# TERRAPIN MONITORING AT THE PAUL S. SARBANES ECOSYSTEM RESTORATION PROJECT AT POPLAR ISLAND

## 2012

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**Ohio University researcher Willem Roosenburg processing the first female terrapin hatched from a Poplar Island nest after she returned to nest on Poplar Island in 2012.**

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## BACKGROUND

The Paul S. Sarbanes Ecosystem Restoration Project at Poplar Island (Poplar Island), formerly known as the Poplar Island Environmental Restoration Project (PIERP), is a large-scale project that is using dredged material to restore the once-eroding Poplar Island in the Middle Chesapeake Bay. As recently as 100 years ago, the island was greater than 400 hectares and contained uplands and high and low marshes. During the past 100 years, the island eroded and by 1996 only three small islands (<4 hectares) remained before the restoration project commenced. The Project Sponsors, the United States Army Corps of Engineers (USACE) and the Maryland Port Administration (MPA), are rebuilding and restoring Poplar Island to a size similar to what existed over 100 years ago. A series of stone-covered perimeter dikes were erected to prevent erosion, and dredged material from the Chesapeake Bay Approach Channels to the Port of Baltimore is being used to fill the areas within the dikes. The ultimate goals of the project are: to restore remote island habitat in the mid-Chesapeake Bay using clean dredged material from the Chesapeake Bay Approach Channels to the Port of Baltimore; optimize site capacity for clean dredged material while meeting the environmental restoration purpose of the project; and protect the environment around the restoration site. Ultimately, this restoration will benefit the wildlife that once existed on Poplar Island.

After completion of the perimeter dikes in 2002, diamondback terrapins, *Malaclemys terrapin*, began using the newly formed habitat as a nesting site (Roosenburg and Allman 2003; Roosenburg and Sullivan, 2006; Roosenburg and Trimbath, 2010; Roosenburg et al., 2004; 2005; 2007; 2008; 2010; 2012). The persistent erosion of Poplar and nearby islands had greatly reduced the terrapin nesting and juvenile habitat in the Poplar Island archipelago. Prior to the initiation of the project, terrapin populations in the area likely declined due to emigration of adults and reduced recruitment because of limited high quality nesting habitat. By restoring the island and providing nesting and juvenile habitat, terrapin populations utilizing Poplar Island and the surrounding wetlands could increase and potentially repopulate the archipelago. The newly restored wetlands could provide the resources that would allow terrapin populations to increase by providing high quality juvenile habitat.

Poplar Island provides 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 document terrapin nesting on Poplar Island. By monitoring the terrapin population on Poplar Island, 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 Poplar Island, as well as understanding how terrapins respond to large-scale restoration projects. The results of terrapin nesting surveys and hatchling captures from 2004 – 2012 are summarized herein to identify how diamondback terrapins use habitat created by Poplar Island and how terrapin use has changed during that time. Additionally, researchers conducted a vegetation removal experiment in 2012 to evaluate how the succession of vegetation on the nesting areas in the Notch and outside Cell 5 affected the nesting behavior of female terrapins; the results from this experiment also are presented.

The 2009 Poplar Island Framework Monitoring Document (FMD; Maryland Environmental Service, 2009) identifies three reasons for terrapin monitoring:

1) Quantify the use of nesting and juvenile habitat by diamondback terrapins on Poplar Island, including the responses to change in habitat availability as the project progresses
2) Evaluate the suitability of terrapin nesting habitat by monitoring nest and hatchling viability, recruitment rates, and hatchling sex ratios.
3) Determine if the project affects terrapin population dynamics by increasing the available juvenile and nesting habitat on the island.

The terrapin's charismatic nature also makes it an excellent species to use as a tool for environmental outreach and education. Some of the terrapin hatchlings that originate on Poplar Island participate in an environmental education program in Maryland schools through the Arlington Echo Outdoor Education Center (AE), Maryland Environmental Service (MES), and the National Aquarium in Baltimore (NAIB). These programs provide students with a scientifically-based learning experience that also allows Ohio University (OU) researchers to gather more detailed information on the nesting biology of terrapins, in addition to providing an outreach and education opportunity for Poplar Island. As part of the terrapin monitoring program at Poplar Island, OU researchers are collaborating with staff at AE, MES, and NAIB to foster both a classroom and field experience that uses terrapins to teach environmental education and increase awareness for Poplar Island. The students raise the terrapins throughout their first winter, and the terrapins attain a body size that is comparable to 2-5 year old wild individuals, thus "headstarting" their growth. The goals of the terrapin outreach program are:

1) Provide approximately 250 terrapin hatchlings to AE, MES, and NAIB to be raised in classrooms.
2) Obtain sex ratio data from the hatchlings as increased body size allows.
3) Conduct a scientifically-based program to evaluate the effectiveness of head-starting.

## METHODS

Specific details of differences in surveys and sampling techniques used during 2002 - 2012 can be found in Roosenburg and Allman (2003), Roosenburg and Trimbath (2010), and Roosenburg et al. (2004; 2005; 2008). Since 2004, survey efforts to find nests have been consistent in the Notch, outside Cell 5, and outside Cell 3 (Figure 1). Construction in Cell 6 has eliminated nesting activity there, and the completion of Cells 4D, 3D, and 1A have resulted in nesting along the perimeter dike of these cells therefore mandating surveys of these recently completed nesting areas. Details of the general survey methods and specific techniques employed during 2012 are described below.

