TERRAPIN MONITORING AT POPLAR ISLAND

Final Report submitted to the
Army Corps of Engineers

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BACKGROUND

Poplar Island is a large scale ecological restoration project that uses 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 is rebuilding and restoring Poplar Island. A series of stone-covered dikes facing the windward shores prevent erosion. Dredged material from the Baltimore Harbor and the Chesapeake and Delaware Canal approach will be used to elevate the areas within the dikes to levels similar to what existed over 100 years ago. The ultimate goal of the project is to rebuild and restore the habitat and its associated 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 reduced from 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 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 Project is a unique opportunity to understand how large scale ecological restoration projects affect terrapin populations and turtle populations in general. We initiated a long-term terrapin monitoring program that will track changes in the terrapin population in the Poplar Island archipelago as the restoration project progresses. By monitoring the terrapin population on Poplar, we can learn how creating new terrapin nesting and juvenile habitat will affect the terrapin populations. This information will contribute to understanding the ecological quality of the restored habitat on Poplar Island, as well as understanding how terrapins are affected by large scale restoration projects.

As with many of the species that inhabit the Poplar Island archipelago, terrapins began nesting on the island prior to completion of the restoration. One major concern about the nesting activity was that terrapins laid many nests in areas where the emerging hatchlings may have entered cells that are under construction or are being drained. Most of the nests that were discovered at the southeast side of cell 5 of Poplar Island were on the dike inside of the cell. Because this area was not completed and was scheduled for continued construction, there was concern that hatchlings remaining inside the cell were in jeopardy. Thus, hatchlings that emerged inside cell 5 needed to be relocated to the opposite side of the dike and into the narrow causeway between Coaches and Polar Island. With these preliminary observations, we established four objectives for the 2002 field season and the initiation of the Poplar Island terrapin monitoring project:

1) capture hatchlings emerging from nests placed inside cell 5 and release them outside of the cell,
2) thoroughly survey all potential nesting areas within the Poplar Island Restoration Project,
3) track all known nests to monitor hatching success,
4) mark and release all hatchlings caught in the study area.

METHODS

Survey of nesting habitats: To understand the extent that terrapins were using Poplar Island, we surveyed potential nesting areas to document habitat use and locate nests. We walked suspected nesting areas where there was access over the rock break-walls and suitable terrapin nesting habitat was available. Many of these areas were surveyed several times a week, particularly cells 3,3B and 5. We located nests using geographic positioning systems (GPS). We numbered and marked nests with survey flags. Nest position was mapped using latitude and longitude data processed through ARCVIEW onto a geo-referenced photographic image of Poplar Island.

Capture of the Hatchlings inside Cell #5: Because the restoration project is still under construction, we captured hatchlings inside cell 5 and moved them into restored habitat along the "notch" of Poplar Island. We capture hatchlings using two techniques. First, after 50 days of incubation, we ringed with aluminum flashing nests located during the nesting season. We also placed antipredator cages over the nests to prevent avian predators from eating hatchlings. After nests were ringed, we monitored them several times daily for the emergence of hatchlings. Despite the survey efforts to locate terrapin nests in cell 5, there were likely to be many undetected nests. This occurred because the terrapin nesting season began in May during 2002 and daily surveys of the nesting habitat did not begin until mid-June. Given the nesting activity observed on our initial visits to the island on 4 June and 25 June, we estimated that cell 5 could have as many as 50 undiscovered nests. To catch the hatchlings emerging from undetected nests inside cell 5, we built a temporary drift fence inside the cell just below the dike. Thus any hatchlings attempting to enter the cell would be caught by the fence and could be moved to suitable and safe habitat.

The drift fence began at the southeast corner of cell 5 where the stone dike ended and the extended to the northeast end of cell 5 where the webbing protected the beach grass in the notch (approximately 1 km in length). The drift fence was made of 25 cm high aluminum flashing with plastic buckets buried level with the substrate surface at approximately 15 m intervals. We buried the fence about 5 cm into the ground and held it in place using reinforcement bar stakes. We suspended wooden lids over the buckets to prevent avian predators from exploiting the fence to catch hatchling terrapins. The fence was checked for hatchlings 2-3 times per day from 20 July until 31 October. The fence was taken down on the 31^{st} of October, 19 days after the last hatchling was caught on the fence.

