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A TWENTY-FIVE YEAR STUDY OF THE WOOD TURTLE (*GLYPTEMYS INSCULPTA*) IN VERMONT: MOVEMENTS, BEHAVIOR, INJURIES, AND DEATH

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***Abstract.*—I studied a Wood Turtle (*Glyptemys insculpta*) population in Vermont for 25 y and I monitored a subset of the turtles using radio-telemetry. Adults comprised 95% of the individuals I captured annually. Females ranged further from the stream than did males, and remained in the uplands for as long as 54 days. Females traveled up to 1.6 km to nest and males patrolled as much as 1.2 km of the stream. Turtles often showed fidelity to hibernacula, but moved to new locations if protective structures in the stream were lost. They also returned to upland sites. Wood Turtles often used cover on land and moved to cover when they detected my presence. Overall, 58.5% of adult turtles suffered predator injury. When combined with mechanical damage, the injury rate was 68.3%. Males were more likely than females to be missing feet (43.5% vs. 5.5%), but suffered tail loss less frequently (21.7% vs. 66.6%) than females. None of the juveniles I encountered had injuries to the limbs or tail. I documented the death of four adults during the study period. One female was killed by a vehicle strike and another female appeared to have drowned. One male was killed by a Fisher (*Martes pennanti*) and I suspect that a second male was also killed by a Fisher.**

Key Words.—breeding; emergence; *Glyptemys insculpta*; hibernacula, injury; mortality; nesting; translocation

INTRODUCTION

The Wood Turtle (*Glyptemys insculpta*) is a species of conservation concern throughout its range. Wood Turtles are imperiled as a result of their unique life history characteristics that render them vulnerable to anthropogenic activities. For instance, the species travels long distances into upland habitats during the summer (Kaufmann 1992a; Compton 1999; Arvisais et al. 2002; Walde et al. 2007). Consequently, in heavily fragmented areas, Wood Turtles appear to suffer high injury and mortality rates during upland forays resulting from agricultural machinery, vehicle strikes, and mammal attacks (Harding 1985; Saumure and Bider 1998; Saumure et al. 2007; Tingley et al. 2009). Wood Turtles are designated a Species of Greatest Conservation Need in Vermont's 2005 Wildlife Action Plan.

Although Wood Turtles have been studied across their range (e.g., Ernst and Lovich 2009; Jones and Sievert 2009), little has been published on the ecology of Wood Turtles in Vermont (Parren and Rice 2004). Dramatic land-use changes have occurred over the past several decades. In the Northeastern US from 1982–2002, the amount of developed land has increased at more than three times the rate of population growth (Environmental Protection Agency 2008). This is an alarming trend that does not bode well for the Wood Turtle. Gibbs and Amato (2000) summarized life-history attributes, including delayed reproduction, longevity, and migration to nesting sites, which limit the ability of turtles to sustain additive mortality sources caused by human alteration of habitat.

Most studies cover a limited period of observation relative to the longevity of this species, up to 58 y in captivity (Oliver 1955). Several authors have shown that long-lived animals, such as turtles, require long-term studies (Harding 1991; Congdon et al. 1993, 1994). For over 25 y, I have been documenting the activities and conditions of individual Wood Turtles in a Vermont population. I first encountered Wood Turtles basking on the bank of a large stream during the fall of 1984 and started keeping journal notes. This evolved into weekly monitoring along with mark-recapture, radio-telemetry, mapping locations, and maintaining a database of observations. Herein, I provide observations and management recommendations from a long-term study of Wood Turtles in the Champlain Valley of Vermont, USA.

MATERIALS AND METHODS

***Study area.*—**The study area was in the Champlain Valley of western Vermont, USA (44°16'N, 73°07'W; Vermont Element Occurrence ID# 6421). Further details on the specific location are withheld to protect the turtle population from illegal collection. The site was primarily composed of Mesic Clayplain Forest at lower elevations and Northern Hardwood Forest at higher elevations (Thompson and Sorenson 2000; Eric

Sorenson, pers. comm.). It encompassed a large, low gradient stream (≤ 1° slope) at approximately 100 m elevation with a pH of about 8. A 1.6 km stretch of the stream, from an upstream road crossing to the intersection with a small river was the primary focus of study. The area was primarily agri-forest with a paved road running parallel to the stream at a distance of 250–650 m. Other natural communities found over the Dunham Dolostone and Monkton Quartzite bedrock included Transition Harwood Limestone Talus Woodland, Hemlock Forest, Hemlock Seepage Swamp with imbedded Rich Fens, Alder Swamp, Sedge Meadow, and Green Ash-Ostrich Fern Riverine Floodplain Forest. Hay meadows, grazed pasture, old shrub-dominated fields, and regenerating woodlands were present. American Beavers (*Castor canadensis*) created and altered habitats in and along the stream.

The upper 600 m was predominantly forested; the stream substrate was rocky with some large boulders, smaller rocks, cobble, and small areas of gravel. Silt deposits occurred in pools and backwater areas. Silt dominated the lower 1 km agricultural section with ca. 10% gravel in riffle areas, as well as a few deposits of pure clay. The slow winding lower section was unconfined by bedrock, with erodible soils (Eric Sorenson, pers. comm.). There were no sandy areas, but sand deposits did occur in and along a small river downstream of the study reach. Stream width varied from 4.5 m in deep meanders to 9–12 m in some rocky riffles or sections with in-stream obstructions such as log jams.

Field methods and analyses.—I recorded Wood Turtle observations for 25 y from October 1984 through May 2010. I captured turtles by hand, dip net, and modified minnow traps set in shallow stream channels primarily from April through October. I identified individual turtles based on physical features and a marginal scute shell notch (Cagle 1939) given upon first capture. When observations of individual were spatio-temporally clustered, I combined location data if points were within 1.5 m; otherwise, I referenced data from mapped locations to physical landmarks on a 1:5,000 orthophoto or GPS coordinates whether by visual detection, trapping, or radio-telemetry. I recorded the following habitat categories: (1) stream or standing water; (2) ≤ 4.6 m from stream; (3) wetland/seep; (4) old field/pasture; (5) woods; (6) brush pile; and (7) scrub-shrub/goldenrod patch. Moreover, I recorded behavior as well as air and water temperature (ºC) for each observation. During the winter, I noted any change of location/position. I recorded encounters between males and females as breeding attempts if a male clasped a female's carapace. I recorded straight line carapace length (CL), plastron length, carapace width (mm), body mass (g), and ring count annually, and parasite load (i.e., leeches) and injuries when I first observed these on on a turtle. I estimated age by counting scute annuli up to 20 y (Harding 1991; Germano and Bury 1998). Like Harding (1991), I found counting annuli to be a useful technique for estimating age to about 20 y; however, I discovered my annuli aging was not always accurate. These estimates were compared to previous age estimates plus years elapsed since last capture. To have a sense of relative age of turtles for which annuli could not be counted with confidence, I used the degree of wear of the carapace and plastron. I considered all such turtles to be an adult with no specific age estimate, and I made comments on wear (e.g., polished dorsal scutes, likely old). I determined sex based on plastron concavity and position of cloacal opening. Observations of the same turtle could generate more than one record per day when separated by a minimum of one hour.

Following an investigation by the Vermont Fish and Wildlife Department in May 2003, two adult males, one 11-y-old male, four adult female turtles, and two, two-y-old juveniles were confiscated. Physical measurements and injuries were recorded for these turtles, which came from a drainage in southeastern Vermont (Lat. 42°45'N, Long. 72°29'W). I was able to return the seven older turtles to their home river during September 2003. It was unlikely that the two juveniles could be returned to a familiar location, so both were released in the study stream in June 2004 so they could be monitored. Similarly, a six-y-old juvenile from another enforcement action was released in the study stream in July 2007. An adult male was acquired from a wildlife rehabilitator in the City of Burlington with no information about its home drainage. I released this male in the study stream with a radio tag on 26 September 2004 and monitored him until 5 October 2005. All captives were kept in an outdoor pen for several days of observation before release.