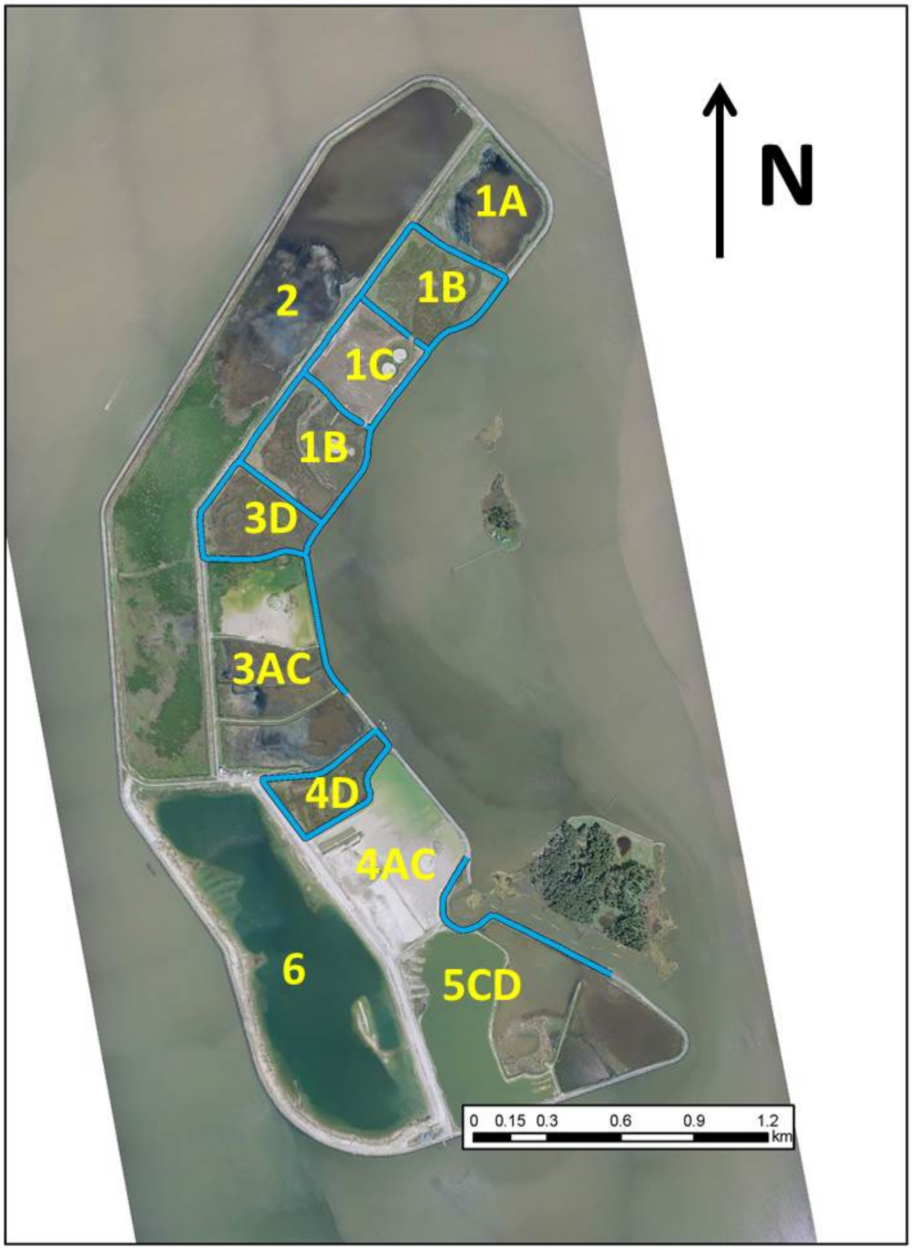


**Figure 1. Map of Poplar Island with blue lines indicating areas surveyed daily for terrapin nesting activity by the research team.**

*Identification of terrapin nests*

From 23 May to 30 July 2012 (the last nest to be confirmed as less than 24 hours old was found on 12 July), OU researchers surveyed the following areas on Poplar Island daily: beaches in the Notch area (surrounding the northwestern tip of Coaches Island near Cell 4AB), areas between Coaches Island and Poplar Island (outside of Cell 5AB), the beach outside the dike near Cell 3AC in Poplar Harbor, and interior perimeter dikes of Cells 4D, 3D, 1A, 1B, and 1C (blue lines in Figure 1). A geographic positioning system (GPS) recorded nest positions and survey flags identified the specific nest locations.

Upon discovering a nest, researchers examined the eggs to determine the age of the nest. If the eggs were white and chalky, the nest was greater than 24 hours old and no further excavation was conducted because of increased risk of rupturing the allantoic membrane and killing the embryo. Researchers excavated recent nests (less than 24 hours old; these nests were identified by a pinkish translucent appearance of the eggs) to count the eggs, and from 2004 through 2012 weighed the individual eggs. Researchers marked nests with four 7.5 $cm^2$ survey flags, and beginning in 2005, laid a 30 cm by 30 cm, 1.25 $cm^2$ mesh rat wire on the sand over the nest to deter avian nest predators, primarily crows.

*Monitoring nesting and hatching success*

After 45 to 50 days of egg incubation, researchers placed an aluminum flashing ring around each nest to prevent emerging hatchlings from escaping. Anti-predator (1.25 $cm^2$) wire also was placed over the ring to prevent predation of emerging hatchlings within the ring. Beginning in late July, the researchers checked ringed nests at least once daily for emerged hatchlings. Researchers brought newly emerged hatchlings to the onsite storage shed where they measured and tagged the hatchlings.

Researchers excavated nests ten days after the last hatchling emerged. For each nest, they recorded the number of live hatchlings, dead hatchlings that remained buried, eggs with dead embryos, and eggs that showed no sign of development. To estimate hatching success, researchers compared the number of surviving hatchlings to the total number of eggs from only the nests that were excavated within 24 hrs of oviposition, which provided an exact count of the number of eggs. Additionally, researchers determined if the nest was still active – with 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, further described in the next section.

*Capture of hatchlings*

Researchers collected hatchlings from ringed nests and also from nests that were discovered by hatchling emergence (hatchling tacks or emergence hole). The presence of egg shells when excavated confirmed all nests discovered by emerging hatchlings. Additionally, researchers found a small number of hatchlings on the beach and in the drift fences from the vegetation removal experiment (see below), which they collected and processed. Because 50 nests had not produced hatchlings by 1 November 2012, these nests were left to be excavated in the spring of 2013. After 30 March 2013 researchers traveled to Poplar Island weekly to recover emerging hatchlings. All overwintering nests that had not emerged by 21 May 2013 were excavated to determine their fate.

*Measuring, tagging, and release of hatchlings*

Researchers brought all hatchlings back to the MES shed onsite where they placed hatchlings in plastic containers with water until they were processed (measured, notched, and tagged), usually within 24 hours of capture. Researchers marked hatchlings by notching with a scalpel the $10^{th}$ right marginal scute and $9^{th}$ left marginal scute, establishing the cohort ID 10R9L for 2012 fall emerging hatchlings. OU personnel gave spring 2013 emerging hatchlings a different cohort ID of 9R12R (notching the 9$^{th}$ and 12$^{th}$ right marginal scutes) to distinguish fall 2012 from spring 2013 emerging hatchlings upon later recapture. Researchers implanted individually marked Northwest Marine Technologies® coded wire tags (CWTs) in all hatchlings. The CWTs were placed subcutaneously in the right rear 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 Poplar Island for the lifetime of the turtle by detecting tag presence using a Northwest Marine Technologies® V-Detector.

Researchers 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 either Cell 4D, Cell 3D, or Cell 1C (which was completed during the summer of 2011). On several occasions, large numbers (>50) of hatchlings were simultaneously released but dispersed around the cell to minimize avian predation.

*Measuring, tagging, and release of juveniles and adults*

All juvenile and adult turtles captured on the island were transported to the onsite shed for processing. Researchers recorded plastron length, carapace length, width, and height (±1 mm), and mass (±1 g) of all juveniles and adults. Biomark Inc. Passive Integrated Transponder (PIT) tags were implanted in the right inguinal region; in the loose skin anterior to the hind limb where it meets the plastron. Additionally, a National Band and Tag Company monel tag was placed in the 9$^{th}$ right marginal scute. The number sequence on the tag begins with the letters PI, identifying that this animal originated on Poplar Island.

*Terrapin Education and Environmental Outreach Program*

During 2012, 235 Poplar Island hatchlings were reared in the terrapin education and environmental outreach programs at AE, the NAIB, and MES. In April 2013, researchers traveled to AE to implant PIT tags in 217 head-started individuals. Researchers also measured and weighed all animals at this time. From late May through July 2013, the head-started terrapins were returned to Poplar Island and released in the Notch.

*2012 Vegetation Removal Experiment*

Five blocks of paired plots, each plot measuring10m by 4-5m, were established in the nesting areas in the Notch and outside Cell 5AB prior to the onset of the nesting season in 2012. Each block consisted of a control plot and experimental plot from which vegetation was removed using a rototiller and then weeded by hand thereafter. Vegetation coverage was sampled within each plot using a 1m$^2$ Daubenmire Frame with point sampling in each 10cm$^2$ square for 100 total points prior to vegetation removal. These samples were conducted at three random locations along three randomly selected transects that ran the length of the plot (10m). Vegetation coverage also was sampled with a single point sample at 1m intervals along each of the three transects. The point sampling method used a pin (survey flag) dropped at the location and documented the number and species of all vegetation that contacted the pin. All plots were surveyed daily to document nesting activity and all nests were documented as described above. At the end of the nesting season all plots were enclosed with a 20cm high drift fence to catch all hatchlings emerging from possible undocumented nests. All documented nests were ringed (see method described above). All hatchlings were recorded and processed as described in method above.