All hatchlings were brought back to MES trailer on the island where they were held in plastic containers with water until they were processed. We marked hatchlings by notching 9th marginal scutes on both the right and left side establishing the ID 9R9L as the cohort mark for 2002. Binary coded wire tags (CWTs) were implanted in all but the first 30 hatchlings. The CWTs were placed subcutaneously in the rear hind limb using a 25 gauge needle. We measured plastron length, carapace length, width, and height (± 0.1 mm) and weighed (± 0.01 g) all hatchlings. Additionally, we checked for anomalous scute patterns and other developmental irregularities. Following tagging and measuring, hatchling were released in the north end of the notch. Many of the hatchlings were held for several days prior to release. On several of the releases, we let go several individuals simultaneously. We released all hatchlings at the north corner of the notch where the vegetation was best established and the stone dike created a small pool that has the characteristics of good juvenile habitat.

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

Monitoring Hatching Success: All nests that we identified during our surveys prior to hatchling emergence were ringed and caged to capture the hatchlings. We counted all hatchlings emerging from each nest. After ten or more days since the last hatchling emerged, we excavated the nest and counted all unhatched eggs. From nests where a sufficient number of hatchlings to account for the entire clutch emerged were excavated shortly after hatchlings were discovered. We documented all remaining eggs that did not complete development and hatchlings that did not emerge successfully. Occasionally, we discovered remaining hatchlings which were removed from the nest and counted as successful individuals. In late October, we excavated remaining nests that had produced hatchlings and determined the fate of remaining eggs. We left intact nests that had not produced hatchlings to prevent disturbance from causing over-wintering individuals to emerge prematurely.

Mark and Release all Hatchlings: In order to determine Poplar Island hatchling survivorship and success, we marked all individuals for identification in future years. Upon collection, we marked hatchlings using two techniques. First, the hatchlings were notched in the marginal scutes. Scute notching is a standard protocol in turtle biology. One problem with scute notching is that as hatchlings grow, the notches can become obscured and difficult to read. Furthermore, the shell frequently can be nicked making positive identification of hatchling marks difficult. Therefore, all hatchlings also will be marked with a binary coded wire tag (CWT, Northwest Marine Technologies ®). The binary coded wire tag is a 1.1mm long by 0.25 mm diameter, individually coded tag that is injected under the skin. The CWTs were read before injection and then placed under the skin in the right hind leg. We held hatchlings for a minimum of 24 hours after injection to monitor tag loss. We detected tag presence or absence using Northwest Marine Technologies' V-Detector. Of the more than 500 individuals that were tagged, we only had one case in which the tag was lost. We re-tagged this individual prior to release. The CWTs should have high retention rates and we will be able to positively identify terrapins originating from Poplar Island for the lifetime of the turtle.

All protocols and animal use has been approved through Institutional Animal Care and Uses Committee at Ohio University.