From May 1997 until April 2004, I used radio-telemetry to monitor the movements of turtles. I attached Lithium tags (Advanced Telemetry System, Isanti, Minnesota, USA) to the side of adult carapaces forward of the tail region with waterproof epoxy and the antennae were glued along the anterior margin of the shell. Total mass of transmitter and glue was < 30 g (< 5% of body mass). I fitted juvenile turtles with 12 g transmitters with trailing antennae. I located each radio-tagged turtle at least once per week, and often daily. I intended to monitor each of the 12 turtles for at least a full year. Five adult females were continuously monitored for 12–15 months, four adult males were monitored for 12–20 months, one adult male was monitored for eight months until death, and two juveniles were monitored for 24 months. I retagged one previously tagged female 5 y later for another four months, a second female I retagged 4.5 y later for seven

TABLE 1. Wood Turtle (*Glyptemys insculpta*) emergence behavior and earliest basking observations in March or April within 4.6 m of the stream in Vermont, USA. (F = female, M = male, juv. = juvenile).

Turtle number	Date	Air/Water ºC	Behavior
15F	19 March 2010	16.5/5.5	Basking
10 F	27 March 1998	6.5/0.0	Head stretched forward underwater
15F	27 March 1999	6.5/4.5	Head out of water
10F	28 March 1998	22.0/4.5	Basking
15F	1 April 2006	12.0/10.5	Basking
15F, 18F, 34F, 8M, 23M, 35M	8 April 1998	9.0–16.0/9.0–9.5	Basking
15F	11 April 2002	15.5/10.5	Basking
15F	11 April 2009	9.5/7.0	Basking
15F	13 April 2005	9.5/8.5	Basking
1F	14 April 1987	missing/missing	Basking
33M juv.	15 April 2000	16.5/13.5	Basking
15F	15 April 2008	10.5/9.0	Basking
1F	18 April 1989	missing/missing	Basking
15F	18 April 1996	11.5/missing	Basking
10F	19 April 1995	missing/missing	Basking
1F	24 April 1986	missing/missing	Basking
10F	28 April 2007	13.0/11.0	Basking
20F	29 April 2003	17.0/missing	Basking
10F, 33M juv.	29 April 2004	23.5/13.5	Basking
10F, 11 juv.	30 April 1993	missing/missing	Basking

months, and a male was retagged 2.5 y later for two months.

To compare distances moved by male and female turtles, I performed Wilcoxon rank sum tests (Ott 1977). I used an online chi-square calculator to compare injury patterns between sexes and sex ratio (Preacher, K.J. 2001. Calculation for the chi-square test: An interactive calculation tool for chi-square tests of goodness of fit and independence. Available from http://www.people.ku.edu/~preacher/chisq/chisq.htm [Accessed 28 December 2010]). I used Yate's correction factor following the advice of Brown (2004) for 2 x 2 chi-squared analyses when expected frequencies were < 10. Differences in Wilcoxon rank sum and chi-square tests were considered significant if $P \leq 0.05$.

RESULTS

Over 25 y, I documented 2,831 observations of 55 turtles and spent up to 400 hours annually doing so. I usually recorded an individual once on a given day, but there were 139 records generated by multiple sightings of the same turtle on the same day (two to five observations on the same day). Radio-telemetry accounted for 2,258 (80%) of observations. Encounters with all untagged turtles, including turtles that were tagged at some other time but presently had no tag, accounted for 20% (n = 573) of total observations. I did not include in the counts above 16 GPS locations of a captive male monitored by radio-telemetry after release, but I included 22 records for two captive juveniles that I encountered after release. I detected 26 of the 55 individuals (47.3%) over four or more years (range: 4–18 y). I observed 12 turtles, including seven that had been radio tagged, for over 10 y. Based on a sample of 45 turtles of known sex over the 25 y study, the ratio of males to females was 1.25:1, which was not significantly different ($\chi^2 = 0.56$, P = 0.456) from an even sex ratio. I first encountered one juvenile as a two-y-old in November 1998 and he was first observed with a concave plastron in October 2007 when an 11-y-old with a CL of 173 mm. Of 50 wild individuals I encountered from 1995–2010, nine (18%) were ≤ 10 y old (range: 2–10, median = 7), had carapace lengths ≤ 165 mm (range: 79–165, median = 143) at first capture, and comprised < 5% of the turtles documented annually.

Emergence and movement relative to stream.—Of 18 first observations of turtles basking < 4.6 m from the stream over 24 springs, the earliest emergence date was 19 March (Table 1). In most years (16 of 18), first observation of a Wood Turtle on land occurred in April. The median date of first observation of Wood Turtles on land < 4.6 m from the stream in early spring was 15 April (Table 1). Not all of my early terrestrial observations were of turtles obviously basking. A three-y-old juvenile (No. 33) was located 0.9 m up the stream bank adjacent to a hibernaculum on 22 April 2000 at 1800. The air temperature was 5.5 ºC, the stream was 6.5 ºC, and it was overcast and damp. I observed the juvenile still on the bank the next morning in the rain at 0715 and 1050. The air was 4.0 ºC and the stream was still 6.5 ºC.

Wood Turtles remained in or near the stream until mid-May when they began to move away. By late May/early June, I observed locations > 90 m from the

TABLE 2. Duration of Wood Turtle (*Glyptemys insculpta*) foraging trips greater than 90 m away from the stream and travel away and along the stream within a single year in Vermont, USA. (F = female, M = male, juv. = juvenile).

Turtle number	Duration of trips (d)	Maximum distance from stream (m)	Maximum distance along stream (m)
10F	3, 17, 19, 21, 16	209	672
13F	22, 5, 4, 46	245	508
15F	9, 54, 10	229	1602
18F	2, 9, 2, 42	271	130
20F	51	425	385
8M	1, 2, 3	115	1521
19M	3, 5, 34	151	469
22M		89	997
24M		72	747
25F juv.	Unknown	149	541
33M juv.		73	287

stream. Females sometimes stayed in upland areas for long periods of time (Table 2). When a turtle returned to the stream it was often for less than a week. Female No. 20 differed by staying near the stream until late July before moving upland for 51 days. Males either were not detected farther than 90 m from the stream or had short duration trips away from the stream (Table 2). The exception was a young adult (No. 19) that spent 34 days in a small shrub swamp.

Five females moved significantly further from the stream than four males monitored for at least a continuous 12-month period (Z = 2.45, P = 0.008). The males all stayed closer to the stream (Table 2). The average maximum distance from the stream for adult females was 276 ± 86.4 m (mean ± standard deviation, n = 5; median = 229 m) compared to that recorded for males: 107 ± 34.4 m (n = 4; median = 102). Females made such long distance forays during the summer and returned to the stream corridor by mid-September. I detected maximum perpendicular distances from 12 June to 6 September, and the maximum recorded distance was 425 m from the stream in pole stage woods with some canopy openings on 6 September. I seldom found juveniles far from the stream.

Maximum documented movement along the stream corridor differed widely among tagged turtles (Table 2). Females averaged 659 ± 562.8 m (n = 5; median = 508 m) and males averaged 934 ± 447.1 m (n = 4; median = 872), which was not significantly different (*Z* = 0.98, *P* = 0.164). Between 26 May and 18 June 1998, female No. 15 moved 1.6 km from a downstream nesting area to a foraging location. She traveled through a hay meadow parallel to the stream located 150 m away. Over 10 days in summer male No. 8 moved upstream 1.2 km and then moved downstream nearly 550 m in a single day. Distances moved along the stream were much more variable than movement away from the stream (Fig. 1).

Translocated turtles.—The origin of a male Wood Turtle that was acquired from a wildlife rehabilitator in the City of Burlington was unknown. Its recent removal from the wild was evidenced by the presence of a leech (*Placobdella* sp.) still attached to its shell. I released this turtle in the study stream that fall and followed him until late June when radio contact was lost. An aerial survey relocated this turtle 20 days later in mid-July. If following the stream, he had moved downstream 4 km and then upstream in a different low gradient river for another 7.2 km to another valley. The straight line distance was 2.4 km separated by a ridge that was ≤ 80 m above the stream. He explored another 1.6 km upstream for 12.8 km of stream corridor before returning to the stretch of river where he had been located in mid-July. He remained in this area until I removed the radio tag in October. The maximum known distance from the stream recorded for this turtle was 142 m. I released a captive three-y-old turtle (No. 46) in June 2004 and I detected it a dozen times through May 2010. It continued to use a 700 m stretch of stream corridor and surrounding uplands near its site of release. I also released a second three-y-old captive (No. 12L) at the same time but I did not relocate it in subsequent years. A captive six-y-old (No. 48) was released a few years later and I found it the following spring in the same general area.

