TERRAPIN MONITORING AT POPLAR ISLAND ENVIRONMENTAL RESTORATION PROJECT

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BACKGROUND

The Poplar Island Environmental Restoration Project (PIERP) is a large-scale restoration project that is using dredged material to restore the eroding 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 Administration 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 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 of the terrapin. Thus, the local terrapin population in the archipelago may be below their former levels. Terrapin populations likely declined due to emigration of adults that, combined with reduction of available high quality nesting habitat, reduced recruitment. By restoring the island and providing nesting and juvenile habitat, terrapin populations utilizing the PIERP and the surrounding wetlands could significantly increase and potentially be restored to their former levels. The restoration also could provide the resources that would allow terrapin populations to increase. 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, a long-term terrapin monitoring program was initiated to track the changes in the PIERP terrapin population as the restoration project progresses. By monitoring the terrapin population on the PIERP, resource managers can learn how creating new terrapin nesting and juvenile habitat affects terrapin populations. This information will contribute to understanding the ecological quality of the restored habitat on the PIERP, as well as understanding how terrapins respond to large-scale restoration projects.

In 2002, Ohio University terrapin researchers identified major terrapin nesting beaches at the PIERP, 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 researchers released hatchlings in a small marsh habitat located between Coaches and the

PIERP. This was the only natural marsh habitat available to hatchling and juvenile terrapins the PIERP during those years. 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 and 2004 studies 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 2004 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 on the PIERP.

METHODS

Identification of terrapin nests: From 15 May to 1 August 2004, the Ohio University researchers surveyed the following areas daily; beaches in the notch area (near Cell 4), areas between Coaches and the PIERP (outside of Cell 5), inside the open upland cell (Cell 6) and the beach outside the dike in Poplar Harbor (outside Cell 3). The researchers occasionally searched the periphery of Cell 4DX for signs of terrapin nesting on the surrounding dikes. Geographic positioning system (GPS) recorded nest position and survey flags identified the specific location. When a nest was identified, researchers examined the eggs to determine the age of the nest. If the eggs were white and chalky in appearance, they considered the nest greater than 24 hours old and no further excavation was conducted. If the nest was recent (less than 24 hours old), then researchers excavated the nest to count the number of eggs and they weighed the individual eggs from some nests.

Monitoring hatching success: After 45 to 50 days of incubation, researchers placed an aluminum ring around the nest to prevent emerging hatchlings from escaping. They also placed anti-predator cages over nests to prevent avian predators from preying on emerging hatchlings within the ring. Beginning in late July, the researchers checked ringed nests at least once daily for emerged hatchlings. If hatchlings had emerged, researchers took them to the MES trailer for processing.

Researchers 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. To estimate hatching success, the number of surviving hatchlings was compared to the total number of eggs counted, from only those nests that were excavated when they were originally discovered. Additionally, researchers determined if the nest was still active – eggs that appeared healthy and had not completed development. The researchers allowed nests containing viable eggs or hatchlings that had not fully absorbed their yolk sac to continue to develop; however, researchers removed fully developed hatchlings from nests.

Capture of hatchlings: Researchers collected hatchlings from ringed nests and from un-ringed nests discovered by hatchling emergence. Additionally, researchers found a small number of hatchlings on the beach, which were collected and processed.

Measuring, tagging, and release of hatchlings: Researchers brought all hatchlings back to the MES trailer on the PIERP where hatchlings were held in plastic containers with water until they were processed. Researchers marked hatchlings by notching the 9th right marginal scute and 10th left marginal scute establishing the ID 9R10L as the cohort mark for 2004. 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 in the future researchers will be able to identify terrapins originating from the PIERP for the lifetime of the turtle. Researchers detected tag presence or absence using Northwest Marine Technologies' V-Detector. They measured plastron length, carapace length, width, and height (± 0.1 mm) and mass (± 0.1 g) of all hatchlings. Additionally, they checked for anomalous scute patterns and other developmental irregularities. Following tagging and measuring, researchers released all hatchlings in Cell 4DX, with the exception of one individual that was released in the north corner of the notch. The researchers held many of the hatchlings for several days prior to release. On several occasions, they released large numbers (>50) of hatchlings simultaneously. Eight hatchlings that emerged from a nest in late October were held over winter and released the following spring. The hatchlings were remeasured at time of release to monitor any growth while in captivity.

All hatchling data were summarized and processed using Microsoft Excel®. All animal use protocols were 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 of Natural Resources – Fisheries Division.