SUMMARY OF ACTIVITIES ON POPLAR ISLAND

4 June 2002 - Willem M.. Roosenburg made initial site visit. Found 4 terrapin nests. Brad Fruh begins regular surveys locating terrapin nests in cell 5 and 3 and 3D.
25 June 2002 - Willem M. Roosenburg, Phil Allman, Andrea Gibson (reporter from Ohio University) visit Poplar Island. Confirmed several nest found by Brad Fruh in addition to continued surveys.
26 June 2002 - Emily Vlahovich begins terrapin surveys at Poplar Island
12 July 2002 - Willem M. Roosenburg and Katherine Kelley made site visit and searched for nests. Surveyed cell 6 and we provided additional training to Emily Vlahovich.
18-19 July 2002 - Willem M. Roosenburg, Peter Markos, Tina Shalek, and Phil Allman set up drift fence in cell 5 along with help from Brad Fruh and Emily Vlahovich.
20-21 July 2002 - Daily surveys of drift fence and nests begin - First nest discovered in June are ringed to catch hatchlings. Phil Allman and Anu Gupta on site to run drift fence and survey for nesting activity.
26-28 July 2002 - Phil Allman and Amy Schroeder visit site to run drift fence and survey for nesting activity.
31 July 2002 - Last nesting activity observed on Poplar Island.
2 August 2002 - First terrapin hatchlings captured on Poplar Island.
2-4 August 2002 - Phil Allman and Elizabeth Cook visit Poplar Island to run drift fence and mark and measure hatchlings.
9-10 August 2002 - Phil Allman and Peter Markos visit Poplar Island to run drift fence and mark and measure hatchlings.
13 August 2002 - Willem M. Roosenburg and Phil Allman site visit to mark and release hatchlings and interviews with local press
19 August 2002 - Willem M. Roosenburg site visit for hatchling release and interviews with CNN
26 August 2002 - Willem M. Roosenburg site visit to mark and release hatchlings.
16-18 August 2002 - Phil Allman and Peter Markos visit Poplar Island to mark hatchlings and run drift fence.
19 September 2002 - Willem M.. Roosenburg travel to the Baltimore Port Authority for presentation at the Poplar Island Site Development Meeting.
20 September 2002 - Willem M. Roosenburg site visit for hatchling marking and release
21 September 2002 - Emily Vlahovich's last day
12 October 2002 - Last hatchling caught
31 October 2002 - Drift Fence removed by Brad Fruh and MES staff

RESULTS

NESTING AREAS: Sixty-eight terrapin nests in two main nesting areas were discovered on Poplar Island (Table 1, figure 1). The first and largest area was on the dam of cell 5 facing Coaches Island (figure 1) where 61 nests were discovered. Nesting on the sand dike between Coaches and Poplar Island was rather evenly distributed, however there appeared to be two minor concentrations. One concentration occurred at the southeast end of the channel and a larger one in the notch area (figure 2). There were two likely reasons for the high levels of nesting activity on these sections of cell 5. First, this region of cell 5 was only one of three areas on Poplar Island

Figure 1. Locations of terrapins nests (yellow dots)on Poplar Island. The northern end of the island is not shown because no nests were found there. Data include all nest discovered during the summer and fall of 2002.

Figure 2. Details of locations of terrapin nests in cell five. Nests marked in blue were discovered recently after oviposition. Nest marked in yellow were discovered when the hatchlings emerged. The red line was the location of the drift fence. Note that many of the nests were inside of cell 5 and thus many of the hatchlings were likely to end up inside this cell still under construction.

where the retaining dike is made solely of sand. Thus terrapins could see and easily have accessed sandy areas in cell 5. We found no indications of nesting along areas of shoreline where rock reinforcement formed the intertidal zone which prevented terrapins from accessing suitable nesting areas. Thus, the concentration at the southeast end of the canal occurs at the first available nesting habitat. Second, the shoreline of Coaches Island opposite cell five appeared to be excellent terrapin nesting habitat, although we did not conduct any surveys on Coaches Island to confirm nesting there. Terrapins may have been familiar with the nesting areas on Coaches Island and then been drawn to Poplar because of the easy access and sandy shores.

Table 1: Summary of number of terrapin nests by location.

Location	Nests Discovered at Oviposition	Nests Discovered by Hatchling Emergence	Total
Cell 5	43	18	61
Cell 3-3B	6	0	6
Cell 6	1	0	1
Total	50	18	**68**

The second nesting area was on the east sides of the Poplar Island on the outside of the dike of cells 3 and 3D, where 6 nests were discovered. In this area there was a high level of terrestrial activity by terrapins, however actual nests were difficult to locate. The shoreline of these cells consists of rock reinforcement that has been filled with sand that has accreted naturally. Additionally, the exposed sand provides the appearance of a beach that may attract terrapins searching for suitable nesting sites. Finally, the eastern to southeastern exposures of this nesting area are preferred by terrapins. We found fewer nests in this area, however we did discover several sets of tracks including some that went to the opposite side of the road suggesting that some nesting was occurring on the inner bank of the dike. Nesting in the cells was unlikely because of the silty soil and high moisture content of the substrate. We did not discover any tracks going into the cell.