Breeding and aggressive behavior.—While I observed most breeding attempts from late August to mid-November (84% of 57 observations), males would attempt to breed during other seasons when they encountered females in the stream. I observed three breeding attempts in April near hibernacula, and six attempts in July. All four males involved in early mating attempts were relatively young adults (ages 16, 17, 19, and one male at both 23 and 24 y). The youngest male (No. 19) observed attempting to breed was a 15-y-old. Ice and snow usually prevented direct observations of turtle activity at hibernacula during winter, but radio signals on 21 January 2001 from a tagged 17-y-old male (No. 19) and a tagged female (No. 20) turtle indicated they were together, or very close under the ice.

Males were often encountered in areas where females were known to frequent. During low stream flow in 1999, I captured males in modified minnow traps that

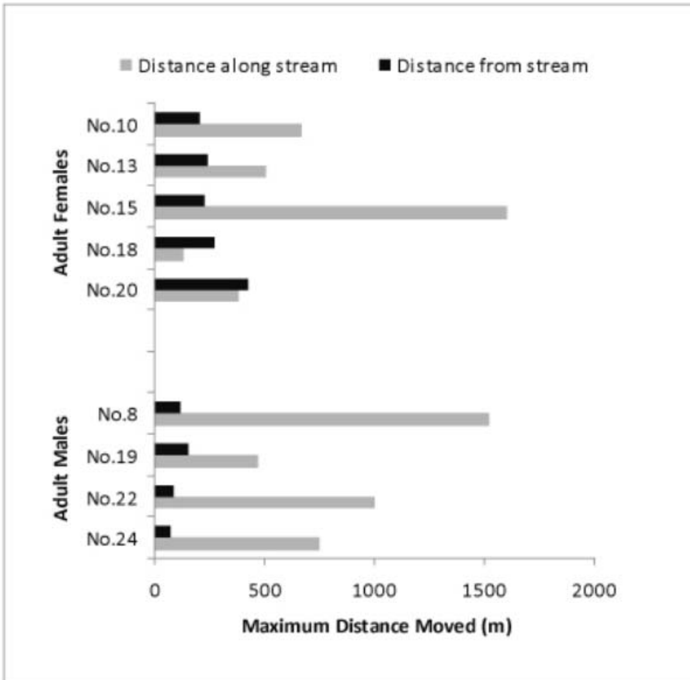

FIGURE 1. Maximum distance adult Wood Turtles (*Glyptemys insculpta*) were detected from and along a stream in Vermont, USA.

blocked stream channels adjacent to a known communal hibernaculum used by females. I observed six breeding attempts by a large turtle (No. 8) between 21 August and 2 October. When No. 8 moved to his wintering site, younger, smaller males stayed in the area and attempted to breed. I watched a 19-y-old male (No. 23) on female No. 15 on 12 November 1998, which was the latest observation of a breeding attempt. The larger male had been seen on this same female on 21 August.

Most breeding attempts I observed were in the stream; only four of 57 observations were on land. I twice noted that females carried males out of the stream onto land. In one case the female remained in a shallow rivulet while the male was exposed to 2.0 ºC air. I observed one breeding attempt 18.3 m from the stream.

I noted male aggressive behavior, which appeared similar to males dominating females, several times. Twice, I saw larger males on top of smaller males (Table 3). A large male (No. 6) drove a smaller adult male (No. 23) out of the stream 19 September 1997 in a section of the stream with a hibernaculum known to be used by several females. A seven-y-old female (No. 25) was chased out of a pool by a 16-y-old male (No. 19) on 10 September 2000.

Wood Turtles where generally not aggressive when handled. The usual defensive response was to pull in head, legs, and tail, sometimes with a hissing sound. If handling lasted for more than a few minutes, turtles often extended their head to observe. If handling was prolonged, Wood Turtles would often try to kick restraining hands off their shell. Some turtles, especially juveniles, would pull into the shell and remain there. A few turtles were very active and would try to run, even if suspended by their shell. Only once did a Wood Turtle, an adult female, attempt to bite during handling.

Nesting.—I documented most nesting activity between 23 May and 21 June, but one turtle that had been severely injured a few years earlier nested 10 July 2001 (Table 4). I found a 34.9 x 22.2 mm turtle egg in the stream nearby 13 July 2001. Locations with nesting activity included a large sand/gravel deposit at a bend in a small river, a smaller sand deposit at another bend, disturbed substrate at a farm road crossing of the stream, and disturbed soil by a house foundation. Egg damage due to nest digging by a Snapping Turtle (*Chelydra serpentina*) was noted at a streamside sand/gravel deposit. I checked a known nesting area annually and mammalian depredation of eggs was not documented.

Three captive Wood Turtles laid eggs in an outdoor pen 17–21 June 2003. Nineteen young from these three nests emerged 8–18 September with caruncles retained and some with egg sac remnants. A hatchling from a wild nest discovered 25 May 1998 emerged 30 August and had lost its caruncle and absorbed its yolk sac. Wet weather in June and July of 1998 allowed vegetation to invade the turtle nest and some eggs were entombed by rootlets. A female was reported digging by a house

TABLE 3. Male Wood Turtle (*Glyptemys insculpta*) aggressive behavior toward smaller turtles in Vermont, USA.

Large turtle			Small turtle				
No.	CL (mm)	Mass (g)	No.	CL (mm)	Mass (g)	Date	Outcome
36	209.6	1030	29	188	810	10 April 1999	On smaller male
8	196.9	1025	24	190.5	905	17 April 1999	On smaller male
6	196.9		23	187.3		19 September 1997	Drove smaller male out of stream
19	190.5	880	25	148.1	385	10 September 2000	Chased juvenile female out of pool

TABLE 4. Wood Turtle (*Glyptemys insculpta*) nesting observations in Vermont, USA.

Turtle Number	Date	Activity	Outcome
15	23 May 1998	On sandy bank	Spent 5 days in area, test digs found
Unknown	25 May 1998	Nest in sand bluff	8 eggs, 1 survives
31	28 May 1998	Digging by house	Left without laying
32	29 May 1998	Digging in sandy gravel during rain	Unknown
31	31 May 2008	Dead on road	3 eggs in body
Unknown	6 June 1999	Nest dug up by Snapping Turtle	6 broken eggs
10	12 June 1997	Digging in disturbed farm road by culvert	Test digs found in clay soil over 2 days
Captive 34	17 June 2003	Observed nesting	6 eggs, 5 survive
Captive 38	17 June 2003	Observed nesting	5 eggs, 2 survive
Captive 41	21 June 2003	Observed nesting	13 eggs, 12 survive
20	10 July 2001	Digging on moist sand bank	1 egg found in water 3 days later

foundation on 28 May 1998. Ten y later on 31 May, I found her crushed on the nearby shoulder of a paved road crossing of the stream. She contained three eggs.

Use of hibernacula.—Turtles hibernated in the stream for at least five months (November–March) per year. Two hibernacula located within 60 m of one another were each used by several individuals (Tables 5 and 6). I observed two to three individuals during seven of 23 consecutive years of turtle detections at the smaller upstream site. At the larger downstream site, I detected two to five individuals in eight of 10 y. Females comprised the majority of the turtles wintering at these communal sites. I found one adult female (No. 1) for 10 consecutive years (October 1984 to May 1993) near the upstream hibernaculum. A tree stub important to this site washed away during an April 2001 flooding event, which also washed female No. 20 out of the downstream hibernaculum. An Eastern Hemlock (Tsuga canadensis) log protected the downstream site from flooding and ice, but it too washed away in an October 2006 flood. Some turtles continued to use these sites after protective structure was lost, but all eventually moved. I found turtles often, but not always, using the same hibernaculum in subsequent years (Tables 5 and 6). Once I located two females (No. 15 and 18) together in a bank cave above water at a hibernaculum they shared.

