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High Conservation Value of an Urban Population of a State-Endangered Turtle

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Abstract: Although reports of urban populations of amphibians and reptiles are increasingly common, the viability of such populations and information on threats to their continued existence remain less well known. From 2010–2018, we studied the nesting ecology of the imperiled Northern Map Turtle (*Graptemys geographica*) in an urbanized area in northeastern Maryland, USA. Mark-recapture data showed an estimated population size of 32 females with an annual survival of 89%. Females nested in highly altered areas such as flower gardens, along railroad rights-of-way, and along fence lines, but nest survival was much higher than in nearby natural areas, mainly due to very low predation rates from Raccoons. However, nesting females were subject to considerable disturbance from vehicle and foot traffic while nesting. To alleviate disturbance, we partnered with the town to construct a wildlife exclusion fence designed to isolate nesting Map Turtles from human disturbance. Due to the high annual survival of nests, this urban population may be important in the overall viability of Northern Map Turtles in this area.

Keywords: turtles; *Graptemys*; urban; nesting; reproduction; population viability; population size

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1. Introduction

The decline of turtle populations world-wide has been well-documented and shows little signs of abating [1,2]. Causes for reported declines of specific taxa include climate change, the predation of eggs by subsidized predators, pollution (e.g., plastic bags), and over-harvesting for the pet and meat trade [3–5]. Because virtually all aquatic turtles use separate terrestrial habitats for nesting, habitat alteration can especially impact reproductive females and their nests, as females may be forced to use highly altered areas for nesting that expose them to potential mortality from cars and subsidized predators, as well as to disturbance that prevents successful nesting [6–8].

Given this susceptibility to habitat alterations, a number of studies have focused on the viability of turtle populations in urbanized areas, where both the nesting (terrestrial) and foraging habitats (aquatic) have experienced changes resulting from anthropogenic sources (see [9,10] for reviews). Although some studies have shown that turtle populations in urban or suburban areas may not be viable [8–11], other authors have suggested that, at least with appropriate management, viability was an achievable outcome [12–18]. For example, Spinks et al. [15] found that imperiled Western Pond Turtles (*Emys marmorata*) on a university campus in California USA had sufficient habitat and protection for adults, but that the lack of nesting habitat limited juvenile recruitment. They suggested that with appropriate provision for nesting habitat, this site could shelter a viable urban population of an imperiled turtle species.

In this study, we report on a long-term study on the nesting ecology and nest success of a population of Northern Map Turtles (*Graptemys geographica*) that utilizes a highly urbanized area for nesting, a riverside town in Maryland known as Port Deposit. We review

the timing of nesting, female population size, habitat use, impact of human disturbance and nest success of Northern Map Turtles nesting in Port Deposit and contrast those data with information collected on Northern Map Turtles nesting in non-urbanized areas. Our emphasis is on the extent to which nesting in this urban area contributes to the viability of the overall Northern Map Turtle population in the Susquehanna River in Maryland.

2. Materials and Methods

2.1. Study Species

The Northern Map Turtle is a widely-distributed species, ranging from southern Canada south to Alabama and northern Louisiana and as far west as Kansas and Oklahoma [19]. Abundant in much of its range, the species faces declines in some areas due to habitat loss, pollution, and commercial collecting [20–22]. In Maryland, Northern Map Turtles are found only in the Susquehanna River and its immediate drainages, between the Maryland/Pennsylvania state line and Chesapeake Bay. Northern Map Turtles in Maryland are considered a state endangered species due to limited distribution and habitat loss (https://dnr.maryland.gov/wildlife/Documents/rte_Animal_List.pdf (accessed on 14 March 2022)).

2.2. Study Area

Data for this study were collected in the town of Port Deposit, Maryland, located in Cecil County, approximately 7.5 km upstream from the mouth of Chesapeake Bay (Figure 1). The town is located on a narrow strip of land approximately 2.2 km in length and 0.19 km in width, bordered on the west by the Susquehanna River and on the east by a high rocky bluff. Total land area (including the bluffs) is 113 ha. A well-travelled state highway (Rt. 222) bisects the town from north to south. The town was incorporated in 1824 but has been developed by humans since the 1700s. As of 2017, the population of the town was about 750 residents, although summer recreation use is high (V. Rinkerman, pers. comm.). Most of the area west of Rt. 222 is used by high-occupancy condominiums, a large marina for boat traffic, and a variety of small businesses. The only undeveloped land is a recreational park (Marina Park on Figure 1) approximately 0.36 km in length on the southern edge of the town.

