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Nest Counts and Hatchling Emergence Timing for the Spiny Softshell (*Apalone spinifera*) and Associated Turtle Species at Managed Sites in Vermont, USA

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Abstract.—**The Spiny Softshell (*Apalone spinifera*) is state-listed as Threatened in Vermont and the focus of a long-term monitoring and management project to enhance nesting outcomes. We protected nests of the Spiny Softshell and three associated turtle species at communal nesting sites in Vermont over an 11-y period. Nesting sites were enhanced by vegetation and substrate management, including raising the elevation of areas prone to flooding. We protected nests by fencing, trapping of mammalian predators, and covering nests with wire mesh. We documented the number of successful nests, number of hatchlings that emerged, and emergence timing for all four associated species, and we compared outcomes between sites and among turtle species. Metrics of Spiny Softshell nesting increased during the study period including nests that produced at least one live young and the number of hatchlings that emerged. Nest depredation was an ongoing challenge, but over 85% of Spiny Softshell nests at our largest site were successful and the number of hatchlings emerging increased from 150 to over 1,000 annually. Prior to this study, the only turtle species documented in Vermont to regularly overwinter in its nest and emerge in the spring was the Painted Turtle (*Chrysemys picta*), but here we present evidence that the Northern Map Turtle (*Graptemys geographica*) regularly overwinters in the nest in Vermont. Neither the Spiny Softshell nor the Snapping Turtle (*Chelydra serpentina*) were documented to overwinter in their nests as hatchlings and emerge the following spring.**

Key Words.—depredation; emergence; Graptemys geographica; nesting; Northern Map Turtle; overwintering; wildlife management

Introduction

The Spiny Softshell (*Apalone spinifera*) has a wide range in North America from southern Ontario and the Great Lakes to the Gulf of Mexico, and east to South Carolina and Georgia, with disjunct populations in Montana and Wyoming and in southeastern Ontario, Québec, and Vermont (Ernst and Lovich 2009). Although the Spiny Softshell has an International Union for Conservation of Nature status of Least Concern and a stable population trend overall (van Dijk 2011), the population in Québec, Canada, and Vermont, USA, is restricted to northern Lake Champlain and is not secure (Galois et al. 2002). The Spiny Softshell in Canada was designated Endangered in 2016 (Committee on the Status of Endangered Wildlife in Canada [COSEWIC] 2016). Thompson (1853) and Babbitt (1936) provided early accounts of the Spiny Softshell in Vermont. At present, two distinct Spiny Softshell populations remain in Lake Champlain, generally centered on the lower Lamoille River of Vermont and Missisquoi Bay in Vermont and Québec. The Spiny Softshell is not native elsewhere in New England.

The Spiny Softshell was listed as Threatened in Vermont in 1987 due to its decline, small population size, and unmitigated threats. Recommended actions listed in the Vermont Eastern Spiny Softshell Recovery Plan include protecting nesting habitat and enhancing nesting success (Vermont Fish and Wildlife Department. 2009. Available from https://vtfishandwildlife.com/node/1633 [Accessed: 27 July 2020]). In the years preceding this study, nest depredation of all turtle nests we surveyed was severe. We recorded a depredation loss of about 155 nests at our largest nesting site (Site A) in 2003, including all 38 documented Spiny Softshell nests. (unpubl. data). We designed our management program to reduce nest depredation.

We investigated nesting and hatchling turtle emergence in the context of our long-term management project (Fig. 1) and our ongoing effort to document Spiny Softshell nests. The live Northern Map Turtle (*Graptemys geographica*) hatchlings in the overwintering posture shown in Nagle et al. (2004) following a late October depredation event prompted us to initiate monitoring to detect overwintering hatchlings. Understanding hatchling emergence patterns is

FIGURE 1. Spiny Softshell (*Apalone spinifera*) hatchlings emerging from nest, Site A, Vermont, USA.

important to the conservation of turtles and may help us address impacts from climate change (Gibbons 2013). The timing of hatchling turtle emergence from their nests and differences among species and nests has been the focus of research because of its implications for turtle conservation (Gibbons and Nelson 1978; Gibbons 2013; Lovich et al. 2014; Riley et al. 2014). Delayed emergence (referred to as overwintering in temperate areas) appears to be a viable option, if not the norm, for many species of turtles based on reports for 43 species from 11 countries and 36 U.S. states and Canadian provinces (Gibbons 2013).