I also documented other hibernacula sites that were less frequently used by females (e.g., small site between two rocks along the bank; bottom of a large stream pool downstream of a rock that diverted flow). I found a juvenile female at three different early spring or winter locations when she was four to eight y old. One male used a newly fallen hemlock tree in the stream one winter, but moved when this structure broke up the next year.

I detected four males using small bank coves (ca. 1 m wide and ca. 2 m long) for hibernation. These were downstream of inside corners of stream bends and had no upstream rock or log deflecting stream flow. These hibernacula were located in a lower section of the stream that had well developed meanders that sometimes overflowed and inundated the surrounding land. In January 1999, flooding created a lake effect with standing water 75 m wide over these meanders. I typically detected single males at these coves, but one November I found a large male with a smaller male.

Males were often found at communal hibernacula in

TABLE 5. Wood Turtles (*Glyptemys insculpta*) detected at a bank stub hibernaculum in Vermont, USA (F = female, M = male; stub washed downstream April 2001).

Turtle Number	Fall only	Winter	Spring only
1F		84–85 to 92–93	
3M			April 91
10F		97–98, 06–07	April 95 and 04
13F	September 03		April 01
15F		98–99, 03–04, 06–07	April 96 and 02
18F	October 99	96–97, 97–98, 98–99	
23M		98–99	

TABLE 6. Wood Turtles (*Glyptemys insculpta*) detected at a hemlock log hibernaculum in Vermont, USA (F = female, M = male, juv. = juvenile; log washed downstream October 2006).

Turtle Number	Fall only	Winter	Spring only
10F	November 01	98–99	
13F	October 97, 00, 01, and 04	98–99, 99–00	April 02 and 04
19M		00–01	
20F		97–98 to 01–02	April 03 and 04
23M	October 97		
25F juv.		00–01	April 99
33M juv.	September 06	98–99 to 05–06	

early fall, but were also there at other times of the year. I detected five adult males 13 times at the communal bank stub site during fall and documented five breeding attempts there. I detected five males 32 times during the fall at the hemlock log site and I recorded seven breeding attempts. I observed a young male (No. 23) several times at the bank stub site in the spring. Two of these observations were of breeding attempts following a winter he was known to have hibernated at this site.

Wood Turtles at their hibernacula were capable of movement in water at or near 0 °C. After I disturbed female No. 15 on a cold day (-5 °C) 28 November 1996, she swam to the surface of the stream, lifted her head out of the water, and observed me before swimming back to the bottom and pushing into leaves. During another winter at a different hibernaculum, I documented No. 15 change location several times under the ice. She was adjacent to a bank stub on 3 January 1999, 3 m upstream on 8 January, 9 m upstream on 7 February, and nearly 14 m upstream on 20 February. The previous winter I observed female No. 10 move 6 m under the ice. Between 7 and 29 December 2001, I documented male No. 22 change position several times over a distance of 5 m while ice began to form on the stream, and male No. 24 moved 3 m between 11 and 20 February 2000.

I observed changes in body positions by hibernating turtles even if their location did not change. Most turtles, once settled, tended to remain at one location, generally moving no more than 2.5 m. I often noted turtles partially buried in the bottom silt of the stream during winter, sometimes with only their head exposed. The median water depth I recorded for 13 turtles was 0.34 m.

Site fidelity and use of cover.—In addition to fidelity to hibernacula, I also detected turtles at some of the same upland locations in subsequent years. I found a male 115 m from the stream at the same location in 1991 and 2002. Females I monitored with radio-telemetry for > 1 y used the same upland areas each year. I found one female using an area 15 m from the stream for 6 y and once I observed three females within 2 m of one another at this site. I also observed female No. 15 walking 1 m behind female No. 10 at a riparian location. I recorded radio signals from a seven-y-old female inside an old beaver lodge and in a bank hole. During the fall, I found her buried in stream silt 18 out of 23 detections (78%). Logs and boulder caves were also used for cover in the stream and I found both males and females together at these sites, sometimes attempting to breed.

For cover on land, Wood Turtles frequently used old goldenrod (*Solidago* spp.) stalks that had fallen over, the branches of Silky Dogwood (*Cornus amomum*), the dense cover of Gray Dogwood (*C. racemosa*), and less often slash/brush piles, large fallen branches, and logs. In the early spring, I observed turtles basking under the lattice of stalks and branches, which obscured them from sight. I detected five adult females radio- tagged for an entire year using cover on land an average of 47.8% of the time (23.6–75.0%) and four adult males monitored throughout the year under cover on land an average of 31.6% of the time (19.4–61.9%). A fifth adult male (No. 23) fitted with a radio-transmitter was predated on land before planned monitoring was complete; all 13 land detections were without overhead cover. I found a juvenile male (No. 33) under cover on land 63% of the time and a juvenile female (No. 25) was found under cover 54% of the time. Sometimes I observed radio-tagged turtles quickly moving to nearby cover, such as the base of a Cinnamon Fern (*Osmunda cinnamomea*), when I was near. I often found myself hunting for nearby radio-tagged turtles, and if I approached Wood Turtles on land within 1.5 m of a stream, they would almost always try to scramble to the stream. I observed a female Wood Turtle 60 m away watching my movements.

Parasites.—I found the leech species *Placobdella ornata* attached to Wood Turtle skin or on their shells. Common sites of attachment were where limbs joined the body inside the carapace and the tail area. Turtles with attached leeches appeared healthy. I found a young male (No. 33) on a sunny portion of the bank in the late afternoon on 7 October 2008 past the time when sunlight penetrated the site. Fifteen leeches were beginning to dry out with some shrunken into balls. Only six of my

22 observations of turtles with leeches were in the spring. I observed newborn leeches on turtles once in the spring and three times in the fall. I found leeches on male turtles more often than on females (81.8% vs. 18.2%) and the average number of leeches on a turtle with leeches was three, excluding newborn leeches.

Injuries and mortality.—Two of 23 adult male (8.7%) and six of 18 adult female (33.3%) Wood Turtles had serious shell damage (i.e., large cracks, missing a large portion of a scute, or shattered scutes that impacted bone), but the difference was not significant between the sexes (χ^2_{Yates} = 2.49, *P* = 0.114). The rate for sexes combined was 19.5%. I used epoxy to repair the shell of a female's splintered shell and when I observed her during winter, she was dug in head first and her rear shell was buoyant. She dragged a rear leg for 1 y.

Ten adult males (43.5%) were missing feet. I observed an adult male Wood Turtle after both front feet had been recently chewed off. I continued to detect him during 1995, but not in subsequent years. He was able to swim and seemed confined to a large stream pool. The following year, I discovered a young adult male in another stream pool who was missing his left front foot and his right foot and forearm. His amputations had completely healed over. Most males were missing a front foot and only one a hind foot. Only one female (5.5%) was missing a foot. Males suffered foot loss significantly more than females (χ^2_{Yates} = 5.59, *P* = 0.018).

Five males (21.7%) had obviously stubbed tails and four others had missing tips only. Twelve females (66.6%) had obviously stubbed tails and four others had missing tips. This represents a significant difference between male and female tail injuries (χ^2_{Yates} = 6.65, *P* = 0.010). None of the three male turtles from the southeastern Vermont drainage had tail injuries, but three of the four females had stubbed tails. None were missing feet. I recorded 21 observations of wild turtles clamping their tail under a hind leg when withdrawing into the shell (15 times by four adult males and six times by three juveniles). Of the four adult males that clamped their tail under a hind leg, I later found one with a bloody tail stub.

Thirteen of 18 adult females (72.2%) and 11 of 23 adult males (47.8%) survived injuries likely inflicted by predators, including one female with shell damage. Females tended to have only a single predator injury, usually a severely stubbed tail. Four of the males had more than a single predator injury. Predators injured 58.5% of all adults. Sixteen females (88.8%) and 12 males (52.2%) had serious injuries from all causes; the overall injury rate for adult Wood Turtles was 68.3%. Three female turtles had both shell and tail injuries. Of the two males with shell damage, one also had an amputated tail and rear foot (No. 6) and the other (No. 3) was later killed by a predator.

