TERRAPIN MONITORING AT POPLAR ISLAND
2003

Final Report submitted to the
Army Corps of Engineers

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BACKGROUND

Poplar Island is a large-scale ecological restoration project that is using dredged material to reconstruct an eroded island in the Middle Chesapeake Bay. As recently as 100 years ago, the island was greater than 400 hectares and contained upland, mid- and low-level wetlands. During the past 100 years the island had eroded and only three, small (<4 hectares) islands remained. In a large-scale project, the Army Corps of Engineers and the Maryland Port Authority are rebuilding and restoring Poplar Island. A series of stone-covered dikes facing the windward shores prevent erosion. Dredged material from the Chesapeake Bay Channels and Delaware Canal approach will fill the areas within the dikes, ultimately restoring the island to a size similar to what existed over 100 years ago. The ultimate goal of the project is to rebuild and restore the habitat for the wildlife that once existed on Poplar Island.

One of the wildlife species targeted in the restoration project is the diamondback terrapin, *Malaclemys terrapin.* These emydid turtles were probably common in the Poplar Island archipelago. However, the persistent erosion of Poplar and nearby islands has greatly reduced the nesting and juvenile habitat. Thus, the local terrapin population in the archipelago may be below their former levels. As the island eroded, the habitat diminished, and terrapins likely declined due to emigration and the resulting reduction in nesting and recruitment. By rebuilding the island and providing nesting and juvenile habitat, terrapin populations in the islands and the surrounding wetlands could significantly increase and potentially be restored to their former levels. The restoration could ultimately provide the nesting and juvenile habitat that will provide the resources that would allow terrapin populations to grow. Nesting habitat includes accessible sandy areas that are above the mean high tide. Juvenile habitat includes the salt flats and fringe marsh common along the Chesapeake Bay shoreline.

The Poplar Island Environmental Restoration Project is a unique opportunity to understand how large-scale ecological restoration projects affect terrapin populations and turtle populations in general. In 2002, we initiated a long-term terrapin monitoring program that will track the changes in the Poplar Island terrapin population as the restoration project progresses. By monitoring the terrapin population on Poplar Island, resource managers can learn how creating new terrapin nesting and juvenile habitat affects this and other terrapin populations. This information will contribute to understanding the ecological quality of the restored habitat on Poplar Island, as well as understanding how terrapins respond to large-scale restoration projects.

In 2002, Ohio University terrapin researchers identified major terrapin nesting beaches at Poplar Island, quantified nest and hatching success rates, and marked and released over 500 hatchlings (Roosenburg and Allman, 2003). A continuing concern is that some nesting beaches are not located in close proximity to suitable hatchling and juvenile habitat, potentially resulting in reduced hatchling survivorship. In 2002, the research team released hatchlings in a small marsh habitat located between Coaches and Poplar islands. This was the only natural marsh habitat available to hatchling and juvenile terrapins on Poplar Island. It is unknown whether this small area can support a large hatchling and juvenile population. Therefore, the researchers released marked hatchlings colleted in the 2003 study in cell 4DX, a recently constructed demonstration marsh. Terrapin researchers will determine the suitability of hatchling habitat in cell 4DX by future surveys of marked individuals in the area. The objectives for the 2003 field season were to:

1) Identify locations of nests at known terrapin nesting sites,
2) Track all known nests to monitor hatching success,
3) Mark and release all hatchlings caught in the study area.

METHODS

Identification of terrapin nests: From June to September 2003, a MES intern and the Ohio University team daily surveyed the beaches in the notch area (near cell 4), areas between Coaches and Poplar Island (outside of cell 5), inside the harbor (cell 6) and the beach outside the dike in Poplar Harbor (before cell 3). Geographic positioning system (GPS) recorded nest position and survey flags identified the specific location.

Monitoring hatching success: Usually within a week of identifying a recently oviposited nest, researchers placed an aluminum ring around it to prevent emerging hatchlings from escaping. They also placed anti-predator cages over nests to prevent avian predators from preying on emerging hatchlings. Beginning in late July, the survey team checked ringed nests at least once daily for emerged hatchlings. If a hatchling had emerged, researchers took it to the MES trailer for processing.