Parren and Rice (2004) provided evidence of Painted Turtle (*Chrysemys picta*), Snapping Turtle (*Chelydra serpentina*), and possibly Wood Turtle (*Glyptemys insculpta*) hatchlings overwintering in their nests in southern Vermont, but this was based on one year with unusually favorable conditions for surviving the winter in the nest. Our long-term conservation project for Spiny Softshells provided the opportunity to gain a better understanding of nesting and the timing of hatchling emergence for four turtle species in Vermont. Herein we describe our turtle nesting site management procedures, monitoring results, and the timing of hatchling turtle emergence, with the goal to recover and delist Spiny Softshells from the Vermont Endangered and Threatened Species List (Vermont Fish and Wildlife

FIGURE 2. North-facing and west-facing beaches and gravel parking area (highlighted in yellow) of Site A used by nesting turtles, Vermont, USA.

Department. 2009. *op. cit.*). Our management emphasis was to suppress mammalian depredation of nests and improve nesting habitat.

MATERIALS AND METHODS

Study sites.—We collected nesting and hatchling data at two turtle nesting beaches along the shoreline of Lake Champlain in northwestern Vermont, USA, which drains north through the Richelieu River to the St. Lawrence River. Site A is located on the shore of Missisquoi Bay, 4.3 km south of Québec, Canada (Vermont Element Occurrence ID# 6416). Site B is located 6.4 km south of Site A (Vermont Element Occurrence ID# 3773). Site A is owned by the Vermont Fish and Wildlife Department, and Site B is owned by the Vermont Forests, Parks, and Recreation Department. Both sites have shale pebble beaches, containing a mixture of flat rounded pebbles, smaller gravel, and sand. Site A has both north- and west-facing nesting beaches, and an old gravel parking area adjoining a vacant building (Fig. 2). Site B had only a north-facing beach. Both sites are classified as Lake Shale Beach, with Green Ash (*Fraxinus pennsylvanica*) and Cottonwood (*Populus deltoides*) trees, willow (*Salix* spp.) shrubs, and herbs such as Indian Hemp (*Apocynum cannabinum*) and Clammyweed (*Polanisia dodecandra*; Thompson et al. 2019).

Nest monitoring.—We monitored Spiny Softshell and Map, Painted, and Snapping turtle nests and hatchling emergence from mid-August through October and sometimes into early November, and again in late March through early June, from 2006–2017. All reported observations occurred during this 11-y period unless otherwise noted. We chose this period because it was when we implemented both monitoring and management in a consistent manner. We visited sites three times per week during late summer/fall and at least once per week in the spring. We were on site at least weekly for predator monitoring during the summer, which allowed us to detect the onset of emergence. In the spring we considered snow cover, cloud cover, and air temperature before first visiting in March or early April to look for evidence of emergence or nest depredation. If spring flooding was threatening nesting substrate or predator activity was detected, we conducted monitoring more frequently. We found nests with turtle emergence by looking for surface disturbance due to hatchling activity that left an emergence hole, shale substrate collapse forming a depression, or a swirl of shale pebbles. We also examined nests disturbed by mammalian predators by noticing a surface scrape, partial depredation, or full removal of nest contents to the surface. We only included nests that had evidence of emergence activity and were not disturbed by a mammalian predator nor dug by accident (no surface disturbance but adjacent to another nest) in the analysis of early emergence and overwintering. We determined nesting outcomes by counting all nest contents (i.e., shells, infertile or spoiled eggs, intact eggs, dead and live embryos, dead and live hatchlings). We collectively refer to all surviving embryos and hatchlings found in nests, as well as hatchlings that emerged, as live hatchlings. If a nest was documented to have at least one live hatchling, we considered it a successful nest.

Parasites and nest protection.—We recorded fly larvae or pupae found in a nest as present and removed. In 2013, we collected fly larvae from nests and kept them over the winter to mature. We identified larvae to species.