I found an adult male Wood Turtle shell 49 m from the stream. The shell was lying on its plastron with no obvious damage or signs of disturbance. This was identical to my observation of a radio-tagged male determined to have been killed by a Fisher (*Martes pennanti*). Hairs removed from within the tagged shell were matched to known Fisher hair samples (Stuart Archambault, pers. comm.).

The study stream passed under a paved road through a 3-m diameter culvert that was 26 m long. Based on my radio-telemetry monitoring, I knew turtles travelled through this culvert and turtle road mortality had only been detected here once in over 25 y. I found female No. 31 dead on the shoulder of the road, apparently run over by a vehicle. The road surface was 6 m above the stream and the bank was steep, but this was the section of the stream were I would encounter this female. There was also a farm road that crossed the stream in the middle of the study area. The farm owner twice reported a Wood Turtle on the farm road, once in a wheel rut. In early June 2005, I found female No. 13 dead in the stream. Her shell was wedged tightly between underwater logs. I last encountered her alive in mid-April before two heavy rain events that increased stream velocity.

DISCUSSION

The Wood Turtle population in this study occupied a low gradient stream in what was once the floor of the Champlain Sea and the calcareous bedrock influenced the natural communities and plants present today. The pH was high and silt dominated the lower section of the study area. This differs from the sand and gravel bottoms of Wood Turtle streams in Michigan (Harding 1991), but in a New Jersey study most Wood Turtles overwintered in mud (Farrell and Graham 1991; see review in Ernst and Lovich 2009). It is likely that Wood Turtles occupy a wider array of stream and terrestrial habitat conditions than previously assumed. Wood Turtle habitat varies across its geographic range (Compton et al. 2002), and habitats used can be quite variable even in a small state such as Vermont.

Emergence and movement relative to stream.—Spring emergence from the stream was typically observed by mid-April, but was documented as early as mid-March. A young turtle that remained on the bank without direct sun and at air temperatures lower than the water in April may have been recovering from the stress of hibernation (Flanagan 2000). In the spring, lethargic Snapping Turtles were sometimes viewed for up to three days lying unresponsive on the bank (pers. obs.).

Females ranged much further from the stream than did males and the range of maximum distances did not overlap. Tuttle and Carroll (2003) also found that females moved further from the stream than males. Kaufmann (1992a) reported a maximum of 600 m distance from a home stream and Compton (1999) reported a maximum of 599 m, both of which are further than the maximum distance of 425 m I documented. At the northern limit of their range, Arvisais et al. (2002) reported all Wood Turtles remained within 300 m of their streams. Some Vermont females spent significant time away from the stream in the uplands without returning to the stream and I recorded stays of 42–54 days. Kaufmann (1992a) reported some turtles remaining away from their stream for up to 33 days.

Wood Turtles appeared to be familiar with their landscape, both near their home stream and at considerable distances from it. I located one male 115 m from the stream at the same upland location I found him at 10 y earlier. In spite of an old injury that affected the use of a hind leg, I found a female 425 m from the stream. It seems likely that she was already familiar with the location. She passed through woods adjacent to the stream, up a slope, and across a meadow in order to access openings within young woods. Arvisais et al. (2002) suggest Wood Turtles may learn the value of some sites, which could explain site fidelity.

I suspect that when a turtle leaves the stream corridor, there are spatio-temporal risks that are weather dependent. Being far away from the stream when the weather turns cold could have dire consequences. There appeared to be some evidence of turtles reacting to changing weather when a morning frost on 11 October 1997 seemed to provoke a female in a riparian wetland to move to her hibernaculum before a killing frost the next morning (pers. obs.). Kaufmann (1992b) stated that Wood Turtles enter water when the air temperature falls to < 10 ºC.

There was much variability among turtle movements along the stream. Some individuals made long journeys for nesting or breeding, while others used much shorter stretches of the stream. One female moved 1.6 km upstream from a nesting area to upland foraging areas. This is considerably less than the 3.6 km moved by a female from her nesting areas in Ontario, Canada (Quinn and Tate 1991) or the 3.7 km movement reported by Walde et al. (2007) in Québec, Canada. Movements of 2.4 km and 2.9 km along the stream by nesting females in a single day have been reported by Walde et al. (2007). Arvisais et al. (2002) determined that movements were larger during the nesting period than other times of the year.

A tagged, captive male of unknown stream origin either traveled a total of 12.8 km along two streams or moved overland 2.4 km to a new drainage and then upstream for another 1.6 km. I never located this turtle far from a main stream channel, so a long overland journey did not seem likely. Male Wood Turtles have been documented moving long distances overland in other populations (e.g., Jones 2009). My limited observations of captive turtle behavior suggest that juveniles, who lack the familiarity with an area that an adult would have developed, are more likely to acclimate to a new area. Displaced adults appear more likely to search for their home, which could place them at greater risk, especially if not in their home stream.

Breeding and aggressive behavior.—Males appeared ready to attempt breeding whenever a female was encountered, regardless of the time of year. Females remaining in the uplands for extended periods may be influenced by males regularly searching for breeding opportunities in the stream. Breeding attempts were not gentle and it appeared males simply dominated the smaller females. Similar to Kaufmann (1992b), I observed females carrying males ashore and attempted mating on land. One breeding attempt on land was far from the stream, which has also been documented by Niederberger and Seidel (1999). Similar to Harding and Bloomer (1979), Kaufmann (1992b) reported that the Wood Turtle will breed April through October and that the mid-September through October breeding period is more important. I too observed breeding at different times of the year and the majority of my observations of attempted breeding did occur later in the year.

Late summer and fall is when males cruise the stream looking for females. I captured males in traps adjacent to a known hibernaculum used by females and I documented large in-stream movements by males. I detected both males and females at a boulder cave in a stream pool over several years. A breeding attempt was observed in this pool, which was not a hibernaculum. It appeared that males actively sought out females in the stream and knew locations that sometimes harbored females.

In late summer and fall, I often detected males at two communal hibernacula comprised of mostly adult females, but I also found males at these hibernacula during some springs. The latest observation of a breeding attempt was 12 November. This is similar to the 6 November date reported for a population in Ontario (Greaves and Litzgus 2007). I documented females moving within a hibernaculum when males were present and this may have been due to the attentions of male turtles. Radio signals from both a male and female turtle at a single location could indicate that sometimes males seek out females under the ice.

Larger male turtles were observed dominating smaller males on three occasions, even driving one smaller male out of the water. These observations agree with those of Kaufmann (1992b) who reported that the dominance encounters between males showed a rank order that was positively correlated with age and weight. A young adult male was seen chasing a juvenile female out of a stream pool. Smaller males did attempt to breed the same females as the dominant males, once the larger males had left the area. A 15-y-old male was the youngest observed attempting to breed an adult female. The youngest age I observed a male to attain a concave plastron was 11 y. Harding and Bloomer (1979) stated that males developed secondary sex characteristics at 160–170 mm, which is < 173 mm recorded for the Vermont male. Kaufmann (1992a) reported plastron concavity by about 10 y of age in Pennsylvania; whereas, Lovich et al. (1990) reported well-developed secondary sex characteristics for turtles as young as 5 y for Pennsylvania and Virginia combined.

Nesting.—Nesting generally occurred from late May through mid-June, and some females traveled long distances to nesting sites and then returned. Road mortality of one female carrying eggs was likely due to nest prospecting along a busy road in an area with limited nesting substrate. It seems likely that younger juveniles would be found in proximity to nesting areas and the best nesting substrate was well downstream of the areas I monitored during this study. This may explain the low percentage of juveniles encountered (< 5% annually); however, Daigle (1997) and Saumure and Bider (1998) list a number of other possible reasons for juvenile turtles being relatively absent. In another Vermont population that is regularly monitored, nesting substrate is abundant and the percentage of juveniles encountered annually exceeds 50% (Mark Powell, pers. comm.). Dispersed nesting and shifting substrate in my study area may be keeping predators from keying in on Wood Turtle nests. Communal nesting areas of other turtle species are heavily preyed upon in Vermont (pers. obs.), but Walde et al. (2007) documented no predation at a communal Wood Turtle nesting area in Québec. One Wood Turtle nest was dug by a Snapping Turtle excavating its own nest and one nest was invaded by rootlets. Behler and Castellano (2005) also observed roots invading Wood Turtle nests.

