when females were encountered as they nested. In 1999, efforts were taken to improve the way in which freshly laid nests were located. To do this, I stationed volunteers in scattered upland locations where they monitored nesting beaches with binoculars. This was done daily throughout the day from 1 June to 31 July. Land-bound female turtles were inconspicuously followed on their forays and observed at a distance. When a female finished nesting, the nest was flagged.

Nest mortality rates were determined in 1998 and 1999 by monitoring flagged nests for predation throughout the nesting season. In 1999, egg and hatchling survivorship was determined in the nest by protecting an additional sample of freshly oviposited nests with predator-excluder panels in the same manner as described by Auger (1989). I define “egg survivorship” as the percentage of eggs in a sample that produce both live and dead hatchlings, and “hatchling survivorship” as the percentage of eggs in a sample that produce only live hatchlings. Excluder panels were removed 5 to 6 weeks after oviposition. One additional clutch was incubated indoors for comparison. These four nests were used to estimate mean clutch size.

In 1999, I measured straight-line plastron length, counted carapacial annuli, and shell-notched captured terrapins using the methods of Cagle (1939). Terrapins accidentally encountered in transit were also marked. Temporal data, such as time of nesting events, hourly nesting levels, and length of nesting season (based on the earliest and latest observed nesting dates) were recorded as well. The nesting behaviors of female terrapins were also observed and recorded.

## Results

Terrapins were found to nest on two islands at JBWR: RBH (Ruler’s Bar Hassock) and LEI (Little Egg Island). Depredated nest counts yielded 1,303 such nests on RBH and 16 on LEI in 1998. In 1999, 1,822 depredated nests were counted on RBH and 18 on LEI. The carcasses of 27 dead adult terrapins (23 females, 4 sex unknown) were also found on RBH and were presumably killed by predators. The vast majority of predation was discovered post facto although raccoons were observed depredating nests on three different occasions.

Raccoons appear to be the primary predators on RBH. I also observed one incident of nest predation by the roots of tall wormwood (*Artemisia campestris caudata*), and/or bayberry (*Myrica pensylvanica*). Evidence of predation by other mammalian and avian predators was not observed on RBH.

Birds appear to be the primary predators on LEI. The condition of these depredated nests was different from that of those found on RBH. Predators removed eggs from only the top portion of nests and left smaller nest scars than on RBH. Depredated nests on LEI were scattered about the island and were observed in much lower densities than on RBH.

The GIS maps show the distribution of depredated nests throughout the principal nesting areas of RBH. The

count-data map (Fig. 2a) indicates that the greatest number of depredated nests ( $n = 238$ ) was found in a large polygon dominated by mixed-grassland and shrubland habitats. The density-data map (Fig. 2b) indicates that the polygon with the highest relative density of depredated nests represents a sandy trail known as the “Terrapin Trail.”

Nest mortality due to predation was 100% ( $n = 4$ ) and 92.2% ( $n = 77$ ) in 1998 and 1999, respectively. An additional 2.6% of nests in 1999 were lost to flooding. Thus, total nest mortality in 1999 (predation + flooding) was 94.8%.

Egg and hatchling survivorship, determined from three protected nests containing a combined total of 35 eggs, was 57% and 54%, respectively. Plant roots destroyed seven eggs (in one nest), seven other eggs did not develop, one egg was accidentally destroyed during nest inspection, and one hatchling was dead. I stopped monitoring these nests daily after removing their excluder panels on 29 August 1999 (to avoid predation and disturbance to developing eggs) thus preventing me from determining the exact number of incubation days. As an alternative, I present the range of days between 29 August and final exhumation on 27 September, during which eggs hatched. The range of incubation for the three nests was 42 to 70 days (nest in shrubland habitat), 41 to 69 days (nest on the beach), and 36 to 64 days (nest on Terrapin Trail). A fourth nest oviposited below the hide tide line was removed and incubated indoors; this nest had 39% egg and hatchling survivorship ( $n = 13$ ). Hatchlings emerged over a 3-day period, 46 to 48 days after oviposition. Five eggs produced viable hatchlings, four eggs contained partially developed embryos, and the remaining four eggs were undeveloped. No significant difference in hatchling survivorship was found between the three naturally incubated nests and the artificially incubated nest ( $\chi^2 = 0.42$ ,  $df = 1$ ,  $p = 0.33$ ). The mean clutch size of these four nests was  $12 \pm 2$  eggs per nest (range 9–13).