By 15 May each year, we rolled 2.54 × 5.08 cm welded-mesh wire off the nesting substrate to allow female turtles access to nesting areas. At Site A, we annually covered 817 m^2 of nesting substrate with wire and 418 m^2 at North Hero. We chose the mesh size so hatchling turtles could pass through (Fig. 3). We installed restricted area signs around the perimeter of the nesting areas to discourage human disturbance. We also hung a rope line to establish a buffer on land. Additionally, we installed a 91 cm tall electric mesh fence to discourage mammal access at Site A. The lowest mesh on the electric fence measured 10 cm tall by 20 cm wide and was intended to allow most turtles to pass through the mesh, while still deterring nest predators. The electric fence had warning signs and was held back from the lake itself for safety reasons and adjusted as water levels changed. We extended plastic snow fence into the lake to discourage mammals from moving around the end of the fence, although we did not physically block access from the lake to the nesting sites. We also installed a

Figure 3. Northern Map Turtle (*Graptemys geographica*) hatchling emerging from nest through 2.54 × 5.08 cm welded mesh wire, Site A, Vermont, USA.

172 cm tall non-electrified mesh fence placed 91 cm in front of the electric fence at Site A. The taller fence was intended to prevent access by Red Fox (*Vulpes vulpes*), which could easily jump the lower electric fence, and further discourage access by other predators. In mid-October we removed the electric fence and taller barrier fence at Site A, as well as rope lines at both sites.

Embryos and hatchlings.—We released live hatchlings found in nests if their shells had stiffened and they were active, or held them in captivity until they were active. We transported embryos and intact eggs in opaque plastic tubs. After placing a dot on the top of the shell, we placed eggs and embryos within a layer of shale nesting substrate in the tub, so the dot remained up. Sometimes we stacked layers of eggs with substrate between and over layers. We incubated tubs of eggs and embryos under a full spectrum reptile light at 29° C at the shale surface and we kept them moist but not saturated. We moved hatchlings to a shallow water tray after hatching, which we later released when active.

Site management.—Regular monitoring of substrate disturbance by mammals was the most relied upon method for detecting predator activity. Motion detection cameras were sometimes used to identify predators. We raked out disturbance of the shale substrate by turtles, mammals, and our activity after each visit to make it less likely that a nest predator would be attracted to the nesting sites and to establish a reference for the next monitoring visit. We removed all turtle eggs, embryos, hatchlings, and eggshells found in nests or on the surface, as well as dead fish and other attractants, to reduce the likelihood of mammalian depredation and fly parasitism.

Staff of the U.S. Department of Agriculture Wildlife Services working under a Cooperative Service Agreement with the Vermont Fish and Wildlife Department trapped nesting sites for medium-sized mammalian predators. We also set traps if Wildlife Services staff were not able to address depredation in a timely manner. We initiated trapping each spring at the onset of turtle nesting activity (mid-May) and again at the onset of hatchling emergence (late August or early September). We and Wildlife Services staff typically set box traps (80 × 26 × 30.5 cm, length by width by height) for 5 d. Wildlife Services staff set foot-hold traps only if Red Fox depredation was suspected, and this only occurred one year during the study period. Trapping mammals was authorized by our permit and signs warning people to leash their pets were posted when trapping was being conducted. When we detected mammalian depredation, we conducted additional trapping.

In late October each year, we held a volunteer beach clean-up day to remove herbaceous vegetation starting to cover the nesting substrate. We did this by hand or with small hand tools, being careful not to penetrate the substrate deeply to avoid overwintering hatchlings. Saplings and overhanging tree branches were trimmed or removed. We also removed rocks, sticks, logs, and other debris. We raked out the area and rolled back the wire mesh over the nesting substrate for the winter so it would continue to deter mammalian depredation. We overlapped and twist tied the edges of the wire so they could not be dug by predators. We secured the wire mesh with rocks to keep it in place. We elevated low-lying sections of nesting beach using hand tools to make them more resistant to flooding and responded to one spring flood by rebuilding some sections of nesting beaches that were inundated when turtles were attempting to nest.