One additional nest was discovered in cell 6 (figure 1). The sandy areas on the interior of cell 6 are suitable nesting sites, however the open water access into this cell may have kept nesting activity lower here than in the other two areas. Nonetheless, the sandy

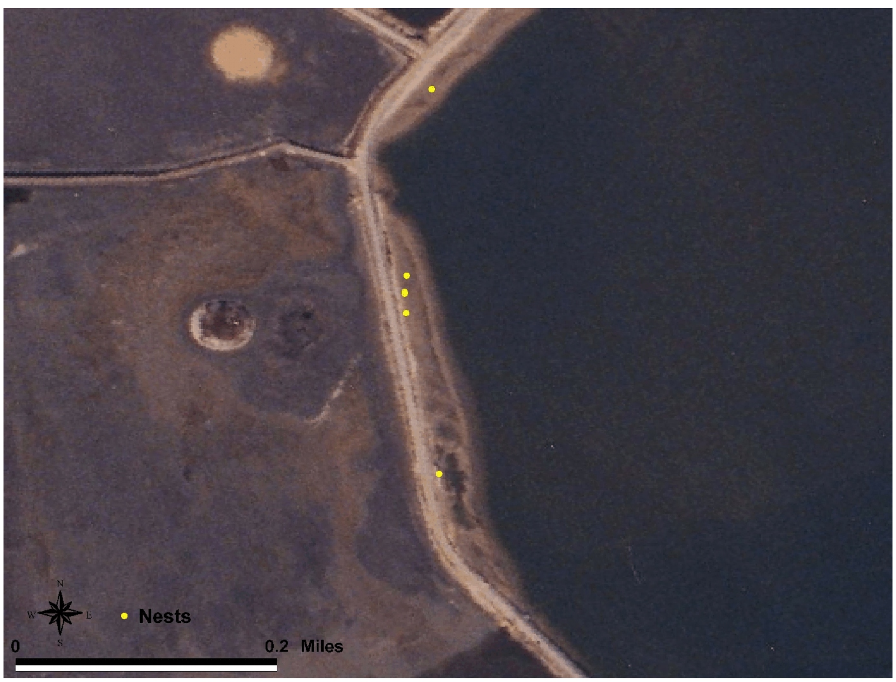

Figure 3. Locations of nests in Cell 3 and 3B. Note that all nests are on the bay-side of the dike indicating that most hatchlings were most likely to head toward water upon emergence.

areas of cell 6 appeared to be good terrapin nesting habitat. In future years we will increase nesting surveys in cell 6. Surveys for nesting activity in cell 6 during 2002 were conducted only when time and personnel permitted.

NEST AND HATCHLING SURVIVORSHIP

Fifty nests were discovered at the time of oviposition or shortly thereafter that were used to evaluate nest survivorship (Table 2). Of the 50 nests, 40 produced hatchlings, 2 produced no hatchlings and 8 remained and are suspected to contain overwintering hatchlings. Of the 42 nests that emerged or were excavated, 95% produced hatchlings.

Table 2. Summary of nest survivorship statistics

	Number	Percent of Total
Total Nests	50	
Nests with Hatchlings	40	80%
Nests without Hatchlings	2	4%
Overwintering Nests	8	16%

Thirty nests were sufficiently studied to present data of egg survivorship (Table 3). We documented 305 hatchlings and evidence of 24 undeveloped eggs or dead hatchlings from the 30 nests. These data suggest that the average clutch size was 10.97 eggs per clutch and that eggs had an average hatching success rate of 92.7% with several nests having apparent 100% survivorship.