Use of hibernacula.—Three types of hibernacula were observed. Communal pool sites were located in a wooded and rocky section of the stream behind upstream boulders or logs that deflected direct stream flow away from the pool. Smaller rocky pools were used by single females. Small bank cove sites were used by males and were typically downstream of an inside bend of the stream in deep meanders with soft substrate. Ice movement in the stream was sometimes dramatic and Wood Turtles appeared to select sites that provided protection. Turtles were detected moving within their wintering sites during winter, but avoided riffle areas where currents were stronger and bottom ice formed. Greaves and Litzgus (2008) suggested that Wood Turtles select near-shore locations to avoid accidental relocation from stronger currents near the middle of a river.

Winter use of a communal hibernaculum, protected by a large hemlock log, had been documented for nine y before the log was swept away. Turtles then stopped using this site. During a previous spring flood, an adult female had been swept out of this hibernaculum and found refuge downstream. This same flood tore out a bank stub that was central to a nearby communal hibernaculum used during at least the previous 17 winters. This sunny site once had small bank caves along the roots of the stub, both above and below water; as well as, a bank-side pool protected by an upstream rock. Two adult females used this hibernaculum before the stub was washed away and continued to use this site for a few years following the loss of the stub. They eventually moved to other locations. Both communal sites had lost important structure and both seemed to have become unsuitable.

Following an ice storm that dropped a hemlock tree into the stream, a young male used the protection it provided during the next winter. The tree deteriorated and he moved to a nearby hibernaculum the following year. In their study in Ontario, Greaves and Litzgus (2008) did not document communal hibernacula nor site fidelity to a site, which may be due to the dynamic nature of the riverine habitat where suitable hibernacula habitat existed one year but was gone the next.

The median water depth in which 13 turtles were observed was only 0.34 m, although deeper water existed at hibernacula. I measured depth when a turtle was visually detected so it is possible this was biased toward locations in shallower water when ice did not cover the hibernaculum. As described above, turtles were mobile and could move to deeper water if needed. When Wood Turtles were seen on the bottom of the stream during the winter they were often not buried. Ultsch (2006) interpreted this above-substrate overwintering of Wood Turtles as a possible indication that they need well-oxygenated water during the winter and are not well able to tolerate anoxia.

Turtles demonstrated their ability to move and respond to disturbance in water at or near 0 °C. Ernst (1986) and Greaves and Litzgus (2007) both reported a Wood Turtle moving 10 m during the winter, although most Wood Turtles observed moved little. Tuttle and Carroll (2003) reported that a subset of their New Hampshire Wood Turtles moved two to 11 m during the winter, which was similar to my observations in Vermont.

Site fidelity and use of cover.—Some turtles were loyal to a hibernaculum and would use one site for years, while others changed sites even when conditions had not changed dramatically. I located one female at a communal site for 10 consecutive years. She was often found basking along the same few meters of bank from the fall of 1984 to the spring of 1993. Harding and Bloomer (1979) reported a similar situation where a female was found on the same log or on the adjacent bank several times over several years. I documented a juvenile male using a communal hibernaculum for eight consecutive years; whereas, a juvenile female used three different hibernacula over 4 consecutive years. Fidelity to a site does not persist when structure important to a hibernaculum is lost, which is a conclusion also reached by Greaves and Litzgus (2008).

Some turtles clearly displayed fidelity to upland areas and would be located in the same areas years later. Similar to my observations, Arvisais et al. (2002) and Compton et al. (2002) reported Wood Turtles using the same activity areas over two y. I was surprised to encounter three females on land together. This area was likely used for foraging, was often sunny, and was only 15 m from a communal hibernaculum used by some of the females. Two females that wintered together were also found on land with one following the other. These observations may indicate some familiarity among Wood Turtles. Kaufmann (1992b) observed non-competitive feeding and suggested possible recognition among Wood Turtles. It was unclear if my Vermont observations of turtles in proximity to one another were due to shared resources, social behavior, or both.

Wood Turtles frequently used cover when on land and also attempted to avoid detection by moving to cover. When I encountered a turtle on land near the stream, it would try to scramble to the safety of the stream. Saumure and Bider (1998) observed a similar flight response at their forested site, but not at their agri-forest site. These hiding and avoidance behaviors are likely useful survival tactics. One young adult male who did not appear to use cover on land was killed by a Fisher. Kaufmann (1992b) stated that Wood Turtles detected small movements at considerable distances, which is consistent with my experience in Vermont.

***Parasites.*—**Leeches were commonly found on Wood Turtles, but did not appear to affect turtle health. Some turtles apparently basked for periods of time sufficient to cause leeches to dry and detach. One male I observed on the bank had *P. ornata* drying out on its shell. One value of basking by turtles has long been believed to be the shedding of attached leeches (Cagle 1950). Saumure and Bider (1996) also report *P. ornata* attached to Wood Turtles in Québec. The higher prevalence of leeches on male Wood Turtles is likely related to males being in the stream more often than females. Kaufmann (1992a), Compton et al. (2002), and Tuttle and Carroll (2003) all reported that males spent more time in the water.

***Injuries and mortality.*—**Most of the shell damage I observed was likely caused by mower strikes and females suffered this most. Because female Wood Turtles move further from their stream and spend more time away from the stream than males, this likely places them at higher risk of encountering farm equipment when actively managed fields are beyond the distance that males typically move. Just the opposite situation was reported for a study area in Nova Scotia by Tingley et al. (2009), where male Wood Turtles were at increased risk from agricultural machinery operating with 43 m of the stream. One female I observed at a hibernaculum the winter immediately following a mower injury appeared buoyant. This was similar to injured captive turtles treated by a veterinarian that sometime displayed buoyancy due to trapped air (Ron Svec, pers. comm.). Agriculture-related mortality was unsustainable in one Québec agri-forest population where researchers documented a 50% decline of a Wood Turtle population from 1995 to 2002 (Daigle and Jutras 2005; Saumure et al. 2007).

Turtles using my study area may have been killed in the past if moving east of the stream where they would have encountered a well-traveled, paved road. All long-distance movements perpendicular to the stream I observed for female Wood Turtles where to the west where there was no adjacent road. Much of the road in the study area exceeded the maximum distance traveled from the stream for males, but not for females. Studies of Painted Turtles (*Chrysemys picta*) and Snapping Turtles in surrounding states have indicated that road mortality can affect the sex ratio by eliminating more females (Marchand and Litvaitis 2004; Steen and Gibbs 2004). The ratio of males to females in my study was not significantly different and long-distance movements parallel to the stream usually did not cause turtles to cross public roads. Twice turtles were reported on a farm road. Only one turtle was found dead on the paved road over the 25 y I monitored the area. Turtles crossed under the road through a large culvert based on radio signals from tagged turtles. Gibbs and Shriver (2002) concluded that road mortality can contribute to declines in terrestrial turtles.

Turtles often wrapped their tail inside their shell when handled. A subset also clamped their tail under a hind leg, which more securely held the tail. I observed this behavior for four adult males and three juveniles. Male tails are longer and more robust than those of females, and are more difficult to dislodge, especially if clamped under a leg. Males will use their tail to help secure a female by folding it under her carapace when attempting to breed (pers. obs.). It seems probable that the significantly higher loss of tails by females was due to their tails being smaller and weaker than those of males, and therefore more easily pulled loose by a predator. Females from a southeastern Vermont Wood Turtle population also had more tail loss, but the sample was small. Tail loss of 33.7% for females and 21.8% for males in a Québec population was not significantly different (Walde et al. 2003). The rate for males in my study was similar (21.7%), but females suffered 66.6% tail loss.