Statistical analyses.—We analyzed monitoring data using program R version 3.6.2 (R Development Core Team 2019) and set a significance level of $\alpha = 0.05$ for all statistical analyses. We evaluated data for how well assumptions for parametric tests were met using the Shapiro-Wilk test for normality as well as the Global Validation of Linear Models Assumptions package gvlma to test for normality, linearity, and heteroscedasticity. We used Welch's *t*-tests to compare sites and species for data that met parametric assumptions and Wilcoxon Rank Sum test when assumptions were not met. We compared the percentage of successful nests and live hatchlings that overwintered at Site A compared to Site B for Map Turtles, and we also compared Painted and Map turtle outcomes at Site A. To examine trends in the number of successful nests and hatchlings that survived over time at nesting sites A and B for Spiny Softshell and Map, Painted, and Snapping turtles, we used simple Linear Regression Analysis. We also examined the trend for all nests detected for Spiny Softshells at Site A. Because data for Painted Turtle hatchlings at Site A was skewed, we transformed data using log(x + 1) to meet assumptions of normality for the regression.

Results

Spiny Softshell.—Early emergence of Spiny Softshell hatchlings occurred from 12 August to 17 October and we never documented overwintering. Overall, we found 54% of the Spiny Softshell nests in the north-facing beach and 46% in the west-facing beaches at Site A. We did not find any nests outside the shale beach substrate. The number of successful nests at Site A significantly increased from 11 in 2006 to 74 in 2016 ($F_{1,9} = 45.41$, $b = 5.81$, $r^2 = 0.835$, $P < 0.001$) and the total number of nests found significantly increased from 43 to 78 ($F_{1,9} = 14.51$, $b = 4.52$, $r^2 = 0.618$, $P = 0.004$). The number of live Spiny Softshell hatchlings also significantly increased from 150 to 1,112 ($F_{1,9} = 59.83$, $b = 90.62$, $r^2 = 0.869$, $P < 0.001$; Fig. 4). We documented that 85.4% of Spiny Softshell nests were successful (427 of 500) and 81.3% of eggs in successful nests produced 6,306 live hatchlings at Site A. Our collection of embryos and hatchlings from nest chambers accounted for 15.7% of all live hatchlings. At Site B, the number of successful

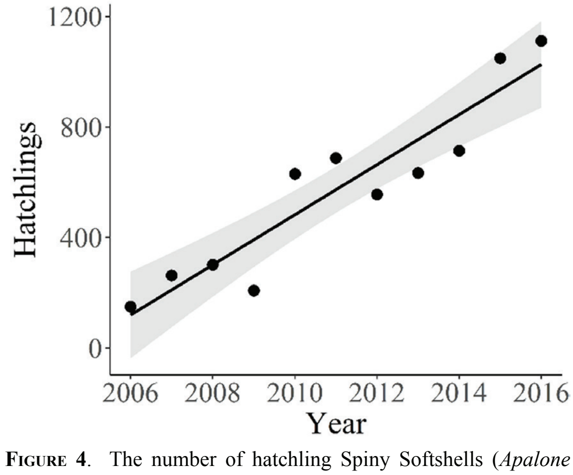

Figure 4. The number of hatchling Spiny Softshells (*Apalone spinifera*) by year documented at Site A, Vermont, USA. Shaded area is the 95% confidence interval and points are live hatchling count data.

nests varied from 0–6 annually and the maximum number of nests documented in any year was only nine. Successful nests did not increase ($F_{1,9}$ = 2.50, P = 0.148). The number of live Spiny Softshell hatchlings at Site B ranged from 0–103 annually and we did not detect a trend over time ($F_{1,9}$ = 0.984, P = 0.347). A total of 35 nests at Site B produced 518 live hatchlings. Of this total, we collected 18.7% of the live hatchlings at Site B from nest chambers.

Snapping Turtle.—We found 28 Snapping Turtle nests that produced 1,130 live hatchlings at Site A and seven nests produced 325 live hatchlings at Site B. Snapping Turtle hatchling emergence was from 22 August to 21 September. We did not document overwintering of hatchlings in the nest. Neither the number of successful nests nor the number of live hatchlings trended significantly over time at Site A ($F_{1,9}$ = 0.004, P = 0.951; $F_{1,9}$ = 0.280, P = 0.610) or Site B ($F_{1,9}$ = 0.298, P = 0.599; $F_{1,9}$ = 0.024, P = 0.884).