The 1999 nesting season lasted for 51 days, from 3 June to 23 July. Female terrapins were most frequently observed nesting between 11:00 a.m. and 12:00 p.m. (range 9:30 a.m. to 9:15 p.m.). Female terrapins produced up to two clutches per year. Six marked female terrapins were captured twice on land in 1999. No terrapins were captured three times. The mean number of annuli was  $9.42 \pm 1.46$  ( $n = 60$ ; range = 7–13). Mean plastral length of female terrapins at JBWR was  $172.9 \pm 8.63$  mm ( $n = 124$ ; range 145–198).

During the nesting season, I regularly observed congregations of 5 to 15 female terrapins patrolling the water 10 m to 15 m offshore, intermittently stopping to observe the beach and adjacent land areas. These congregations usually formed 2 to 3 hours prior to high tide. As high tide was rising, some of the congregants (approximately 20% to 35%) would approach the shoreline and visually survey the beach. These terrapins would frequently retreat back into the water and repeat the cycle multiple times before actually making their final approach to land or retreating far out into the bay. Females always approached land at areas of gently sloping shoreline with the exception of one female that climbed a steep rock jetty to get to a flat sand embankment approximately 3 m above the shore. The size and frequency of female congregations decreased as the nesting season waned in late July.

Once on land, female terrapins immediately began to search for nesting sites. The roundtrip journey from the

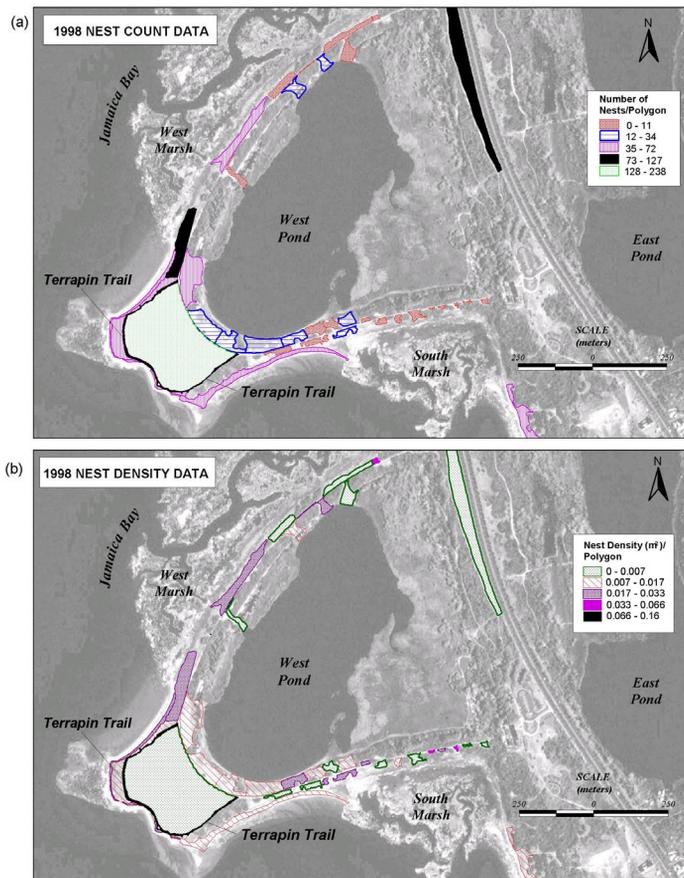


Fig. 2. (a) View of principal nesting areas on Ruler's Bar Hassock showing count data among polygons in 1998. (b) View of principal nesting areas on Ruler's Bar Hassock showing density data among polygons in 1998

water to the nest and back typically took 30 to 50 minutes, although nesting forays as long as two hours were observed. Nesting terrapins facially probed the ground before selecting a nest site. Digging behavior often followed facial probing. After digging, females would either complete the nest or abort it and move to a different location. Nests were aborted after varying levels of excavation effort, from slight surface scratches to completely excavated nest chambers. The mean number of these “test” digs, when displayed, was  $1.92 \pm 1.91$  digs per terrapin ( $n = 24$ ; range 1–10).

## Discussion

This study presents evidence that diamondback terrapins are nesting on two islands at JBWR. Raccoons appear to be the primary nest predator on RBH based on tracks, scat, nest scars, eggshell evidence, and direct observation. Raccoon predation is occurring at high levels, yet the size of this raccoon population is still unknown. Inspection of the carcasses of 27 dead adult terrapins indicates that these turtles were also killed by raccoons, based on evidence such as severed rear limbs, punctured body cavities, and evisceration adjacent to the hindquarters, as reported by Seigel (1980). Additionally, carcasses were often found far from the water in upland nesting areas, upside down. Predation on nests and adult terrapins by animals other than raccoons is uncommon at JBWR and was not reported during this study. Root predation may be a source of significant nest mortality at JBWR, but due to the cryptic nature of such predation and the small number of in-ground nests monitored, the level to which it is occurring at JBWR is still unknown.