Table 3. Summary Statistics of egg survivorship

Nests	30
Total Number of Eggs	329
Total Number of Hatchlings	305
Hatching Success	92.7%
Range	33%- 100%
Mean Clutch Size	10.97

HATCHLINGS

We captured five hundred and sixty-five hatchlings on Poplar Island between August 1 and 12 October 2002 (Table 2). Ringed nests produced 323 hatchlings, 222 were caught by the drift fence and 20 hatchlings were caught by hand or were discovered in nests that were identified by the hole left by previously emerged hatchlings. We located 18 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 leads into the nest chamber.

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

Technique	Number
Drift Fence	222
Ringed Nests	323
Caught by Hand	9
Nest discovered by emerging hatchlings	11
Total	**565**

The average Poplar Island hatchling measurements are summarized in table 5. Hatchlings had an mean plastron length of 27.7 mm and an mean carapace length of 31.3 mm. The average weight of hatchlings was 7.52 g. One hundred and nineteen hatchlings (21%) had shell scute pattern anomalies. The scute anomalies included extra marginal, vertebral, pleural and plastron scutes.

Table 5. Summary statistics of terrapin size metrics taken from the 565 hatchlings emerging from nests on Poplar Island.

	Plastron Length (mm)	Carapace Length (mm)	Carapace Width (mm)	Height (mm)	Mass (g)
Mean	27.7	31.3	27.8	16.5	7.52
Standard Deviation	1.57	1.61	1.53	1.12	0.96

CONCLUSIONS

Portions of Poplar Island are excellent terrapin nesting habitat. This is supported by the large number of nests that we discovered during the summer of 2002, the high survivorship of the nests, and the high rate at which eggs developed into successful hatchlings. The survivorship of known nests on Poplar was much higher than normally encountered for terrapins because of the lack of nest predators on the 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, Poplar Island restoration is successfully creating terrapin nesting habitat.

Terrapin nesting on the island was restricted to 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 breached to provide water flow, terrapins are likely to follow and begin nesting on other parts of the island. During 2002, their only access to nesting sites was over those portions of the retaining dike where there was no rock or the rock has been covered with sand. Because of the incomplete construction and below mean high water elevation of many of the cells, most of the nesting occurred on or in close proximity to the dikes (figures 1, 2, and 3). As the mid-level portions of the wetland cells are created, they are likely to be good terrapin nesting habitat, particularly if some are built with sufficient elevation and sandy soil.

Because of the high levels of nest survivorship, there was strong recruitment during the 2002 nesting season. Hatching success was comparable to what has been observed previously for Maryland terrapin nests that have survived predators (Roosenburg, 1992). Our estimates of hatching success were based on estimates of clutch size determined at the time of hatchling emergence. A more accurate estimate of hatching success could have been obtained by excavating nests and counting eggs immediately after oviposition and comparing these values with the number of hatchlings emerging from the nest. Eggs and partially developed hatchlings can decompose or be eaten by maggots (Roosenburg personal observation) overestimating egg survivorship because they were not included in estimates of clutch size. Similarly, clutch size determined by counting hatchlings and dead eggs and embryos can be an underestimate. We estimated average clutch size on Poplar Island at 11 eggs per nest which is less than the average of 13 eggs per nest observed in the Patuxent River of Maryland (Roosenburg and Dunham, 1997). In addition to the reason stated above, clutch size may have been lower on Poplar because of the greater potential for disturbance of nesting females. Heavy equipment using dike roads may have disturbed females while nesting resulting in incomplete nests. Terrapins will abandon nesting when disturbed resulting in incomplete nests (Roosenburg personal observation). We encountered several nests that had small (<5 eggs) clutch sizes and were not fully covered with sand suggesting they were incomplete and that the female had abandoned the nest.