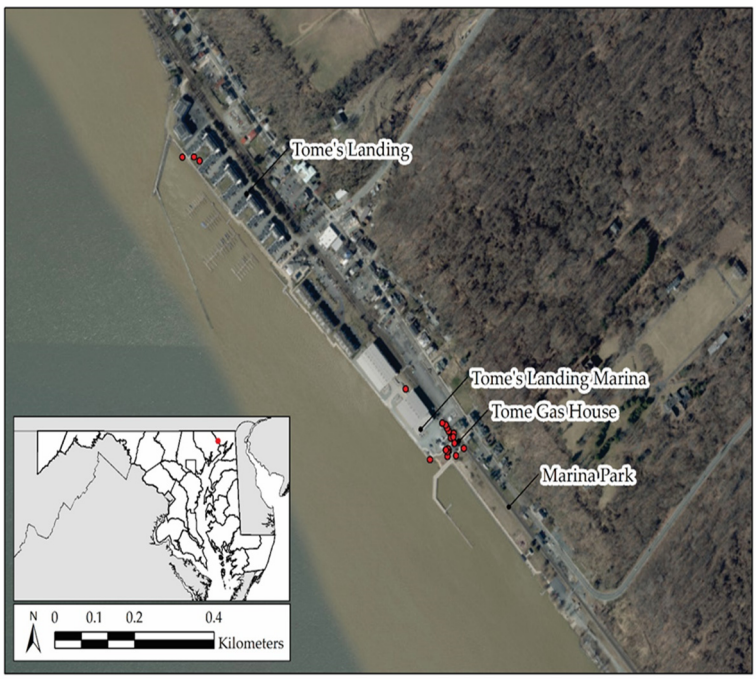

Figure 1. Aerial view of Port Deposit, MD. Red dots show active nesting areas.

The Susquehanna River borders the town on the west and represents the foraging and overwintering habitat for Northern Map Turtles [23,24]. The river is approximately 1.2 km in width adjacent to the town, with a current flow that varies widely with tidal influences from Chesapeake Bay and water releases from the Conowingo Hydroelectric Dam, located 8.0 km upstream of Port Deposit. High water releases from the dam during storm events create periodic high water and flooding in Port Deposit. Conversely, low water releases from the Dam coupled with southern winds and tides can create a reverse flow or slack water near the town. Except for a 10 m wide restored shoreline directly in front of our primary study site (see Figures S1–S3), the entire shoreline of the river in Port Deposit is armored with large rocks and boulders ("rip-rap") and concrete or wood retaining walls.

2.3. Observations of Nesting

We used multiple methods to observe nesting females in Port Deposit. From 2009–2014, nesting females were located and observed by walking survey routes along the strip of land between the Susquehanna River and Rt. 222 in the vicinity of the Tome Gas House and nearby condominiums. Surveys were conducted at arbitrary intervals and frequencies from mid-May through mid-July. In addition, local residents sometimes observed a nesting female and alerted us to its presence. More intensive observations were conducted starting in 2015, when we used a wildlife blind located at the southern corner of the Gas House to observe nesting females. The blind was manned 5–7 days per week, 6–12 h per day from 20 May–26 July. Observations from the blind were supplemented by video recordings made using multiple GoPro (Hero 4) video cameras set up along the shoreline of the Susquehanna River and in areas near the Gas House not easily visualized from the wildlife blind. From 2017–2019, observations were made primarily using cameras, GoPro cameras in 2017 and four Day 6 Plotwatcher Pro Model TLC-200-C game cameras in 2018–2019, supplemented by observations made from a renovated Gas House, which has a balcony designed to allow visualizations of the nesting areas without the need of a blind. Cameras were set to record time-lapse images from 30 min before dawn to 30 min after dusk each day and were deployed from 20 May–20 July in 2017 and 2019.

2.4. Handling and Marking

Females found excavating nests or found heading away from the Susquehanna River were observed from a distance until nesting was completed or until they attempted to return to the river. Turtles not actually observed nesting were either inspected for the presence of oviductal eggs either by manual palpation or by the use of an ultrasound imaging unit (Medison SonoVet 600). All unmarked turtles were given an individual mark by notching or drilling marginal scutes [25]. Except for individuals marked within the past 30 days, all turtles were measured for straight-line carapace (SCL) and plastron length (SPL) using tree calipers accurate to 0.5 cm and weighed using a Pesola balance accurate to 5 g. All adults were released at the site of capture within one hour.