Little Egg Island is too small, dry and isolated to support a resident population of raccoons, and they have not been observed by park biologists (D. Avrin and R. Cook, National Park Service, pers. comm.). The condition of depredated nests on this island is consistent with Burger's (1977) description of avian predation in which gulls and crows only removed a few eggs from the top portion of nests and left smaller nest scars than raccoons. Rats and mice may inhabit the island, but I did not observe any, nor did I find any evidence of their presence such as tracks or scat around the nests.

The different nest predation scenarios observed on RBH and LEI certainly warrant further investigation and comparison. Only 16 and 18 depredated nests were found on LEI in 1998 and 1999, respectively, far fewer than on RBH. Depredated nests on LEI were also scattered throughout the island, far apart from one another. This may indicate that overall nest density is lower on LEI than on RBH and that fewer nests are laid on LEI than in comparably sized areas of RBH. If this is the case, then RBH may represent the main nesting area at JBWR, and considering the current predation situation, the entire terrapin population may be in jeopardy. Alternatively, nesting levels may be similar on both islands, and these findings may simply indicate that avian predators do not destroy as many nests as raccoons do. A thorough study of nesting and predation on LEI would likely clarify this disparity. If large numbers of nests are oviposited on LEI each year, then it may represent a safe nesting haven compared to RBH.

The GIS maps present information on the distribution of depredated nests in two distinct ways. The count data show that the greatest number of nests were laid in a large, sparsely vegetated polygon on the western side of RBH comprising shrubland and a mixed-grassland habitat. This result may be an artifact due to the large size of the polygon. The density-data map reduces the bias associated with comparing polygons of different sizes and indicates that nest densities were highest in small, narrow, non-vegetated habitats such as the Terrapin Trail and the western beaches of RBH. Roosenburg (1992) suggests that predation of terrapin nests may be density dependent. If this is the case, a possible drawback to high-density nesting areas such as a narrow trail is that concentrated nesting may facilitate raccoon predation. Burke et al. (1998) found that raccoon predation on nests of several turtle species was not density dependent or a function of habitat. This finding may not apply to a human-made habitat such as the Terrapin Trail. This trail is narrow (< 2 m), sandy, and clear of vegetation. It runs through heavily vegetated habitats, providing terrapins with a major corridor in which to nest and traverse upland areas. Raccoons also use the Terrapin Trail, and it may act as a significant travel corridor for them as well. Thus, encounters between raccoons and nests on the trail may be greater simply as a function of high use by both species. In any case, valuable information can be gained from the GIS data maps, and the results seem to indicate that terrapins at JBWR use multiple nesting habitats in different ways. A possible explanation for the discrepancy between the count data and density data might be that mixed-grasslands and shrubland habitats simply cover more area than non-vegetated habitats such as the Terrapin Trail and beaches. The difference may also be due in part to microhabitat variation within polygons.

Observations of the three nests used in the survivorship study indicate that habitat type and nest location may affect the rate of emergence. All three nests were exhumed on 29 September 1999. Two nests contained all their hatchlings when exhumed, yet hatchlings from the remaining nest had all emerged and left the nest. This remaining nest was located directly on a sandy beach and was exposed to sunlight for the greatest amount of time per day. The two nests from which hatchlings had not emerged were located in areas where the daily amount of sunlight was less,

due to the surrounding vegetation. Based on the date of exhumation (29 September), hatchlings in these nests may have been prepared to overwinter.

Several findings in this study display significant departure from previous research conducted on terrapin populations in the northeast. Hatchlings in the three protected nests all hatched within 70 days of oviposition. Cook (1989) reported that the mean incubation time for terrapin eggs in Jamaica Bay was 81 days. In New Jersey, Burger (1977) reported incubation periods of 61 to 104 days (mean = 76 days), and in Massachusetts, Auger and Giovannone (1979) reported incubation periods of 87 to 148 days (mean = 108 days). Another unexpected result from this study was the duration of the nesting season. The 51-day nesting season at JBWR was substantially longer than the 34-day and 44-day nesting seasons reported by Burger (1977) in New Jersey and the 34 day nesting season previously reported at JBWR (Cook 1989). Double clutching was not previously reported from JBWR and mean clutch size was smaller than Cook (1989) reported.