One interesting aspect of terrapin nesting on Poplar Island was the high rate at which nests over-wintered. Eight (16%) of the known nests had not emerged as of 31 October 2002 suggesting that the hatchlings will overwinter in the nest and emerge in the following spring. Little is know about terrapin overwintering and the how the delayed emergence affects nest survivorship. Hatchling overwintering is poorly understood for Chesapeake terrapins because in other areas most nesting sites are laid close to mean high water. Exceptionally high tides erode these nests and force hatchlings to emerge making it difficult to follow over-wintering survivorship. Terrapin nesting inland usually occurs in agricultural fields and other vegetated areas where it is extremely difficult to locate nests. The lack of vegetation on Poplar makes it easy to locate nests at greater distances from the shore. Two factors likely contribute to overwintering in the nest. First, the extended nesting season until the end of July ensures that some hatchlings do not complete development until late September. All nests overwintering on Poplar were laid after the first of July. Second, substrates of inland sites including Poplar Island typically have a lower sand content and thus are harder and more compact. The compact soil makes it more difficult for the hatchlings to emerge, thus the hatchlings cannot emerge before cooler climates of the Fall. Poplar Island offers a wonderful opportunity to understand and learn more about nest overwintering.

The hatchlings produced on Poplar Island were similar in size and weight to those captured in the Patuxent River in Maryland (Roosenburg, unpublished). The 21% frequency of shell scute anomalies on the hatchlings was higher than expected. The shell anomalies werewas most likely due to warmer incubation temperatures during the summer of 2002. The summer of 2002 was one of the warmest summers on record, particularly during July and August which is when most embryos were developing. Second, there was little vegetation on Poplar that could provide shaded, cooler incubation environments (Jeyasuria et al., 1995). Warmer incubation temperatures cause higher frequencies of shell anomalies in terrapins (Herlands et al, 2002). However there is no evidence to suggest that these anomalies have any detrimental effects on terrapins or other turtle species. Shell anomalies occur at a higher frequency on female terrapins than on males because of temperature-dependent sex determination (TSD). For terrapins, warmer incubation temperatures produce females and cooler conditions produce males (Jeyasuria et al., 1995, Roosenburg and Kelley, 1996). The warm summer is likely to have resulted in a higher frequency of shell anomalies and a preponderance of females during 2002. The continued monitoring of the Poplar Island terrapins will be able to confirm this observation.

The initial success of terrapin nesting on 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 stabilization of shorelines. With proper management, areas such as Poplar Island may become areas of concentration for species such as terrapins and thus become a source population for the recovery of terrapins through out 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 measure that can be taken to 1) prevent the turtles from entering cells under construction, 2) accommodate and enhance the nesting habitat on the island. First, construction of fences in cell 5 and cell 3 and 3B. The fences should prevent female terrapins and hatchlings from entering into the cells. We recommend that the fences be set up on the seaward side of the road on the dike and that the fence be constructed of flashing with a construction barrier above. This will prevent terrapins from crossing the road and entering cells. Additionally, this will reduce the risk of terrapins getting hit by construction equipment that uses these roads. Second, we suggest that in spring 2003 after the last overwintering nests have emerged and before nesting season begins, that additional sand be brought into the areas, particularly along cell 3, to create more nesting habitat. 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 nesting sites. Additionally, the sand could greatly improve the habitat along the dike of cell 3 where females frequently encounter rocks while trying to excavate a nesting cavity. Third, as plans proceed to develop mid-level wetland habitat inside cells, creating terrapin nesting habitat should be a considered. We advocate leaving portions of the mid-level wetland open, without vegetation for suitable terrapin nesting habitat. Particularly, mid-level areas close to the ring canal of the cell that could provide easy access for females searching for nesting habitat. Third, predator control on the island will be paramount to the continued success of terrapin recruitment. Raccoon populations should be kept at a minimum on the island to ensure the high levels of nest survivorship similar to what was observed in 2002. Finally, efforts should be made to educate and promote the use of by-catch reduction devices (BRD) on crab pots fished in and around Poplar Island. Crab pots are well-known predators of terrapins and can have dramatic effects of their populations (reviewed in Roosenburg, 2002). Promoting or requiring the use of BRDs in the vicinity of Poplar Island could greatly reduce the mortality of juvenile and male terrapins. The recommendations offered here will contribute to the continued 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.

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Department of Natural Resources.

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