During focal studies in 2015, five freshly dug nests were equipped with temperature probes but were otherwise left undisturbed. In most years, a small florescent flag was left 1 m away from the nest to facilitate location and a GPS reading was taken as well. After about 60–80 days, we covered nests with small-mesh hardware cloth to prevent hatchlings from emerging from the nest, which typically occurs during the following spring. Once hatchlings emerged in the spring, they were processed as above, except that we used dial calipers for length measurements (0.1 cm accuracy) and either an electronic or spring balance for mass (0.1 g accuracy). From 2012–2015, hatchling were marked using VIE tags [26]. Hatchlings in other years were unmarked. Hatchlings were released within 1 m of the edge of the Susquehanna River adjacent to the Gas House, generally within two hours of capture.

2.5. Population Size and Survival

We used the POPAN formulation within Program MARK [27] to estimate the size of the nesting population and female survivorship rates under a Cormack–Jolly–Seber open population model. Parameters were survival (Phi), recapture probability (p), probability of entry (pent), and population size (N). We binned capture histories from each year into a single binary value of 0 or 1 to form encounter histories. For example, an individual captured in 2009, 2012, and 2014 received an encounter history of 10101. We then used the corrected Akaike's Information Criterion (AICc) to rank the models and used model averaging to produce parameter estimates from the models whose AICc weight was greater than 0.01. We removed models that failed to converge from the model-averaging process. We used Program Release within Program MARK to test the fit of our data to the assumptions of the Jolly–Seber models. Although our power was low due to small sample sizes, these goodness-of-fit tests showed no evidence that there were violations of the assumptions of the Jolly–Seber models.

3. Results

3.1. Timing of Nesting, Nesting Effort, and Population Characterization

Nesting attempts were documented in all years of the study. The earliest nesting event was observed on 22 May 2015 and the latest on 18 July 2017. These dates are comparable to the timing of nesting seen at a nearby non-urban ("natural") sites located several km upstream of Port Deposit (exact localities obscured deliberately due to concerns regarding illegal collection).

Between 2009 and 2018, we processed 21 individual female Northern Map Turtles nesting or attempting to nest at Port Deposit. Seventeen individuals were found in the immediate vicinity of the Gas House and four were found nesting or attempting to nest 0.34 km upstream near a series of condominiums. One female was found at both sites. These 21 females were captured a total of 82 times from 2009–2015 and 2017–2018. Numbers of captures per female ranged from 1–14. Females were found nesting in 1–7 years; 10 females were found only in a single year, two in two separate years, three in three years, two in four years, three in six years, and one female was found nesting in seven of the nine years of the study. Of the ten females that nested in only a single year, three were from 2015–2018, where there were fewer chances for nesting in multiple years. Mean clutch size of 11 intact nests was 9.0 $\pm$ 0.60 eggs. Two females laid at least three clutches (one each in 2014 and 2015), but our data on multiple clutches are limited at Port Deposit.

Numbers of nesting females found per year ranged from 2–11 (Table 1). Using data only from 2012–2015 and 2017–2018 (when we had the highest sampling effort), the mean number of individual females found nesting per year was 7.5 $\pm$ 0.76 (SE). Numbers were fairly consistent among those six years of sampling (range = 5–10/year).

Table 1. Numbers of individual nesting females found in each year of the study, the number of nests located, and the predation rate and nest success of those nests. Nest success is defined as the percent of nests that had at least some successful hatchlings emerge. Lower numbers of females in 2009–2010 are likely due to limited sampling effort in those years.

Year	No of Females	No of Nests	Predation %	Nest Success
2009	3	-	-	-
2010	2	-	-	-
2011	4	5	0%	100%
2012	7	4	0%	100%
2013	9	8	0%	100%
2014	6	7	0%	100%
2015	11	8	0%	50%
2017	8	2	0%	100%
2018	7	6	0%	100%

Using only data from a female's first capture, mean female SCL was 236.2 ± 3.51 mm and mean body mass was 1704.5 ± 89.18 g. There was a pattern of smaller females nesting later in the study; there was a negative correlation between the date of first capture of an individual female and body size (Figure S4; r = −0.50, $p < 0.05$), suggesting we saw more smaller females as the study progressed. We interpret these females to be females nesting for the first time at the site.