Painted Turtle.—Early emergence from Painted Turtle nests occurred from 29 August to 8 October and emergence from overwintered nests from 21 March to 28 May. The percentage of successful Painted Turtle nests that overwintered at Site A varied widely from year to year (0–100%). Annual sample sizes were small (range, 0–5 early emergence nests; 0–9 overwintered nests), but overall we found 57.7% of 52 successful nests overwintered and accounted for 41.6% of the 310 live hatchings. We found most of the overwintered nests at Site A in the old gravel parking area (65.6%), followed by the west-facing beaches (31.3%), and only 3.1% were in the north-facing beach. We found 16 early emergence nests of Painted Turtles at Site B and 86 live hatchlings. We did not find any overwintered Painted Turtle nests at Site B.

Neither the number of Painted Turtle nests ($F_{1,9}$ = 0.985, P = 0.347) nor the number of live Painted Turtle hatchlings at Site A ($F_{1,9}$ = 0.400, P = 0.543) trended significantly over time when combining early emergence and overwintering for each nesting year. At Site B, the number of early emergence Painted Turtle nests declined significantly over time ($F_{1,9}$ = 7.843, b = -0.33, r^2 = 0.466, P = 0.021). The number of successful nests ranged from 0–5 annually.

Map Turtle.—Early emergence from Map Turtle nests occurred from 17 August to 16 November. During late October 2006, nest depredation believed to have been due to a Red Fox allowed us to find 12 Map Turtle nests and 54 live hatchlings that appeared to be prepared to overwinter. Emergence from overwintered nests occurred from 30 March to 4 June. The percentage of overwintered Map Turtle nests at Site A varied widely from year to year (0–65.8%). Annual sample sizes ranged from 9–33 for early emergence nests and 0–52 for overwintered nests. We documented that 44.5% of 411 successful nests overwintered and accounted for 36.9% of the 3,862 live hatchings that we found. At Site A, 81.4% of the overwintered nests were in the west-facing beaches, 10.4% in the old gravel parking area, and 8.2% were in the north-facing beach. The percentage of successful Map Turtle nests that overwintered at Site B varied from 0–40.0% annually. We found that 8.9% of 146 successful nests overwintered and accounted for 3.7% of the 1,456 live hatchings. Annual sample size ranged from 3–23 for early emergence nests and 0–4 for those that overwintered.

The percentage of Map Turtle nests that overwintered was significantly greater at Site A compared to Site B (Z = -2.473, P = 0.013). The percentage of live Map Turtle hatchlings overwintering also was significantly greater at Site A than Site B (Z = -2.972, P = 0.003; Fig. 5). When combining early emergence and overwintering of live hatchlings for each nesting year, the number of successful Map Turtle nests did not differ significantly by year ($F_{1,9}$ = 3.026, P = 0.116), nor did the number of hatchings ($F_{1,9}$ = 2.167, P = 0.175) at Site A or at Site B (nests: $F_{1,9}$ = 1.056, P = 0.331; hatchings: $F_{1,9}$ = 1.279, P = 0.287).

Comparison of Painted Turtle and Map Turtle.—The percentage of overwintered Painted Turtle nests compared to Map Turtle nests at Site A were significantly different (t = 2.437, df = 17.19, P = 0.026). While we found a greater percentage of overwintered Painted Turtle nests, the percentage of live hatchlings that had successfully overwintered was not different between Painted and Map turtles at Site A (t = 0.962, df = 13.45, P = 0.353). We could not make a similar comparison