An additional finding in this study departs from previous research on a more range-wide scale. The mean plastron length of adult female terrapins at JBWR was 173 mm. This is 15 to 18 mm larger than reports from other well-studied terrapin populations in New Jersey (mean = 154 mm [Montevecchi and Burger 1975]), Florida (mean = 154 [Seigel 1984]), and South Carolina (mean = 157 mm [Zimmerman 1992]). A plausible explanation for this may be that recruitment of new terrapins has decreased significantly at JBWR due to predation. If this is the case, then the current population of adult female terrapins at JBWR may consist of older larger females, the majority of which were recruited into the population prior to the arrival of raccoons.

The nest-digging behaviors of terrapins at JBWR are similar to those reported by Burger (1977), although Burger and Montevecchi (1975) did not observe facial probing or test digging among terrapins. Whereas general behavior such as digging technique and sequence do not seem to vary among terrapin populations, specific behaviors such as duration of nesting events, facial probing, and test digging do appear to vary (Auger and Giovannone 1979, Roosenburg 1994).

The future of diamondback terrapins at JBWR appears to be somewhat uncertain. The current population appears to be quite large based on the number of depredated nests counted at JBWR. Even if every female were assumed to double clutch, there would still be nearly 1,000 female terrapins nesting at the refuge. Additionally, using the 0.65 male:female sex ratio reported at JBWR by Morreale (1992), it could be assumed that approximately 650 male terrapins are present as well. Factors that may be contributing to the robustness of this population include regulatory protection, a hunting ban within JBWR, minimal use of crab pots throughout Jamaica Bay, and limited fisheries activity overall due to health restrictions caused by contamination levels in the bay.

The Jamaica Bay terrapin population may be larger now than it ever was historically. In fact, terrapins were rare enough in the bay to have gone undetected by humans more than 160 years ago (Garber 1988). Prior to 1910, Jamaica Bay consisted primarily of mud flats, *Spartina* marsh, and only one upland island, Ruffle Bar (Black 1981). Anthropogenic alterations since then (i.e. dredging, filling of marshes, and the creation of four dredge spoil islands) have greatly increased the amount of available nesting habitat. Nevertheless, unprecedented raccoon predation is occurring at population-threatening levels. It is likely that raccoons are having a serious impact on the terrapin population and, without intervention, a dramatic decrease in the size of the terrapin population may be imminent. However, if such a decrease is occurring it may not be immediately apparent. One of the major problems in detecting the impacts of predation on turtle nests is that adults are long lived. Even if raccoons eliminate 100% of the eggs for several years, the large persistent adult population could mask the losses. It may take as long as 10 to 15 years before a noticeable population decline becomes apparent, by which time severe damage to the population may have already occurred.

In conclusion, it is hoped that this research can be used by the National Park Service in developing and implementing future management plans for reducing raccoon predation on terrapin nests. Several management options exist, such as lethal removal, conditioned taste and scent aversion, and installation of predator excluder panels. Ratnaswamy et al. (1997) found that lethal removal of 50% of raccoons and conditioned taste aversion tests using chicken eggs injected with estrogen did not significantly reduce predation on sea turtle nests. Predation was significantly reduced when nests were screened, but this method was costly and could be extremely inefficient when dealing with thousands of nests and limited management resources. To determine the best control methods at JBWR, future research should look at the overall ecological significance of raccoons and the appropriate level of predator control necessary (Ratnaswamy and Warren 1998). If raccoons are found to have a high level of ecological importance, then non-lethal control methods may be more appropriate than lethal methods. Aversion conditioning may prove more effective if terrapin eggs are used instead of chicken eggs. Scent aversion conditioning may be possible by applying a non-harmful, deterring smell on the ground above the nests. If lethal removal is considered, it may be necessary to remove much more than 50% of the raccoons in the Refuge.

## Acknowledgments

I thank Dr. Russell Burke for his constant support, accessibility, suggestions, and encouragement. I thank Dr. John Tanacredi of the National Park Service for allowing this project to commence with minimal advance preparation, and for his support throughout the project's duration. I give special thanks to Dr. George Frame for his assistance in the field and also at the park headquarters, where he helped me with countless issues. I am grateful to Dave Taft and Don Riepe from the National Park Service. I also thank Drs. Robert Cook, Richard Seigel, Jeffrey Lovich and Willem Roosenburg for their insights, suggestions, and informational support regarding terrapin biology. I thank Hofstra University and the Hudson River Foundation for providing me with financial support for this project. I greatly appreciate the help that Heather Depew and Nicole Weiss provided with mapping. Finally, I thank the three people who inspired and encouraged me the most throughout the years, Myron Feinberg, Florence Feinberg, and Jason Feinberg.

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