3.2. Population Size and Survival Estimates

Using Program RELEASE within MARK, we detected no significant variation from the model assumptions, although sample sizes were small and the power was low. Table 2 shows the competing models, two of which had identical AICc values. We used the model averaging function that combines the results of all of the models with an AICc weight that summed to one. This resulted in an estimated population size of 32 female turtles nesting at Port Deposit (95% CI = 22–42 individuals) and an estimated apparent annual survivorship of 89% (95% CI = 79–95%).

Table 2. Models of survival and population size for female Northern Map turtles using the POPAN function in Program MARK. Models with the lowest AICc values and highest AICc weights were selected as the best-supported models. Parameters (Para) followed by (t) denote time varying estimates, whereas parameters followed by (.) denote time constant estimates. Model Likelihood was 1.000 for the first two models and 0.0000 for the remaining four models.

Model	AICc	DeltaAICc	AICc Wt.	#No of Para.	Deviance
{Phi(t)p(.)pent(.)N(.)}	4332.6402	0.0000	0.5000	11	4188.9071
{Phi(t)p(.)pent(.)N(t)}	4332.6402	0.0000	0.5000	11	4188.9071
{Phi(t)p(.)pent(t)N(.)}	4356.2622	23.6220	0.0000	18	4186.0426
{Phi(t)p(.)pent(t)N(t)}	4356.2622	23.6220	0.0000	18	4186.0426
{Phi(.)p(.)pent(.)N(.)}	7113.1043	2780.4641	0.0000	4	6988.5869
{Phi(.)p(.)pent(.)N(t)}	7113.1043	2780.4641	0.0000	4	6988.5869

3.3. Nest Location and Success

We identified 36 nests within the town limits of Port Deposit between 2009–2018. A total of 29 of these were in the immediate vicinity of the Gas House and seven were located 0.34 km upstream adjacent to a series of riverside condominiums. Most females came on shore along the beach in front of the Gas House, crossed into the gravel parking lot of the Tomes Landing Marina, and moved along the chain link fence separating the Marina from the adjacent railroad tracks (Figure 2). Females often moved laterally along these tracks, usually digging a nest on one side of the fence, but sometimes immediately underneath the fence. Table 3 shows the numbers and distances from water for 23 newly constructed nests found during the period when we made the most intensive focal observations of nesting females (2013–2015). These nests ranged from 1–62 m from the water, with the majority of nests (12 of 23) dug between 30–60 m from the river. The shorter distance from water seen in 2015 was a consequence of a silt fence placed around the perimeter of the Gas House to prevent turtles from moving onto the railroad tracks and adjacent marina.

We monitored 17 of these nests for predation and eventual nest emergence. Only one nest was found predated during our study (6% of total). Of the 16 nests followed for emergence, all but one nest emerged the following spring, with emergence dates ranging from 30 April–11 June. Only one nest emerged in the late summer, and this nest was disturbed by human residents some weeks after egg deposition. The mean SCL of 93 viable hatchlings from these nests was 30.9 mm (±0.5 SE) and the mean BM was 6.6 g (±0.3 SE). Based on a mean clutch size of 9.0 eggs/nest (see Section 3.1), this gives an overall emergence success of 64.6%.

Figure 2. Photo of Gas House: nest locations shown in red, exclusion fence in yellow.

Table 3. Distance (m) between nest sites and the closest entrance to the Susquehanna River for Northern Map Turtles at Port Deposit from 2013–2015. Means shown ±1 SE in last row. There were significant differences among the three years, with 2015 having the shortest distances from the water (Kruskal–Wallis test = 6.35, $p = 0.04$).