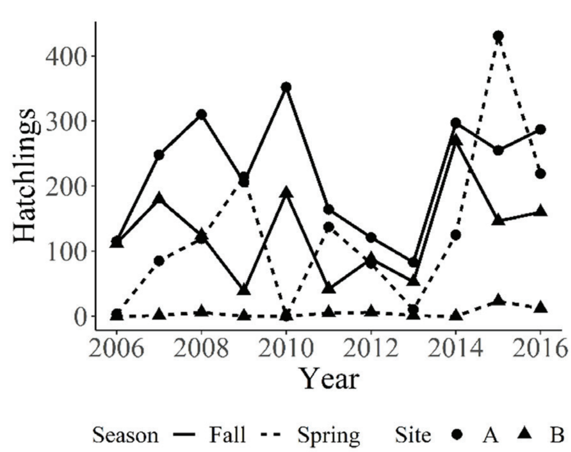

Figure 5. The number of Northern Map Turtle (*Graptemys geographica*) hatchings that emerged by the fall and those that overwintered (spring emergence) at Site A and Site B, Vermont, USA.

between Painted and Map turtles at Site B because we found no overwintered Painted Turtle nests there.

We documented 61 Painted Turtles and 515 Map Turtles that did not survive the winter in nests that had evidence of overwintering. This represents 32.1% of all Painted Turtle and 25.8% of all Map Turtle hatchlings found in the spring. We did find failed nests by accident and documented another 12 dead Painted Turtles and 30 dead Map Turtles in the spring as a result.

Parasites.—All larvae parasitizing turtle nests were a type of flesh fly (*Tripanurga importuna*), except for one specimen of a generalist flesh fly scavenger (*Sarcophaga* = *Robineauella nearctica*). We only detected fly larvae during early emergence. Fly larvae occurred in 14.9% of 228 Map Turtle nests at Site A, 15.8% of 133 Map Turtle nests at Site B, and 18.2% of 22 Painted Turtle nests at Site A. No fly larvae occurred in the 16 Painted Turtle nests at Site B.

Discussion

We documented that the number of successful Spiny Softshell nests and live hatchlings substantially increased at Site A. We learned from our monitoring that mammalian digging of nests can happen after the early emergence period. Spiny Softshell nests were even depredated through snow. We adjusted our management and continued to protect nesting substrate from fall through early spring with wire mesh laid over the nesting substrate, which minimized depredation of overwintering hatchlings, likely discouraging mammals from associating the nesting sites with food, and hopefully lessened the depredation pressure on new nests that would be laid the following spring.

While lake flooding was out of our control, we were able to make some sections of nesting beaches more resistant by building up the elevation of the nesting substrate that was low lying or scoured by wave action. During the spring of 2011, all nesting areas were under water during the beginning of the nesting season. With the help of volunteers, we built up some sections of the nesting beaches at Site A so that they rose above lake level. We noticed both Spiny Softshell and Map Turtles watching us from the lake over several days and each morning when we returned, we could see that the new nesting substrate had been heavily used by nesting turtles. We believe our response to this flooding event was responsible for increasing the 2011 nesting season success at Site A.

Our efforts to manage nesting areas for turtles, including limited artificial incubation of nests found during the early emergence period and captive care, was time intensive but many nests laid by four species likely received protection. Managers of a nearby nesting site in Québec have collected newly laid Spiny Softshell eggs and incubated them in captivity until hatching as a temporary conservation measure (Lazure et al. 2019). We do not believe this is a feasible approach for Vermont due to our large number of nests and the risk of disturbing nesting turtles at concentrated nesting sites. It has been suggested that the frequent presence of humans at nesting sites likely discourages Spiny Softshell nesting (Tornabene et al. 2018), and we have noticed that even careful nest monitoring can sometimes cause Spiny Softshells to leave the nesting beaches.

Overwintering.— Until recently, only Painted Turtle hatchlings were known to regularly overwinter in the nest in Vermont (Parren and Rice 2004). We have now documented that Map Turtle hatchlings overwintered in their nests at two northern Vermont nesting sites. In southern New Hampshire, USA, Carroll and Ultsch (2007) reported that Painted Turtle, but not Snapping Turtle, overwintered in their nests. Snapping Turtles may rarely overwinter in the nest in Vermont (Parren and Rice 2004), but we did not find successful overwintering at the two sites we intensively monitored. Obbard and Brooks (1981) reported on the rare exception of one Snapping Turtle nest successfully overwintering in Ontario. We also did not detect overwintering by the Spiny Softshell.