The significantly greater foot/limb loss observed in males is difficult to interpret. Males are more likely to be found within the stream corridor and patrolled the stream looking for females. Having their activity more concentrated in (Kaufmann 1992a; Compton et al. 2002; Tuttle and Carroll 2003) and near the stream could increase encounters with potential predators, of which there were many: Fisher, American Mink (*Neovison vison*), weasels (*Mustela* spp.), North American River Otter (*Lontra canadensis*), Raccoon (*Procyon lotor*), Striped Skunk (*Mephitis mephitis*), Virginia Opossum (*Didelphis virginiana*), Red Fox (*Vulpes vulpes*), Gray Fox (*Urocyon cinereoargenteus*), and Coyote (*Canis latrans*). Otter and Raccoon sign was often encountered along the stream (per. obs.). Carroll and Ultsch (2006) reported a major predation event on Wood Turtles during hibernation in New Hampshire, which they attributed to otter. Saumure and Bider (1998) suspected that higher rates of limb loss at their forest site were due to abundance and/or density of predators being higher than at their agri-forest site. The Raccoon is considered to be an important predator of turtles in North America and is also considered to be a subsidized predator (i.e., a native species able to survive and expand in part due to resources provided by humans; Mitchell and Klemens 2000). Biologists responsible for furbearer management in Vermont believe the high Raccoon numbers in the Lake Champlain valley are likely due to human alterations to the landscape that benefit Raccoons, a decline in trapping pressure, and access to water (Kim Royar, pers. comm.). Raccoons, Striped Skunks, and Red Foxes are the primary predators of turtle nests at managed sites along Lake Champlain (pers. obs.).

In Ontario, 60% of adult Wood Turtles examined had injuries to limbs, tail, or shell likely caused by predators (Brooks et al. 1992), which is very similar to the 58.5% documented in this study. In a New Jersey study, 16.8% of all turtles had injuries thought to be from Raccoons (Farrell and Graham 1991) and in Michigan 9.7% of adults were missing at least one limb (Harding and Bloomer 1979). I observed that males were more apt to have multiple predator injuries. One male that had recently lost both its front feet may have gained some security and mobility by living in a large stream pool. Although this sort of injury would likely impact survival, in a subsequent year I found a different male missing front feet that had completely healed over. The lack of front feet likely renders males less able to successfully breed. At an agri-forest site, Saumure et al. (2007) reported that 12% of marked turtles had limb loss (excluding minor injuries) and no double amputations were documented. Saumure and Bider (1998) reported a limb loss rate of 32.3% for a forested site compared to 15.2% at the same agri-forest site. Harding (1985) documented a limb mutilation or loss rate of 12.5%. He found that the recapture rate of turtles missing at least 50% of one limb was significantly less than for turtles with intact limbs.

Saumure and Bider (1998) examined adult and juvenile injuries combined and determined a rate of 72.7% for an agri-forest site and 71.0% for a forested site in Québec. They did not find differences in injury rates for males and females. In the Vermont study, juveniles did not have injuries and 88.8% of females and 52.2% of males had serious injuries. The overall injury rate for adult Wood Turtles was 68.3%. Injury rates are likely influenced by habitat, land use, and predator abundance found during the period of observation. My study area was a mixture of forest, farms, old fields, and rural home sites. Saumure and Bider (1998) found that carapace injuries were twice as likely at their agri-forest site and limb injuries due to predators were more common at the forested site. Walde et al. (2003) found a lower overall injury rate of 34.6% in their forested Québec population.

Adult Wood Turtles are able to survive encounters with some predators, although sometimes losing appendages. Pulling into the shell may deter some predators, but is not an effective defense against Fisher. Fishers frequented areas used by Wood Turtles. One male Wood Turtle was confirmed killed by a Fisher and a Fisher likely killed a second male. Fisher are also known to have killed a Raccoon and suspected to have killed a nesting Wild Turkey (*Meleagris gallopavo*) in the study area (pers. obs.).

Stream scouring conditions are a risk to turtles while hibernating and also at other times of year (Jones and Sievert 2009). A hibernaculum that provides protection from high velocity flows and ice movement would have survival value. If a turtle were swept out of a site during winter its survival would be at risk. One turtle was displaced by spring flooding, but found refuge along the bank. High water velocity after ice-out likely trapped another turtle underwater, until it drowned. Jones and Sievert (2009) report long distant displacement after flooding and although most Wood Turtles survived the initial displacement; they then suffered a higher rate of mortality. They suggest Wood Turtles avoid stream gradients greater than 1% as a possible adaptation to avoid severe floods. Even though the current study stream had a gradient of < 1%, mortality from flooding did occur. The impacts of Tropical Storm Irene on 28 August 2011 largely missed the study area, but other Wood Turtle populations were likely impacted due to severe flooding of many Vermont rivers and streams. The increased variability and more frequent high-flow events due to climate change expected in the study area (Stager and Thill 2010) and throughout the Northeast

(Hayhoe et al. 2007) may further expose Wood Turtle populations to the impacts of floods.

Management recommendations and future directions.—Although Vermont is a rural state, Wood Turtle populations are still at risk from continued habitat alteration and loss, agricultural activities, increased road mortality, and collection due to increasing human population and development. Wood Turtles remain widely distributed in Vermont (The Vermont reptile and amphibian atlas: digital 2005 edition. Available from http://www.vtherpatlas.org [Accessed 2 January 2011]), but only a few populations are actively monitored. Water quality buffers for rivers and streams focus on meander width and are too narrow to protect enough Wood Turtle habitat. Like many other parts of the Wood Turtle's range, Vermont continues to be developed and habitat is altered or lost. The Wood Turtle's future is threatened in large measure due to its habit of moving long distances overland from its home stream where it encounters agricultural equipment and vehicles on roads (Saumure et al. 2007). Even recreational development can negatively impact Wood Turtle populations (Garber and Burger 1995). Sometimes developers naively suggest recreation paths along rivers or streams as mitigation for housing developments (pers. obs.).

One possible way to lessen the impact of farm activities is to raise the mower height (Saumure et al. 2007). The Vermont Fish and Wildlife Department has a Wood Turtle fact sheet that recommends raising mower height to 150 mm to protect this species and Saumure et al. (2007) and Tingley et al. (2009) recommend 100 mm. Erb and Jones (2011) conducted experiments using turtle models and found that changing mower blade height settings $\leq$ 150 mm did not change mortality rates, sickle bar mowers caused lower mortality than rotary mowers, and tire crushing itself can be an important source of turtle mortality.

As reported earlier, illegal collection of Wood Turtles in Vermont does sometimes occur, and we must remain vigilant and take actions to stop these activities. Some caring people do report the sale of native turtles advertised on the internet (pers. obs.). The Vermont River Conservancy, with support from the Vermont Housing and Conservation Trust Fund, protected important Wood Turtle habitat in Vermont during 2010. More such projects are needed.

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LITERATURE CITED

Arvisais, M., J.-C. Bourgeois, E. Lévesque, C. Daigle, D. Masse, and J. Jutras. 2002. Home range and movements of a Wood Turtle (*Clemmys insculpta*) population at the northern limit of its range. Canadian Journal of Zoology 80:402–408.

Behler, J.L., and C.M. Castellano. 2005. *Glyptemys insculpta* (North American Wood Turtle). Nest invading plants. Herpetological Review 36:311.

Brooks, R.J., C.M. Shilton, G.P. Brown, and N.W.S. Quinn. 1992. Body size, age distribution, and reproduction in a northern population of Wood Turtles (*Clemmys insculpta*). Canadian Journal of Zoology 70:462–469.

Brown, J.D. 2004. Yates correction factor. Shiken: JALT Testing and Evaluation SIG Newsletter 8.1:22.

Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 139:170–172.

Cagle, F.R. 1950. The life history of the slider turtle, *Pseudemys scripta troosti* (Holbrook). Ecological Monographs 20:31–54.

Carroll, D.M., and G.R. Ultsch. 2006. *Glyptemys insculpta* (Wood Turtle). Predation. Herpetological Review 37:215–216.

Compton, B.W. 1999. Ecology and conservation of the Wood Turtle (*Clemmys insculpta*) in Maine. M.Sc. Thesis, University of Maine, Orono. USA. 91 p.

Compton, B.W., J.M. Rhymer, and M. McCollough. 2002. Habitat selection by Wood Turtles (*Clemmys insculpta*): an application of paired logistic regression. Ecology 83:833–843.

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels 1993. Delayed sexual maturity and demographics of Blanding's Turtles (*Emydoidea blandingii*): implications for conservation and management of long-lived organisms. Conservation Biology 7:826–833.

Congdon, J.D., A.E. Dunham, and R.C. van Loben Sels. 1994. Demographics of Common Snapping Turtle (*Chelydra serpentina*): implications for conservation and management of long-lived organisms. American Zoologist 34:397–408.