To estimate hatching success and clutch size statistics, project team members excavated nests ten days after the last hatchling emerged. For each nest, they recorded the number of live hatchlings, dead hatchlings, and eggs that appeared to be incompletely developed. Additionally, they determined if the nest was still active – eggs that had appeared not to complete development. The study team allowed nests containing viable eggs or hatchlings that had not fully absorbed their yolk sac to continue to develop; however, team members removed fully developed hatchlings from nests.

In mid-September 2003, NOAA forecasted the approach of Tropical Storm Isabel to the Chesapeake Bay region. A 1.5-2.5-m storm surge threatened Poplar Island and vicinity, creating the potential for all terrapin nests at Poplar Island to be submerged. To mark and tag hatchlings that may have escaped from ringed nests during the storm surge, team members excavated a large number of nests (those that were suspected based on age to have live hatchlings, active nests with eggs that had not hatched were left *in situ*) and removed hatchlings in the days immediately preceding the storm. The storm surge submerged all nesting habitat on Poplar Island, and the storm destroyed or contributed to the loss of many of the remaining nest rings. After the storm, project members located some of these nests and replaced their rings. They excavated all remaining nests to verify that rings were in the proper locations. They also removed fully developed hatchlings remaining in the nests at this time.

Capture of hatchlings: Project team members collected hatchlings from ringed nests and from un-ringed nests discovered by hatchling emergence. Additionally, team members also found a small number of hatchlings on the beach, and these were collected and processed.

Measuring, tagging, and release of hatchlings: Scientists brought all hatchlings back to the MES trailer on Poplar Island where they held hatchlings in plastic containers with water until they were processed. Team members marked hatchlings by notching the 10th marginal scutes on both the right and left side establishing the ID 10R10L as the cohort mark for 2003. Researchers implanted individually marked binary coded wire tags (CWTs, Northwest Marine Technologies ®) in all hatchlings. The CWTs were placed subcutaneously in the right rear hind limb using a 25-gauge needle. The CWTs should have high retention rates (Roosenburg and Allman, 2003) and team members will be able to identify terrapins originating from Poplar Island for the lifetime of the turtle. Scientists detected tag presence or absence using Northwest Marine Technologies' V-Detector. They measured plastron length, carapace length, width, and height (± 0.1 mm) and weighed (± 0.01 g) all hatchlings. Additionally, they checked for anomalous scute patterns and other developmental irregularities. Following tagging and measuring, team members released hatchlings, with the exception of one individual, in 4DX. They released one hatchling in the north corner of the notch. We held many of the hatchlings for several days prior to release. On several of the releases, the researhers released several individuals simultaneously. They held over the winter eight hatchlings that emerged from a nest in late October. They released these hatchlings the following spring after they were processed.

All hatchling data were summarized and processed using Microsoft Excel®.

All protocols and animal use was approved through Institutional Animal Care and Uses Committee at Ohio University and a Scientific Collecting Permit issued to Willem M. Roosenburg from the Maryland Department on Natural Resources – Fisheries Division.

RESULTS

NEST AND HATCHLING SURVIVORSHIP

The project team found 63 terrapin nests on Poplar Island during the summer of 2003 (raw nest data provide in Table 2 of the Appendix). These nests were found in the notch, on the outside of cell 5 and cell 3 (Table 1, Figure 1). They did not find any nests in cell 6 during 2003. Forty-nine nests were discovered at the time of oviposition or shortly thereafter and were used to evaluate nest survivorship (Table 2). Of the 49 nests, 11 were washed away or partially washed away by Tropical Storm Isabel, 35 produced hatchlings, 1 produced no hatchlings and 7 had overwintering hatchlings. There were 5 potential nest sites that could not be located or did not contain evidence of eggs. These nests were not included in the summary statistics.

Table 1. Summary of the number, location and predation of diamondback terrapin nests discovered on Poplar Island during the summer of 2003.

Location	Nests Discovered at Oviposition	Nests Discovered by Hatchling Emergence	Depredated	Total
Coaches Beach	31	11	1	43
3D Beach	9	2	0	11
Inside Notch Beach	9	0	0	9
Total	49	13	1	63

Figure 1. Location of terrapins nests on Poplar Island Environmental Restoration Project found during the 2003 nesting season. Yellow dots are the locations of individual nests. Locations determined using GPS and GIS software ARCVIEW.