In Pennsylvania, USA, 95% of Map Turtle nests exhibited overwintering (Nagle et al. 2004) and in northern Indiana, USA, Map Turtles routinely overwintered in their nest (Baker et al. 2003). We documented that the proportion of Map Turtle nests that overwintered varied by year and location in Vermont. We found that many Map Turtle nests at Site A had overwintered compared to only a few at Site B. We found most of the overwintered Map Turtle nests at Site A were in the west-facing beaches, which had better solar exposure. Site B only had a north-facing beach and we found only a few overwintering Map Turtle nests there or in the north-facing beach at Site A. We found overwintering Painted Turtle nests at Site A but not Site B. We found most of the overwintering Painted Turtle nests at Site A in the old gravel parking area, which had good solar exposure and was protected from north winds by an old building. Few were found in the north-facing beach. We believe the different outcomes at these two sites likely reflected areas of warmer nesting substrate at Site A, although we did not collect data to confirm this.

Hatchlings overwintering in their nest are at risk from flooding, dehydration, and exposure to severe cold (Costanzo et al. 2008), and we observed depredation of nests to be a year-round issue in our study. In some cases, winter mortality attributed to spring flooding may be modest (DePari 1996), but the extreme spring 2011 flooding resulted in no detection of overwintering hatchlings. Remaining in the nest lengthened the time hatchlings were at risk of a mammal depredating a nest, yet many did overwinter at Site A. This risk was evident at the end of the 2006 early emergence season when 12 Map Turtle nests were depredated, emphasizing the need to continue to protect nesting substrate from predators after the early emergence season. Despite the risks of remaining in nests until spring, overwintering Painted and Map turtle hatchlings represented an important contribution to the total number of live hatchlings at Site A.

Map Turtles in central Pennsylvania exhibited an overwhelming tendency to overwinter in their nest (Nagle et al. 2004). They speculated that early emergence by hatchlings of some turtle species may be an adaptive response to nest conditions, which would likely provide poor environments for successful overwintering. Others have suggested that if conditions in the nest are not optimal for development, overwintering in the nest may be a passive response to a poor nest environment (Riley et al. 2014). Hatchlings need to be fully developed by the fall, however, to successfully overwinter in their nest (Ultsch 2006; Gibbons 2013). We found both Painted Turtles and Map Turtles that did not survive the winter in nests. We suspected that if all hatchlings in a nest failed to emerge in the spring, we were unlikely to detect and document that nest; however, we did find a small number of failed nests in the spring. We believe we may have overlooked more Painted Turtle nests than those of other species due to the smaller size of hatchlings, and in some cases, smaller clutch sizes, which reduced the amount of disturbance to the substrate when hatchlings emerged.

Fly larvae in turtle nests are most likely to infest a nest at hatching and preferentially scavenge necrotic tissue, including damaged turtle eggs, but will opportunistically prey on live embryos and hatchlings (Bolton et al. 2008). Fly larvae may stimulate early emergence of Painted Turtle hatchlings (Riley et al. 2014). In Vermont, fly larvae did not appear to be the primary factor prompting early emergence. We found no evidence of fly larvae in the majority of early emergence Painted and Map turtle nests. It was not clear to us what prompted some hatchlings to emerge early while others overwintered in their nest.

Monitoring and management.—Our monitoring and management actions were consistent throughout the study period, but nesting turtles and nests were exposed to a wide range of environmental variability. Turtle nests in Vermont failed due to flooding, mammalian depredation, and infestations of parasitic fly larvae; however, our experience demonstrates that large communal nesting sites can be protected and enhanced through a suite of management actions. Prior to this study, we did not know how to confidently distinguish hatchling emergence sign from some insect burrows and mammal tracks in the shale. We struggled to control nest depredation while learning from it. By the time this study began we had increased the area of shale substrate available for nesting by removing encroaching vegetation that had overgrown the shale. We had planted Northern White Cedars (*Thuja occidentalis*) to visually screen the nesting beaches from human activity along a seasonal road at Site A. We learned how to restrict mammalian predator access to turtle nests, maintain and enhance available nesting substrate, increase solar exposure, and decrease the chance of flooding by increasing the elevation of some sections of nesting beaches. We collected and provided captive care to embryos and hatchlings found in nests with partial emergence, which prevented further nest depredation and increased the numbers of hatchlings that survived the nesting period.