*Data Analysis and Processing*

Researchers summarized and processed all data using Microsoft Excel® and Statistical Analysis System (SAS). Graphs were made using Sigmaplot®. Institutional Animal Care and Uses Committee at OU (IACUC) approved animal use protocols (13-L-023) and Maryland Department of Natural Resources (MD DNR) – Wildlife and Heritage issued a Scientific Collecting Permit Number SCO-52238 to Willem M. Roosenburg (WMR).

## RESULTS AND DISCUSSION

*Nest and Hatchling Survivorship*

During the 2012 terrapin nesting season (23 May – end of July), the researchers located 200 nests on Poplar Island (Table 1, raw nest data provided in Appendix 1). Of these 200 nests, 138 successfully produced hatchlings and 51 nests were unsuccessful, of which predators destroyed 42 nests completely and another 39 nests were partially depredated some of which produced hatchlings (Table 1). Six nests failed because the eggs did not develop or eggs were thin-shelled which results in nest failure. Four nests were lost due to inundation by the high tide or washed out due to heavy rains because the nest site was in an area of high erosion.

| YEAR | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| TOTAL NESTS | 68 | 67 | 182 | 282 | 191 | 225 | 218 | 189 | 166 | 211 | 200 |
| NESTS PRODUCED HATCHLINGS | 38 | 50 | 129 | 176 | 112 | 166 | 180 | 145 | 125 | 180 | 138 |
| NESTS THAT DID NOT SURVIVE | 1 | 7 | 17 | 70 | 69 | 44 | 28 | 34 | 42 | 20 | 51 |
| DEPREDATED (ROOTS OR ANIMAL)* | 0 | 0 | 12 | 46 | 54 | 18 | 12 | 10 | 9 | 24/6 | 81/39 |
| WASHED OUT | 1 | 6 | 3 | 11 | 13 | 2 | 6 | 3 | 4 | 3 | 4 |
| UNDEVELOPED EGGS, WEAK SHELLED EGGS, OR DEAD EMBRYOS | 0 | 1 | 0 | 12 | 1 | 19 | 10 | 12 | 11 | 5 | 6 |
| DESTROYED BY ANOTHER TURTLE OR NEST WAS IN ROCKS | 0 | 0 | 2 | 0 | 0 | 3 | 0 | 0 | 2 | 0 | 2 |
| DESTROYED BY BULLDOZER | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| DEAD HATCHLINGS | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 2 | 6 | 3 | 0 |
| FATE OF NEST UNKNOWN | 29 | 10 | 36 | 36 | 10 | 19 | 10 | 10 | 17 | 9 | 7 |

**Table 1 - Summary of the diamondback terrapin nests found on Poplar Island and their fate from 2002 to 2012. *The two values for depredated nests indicates the total number nest that experienced some level of predation and the second number identifies those that were partially depredated.**

The number of terrapin nests on Poplar Island has averaged 207 nests per year since 2004 (Table 1); 2012 was an average year which deviated only -7 nests from the mean. The increase in nests in the Notch in 2011 and 2012 is attributed to the increase in availability of open sandy nesting areas. The sand storage in Cell 4AB and the subsequent north westerly wind caused erosion of sand to the perimeter dike in the Notch during 2011 and 2012 created large open sandy areas that were heavily used by nesting females. The nesting habitat in the Notch also has high nest survival (Figures 2 and 3). The increase in open nesting habitat in the Notch may have contributed to reduced nesting on the outside of Cell 5AB, where vegetation has reduced the availability of open areas further, and attracted nesting females to the Notch. Nonetheless, the area between Poplar Island and Coaches Island remains the primary nesting area on Poplar Island. The completion of additional wetland cells has led to the expansion of nesting on other parts of the island (Figures 2 and 3). During 2012, the first nests were discovered on the cross dikes between Cells 1A, 1B, 1C, and 1D (Figure 3) indicating that terrapins are using these wetland cells to access potential nesting sites and that the sparse vegetation on these cross dikes provides the open areas selected by females for nesting. In particular, the cross dikes between Cell 1AB and Cell 1BC attracted nesting females. Areas with dense vegetation typically support fewer terrapin nests in the Chesapeake Bay region (Roosenburg, 1996) and pose a threat to terrapin nests because the roots of grasses can either entrap hatchlings or prey directly on the eggs (Stegmann et al., 1988). The outside of Cell 3AC remains a reliable nesting area used by females as well as the open areas that have become established on the southern side of Cell 4D (Figure 3).

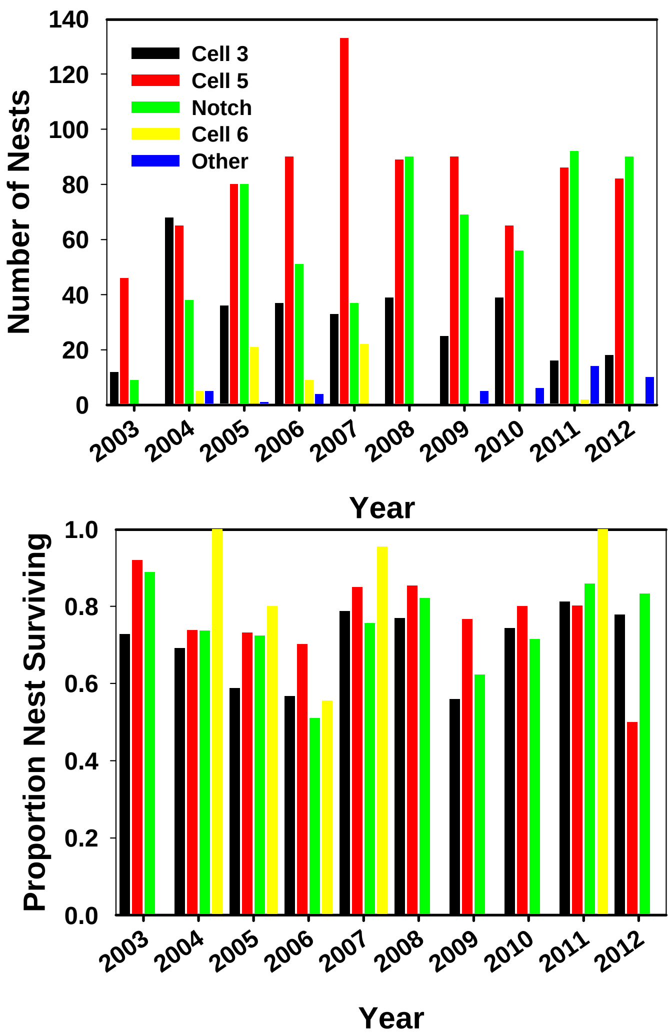


**Figure 2 – The number of nests in each of the major nesting areas for each year of the study (top panel) and the proportion of nests surviving (bottom panel).**