Table 2. Summary of nest survivorship and causes of mortality during the 2003 nesting season.

	Number	Percent of Total
Total Nests	49	
Lost/ Partially Lost in Hurricane	11	22%
Nests with Hatchlings	35	71%
Nests without Hatchlings	1	2%
Overwintering/ Partially Overwintering	7	14%

Thirty nests were studied sufficiently to determine egg survivorship (Table 3). We documented 354 hatchlings and evidence of 35 undeveloped eggs or dead hatchlings from the 30 nests. These data suggest that the average clutch size was 13.0 eggs per clutch and that eggs had an average hatching success rate of 91% with several nests having apparent 100% survivorship.

Table 3. Summary statistics of egg survivorship.

Nests	30
Total Number of Eggs	389
Total Number of Hatchlings	354
Hatchling Success	91%
Range	29-100%
Mean Clutch Size	13.0

HATCHLINGS

Project members captured three hundred and eighty-seven hatchlings on Poplar Island between August 1 and 22 October 2003 (Table 4). Ringed nests produced 377 hatchlings, 8 hatchlings were caught by hand, and 2 were discovered in nests that were identified by the hole left by previously emerged hatchlings. Project scientists located 13 nests by the emergence of hatchlings. This was possible at Poplar Island because the substrate is harder than the normal sand beaches on which terrapins usually nest. Hence, the emerging hatchlings left a distinct depression or an actual hole that led into the nest chamber.

Table 4. Summary statistics of the number of hatchlings caught using different techniques.

Technique	**Number**
Ringed Nets	377
Caught by Hand	8
Nest discovered by emerging hatchlings	2
Total	387

The mean Poplar Island hatchling measurements are summarized in Table 5 (raw data provided in Table 1 of Appendix). Hatchlings had a mean plastron length of 26.9 mm and a mean carapace length of 31.1 mm. The average weight of hatchlings was 7.5 g. Eighty-two hatchlings (22%) had shell scute pattern anomalies. The scute anomalies included extra marginal, vertebral, and pleural scutes.

Table 5. Summary statistics of terrapin size metrics taken from the 387 terrapins emerging from nests on Poplar Island.

	Plastron Length (mm)	**Carapace Length (mm)**	**Carapace Width (mm)**	**Height (mm)**	**Mass (g)**
Mean	26.9	31.1	27.5	15.7	7.5
Standard Deviation	1.5	1.5	1.4	0.8	1.0

Overwintering

Seven nests remained after 12 October from which hatchlings had not emerged. Hatchlings remain in overwintering nests and emerge in the following spring. Project personnel could not relocate two of the overwintering nests on 22 April 2004. One nest was near the water's edge outside cell 5 and we were unable to locate the ring and nest markers. The ring and markers were lost, most likely during a storm that coincided with a high tide. The second nest was on the dike of cell five, where wind may have eroded sand around the ring and then blown the ring away. There also were signs of recent earth moving activity in the area where this nest was. One nest contained only eggs with partially developed, dead embryos. This nest was the last nest laid in early August and the embryos most likely died because they had not completed development before the onset of cold weather. Four of the nests contained dead hatchlings. In each case, the roots of grasses had grown around the head either suffocating or dehydrating the neonates and killing the hatchlings. Two nests produced one live hatchling each. One of these nests also had empty eggshells suggesting that some of the hatchlings had emerged in the fall. This was most likely the nest that produced 8 hatchlings on 22 October 2003. Although terrapin overwintering in the nest has always been suspected in Maryland, this represents the first documented case of successful overwintering.

Conclusions

The findings of the 2003 nesting season continue to support the assumption that portions of Poplar Island are excellent terrapin nesting habitat. The large number of nests discovered and the rate at which eggs developed into hatchlings are comparable to other nesting areas in the Chesapeake Bay. What makes Poplar Island such excellent terrapin nesting habitat is the absence of nest predators which results in high nest survivorship rates that are much greater than other nesting areas that have been studied. As observed in 2002 (Roosenburg and Allman, 2003), the survivorship of known nests was much higher than normally encountered for terrapins because of the lack of nest predators on the Poplar Island. Raccoons, foxes, and otters are known terrapin nest predators and contribute to low nest survivorship in areas where predators occur, sometimes depredating 95% of the nests (Roosenburg, 1994). Additionally, the lack of raccoons on Poplar Island minimized the risk to nesting females that also may be depredated by raccoons (Seigel, 1980; Roosenburg personal observation). Thus, the Poplar Island restoration project is successfully creating terrapin nesting habitat.