Daigle, C. 1997. Size and characteristics of a Wood Turtle, *Clemmys insculpta*, population in southern Québec. Canadian Field-Naturalist 111:440–444.

Daigle, C. and J. Jutras. 2005. Quantitative evidence of decline in a southern Québec Wood Turtle (*Glyptemys insculpta*) population. Journal of Herpetology 39:130–132.

Environmental Protection Agency. 2008. EPA's 2008 report on the environment: highlights of national trends. Environmental Protection Agency, Washington, DC, USA.

Erb, L., and M.T. Jones. 2011. Can turtle mortality be reduced in managed fields? Northeastern Naturalist 18:489–496.

Ernst, C.H. 1986. Environmental temperatures and activities in the Wood Turtle, *Clemmys insculpta*. Journal of Herpetology 20:222–229.

Ernst, C.H., and J.E. Lovich. 2009. Turtles of the United States and Canada. 2nd Edition. Johns Hopkins University Press, Baltimore, Maryland, USA.

Farrell, R.F., and T.E. Graham. 1991. Ecological notes on the turtle *Clemmys insculpta* in northwestern New Jersey. Journal of Herpetology 25:1–9.

Flanagan, J. 2000. Disease and health considerations. Pp. 85–95 *In* Turtle Conservation. Klemens (Ed.). Smithsonian Institution Press, Washington, DC, USA.

Garber, S.D., and J. Burger. 1995. A 20-yr study documenting the relationship between turtle decline and human recreation. Ecological Applications 5: 1151–1162.

Germano, D.J., and R.B. Bury. 1998. Age determination in turtles: evidence of annual deposition of scute rings. Chelonian Conservation and Biology 3:123–132.

Gibbs, J.P., and G.D. Amato. 2000. Genetics and demography in turtle conservation. Pp. 207–217 *In* Turtle Conservation. Klemens (Ed.). Smithsonian Institution Press, Washington, DC, USA.

Gibbs, J.P., and W.G. Shriver. 2002. Estimating the effects of road mortality on turtle populations. Conservation Biology 16:1647–1652.

Greaves, W.F., and J.D. Litzgus. 2007. Overwintering ecology of Wood Turtles (*Glyptemys insculpta*) at the species' northern range limit. Journal of Herpetology 41:32–40.

Greaves, W.F., and J.D. Litzgus. 2008. Chemical, thermal, and physical properties of sites selected for overwintering by northern Wood Turtles (*Glyptemys insculpta*). Canadian Journal of Zoology 86:659–667.

Harding, J.H. 1985. *Clemmys insculpta* (Wood Turtle). Predation-mutilation. Herpetological Review 16:30.

Harding, J.H. 1991. A twenty year Wood Turtle study in Michigan: implications for conservation. Pp. 31–35 *In* Proceedings of the First International Symposium on Turtles and Tortoises: Conservation and Captive Husbandry. Beaman K.R., F. Caporaso, S. McKeown, and M.D. Graff (Eds.). Chapman University, Orange, California, USA.

Harding, J.H., and T.J. Bloomer. 1979. The Wood Turtle, *Clemmys insculpta*: a natural history. Bulletin of New York Herpetological Society 15:9–26.

Hayhoe, K., C.P. Wake, T.G. Huntington, L. Luo, M.D. Schwartz, J. Sheffield, E. Wood, B. Anderson, J. Bradbury, A. DeGaetano, T.J. Troy, and D. Wolfe. 2007. Past and future changes in climate and hydrological indicators in the U.S. Northeast. Climate Dynamics 28: 381–407.

Jones, M.T. 2009. Spatial ecology, population structure, and conservation of the Wood Turtle, *Glyptemys insculpta*, in central New England. Ph.D. Dissertation, University of Massachusetts, Amherst, Massachusetts, USA. 243 p.

Jones, M.T., and P.R. Sievert. 2009. Effects of stochastic flood disturbance on adult Wood Turtles, *Glyptemys insculpta*, in Massachusetts. Canadian Field-Naturalist 123:313–322.

Kaufmann, J.H. 1992a. Habitat use by Wood Turtles in central Pennsylvania. Journal of Herpetology 26:315–321.

Kaufmann, J.H. 1992b. The social behavior of Wood Turtles, *Clemmys insculpta*, in central Pennsylvania. Herpetological Monograph 6:1–25.

Lovich, J.E., C.H. Ernst, and J.F. McBreen. 1990. Growth, maturity, and sexual dimorphism in the Wood Turtle, *Clemmys insculpta*. Canadian Journal of Zoology 68:672–677.

Marchand, M.L., and J.A. Litvaitis. 2004. Effects of habitat features and landscape composition on the population structure of a common aquatic turtle in a region undergoing rapid development. Conservation Biology 18:758–767.

Mitchell, J.C., and M.W. Klemens. 2000. Primary and secondary effects of habitat alteration. Pp. 5–32 *In* Turtle Conservation. Klemens (Ed.). Smithsonian Institution Press, Washington, DC, USA.

Niederberger, A.J., and M.E. Seidel. 1999. Ecology and status of a Wood Turtle (*Clemmys insculpta*) population in West Virginia. Chelonian Conservation and Biology 3:414–418.

Northeast Endangered Species and Wildlife Diversity Technical Committee. 1999. Wildlife species of regional conservation concern in the northeastern United States. Northeast Wildlife 54:93–100.

Ott, L. 1977. An Introduction to Statistical Methods and Data Analysis. Wadsworth Publishing Company, Inc. Belmont, California, USA.

Parren, S.G., and M.A. Rice. 2004. Terrestrial overwintering of hatchling turtles in Vermont nests. Northeastern Naturalist 11:229–233.

Quinn, N.W.S., and D.P. Tate. 1991. Seasonal movements and habitat of Wood Turtles (*Clemmys insculpta*) in Algonquin Park, Canada. Journal of Herpetology 25:217–220.

Saumure, R.A., and J.R. Bider. 1996. *Clemmys insculpta* (Wood Turtle). Ectoparasites. Herpetological Review 27:197–198.

Saumure, R.A., and J.R. Bider. 1998. Impact of agricultural development on a population of Wood Turtles (*Clemmys insculpta*) in southern Québec, Canada. Chelonian Conservation and Biology 3:37–45.

Saumure, R. A., T.B. Herman, and R.D. Titman. 2007. Effects of haying and agricultural practices on a declining species: The North American Wood Turtle, *Glyptemys insculpta*. Biological Conservation 135:581–591.

Stager, J.C., and M. Thill. 2010. Climate Change in the Champlain Basin: What Natural Resources Mangers Can Expect to Do. The Nature Conservancy, New York and Vermont, USA.

Steen, D.A., and J.P. Gibbs. 2004. Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18:1143–1148.

Thompson, E.H., and E.R. Sorenson. 2000. Wetlands, Woodlands, and Wildland: A Guide to the Natural Communities of Vermont. University Press of New England, Hanover, New Hampshire, USA.

Tingley, R., D.G. McCurdy, M.D. Pulsifer, and T.B. Herman. 2009. Spatio-temporal differences in the use of agricultural fields by male and female Wood Turtles (*Glyptemys insculpta*) inhabiting an agri-forest mosaic. Herpetological Conservation and Biology 4:185–190.

Tuttle, S.E., and D.M. Carroll. 2003. Home range and seasonal movements of the Wood Turtle (*Glyptemys insculpta*) in southern New Hampshire. Chelonian Conservation and Biology 4:656–663.

Ultsch, G.R. 2006. The ecology of overwintering among turtles: where turtles overwinter and its consequences. Biological Reviews 81:339–367.

Walde, A.D., J.R. Bider, C. Daigle, D. Masse, J. Bourgeois, J. Jutras, and R.D. Titman. 2003. Ecological aspects of a Wood Turtle, *Glyptemys insculpta*, population at the northern limit of its range in Québec. Canadian Field-Naturalist 117:377–388.

Walde A.D., J.R. Bider, D. Masse, R.A. Saumure, and R.D. Titman. 2007. Nesting ecology and hatchling success of the Wood Turtle (*Glyptemys insculpta*) in Québec. Herpetological Conservation and Biology 2:49–60.

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