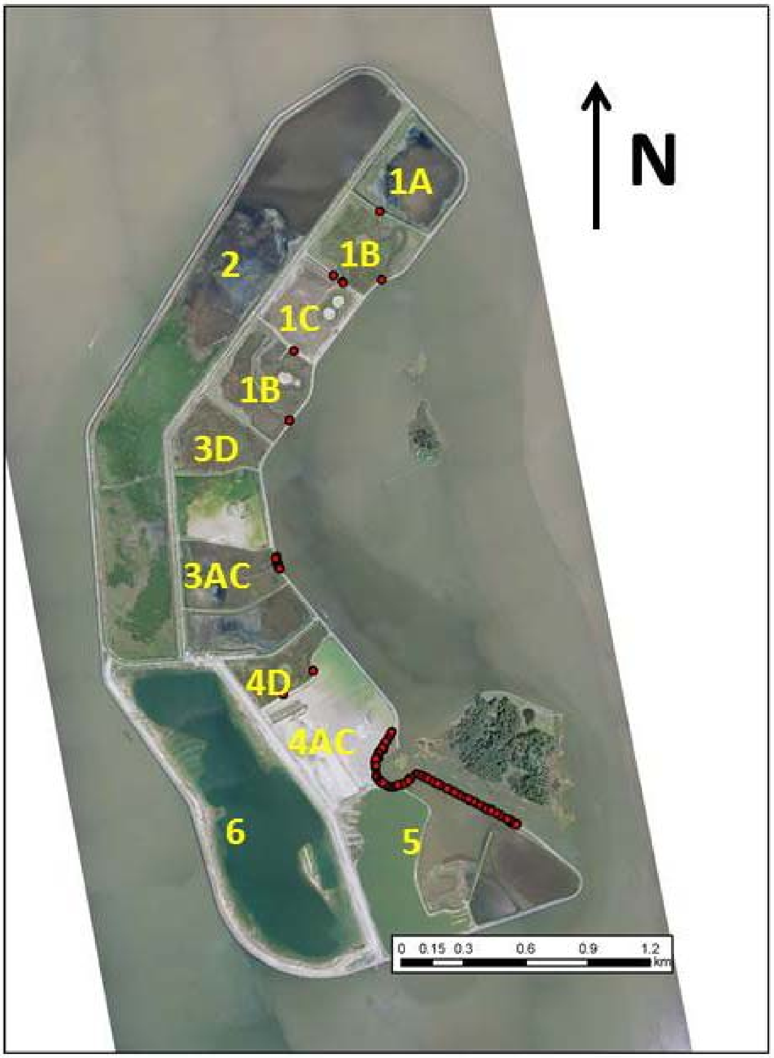


**Figure 3 – Terrapin nesting locations on Poplar Island during 2012**

Survivorship of nests (the proportion of nests producing hatchlings) decreased from 80.2% in 2011 to 50.0% in 2012 in the area outside of Cell 5AB (Figure 2). Predation by deer mice (*Peromyscus maniculatus*) was the primary cause for the decline in nest survivorship eating eggs throughout incubation. Researchers used small mammal traps to confirm that deer mice were eating terrapin eggs. Nest predation did not increase in the other areas around the island: outside Cell 3AC and the Notch, where vegetation density is considerably less than outside Cell 5AB. Although some predation by small mammals has been noted in the past, 2012 was the first year that a large portion of the nests were eaten. In the past this predation was suspected to have been caused by short-tailed shrew (*Blarina brevicauda*). OU researchers suggest that the increase in vegetation provided habitat and the forage (grass seeds) that resulted in a large population of deer mice on the dike outside Cell 5AB during the summer of 2012. Terrapin nests likely were a secondary prey source for deer mice, but high mouse population levels may have resulted in depleting the natural food sources and resulted in the high predation rates on terrapin nests particularly later in the nesting season (late July/early August). If the population of deer mice on Poplar Island is cyclic, it may be anticipated that in future years terrapin nest predation by deer mice may cycle as well.

Researchers continued to place hardware cloth over the nests to prevent crow predation during 2012. This mechanism was not successful in deterring predation by deer mice and eastern king snakes on terrapin nests (*Lampropeltis getulus*). Five eastern king snakes were captured on Poplar Island; 4 new individuals and one that had been marked in previous years. Researchers suspect that king snakes are coming from Coaches Island and preying on the readily available terrapin nests, in addition to northern water snakes (*Nerodia sipedon*) and deer mice. Five nests were confirmed as depredated by king snakes during 2012 with additional nests suspected, but not confirmed. The number of 2012 confirmed predation events by king snakes is down from 18 in 2011. Despite the high rate of nest predation in Cell 5, the lack of raccoons and foxes combined with researchers protecting nests from crows contributed to the continued high nest survival on Poplar Island.

Mean within nest survivorship (proportion of eggs within nest surviving) was 0.597 during 2012. This is down slightly from 0.624 during 2011 but well above the low observed in 2010 of 0.429. The fluctuation in survivorship is most likely due to the fluctuation of temperature and rainfall among summers in which hotter, dryer summers reduce survivorship within nests, and wetter summers have higher survivorship. The 2010 nesting season was the hottest and driest on record, while 2012 had considerably more rainfall events during the summer. During hot and dry conditions, soil water potential drops and eggs can become desiccated and die as a consequence. In 2012, researchers documented six nests in which eggs had not completed development and died within their nests; desiccation or overheating were the suspected primary cause for this within nest mortality. Possibly contributing to the increase in mortality is the increasing presence of vegetation on the nesting beaches, particularly in the Notch and outside of Cell 5. Vegetation competes with turtle eggs for soil moisture and can tolerate lower soil water potentials than eggs, in addition to the roots ability to encase eggs and draw the moisture out (Stegmann et al., 1988).

Researchers noted three nests with thin-shelled or kidney shaped eggs on Poplar Island. Thin-shelled eggs also have been observed in the Patuxent River terrapin population (Roosenburg, personal observation). In all three clutches only a few of the eggs were thin-shelled or miss-shaped. In previous years, OU researchers have noted nests in which all of the eggs have thin shells; these eggs are frequently broken during oviposition and seldom hatch. The cause of the thin-shelled eggs is unknown at this time, but it is not unique to Poplar Island. Two possible causes that remain to be evaluated include a toxicological effect of a ubiquitous factor in the Chesapeake Bay, or a resource limitation making the females unable to sequester sufficient amounts of calcium to shell the eggs.

*Reproductive Output*

Clutch size (Analysis of Variance; ANOVA, $F_{6,849} = 1.83$, $P > 0.05$) and clutch mass (ANOVA, $F_{8,851} = 1.33$, $P > 0.05$) did not differ among years. Average egg mass (ANOVA, $F_{6,851} = 3.24$, $P < 0.05$) differed among years (Table 2). The difference in clutch size that resulted at the end of 2011 has disappeared with the inclusion of the 2012 data. Clutch size decreased by almost a 0.5 egg from 2011 to 2012. Average egg mass remained different among years and 2012 saw the largest average egg mass ever reported for Poplar Island while 2011 had the smallest egg mass. Researchers can only speculate what may be driving the variation observed among years in reproductive output but suggest two potential causes. The first potential cause is underlying environmental variation (e.g. temperature or resources) that may result in different allocation strategies that determine the number and size of eggs and the total clutch mass. A study investigating environmental correlates of reproductive characteristics could reveal significant patterns associated with environmental variation. Second, there may be changes in the demographic structure in the Poplar Island terrapin population such that the strong recruitment driven by the creation of new and predator-free nesting habitat has resulted in a greater number of younger females. Younger females may have different reproductive characteristics than the older females that dominated the population in the early years of the project. Additionally, younger females may be more variable in the production of eggs. Identification of known-aged female clutches could address these questions. Continued monitoring of terrapin reproductive biology on Poplar Island will be important in determining the underlying causal factors of variation in reproductive output.