RESULTS

Nest and Hatchling Survivorship: During the 2004 terrapin nesting season, the researchers located 175 nests on the PIERP. They located four more nests after the nesting season as the hatchlings emerged from their nests (raw nest data provide in Table 1 of the Appendix). This represents a 284% increase compared to the nesting that occurred in 2003. Nests were found on the beach on the outside of Cell 5, Cell 3, and the notch area (Figure 1). Additionally, researchers found five nests in Cell 6 (Table 1). Predators destroyed 13 nests completely and partially destroyed 7 nests. The majority of the predation occurred opposite Coaches' Island in the notch and on the outside of Cell 5. We suspect that birds, particularly in the case of partially depredated nests, did the majority of the predation of the nests. At least two of the depredated nests appeared to have been destroyed by foxes as indicated by the manner the nest was dug and foot prints around the nest. Additionally, 3 nests were washed away during high tides because the females laid their eggs to close to the high tide line. One nest had thinly shelled eggs and all of these eggs were destroyed. All of the eggs in another nest were destroyed because the female laid the nest between two rocks and crushed the eggs while placing them. Finally, two nests were destroyed when a female subsequently laid her nest directly on a preexisting nest. Of the remaining 159 nests, 126 of these produced hatchlings either as evidenced by live hatchlings or hatchling tracks emerging from the nest indicated that they had escaped. This resulted in an overall nest success of 70.4% including depredated nests and 79.2% of the nests that survived predation. The researchers were not able to determine the fate of 33 nests and could not confirm whether these nest survived and produced hatchlings that escaped capture or that these nest died for some unknown reason.

Table 1. Summary of the number, location and predation of diamondback terrapin nests discovered on Poplar Island during the summer of 2004.

Location	**Nests Discovered**	**Depredated**	**Washed Away**	**Nests Hatched**
Cell 5 Beach	65	11	0	52
Cell 3 Beach	72	2	3	46
Notch	37	7	0	26
Cell 6	5	0	0	2
Total	179	20	3	126

The researchers also recorded data of clutch size, total clutch mass and egg size. These data are summarized in Table 2. Because clutch size data was collected for most nests, the average within clutch survivorship was calculated to be 71.0% (SD = 26.4%, n = 100, Table 2).

Table 2. Summary of average clutch size, clutch mass, egg size, and numbers of hatchlings per nest from the PIERP.

	Clutch Size	Number of Hatchlings	Clutch Mass	Egg Size
Mean	13.84	10.12	131.03	9.79
Standard Deviation	3.242	4.445	29.438	0.893

Figure 1. Location of terrapins nests on the Poplar Island Environmental Restoration Project found during the 2004 nesting season. Yellow dots are the locations of individual nests. Locations determined using GPS and GIS software ARCVIEW.

Hatchlings: Researchers captured one thousand three hundred and thirty-six hatchlings on the PIERP between 5 August 2004 and 14 April 2005. All hatchlings except for 1 were caught at the location of the nests. These include ringed nests and the five nests that were discovered by the tracks left by hatchlings emerging from previously undiscovered nests. This finding suggests that there was thorough coverage of the nesting areas and a high percentage of the nests were located shortly after oviposition.

The mean PIERP hatchling measurements are summarized in Table 3 (raw data provided in Table 2 of Appendix). Hatchlings had a mean plastron length of 27.5 mm and a mean carapace length of 31.6 mm. The average weight of hatchlings was 7.6 g.

One hundred eighty-eight (14.1%) had shell scute pattern anomalies. The scute

Table 3. Summary statistics of terrapin size metrics taken from the 1336 terrapins emerging from nests on Poplar Island.

	Plastron Length (mm)	Carapace Length (mm)	Carapace Width (mm)	Height (mm)	Mass (g)
Mean	27.5	31.6	27.7	15.4	7.6
Standard Deviation	1.6	1.5	1.3	0.8	0.9

anomalies included extra marginal, vertebral, and pleural scutes. This year researchers discovered 16 hatchlings that had a developmental defect that resulted in an under-bite and incomplete development of the cranium.

Over-wintering: On 7 October 2004, researchers went to the PIERP to excavate nests that had produced hatchlings and to identify nests that might over-winter. Twenty-six nests were identified that might over-winter; however 12 of these nests and hatchlings emerged between 8 October and 28 October. Fourteen nests remained to over-winter. On 14 April 2005, researchers returned to the PIERP to excavate the remaining over-wintering nests and recovered 121 live hatchlings. Thirteen of the 14 nests produced hatchlings and 2 had 100% hatchling over-winter survivorship. Average over-winter survivorship was 69.5% (n = 11). Over-wintering hatchlings were significantly smaller in plastron length (ANOVA, $F_{1,1335} = 63.34$, $P < 0.0001$, Table 4) and were lighter (ANOVA, $F_{1,1335} = 98.89$, $P < 0.0001$, Table 4). This represents the first confirmed successful over-wintering of terrapin hatchlings in the nests in Maryland.