Project scientists believe that the amount of terrapin nesting on Poplar Island is increasing. This conclusion is based on the discovery of a comparable number of nests to 2002. However, the effort for finding nests during 2003 was reduced. During the peak June season, there were no surveys of the nesting areas for two weeks. Detailed nesting surveys during this period would have yielded a far greater number of nests. Because a barrier fence was built on the outside of the road around cell 5 to prevent terrapins from nesting inside the cell, no drift fence was constructed to catch hatchlings from unobserved nests. Therefore, the total number of hatchlings caught in 2003 was fewer than 2002. However, the number of hatchlings caught in nest rings during 2003 was similar to 2002. This is notable because Tropical Storm Isabel contributed to the loss of some nests.

As observed in summer 2002 (Roosenburg and Allman, 2003), terrapin nesting on the island occurred in those areas where terrapins could easily access potential nesting sites. The stone face of the retaining dike around Poplar is a barrier that prevents terrapins from accessing potential nesting sites on many parts of the island. As wetland cells are completed, and the exterior dikes are breached to provide water flow, terrapins are likely to follow and begin nesting on other parts of the island.

Loud heavy machinery is a conspicuous component of the Poplar Island landscape. Terrapins will abandon nesting when disturbed, resulting in incomplete nests (Roosenburg and Dunham, 1997). We found no evidence that construction activities disturbed nesting terrapins at the Island in 2003. This was most likely due to the absence of construction activity in cell 5 during the 2003 nesting season. Mean clutch size (13 eggs per nest, range = 7-20 eggs per nest) was normal for Chesapeake Bay terrapins (Roosenburg, unpublished data). However, in 2002, several nests had clutch sizes of fewer than five eggs, and mean clutch size was 11 eggs per nest (Roosenburg and Allman, 2003). Incomplete nests found in 2002 may have resulted from abandonment of nesting by disturbed females (Roosenburg and Allman, 2003). Construction activity may disturb terrapin nesting at Poplar Island when it occurs in close vicinity to nesting beaches. However, most heavy construction activity at Poplar occurs far from nesting beaches and does not seem to disturb nesting females.

Hatchling and juvenile terrapins require shallow marsh habitats. Currently, these habitats are limited on Poplar Island, and terrapin nesting beaches such as the beach outside of cell 3 are not located in close proximity to marsh habitat. Consequently, hatchlings from these areas may not have access to suitable hatchling and juvenile habitat, which may result in reduced hatchling survivorship. To mitigate this potential problem, and to evaluate the potential for the creation of marsh habitats for hatchling and juvenile terrapins, team members released hatchlings into cell 4DX, a newly-constructed demonstration marsh. Although not a mature marsh yet, cell 4DX supports fish and invertebrate populations that may serve as food sources for young terrapins. Future surveys of marked terrapins in cell 4DX will determine the suitability this habitat.

To mark and tag hatchlings that may have otherwise escaped from ringed nests during Tropical Storm Isabel and the associated storm surge, team members excavated a large number of nests and removed hatchlings in the days immediately preceding the storm. Therefore, they were unable to determine hatchling overwintering rates because some of the nests that they excavated may have otherwise overwintered. Additionally, our hatchling success estimates assume that all excavated hatchlings would have survived and emerged on their own. However, hatchlings may die before emerging from nests. Consequently, the researchers may have overestimated hatchling success. However, most hatchlings left in nests during Tropical Storm Isabel survived the inundation caused by the storm surge. The fact that most hatchlings that remained in the nest survived Tropical Storm Isabel indicates that the estimate of hatchling survivorship based on excavated nests prior to the storm is accurate.