2013	2014	2015
1.06	62.4	19.0
31.6	7.6	19.6
47.9	14.7	22.0
50.4	41.9	22.1
59.7	59.7	23.2
53.8	40.5	4.3
57.4	60.3	9.5
52.9	-	18.0
Mean: 44.3 ± 6.88 m	41.0 ± 8.43 m	17.2 ± 2.38 m

3.4. Disturbances from Residents and Visitors

Given that the primary nesting grounds in Port Deposit are adjacent to an active marina and highly occupied condominiums, disturbance by humans was common in our study. During focal studies in 2015, we found that 33% of nesting attempts were aborted by turtles disturbed by humans while turtles were attempting to nest. We were careful to only count a turtle as "disturbed" if there was a clear proximate link between human activity and turtle behavior. Most of these disturbances represented humans simply walking within about 15–20 m of nesting areas and generally did not appear to represent a deliberate act by humans. Some disturbances were more serious in nature, including almost being run over by delivery trucks or passenger vehicles. Some females became disoriented enough by the fencing and concrete abutments adjacent to the railroad tracks to abandon their nesting attempts and/or to be unable to find their way back to the river without our intervention. For example, a female on 2 June 2013 was on land for almost six hours without nesting,

apparently unable to navigate back to the river due to human-made obstructions. We eventually captured this female and released her in the river.

4. Discussion

4.1. Persistence of a Nesting Population in an Urban Environment

Turtles in urban environments are generally considered to be under significant pressure from anthropogenic sources, including, but not limited to, road mortality, collecting for pets, pollution, altered thermal environments, and the presence of dense populations of subsidized predators [6,10,11,28–30]. However, a few studies have found that turtles in such environments can persist and even appear to be viable over long time periods (e.g., [12–15]). In the current study, we found that a modest-sized (N = 32 females) population of Northern Map Turtles has successfully nested for over a decade in a highly urbanized environment. This population displays adult annual survival rates (89%) that are at least comparable to those in other *Graptemys* populations [31–33] and also shows much lower rates of nest predation than seen in nearby nesting areas for this species in Maryland (unpublished data).

Northern Map Turtles are known to utilize a wide variety of nesting habitats [34,35], but sandbars are the most commonly used habitat in most locations [20]. Indeed, the most intensively used nesting habitat for Map Turtles in Maryland is a relict sandbar several km upstream of Port Deposit, where as many as 140 nests have been found in one year (unpublished data). Thus, nesting by a state-endangered turtle in the midst of a heavily altered urban area presents two questions: (1) why do Map Turtles persist in nesting in an urban area where they are subject to behavioral disturbances by humans, and (2) does this nesting population have any significant conservation value for this state-endangered taxa?

The riverside areas in Port Deposit have been developed and used by humans since at least 1812 for purposes including cargo storage, rock quarrying, natural gas storage, the construction of prefabricated highway tunnels, a commercial marina, and high-density condominiums (https://www.portdeposit.org/history (accessed on 14 March 2022). Despite the extensive historic and current human development of this site, a nesting population of Northern Map Turtles has persisted at Port Deposit during the duration of our study, and, based on interviews with local residents, for some years before our study began. Given that (1) >50% of 21 females have returned to nest at Port Deposit in multiple years (some at least seven times over a ten-year period), and that (2) less-disturbed nesting sites are found within 8 km of Port Deposit (B. Durkin, unpublished data), it seems likely that females at Port Deposit have high fidelity for this site, despite the high levels of human activity and habitat alteration. This idea is supported by radio-telemetry data from 2009–2011, which showed only one female nested both in Port Deposit and other, more natural areas (T. Richards Dimitrie, unpublished data). In 2011, after being disturbed in Port Deposit during nesting attempts three times over a 4-day period, Female #23 nested on one of the in-river islands. Continued disturbance in the town could have forced nesting at another site [36]. The female returned to nest in Port Deposit in subsequent years. Thus, nesting females appear to show high levels of nesting site fidelity despite ongoing human disturbance. Finally, as our study progressed, we found smaller females nesting at Port Deposit (Section 3.1). This suggests that first-time nesters were using the Port Deposit area, despite ongoing human disturbance.

The simplest explanation for persistent nesting at Port Deposit is natal imprinting, a behavior known to occur in other species of *Graptemys* [36]. However, such behaviors cannot be demonstrated via mark-recapture in our population, so this remains speculation.

4.2. Importance to Population Viability

Northern Map Turtles are listed as endangered in Maryland, and our population estimates suggest a maximum of about 250–300 adults between the Pennsylvania state line and the mouth of the Susquehanna River (unpublished data). With such a small total population, successful reproduction and recruitment is clearly critical. In addition to Port

Deposit, Northern Map Turtles nest at multiple sites downstream of the Conowingo Dam, most predominately on a sandy depositional area upriver of Port Deposit and on islands in the Susquehanna River (Seigel, unpublished data). Observations on these sites have shown much larger numbers of nests than seen at Port Deposit, >35 nests/year on islands, and >140/year at the sandy depositional site (B. Durkin, unpublished data). However, nest success at both sites is much lower than at Port Deposit, with both sites showing high predation rates (>90%) from Raccoons (*Procyon lotor*) and extensive river flooding resulting in high overwinter mortality (B. Durkin, unpublished data).