Table 4. Summary statistics of terrapin size comparing hatchlings from nests emerged in the fall and those that over-wintered in the nest on the PIERP.

Fall Emergers	Plastron Length (mm)	Carapace Length (mm)	Width (mm)	Mass (g)	Height (mm)
Mean	27.6	31.7	27.7	7.7	15.4
S.D.	1.5	1.4	1.2	0.8	0.8
Over-winterers					
Mean	26.4	30.5	27.4	6.9	15.1
S.D.	1.8	2.2	1.8	1.1	0.8

Adult and Juvenile Terrapins: The researchers and MES personal assisted in the capture of 10 adult females on the PIERP during the 2004 nesting season. Researchers marked all females with PIT tags and a monel metal tag in the 9^{th} marginal scute on the right side. Data of these animals can be found in the Appendix, table 3. The researchers also collected data from 16 hatchlings that were captured in 2003 and held over the winter in the MES offices. Two of the terrapins died over the winter, the remaining 14 were measured, marked with CWTs and released in Cell 4DX. These data also can be found in the Appendix, Table 3.

CONCLUSIONS

Upon conclusion of the 2004 nesting season, it is clear that terrapin nesting activity on the PIERP increased from 2003. The 284% increase in nesting from 2003 is dramatic and can be attributed to two factors. First, the amount of nesting activity on the island is increasing as more females are discovering the nesting areas and making use of them. Second, the greater number of nests is due to an increase in the survey effort. During 2004, the survey effort for nests was daily and under optimal nesting conditions, twice daily. This was possible because Dana Spontak was dedicated full-time to locating terrapin nests. The fact that relatively few nests were discovered by hatchlings emerging suggests that the nesting beach surveys were very thorough. Although it is impossible to distinguish between these two potential causes for the increase; it is likely that both factors are contributing.

The PIERP is excellent nesting habitat and both nest and hatchling survivorship are high. During 2003 nest survivorship was 71% (Roosenburg et al., 2004) compared to 72% in 2004. Within nest survivorship decreased from 93% in 2003 (Roosenburg et al,. 2004) to 71% in 2004. The cause of this decrease is not known. However, the following is a list of factors that could have contributed to the lower survivorship: above average temperatures during the summer of 2004, higher escape rate of hatchlings from ringed nests, and predation of hatchlings inside the rings. Several times, researchers identified small mammal tracks inside nest rings. These mammals may have preyed upon hatchlings that were held in the ring. Researchers could not confirm what kind of mammal was visiting these rings or whether they indeed consumed hatchlings, however Draud et al., (2005) found that rats prey on hatchling terrapins in New York. Higher then average summer temperatures during 2004 also could have been the cause of decreased survivorship, and hatchlings with deformed crania. Terrapin developmental anamolies occur more frequently at higher incubation temperatures (Herlands et al., 2002), and if incubation temperatures get too high, they can be lethal (Roosenburg, pers. obs.). The same higher temperatures may have reduced survivorship in many of the nests killing embryos.

Although predation rates of nests were low compared to mainland terrapin nesting sites, researchers did identify the first cases of terrapin nest predation on the PIERP. The foxes that colonized the island during 2004 clearly destroyed two of the nests. This was determined by the presence of their tracks near the excavated nest and the manner in which the nests were dug (similar to the digging of a dog). It was interesting that the foxes did not destroy more terrapin nests, and it is likely that the fox removal efforts by the United States Fish and Wildlife personnel can be credited for keeping the predation rates low. Researchers also suspect that birds may be learning to prey on terrapin nests. This was indicated because a portion of the nests were partially destroyed and appeared to be too deep for the predator. Other researchers have observed birds excavating terrapin nests and noting that they frequently do not destroy the entire clutch of eggs (Wood and Butler, 2004, pers. comm.).

Despite the slight increases in hatchling mortality, the PIERP is excellent terrapin nesting habitat. The absence of efficient nest predators such as raccoons results in high nest survivorship rates that are much greater than other nesting areas that have been studied. As observed in 2002 and 2003 (Roosenburg and Allman, 2003; Roosenburg et al., 2004), the survivorship of known nests was much higher than normally encountered for terrapins because of the lack of nest predators on the PIERP. 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 the PIERP minimized the risk to nesting females that also may be depredated by raccoons (Seigel, 1980; Roosenburg pers. obs.). Thus, the PIERP restoration project is successfully creating terrapin nesting habitat.