The increased numbers of Spiny Softshell nests and hatchlings that emerged or were collected from their nests likely benefited from our management. We observed that more Spiny Softshell nests escaped depredation over time, but some of the increase in both successful nests and live hatchlings over time may have been influenced by the increase in all nests we found. The area of shale beach that was not overgrown by vegetation had been enlarged through management and may have led to recruitment of nesting females to the beaches at Site A. The other three turtle species that nested in the same areas as the Spiny Softshell likely benefitted from our management efforts also, but there were no obvious increases in the number of successful nests or hatchlings for those species during the study period. The other turtle species had more nesting options along the shoreline of Lake Champlain and tributary rivers. At Site A, Painted and Map turtles used an old gravel parking area, something Spiny Softshells never did.

The protection of the Spiny Softshell in Lake Champlain depends on the preservation of the remaining natural habitat, and the restriction of human activities in critical areas (Galois et al. 2002). We are committed to continuing to protect communal nesting beaches used by the Spiny Softshell through management. We are making progress toward recovery of the Spiny Softshell in Vermont, but we will likely need to continue management of important nesting areas to maintain and enhance Spiny Softshell populations.

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Steven G. Parren received his Bachelor of Science in Natural Resources Conservation from the University of Connecticut in Storrs, Connecticut, USA. He worked on wildlife projects in Washington State and Alaska before earning his M.S. in Conservation Planning from the University of Vermont in Burlington, Vermont, USA, where his research focused on forest habitat selection by small mammals. Steve has worked for the Vermont Fish and Wildlife Department since 1987 and is the Wildlife Diversity Program Manager. He was involved with long-term conservation efforts to restore the Common Loon (*Gavia immer*), Osprey (*Pandion haliaetus*), and Peregrine Falcon (*Falco peregrinus*) in Vermont. In addition to his administrative duties, Steve's field projects have included management of nesting areas for the state-listed as Threatened Eastern Spiny Softshell (*Apalone spinifera*) and monitoring of the state-listed as Endangered Spotted Turtle (*Clemmys guttata*). Steve has been monitoring a population of Wood Turtles (*Glyptemys insculpta*) since 1984. He is holding female No. 15, aka Crack Fold. (Photographed by Molly K. Parren).

Molly K. Parren began her career monitoring turtle nesting beaches on Lake Champlain as a volunteer for the Vermont Fish and Wildlife Department. She received her B.S. in Conservation Biology in 2012 from St. Lawrence University in Canton, New York, USA. Following college, she worked on a variety of wildlife projects in Vermont, Kenya, Colorado, Wisconsin, and the Mojave Desert of California. In 2019, she earned her M.S. in Natural Resources: Wildlife from Humboldt State University in Arcata, California, USA. Her thesis focused on the influence of drought and Coyotes (*Canis latrans*) on the use by mammalian mesopredators of human disturbed areas in California. She is now a Research Associate at the American Turtle Observatory, New Salem, Massachusetts, USA, working on regional conservation projects for Blanding's Turtle (*Emydoidea blandingii*) and Spotted Turtle (*Clemmys guttata*) on the East Coast. She is holding a Greater Short-horned Lizard (*Phrynosoma hernandesi*). (Photographed by Daniel J. Martin).

Katherina D. Gieder has been working as a Biometrician and Research Coordinator at the Vermont Fish and Wildlife Department for 3 y. During that time, she has contributed her expertise to research projects ranging from Moose (*Alces alces*) survival and recruitment as affected by winter ticks (*Dermacentor albipictus*), American Marten (*Martes americana*) occupancy and detection in the Green Mountain National Forest, and wind turbine effects on Black Bear (*Ursus americanus*) habitat use and movements. Katherina received her Ph.D. from Virginia Tech University, Blacksburg, USA, in 2014 researching the effects of sea-level rise on shorebird habitat along the U.S. Atlantic Coast. In her current position with Vermont Fish and Wildlife, Katherina has been mainly focused on population dynamics data analysis and study design for fish and wildlife monitoring. (Photographed by Thomas J. Gieder).