In contrast to these sites, we have seen no nest predation at Port Deposit in six of the seven years for which we have data, with the predation rate in the remaining year at only 12.5% (Table 1). Nest emergence is also higher at Port Deposit (64%) compared with the nearby natural site, despite nesting in highly altered soils that have been compacted by human activities. This may be due to no mortality from flooding at Port Deposit, something seen commonly at the nearby natural site (B. Durkin et al., in prep.) Thus, although the total number of nests per year at Port Deposit is low compared with other sites in Maryland, the absence of predation means that a substantial proportion of the nest success in the lower Susquehanna River is concentrated at this urban site.

4.3. Constraints of Nesting in an Urban Environment

Although the Port Deposit nesting site appears to evade most of the causes of nest failure seen elsewhere in the Susquehanna River (predation and flooding), there are also some negative issues resulting from nesting in a developed environment. The fact that nesting females often cross a parking lot in an active commercial marina and then nest in an area open to considerable foot and vehicular traffic means that turtles are subject to constraints not seen in other more natural areas. This includes disturbance from humans while attempting to nest, and potential mortality from both vehicles and being blocked from returning to the river following nesting. In addition, a total of five hatchlings from nests not covered with a nesting cage have been found dead in the marina parking lot, either from being desiccated by not reaching the river, stepped on by humans, or run over by cars. Since 2008, one gravid female has been found dead on the road north of the town.

In order to alleviate some of these issues, we erected a wildlife exclusion fence in 2015 that surrounds the immediate area of the Gas House (Figure 2, yellow line). Originally constructed using highway silt fencing and now made of metal bars wrapped in narrow-mesh hardware cloth and privacy netting (Figure 3), this fence is designed to prevent females from accessing the marina parking lot and adjacent railroad track. This concept is similar to the approach taken by Nagle and Congdon [35] to prevent road mortality in a population of *G. geographica* in central Pennsylvania. This fence has been at least partially successful, as shown by the change in distance from water of nests located in 2015 (Table 1), which reflects the inability of many females to nest beyond the fenced area. In addition, the current fence (wrapped with dark mesh netting) has been largely successful in reducing human disturbance to an effective zero. Data on the overall effectiveness of this wildlife exclusion fence are still being collected as of this writing and will be reported elsewhere.

4.4. Comparisons with Other Populations

In most respects, the Port Deposit population is similar to other populations of *G. geographica*, at least those in the northern portion of the range (see [13] and references therin). For example, our average clutch size (9.9 eggs/clutch) is close to that found in central Pennsylvania (10.6 eggs) and Missouri (10.1), although lower than clutch sizes in Quebec (12.7) and Ontario (13.2 eggs), and from a nearby natural area in Maryland (14.7). Our observations of apparent multiple clutches in at least some females and overwintering of eggs are also consistent with other populations of this species [13]. Our estimate of female annual survival (89%) is also similar to the 87.3% survival seen in females from Ontario [32].

Figure 3. Wildlife exclusion fence erected around nesting grounds at the Gas House to separate nesting turtles from human disturbance.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d14050354/s1, Figure S1: Map Turtle nesting beach prior to reconstruction; Figure S2: Reconstruction of Map Turtle nesting beach as a Living Shoreline; Figure S3: Map Turtle nesting beach following reconstruction. Figure S4: Correlation of date of study versus body size of nesting females.

Author Contributions: Conceptualization, B.P.D., T.M.R.-D. and R.A.S.; methodology, B.P.D., T.M.R.-D. and H.J.H.; formal analysis, B.P.D., H.J.H. and R.A.S.; writing—original draft preparation, R.A.S.; writing—review and editing, B.P.D., T.M.R.-D., K.P.A. and H.J.H.; field data acquisition, B.P.D., T.M.R.-D. and K.P.A. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: All handling procedures were approved by the Towson University IACUC Committee (IACUC 06612 RS-01 and renewals). State permits for handling Northern Map Turtles were provided by the Maryland Department of Natural Resources (Endangered Species Permit #53959).

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to the protected status of this species in the state of Maryland.

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