As observed in summer 2002 and 2003 (Roosenburg and Allman, 2003; Roosenburg et al., 2004), terrapin nesting on the island occurred in areas where terrapins could easily access potential nesting sites. These areas are outside of Cells 3 and 5 and inside of Cell 6 and the notch. In 2004, the erosion fence along the dike around Cell 5 was extended to include all of the notch. The erosion fence prevented terrapins from crossing the road and nesting within Cell 4 as they did last year. Although this fence is effectively preventing terrapins from nesting in Cells 4 and 5, it also is causing many females to lay their nests at the base of the fence. Therefore, it is recommended that the effect of the fence on terrapin nesting be carefully monitored. Throughout the remainder of the island, the stone face of the retaining dike around Poplar is a barrier that prevents terrapins from accessing potential nesting sites. As wetland cells are completed, and the exterior dikes are breached to provide water flow, terrapins are likely to follow and begin nesting on interior parts of the island.

The large number of nest combined with the high nest survivorship resulted in a record 1336 hatchlings captured on the PIERP. Hatchlings started emerging from the nests on 5 August 2004; the last hatchlings emerged in 14 April 2005. Researchers released all of the hatchlings in Cell 4DX however, it was noted that many of the hatchlings, particularly those released in September and October, headed to shore as opposed to heading to the water. Recent data of hatchling terrapins in New York suggests that they spend their first winter in terrestrial vs. aquatic habitats (Draud, 2004 pers. comm.). This may be a mechanism to avoid predation and to avoid freezing in shallow marsh sediments. Researchers witnessed many of the Poplar hatchlings distinctly heading away from the water. This behavior is interesting and potentially problematic because these hatchlings may be entering cells that are targeted for filling in the upcoming fall and winter. The researchers suggest that it would be appropriate to further study the movement of these juvenile terrapins to determine how they are using the island habitat and if they are in jeopardy of being submerged when dredged material is added to the island.

The hatchlings produced on the PIERP were similar in size and weight to those captured during previous studies in the Patuxent River in Maryland (Roosenburg, 1992) and in previous years on the PIERP. The frequency of shell scute anomalies and cranial developmental anomalies, 14%, is slightly higher than the average for terrapin populations that normally average about 10% (Herlands et al., 2002). A high frequency of shell scute anomalies was also observed in 2002 and 2003 (Roosenburg and Allman, 2003, Roosenburg et al., 2004). 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 the PIERP 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. However, individuals with the cranial anomalies also appeared to have abnormal behavior including reduced swimming and feeding ability. 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 anomalies may be indirect evidence that the PIERP may be producing a higher than average number of female hatchlings. Continued monitoring of the PIERP terrapins will be able to confirm this hypothesis.

Although, in past years over-wintering on the PIERP had occurred, this was the first year that a significant number of nests over-wintered successfully. The recovery of 121 hatchlings from 14 over-wintering nests was the first evidence of successful over-wintering in the nest of hatchling terrapins in Maryland. Over-wintering in the nest had always been suggested as a strategy but prior evidence had indicated that its importance was questionable because survivorship had been low and only one live hatchling has ever been recovered from over-wintering nests. Over-wintering hatchlings were smaller and lighter than hatchlings that emerged in the fall. How this will effect their subsequent survivorship is unknown at this time. However, the reduction in weight, approximately 0.8 grams, may well reflect the use of residual yolk energy that was used during the winter. In addition to the over-wintering of the nests, researchers also noticed that hatchlings released after processing clearly preferred to stay on land as opposed to remaining in the water. These hatchlings actively left the water and sought higher ground. These observations are similar to terrapin populations in New York where the hatchlings that emerge from their nests in the fall spend their winters in terrestrial environments below the surface sometimes buried up to 10 cm (Draud, 2004 pers. comm.). The PIERP offers a wonderful opportunity to study terrapin over-wintering because of the large number of nests that survive predation.

The initial success of terrapin use of the PIERP predicts that similar projects may have success 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 the PIERP 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 the PIERP may become areas of concentration for species such as terrapins and thus become source population for the recovery of terrapins throughout the Bay.

RECOMMENDATIONS

As the restoration project at the PIERP continues, terrapins will continue to use the habitat for nesting. There are some short-term measures that can be taken to improve nesting habitat on the island. First, we suggest that in Spring 2005, 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. Second, 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 - 2004. Finally, efforts to promote the use of by-catch reduction devices (BRDs) on crab pots fished in and around the PIERP 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 PIERP 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 the PIERP by terrapins. As terrapin monitoring continues, we will be able to evaluate the success of these measures if implemented.

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