| **Year** | **Clutch Size** | **Clutch Mass (g)** | **Egg Mass (g)** |
|---|---|---|---|
| **2004** | 13.68 (0.379) | 127.55 (4.372) | 9.80 (0.110) |
| **2005** | 13.62 (0.245) | 133.11 (2.541) | 9.92 (0.087) |
| **2006** | 13.48 (0.248) | 133.28 (2.570) | 9.97 (0.081) |
| **2007** | 13.11 (0.241) | 127.4 (2.502) | 9.86 (0.086) |
| **2008** | 12.90 (0.260) | 128.0 (2.890) | 10.06 (0.092) |
| **2009** | 13.85 (0.242) | 137.1 (2.335) | 10.02 (0.091) |
| **2010** | 13.33 (0.364) | 133.1 (3.850) | 10.10 (0.198) |
| **2011** | 14.08 (0.290) | 131.5 (2.688) | 9.46 (0.142) |
| **2012** | 13.67 (0.309) | 131.7 (3.697) | 10.13 (0.162) |

**Table 2. Average and standard error of clutch size, clutch mass, and egg mass from 2004-2012 on Poplar Island.**

*Hatchlings*

Researchers captured, tagged, and notched 961 terrapin hatchlings on Poplar Island between 26 July 2012 and 23 May 2013 (Table 3; Appendix 2). Sixty-four hatchlings were caught in the drift fences surrounding the experimental plots and an additional 14 hatchlings were caught by hand on the nesting beaches. All other hatchlings were captured in the rings surrounding the nests. Researchers found 29 nests after 30 July 2012 through 21 May 2013 that were discovered either when the hatchlings emerged or predators had excavated the nests and left egg shells. Hatchling carapace length and mass were similar among all years of the study (Table 3). Since 2002, 12,289 hatchlings have been captured, tagged, and notched on Poplar Island (Table 3, these values include animals that were put into the headstart program).

| YEAR | NUMBER OF HATCHLINGS | MEAN CARAPACE LENGTH (mm) | MEAN MASS (g) |
|---|---|---|---|
| **2002** | 565 | 31.28 (1.61) | 7.52 (0.96) |
| **2003** | 387 | 31.13 (1.50) | 7.50 (0.99) |
| **2004** | 1,337 | 31.57 (1.47) | 7.61 (0.89) |
| **2005** | 1,526 | 30.98 (1.94) | 7.45 (1.10) |
| **2006** | 855 | 30.95 (1.71) | 7.38 (1.01) |
| **2007** | 1,616 | 31.26 (1.72) | 7.50 (0.91) |
| **2008** | 1,443 | 31.03 (1.34) | 7.42 (0.14) |
| **2009** | 1,430 | 30.99 (1.83) | 7.33 (0.99) |
| **2010** | 785 | 30.45 (0.06) | 7.38 (0.04) |
| **2011** | 1,382 | 30.41 (2.02) | 7.40 (1.15) |
| **2012** | 961 | 30.83 (2.26) | 7.37 (1.30) |
| **Total** | 12,289 | | |

**Table 3 - Number of hatchlings, mean and standard error of carapace length, and mean mass of terrapin hatchlings caught on Poplar Island from 2002-2012.**

2012 was a year with reduced hatchling recruitment although the number of nests discovered was similar to 2011 (Table 1 and 3). The decrease in the number of hatchlings was mostly due to the high predation rates on Cell 5 nests resulting in only 50% survivorship of nests in this nesting area. Other nesting areas had nest survival rates comparable to previous years (Figure 2). The relationship between average clutch egg mass and average clutch hatchling mass suggests that incubation conditions were normal during 2012. Only in 2008 and 2010, summers when incubation conditions were dryer than normal due to lower rainfall and higher temperatures, did the relationship between egg mass and hatchling differ (ANCOVA; $F_{8, 343} = 4.53$; $P < 0.0001$) resulting in larger eggs producing smaller than normal hatchlings (Figure 4). These findings suggest that hatchling size is affected by both egg size and the environmental conditions experienced during incubation.

*Overwintering*

There were 40 nests that OU allowed to overwinter during the winter of 2012-2013 and all overwintered successfully (Table 4). In the spring, the accumulation of sand within the rings surrounding the nests resulted in several nests emerging, as indicated by the texture of the egg shells, but the hatchlings escaped as the sand had completely covered the rings.

In 2012, there was an increase in the number of nests that had both fall and spring emerging hatchlings (Table 4). Furthermore, the accumulation of sand in the Notch completely buried some nests, and other nests' rings were either ripped away by wind or washed out by unusually high tides during the winter and never found - accounting for unknown nests (Table 4). Researchers recovered no dead hatchlings from any overwintering nests, suggesting that despite a low number of nests overwintering, overwintering success was high. Many of the overwintering nests contained large numbers of dead eggs indicating that most of the mortality occurred while the eggs were developing and not in the nest post-hatching.

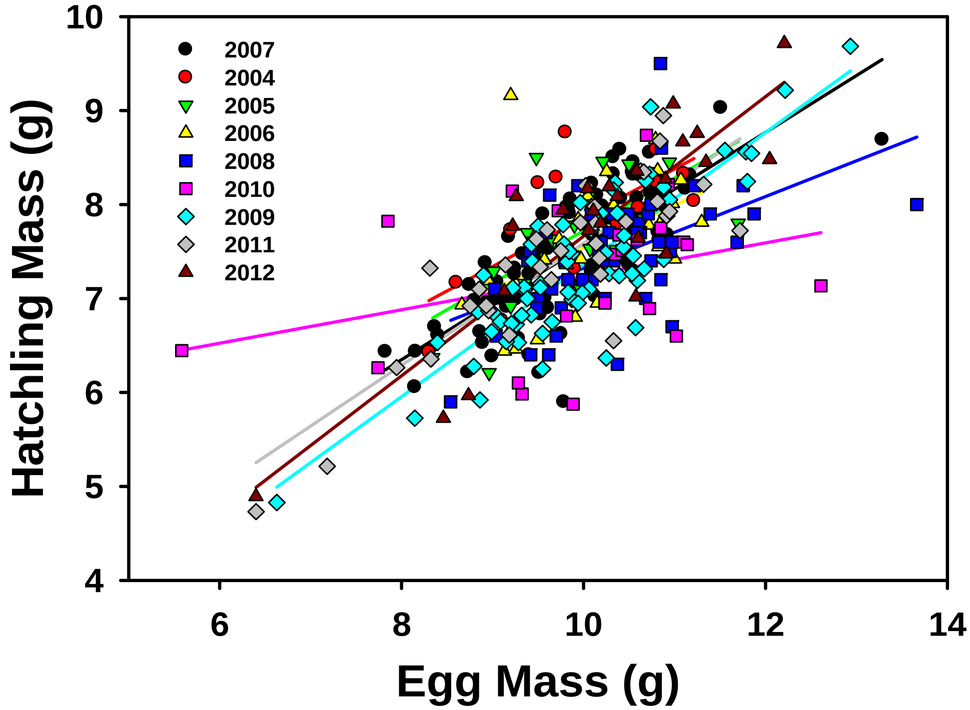


**Figure 4. The relationship between average egg mass and average hatchling mass by clutch for 9 years on Poplar Island. The relationship is similar for all years except 2010 when the slope decreased.**

| | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 |
|---|---|---|---|---|---|---|---|
| Total Nests - Notch & Outside of Cell 5 | 146 | 170 | 183 | 159 | 124 | 178 | 172 |
| Depredated Nests and Nests destroyed before fall emergence | 47 (32.2%) | 18 (10.6 %) | 17 (9.3%) | 12 (7.5%) | 4 (3.2%) | 15 (8.4%) | 46 (26.7%) |
| Fall Emerging Nests | 49 (33.6%) | 92 (54.1%) | 113 (61.7%) | 68 (42.8%) | 77 (62.1%) | 134 (75.3%) | 62 (36.0%) |
| Nests Over-wintering | 44 (30.1%) | 60 (35.3%) | 44 (24.0%) | 74 (46.5%) | 21 (16.9%) | 22 (12.4%) | 40 (23.3%) |
| Spring Emerging Nests | 33 (22.6%) | 50 (29.4%) | 40 (21.9%) | 66 (41.5%) | 21 (16.9%) | 22 (12.4%) | 40 (23.3%) |
| Over-wintering Nests that did not Emerge | 6 13.6% | 4 (2.4%) | 4 (2.2%) | 8 (5.0%) | 0 (0.0%) | 0 (0.0%) | 0 (0.0%) |
| Unknown Nests | 11 (7.5%) | 6 (3.5%) | 9 (4.9%) | 5 (3.1%) | 5 (4.0%) | 7 (3.9%) | 25 (14.5%) |
| Both Fall & Spring Emerging Nests | 1 (0.7%) | 0 (0%) | 1 (0.5%) | 4 (2.5%) | 4 (3.2%) | 4 (2.2%) | 12 (7.0%) |

**Table 4 – Nest fate and overwintering percentage of the nests during the 2006 – 2012 nesting seasons on Poplar Island.**

Researchers also PIT tagged terrapins that were part of the AE, NAIB, and MES head-start programs. Researchers tagged and processed 223 terrapins in April 2013 (Appendix 3). During May, June, and July 2013 head-started hatchlings were transported to Poplar Island and were released for the first inside the wetlands in Cell 1A and Cell 1B in addition to the releases in the Notch, Cell 4D and Cell 3D. Two hatchlings died during the rearing phase of the project.

*Vegetation Removal Experiment*

Details of the vegetation removal experiment are provided in Appendix 4: Undergraduate Honors Thesis for ElizaBeth Clowes at Ohio University, which was successfully defended in May 2013. Herein is a brief summary of the major findings of the experiment.

More nests were discovered in the vegetation removal plots than in the control plots (Table 5) indicating that terrapins select open sandy areas and use areas with dense vegetation less frequently on Poplar Island. Because the vegetation in Block 1 (North end of the Notch) was distinctly different from the other four blocks (see Appendix 4, Figure 5), data also were analyzed with Block 1 removed. The number of nests in open areas remained greater than control areas (Table 5). This result demonstrates that open areas with no or sparse vegetation are preferred and is a potential explanation for the decrease in nesting that has occurred outside Cell 5 where the vegetation has become both tall and dense (Figure 5).

| SCENARIO | NULL PROBABILITY (EQUAL PREFERENCE) | NESTS IN EXPERIMENTAL PLOTS | NESTS IN CONTROL PLOTS | TOTAL COMBINED TRIALS (ALL CONTROL V. ALL EXP) | EXACT P-VALUE CALCULATED |
|---|---|---|---|---|---|
| ALL PLOT SETS | 0.5 | 18 | 4 | 22 | 0.004344 |
| BLOCK 1 EXCLUDED | 0.5 | 13 | 1 | 14 | 0.001831 |

**Table 5. Final combined nest counts and calculated P-values (binomial exact test, two-tailed). Given major differences between control and experimental plots in Block 1, its nests were excluded and a second calculation was performed.**

Vegetation encountered in the plots was dominated by switchgrass (*Panicum virgatum)* (Table 6), which frequently was greater than 1m in height and occurred in clumps with dense root mats that are impenetrable for a digging female terrapin. Although switchgrass is an excellent perennial species for erosion control in nutrient poor substrates, such as the sandy dikes on Poplar Island, it reduces potential nesting sites for terrapins. Its tall stature also hinders the terrapins in sighting potential nesting areas that may lay beyond the grasses further inland.

| Common Name | Scientific Name | % Daubenmire | % Transect |
|---|---|---|---|
| Smooth Cordgrass | *Spartina alterniflora* | 20.0 | 13.3 |
| Switchgrass | *Panicum virgatum* | 83.3 | 76.7 |
| Saltmarsh Hay | *Spartina patens* | 53.3 | 36.7 |
| Common Lambsquarter | *Chenopodium album* | 20.0 | 13.3 |
| Black-eyed Susan | *Rudbeckia hirta* | 16.7 | 6.7 |
| Sea Rocket | *Cakile edentula* | 3.3 | 0.0 |
| Barnyard grass | *Echinocholoa walteri* | 30.0 | 16.7 |
| Redtop | *Agrostis alba* | 10.0 | 13.3 |
| Field Bromegrass | *Bromus arvensus* | 60.0 | 50.0 |
| Little Bluestem | *Schizachyrium scoparium* | 23.3 | 23.3 |
| Virginia Pepperweed | *Lepidium virginicum* | 23.3 | 26.7 |
| Trailing Fuzzy Bean | *Strophostyles helvola* | 10.0 | 6.7 |
| Horseweed | *Conyza canadensis* | 60.0 | 50.0 |
| Annual Wormwood | *Artemisia annua* | 3.3 | 0.0 |
| Winged Pigweed | *Cycloloma atriplicifolium* | 3.3 | 0.0 |
| Salt Marsh Fleabane | *Pluchea purpurascens* | 3.3 | 0.0 |
| Evening Primrose | *Oenothera biennis* | 3.3 | 0.0 |
| Groundsel Tree | *Baccharis halimifolia* | 3.3 | 6.7 |

**Table 6. Plant species found on Cell 5 exterior dike at Poplar Island. Percentages of occurrence in modified Daubenmire and transect sampling are displayed.**

The results of the vegetation removal experiment suggest that open areas for terrapin nesting should be maintained on Poplar Island to ensure high levels of successful nests. The shift in nesting density from Cell 5, where vegetation has increased both in stature and density, to the north side of the Notch where the 2011 wind erosion of the sand from the Cell 4AB stock piles has maintained open sandy areas reflects natural support for the results reflected in this vegetation removal experiment. Perhaps the most interesting outcome of this experiment is how successful the small experimental plots (10m x 4m) were in attracting nesting females, suggesting that the size of the open areas can be relatively small to successfully attract nesting terrapins.