The hatchlings produced on Poplar Island were similar in size and weight to those captured during previous studies in the Patuxent River in Maryland (Roosenburg, 1992). The frequency of shell scute anomalies, 22%, was higher than expected. High frequency of shell scute anomalies was also observed in 2002 (Roosenburg and Allman, 2003). Warmer incubation temperatures cause higher frequencies of shell scute anomalies in terrapins (Herlands et al., 2002). The high frequency of shell scute anomalies in Poplar hatchlings could be due, in part, to the limited vegetation on Poplar Island that could provide shaded, cooler incubation environments (Jeyasuria et al., 1995). Although shell anomalies have been associated with higher incubation temperatures, there is no evidence to suggest that these anomalies have any detrimental effects on terrapins or other turtle species. Shell anomalies occur at higher frequency in female terrapins than in males and may be linked to temperature-dependent sex determination (TSD). For terrapins, warmer incubation temperatures produce females, and cooler conditions produce males (Jeyasuria et al., 1995; Roosenburg and Kelly, 1996). The higher frequency of shell anamolies may be indirect evidence that Poplar Island may be producing a greater than normal number of female hatchlings. Continued monitoring of Poplar Island terrapins will be able to confirm this hypothesis.

The initial success of terrapin use of Poplar Island predicts the success that similar projects may have in creating terrapin nesting habitat. One of the major factors threatening terrapin populations throughout their range is the loss of nesting habitat to development and shoreline stabilization (Roosenburg, 1991; Siegel and Gibbons, 1995). Projects such as Poplar Island that combine the beneficial use of dredged material and ecological restoration have the potential to create habitat similar to what has been lost to erosion and human practices. With proper management, areas such as Poplar Island may become areas of concentration for species such as terrapins and thus become source populations for the recovery of terrapins throughout the Bay.

RECOMMENDATIONS

As the restoration project at Poplar Island continues, terrapins will continue to use the habitat for nesting. There are some short-term measures that can be taken to 1) prevent terrapins from entering cells under construction and 2) to improve nesting habitat on the island. First, the terrapin researchers recommend construction and/ or continued maintenance of fences around cells 4 and 5. The fences should prevent nesting females and hatchlings from crossing the road and entering the cells. This also will reduce the risk of terrapins being hit by construction equipment that uses these roads. Second, we suggest that in Spring 2004, after the last overwintering hatchlings have emerged, and before the nesting season begins, that additional sand be brought into areas, particularly along the outside of cell 3, to create more nesting habitat. This may be particularly appropriate for areas adjacent to the jetties that are proposed for the entrance to cell 3D and the Poplar Harbor area. Because terrapins avoid nesting in areas with dense vegetation (Roosenburg 1996), providing open, sandy areas on the seaward side of the dikes should reduce efforts by terrapins to enter into cells under construction to find suitable, open areas. Additionally, the sand could greatly improve the habitat along the outside dike of cell 3, where females frequently encounter rocks while trying to excavate a nesting cavity. Third, predator control on the island will be paramount to the continued success of terrapin recruitment. Keeping raccoon and fox populations to a minimum will maintain the high levels of nest survivorship observed in 2002 and 2003. Finally, efforts to promote the use of by-catch reduction devices (BRDs) on crab pots fished in and around Poplar Island archipelago will increase adult survivorship. Crab pots drown terrapins and can have dramatic effects on their populations (reviewed in Roosenburg 2004). Promoting or requiring the use of BRDs in the Poplar Island archipelago could greatly reduce the mortality of juvenile female and male terrapins. The recommendations offered herein will contribute to the continuing and increasing use of Poplar Island by terrapins. As terrapin monitoring continues, we will be able to evaluate the success of these measures if implemented.

ACKNOWLEDGMENTS

We are grateful to S. Johnson, M. Mendelsohn, and B. Walls of the Army Corps of Engineers for their support and excitement about discovering terrapins on Poplar Island. Much of the fieldwork in this project was completed by B. Fruh and E. Vlahovich of the Maryland Environmental Service, without their contribution this work would not have been completed. We also are indebted to the MES staff on Poplar that checked ringed nests during weekends and holidays. L. Koch from Ohio University participated in field work. This work was supported through an Army Corps of Engineers Contract to WMR at Ohio University. All animal handling protocols were approved by the Institutional Animal Care and Use Committee (IACUC) at Ohio University (Protocol #

L02-04) issued to WMR. All collection of terrapins was covered under a Scientific Collecting Permit number 2003-51 issued to WMR through the Maryland Department of Natural Resources.

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