*Highlights of the 2012 Field Season*

Two interesting observations occurred during the 2012 field season. First, researchers located the first female terrapin that was marked as a Poplar Island hatchling (2004) returning to nest. The female terrapin was caught by MES personnel in the vicinity of the trailers in the center of the island (Figure 1); she likely emerged from Cell 4D. The female was gravid (carrying eggs) and had come ashore to nest. Her origin from Poplar Island was confirmed by the presence of a CWT and notch code identifying her from the 2004 cohort and thus was an 8-year-old female. The second highlight was the capture of three hatchling eastern mud turtles (*Kinosternon subrubrum*) in the Notch, suggesting that mud turtles are reproducing on the island. Mud turtles have been recovered in the past in the Notch area but never any indication of nesting. These three

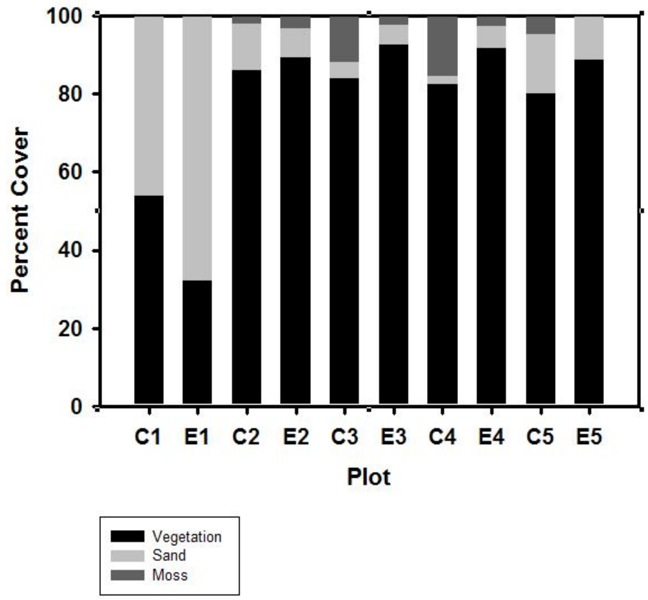


**Figure 5. Percent ground cover and open substrate in control and experimental plots prior to vegetation removal based on Daubenmire Frame sampling.**

hatchlings were caught in the drift fence surrounding one of the vegetation removal plots, which suggests that they are nesting on Poplar Island.

## CONCLUSIONS

2012 was an average year for terrapin nesting, however the higher than normal predation rates of nests outside Cell 5 resulted in decreasing nest survival to 50% and thereby reduced the number of hatchlings recovered. Most of this nest predation was caused by deer mice that were trapped by researchers in the vicinity of the nests. It is possible that the population of deer mice cycles in responses to resources (primarily seeds from grasses and forbs) and that there may have been a peak in the deer mouse population during 2012 that coincided with the terrapin nesting season. Evaluating the level of mouse predation in 2013 may help distinguish between a cyclical or an increasing population level of deer mice on Poplar Island. Nonetheless, Poplar Island continues to provide excellent nesting habitat for terrapins since the completion of the perimeter dike. Nest survivorship remains high on Poplar Island relative to the Patuxent River mainland population (Roosenburg, 1991) mainly because the primary nest predators are absent from the island, and avian predation is reduced by the hardware cloth laid over the nests. Unfortunately the hardware cloth placed over the nests is not an effective deterrent for mice. In those areas on Poplar Island where mouse predation was not a problem, nest survivorship remained high due to the lack of raccoons and foxes that decimate nests on mainland nesting sites.

The sand stockpile in Cell 4AB and its erosion by wind in 2011 created high quality (open sandy) terrapin nesting habitat in the Notch. The large deposit of sand created a large sand dune in the Notch that continued to attract terrapins to nest in 2012. Furthermore, windblown erosion created open sandy areas in Cell 4D and the Notch that were previously overgrown with vegetation. Indeed, Figure 3 illustrates the high density nesting that occurred in these areas of newly formed nesting habitat, including nests on the actual sand pile in Cell 4AB. However, when this sand source is depleted for construction vegetation will likely colonize and deteriorate the quality of the nesting habitat. Targeting of vegetation-free areas by nesting females indicates the need to maintain these types of habitat throughout the island to provide high quality nesting habitat on Poplar Island. This conclusion also was supported by the vegetation removal experiment which demonstrated that terrapins placed more nests in the open cleared areas than in the control areas. Researchers are concerned by the increasing vegetation, particularly outside Cell 5 and in the Notch. The accumulated sand in the northern portion of the Notch and the southern boundary of Cell 4D made available large portions of suitable nesting habitat (with little vegetation) that was used heavily during 2012. The number of nests found annually also indicates that 70-125 adult females are using Poplar Island for nesting. This estimate is based on a maximum reproductive output of three clutches per year per female, as has been observed in the Patuxent River population (Roosenburg and Dunham, 1997).

During 2012, the researchers conducted twice daily surveys of the nesting areas in the Notch, outside Cell 5, and outside Cell 3, in addition to once daily surveys in Cell 4D, Cell 3D, Cell 1A, Cell 1B, and Cell 1C. This was possible because one researcher was dedicated full-time to locating terrapin nests and three other OU researchers assisted her throughout the nesting season. The researchers discovered 29 nests by noting hatchlings emerging after the nesting season had ended, and confirmed the nest with the presence of egg shells. Many of these nests were probably laid during the weekends of the nesting season when researchers could not complete nesting surveys. Furthermore, the extremely dry conditions during July make it more difficult to locate recently laid nests because the disturbances in the sand that identify nests erode quickly in dry soils.

Raccoons, foxes, and otters are known terrapin nest predators and contribute to low nest survivorship in areas where these predators occur, sometimes depredating 95% of the nests (Roosenburg, 1994). The lack of raccoons on Poplar Island minimizes the risk to nesting females (Seigel, 1980; Roosenburg, pers. obs.). Nest predation in 2012 increased because of the high predation rates by mice on the nesting area outside Cell 5. Nonetheless, the absence of efficient nest and adult predators on Poplar Island generated nest and adult survivorship rates that remain higher compared to similar nesting areas with efficient predators. As was similarly observed in 2002 through 2011 (Roosenburg and Allman, 2003; Roosenburg and Sullivan, 2006; Roosenburg and Trimbath, 2010; Roosenburg et al., 2004; 2005; 2007; 2008, 2011), the nest survivorship and hatchling recruitment on Poplar Island continues to be higher relative to mainland populations.

Poplar Island produced 961 hatchlings during the 2012 nesting season. Hatchlings started emerging from the nests on 30 July 2012; the last hatchlings were excavated on 21 May 2013. This was made possible because Willem Roosenburg was on sabbatical during the spring of 2013 and thus was able to visit the island weekly after the 1st of April. Researchers released all of the hatchlings in the wetlands of Cell 4D, Cell 3D, Cell 1A, and Cell 1C, however many of the hatchlings released in September and October 2012 clearly preferred to stay on land as opposed to remaining in the water, because hibernating in water may be physiologically more costly than hibernating on land.

During the winter of 2012-2013, 40 nests overwintered successfully. The recovery of 221 hatchlings from overwintering nests confirms overwintering as a successful strategy used by some terrapin hatchlings. However, excavation of many of these nests in the following spring discovered dead eggs, indicating that these nests never developed successfully during the summer incubation period. Other nests contained empty egg shells from which hatchlings had emerged but had escaped the ring. In these cases it was impossible to confirm whether these nests emerged in the fall or the spring. Continued studies of overwintering and spring emergence will be conducted to better understand the effect of overwintering on the terrapin's fitness, life cycle, and natural history. Poplar Island offers a wonderful opportunity to study terrapin overwintering because of the large number of nests that survive predation.

The educational program conducted in collaboration with AE, NAIB, and MES successfully head-started many terrapins. Students increased the size of the hatchlings they raised to sizes characteristic of 2-5 year old terrapins in the wild. All hatchlings were PIT tagged to determine the fate of these hatchlings in the future through the continued mark-recapture study, which is sponsored by Maryland Department of Natural Resources (MD-DNR). During the summer of 2009-2012 mark-recapture efforts in the Poplar Island Harbor and the area between Poplar and Coaches Island have relocated several headstart and natural release hatchlings. The preliminary results indicate that some terrapins from the island are remaining within the archipelago and surviving. Researchers were rewarded this year with the return of a Poplar Island hatchling as an onsite nesting adult from the 2004 cohort. The presence of CWTs in this individual confirmed its origin from Poplar Island.

The initial success of terrapin nesting on Poplar Island indicates that similar projects also may create suitable terrapin nesting habitat. Although measures are taken on Poplar Island to protect nests, similar habitat creation projects should have high nest success until raccoons or foxes colonize the project. Throughout their range, terrapin populations are threatened by loss of nesting habitat to development and shoreline stabilization (Roosenburg, 1991; Siegel and Gibbons, 1995). Projects such as Poplar Island combine the beneficial use of dredged material with ecological restoration, and can create habitat similar to what has been lost to erosion and human practices. With proper management, areas like Poplar Island may become areas of concentration for species such as terrapins, thus becoming source populations for the recovery of terrapins throughout the Bay.

The Poplar Island FMD identifies three purposes for the terrapin monitoring program. The first purpose is to quantify terrapin use of nesting and juvenile habitat on Poplar Island, including the responses to change in habitat availability throughout the progression of the project. The current monitoring program is detailing widespread use of the island by terrapins, evidenced by a comparable number of nests found relative to mainland sites in the Patuxent River as well as the recovery of several marked individuals in our mark-recapture study. The second purpose is to evaluate the suitability of the habitat for terrapin nesting through determining hatchling viability, recruitment rates, and sex ratios. The high nest success and hatching rates on Poplar Island indicate the island provides high quality terrapin nesting habitat, albeit limited in availability because of the rock perimeter dike around most of the island. The third purpose is to determine if the project is affecting terrapin population dynamics by increasing the amount of juvenile and nesting habitat on the island. During 2012, OU researchers initiated the first intensive trapping in wetland cells (funded by MD-DNR) and recaptured large numbers of both headstart and wild hatchlings that originated from Poplar Island. Furthermore the discovery of nests and nesting females on the dikes around completed wetland cells indicates that terrapins are using and this newly created habitat.

The Poplar Island FMD also identifies three hypotheses for the terrapin monitoring program. Hypothesis one is that there will be no change in the number of terrapin nests or the habitat used from year to year. During 2012 researchers discovered 200 nests, which is not statistically different from the mean of 207 nests per year supporting this hypothesis. Hypothesis two states that nest survivorship, hatchling survivorship, and sex ratio will not differ between Poplar Island and reference sites. This hypothesis is rejected as nest success and hatchling survivorship is much higher on Poplar Island because of the lack of major nest predators, and the sex ratio of hatchlings on Poplar Island is highly female biased. Hypothesis three states that there will be no change in terrapin population size on Poplar Island; particularly within cells from the time the cells are filled, throughout wetland development, and after completion and breach of the retaining dike. The status of this hypothesis remains undetermined as there is not enough data currently to form a conclusion.

## RECOMMENDATIONS

Terrapin nesting is expanding on Poplar Island as wetland cell completion creates both access to and availability of nesting habitat. The discovery of nests on the dikes of Cells 3D, 4D, 1A, 1B, and 1C indicate that female terrapins are entering wetlands and using them as access routes to nesting areas. Researchers have frequently noted terrapins inside wetland Cells 4D and 3D. Although the dikes around the new wetland cells, particularly Cell 3D,1A, 1B, and 1C, are sufficiently elevated for terrapin nesting, the amount of nesting activity could potentially increase if open sandy areas were created strategically near inlets and open water within the cells. Particularly, the terminal ends of the cross dikes that lie between Cells 1AB and 1BC could attract terrapin nesting because of their proximity to the channels (Figure 6). OU researchers recommend supplementing sand and maintaining open areas that could attract nesting females to these areas. As the nesting beach outside Cell 3AC continues to decrease in size and the vegetation continues to increase in the Notch and outside Cell 5, the amount of accessible high quality nesting habitat is decreasing. The accumulation of sand in the Notch during 2010-2012 has created open sandy habitat that was heavily used by terrapins during the 2012 nesting season, indicating that the availability of open sandy habitat can enhance terrapin nesting activity on the island. The outcome of this natural experiment and the vegetation removal experiment suggest that short and long-term measures can be taken to improve nesting habitat and thereby increase nesting on the island, particularly as the terrapin population expands.


**Figure 6. Aerial photo of the cross dikes between Cells 1A/B and B/C (still under construction) highlighting potential nesting areas that could be expanded and maintained vegetation free with minimal danger of erosion.**

The northeast expansion of Poplar Island provides an opportunity and the recommendation to create dedicated terrapin nesting habitat in the sheltered areas of Poplar Harbor between Poplar Island and Jefferson Island. In particular, areas to be built to the northeast of Jefferson Island would be ideal for creating terrapin nesting habitat. The creation of these nesting areas could help offset the natural loss of nesting habitat that has occurred on the outside of Cell 3C in recent years. Although this area of the expansion is proposed to be an upland cell, the creation of offshore bulkheads and backfilling of sand as illustrated in Figure 7 could provide a large amount of terrapin nesting habitat in an area where terrapins have been captured in high concentrations. Building structures such as those illustrated in Figure 7 on the outside of the barrier dike would preclude the need to build additional fencing to prevent turtles from getting into the cells under construction. Furthermore, nesting areas without marsh and beach grasses could be provided for terrapin nesting habitat within the cells under construction. 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 cells under construction to find suitable, open areas.

Predator control on the island will be paramount to the continued success of terrapin recruitment and therefore, continuation is recommended. The continued lack of raccoon and fox populations will maintain the high nest survivorship observed in 2002 through 2012. At this time it is uncertain if the nest predation by mice will continue to decrease nest survival in Cell 5. Researchers will continue to monitor nesting and predation in this area and if necessary implement a trapping program to reduce the mouse population in future years. At this time researchers are unaware of a successful non-lethal method to reduce the mouse population. The high nest success due to screens placed over the nests is an effective

**Figure 7 – Shoreline stabilization and the creation of terrapin nesting habitat in Calvert County Maryland – Red dots indicate terrapin nests.**

mechanism to reduce crow predation. A sustained program to eliminate mammalian predators and prevent avian predation will facilitate continued terrapin nesting success on Poplar Island.

Researchers also recommend the continuation of terrapin nesting monitoring on Poplar Island. The area of newly deposited sand in the Notch with little vegetation creates a natural experiment that will allow us to evaluate how the creating new nesting areas may benefit nesting activity on the island. Furthermore, continuation of the experimental removal of vegetation in parts of Cell 5 and the Notch as a mechanism to increase nesting densities where it has declined in recent years is recommended. Additionally, continued monitoring will document the further expansion and use of terrapin habitat on the island (the purpose of this monitoring as listed in the FMD). During 2012, the first nests in Cell 1C and Cell 1B were discovered after these cells were opened to tidal flow, thus allowing access to nesting sites within those cells. OU researchers plan to continue to include additional cells into the nesting surveys as the wetland cells are completed.

Finally, researchers recommend the continuation of the head-start/education program. The terrapin is an excellent ambassador for the island because of its charismatic nature, but also because the project has successfully created habitat for this species. Thus the terrapin education program is an extremely effective mechanism to teach about Poplar Island and its environmental restoration. The message that terrapins provide is not only absorbed by K-12 students, but by all visitors to the island and therefore is an invaluable tool to promote Poplar Island. These five recommendations offered by OU will contribute to continuing and increasing public and scientific understanding of the effect of Poplar Island on terrapin populations and promotes their use as stewards for Poplar Island.

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