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Responses of a Spotted Turtle (*Clemmys guttata*) Population to Creation of Early-successional Habitat

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***Abstract*.—The maintenance or creation of early successional habitat is commonly employed by natural resource managers, often for the benefit of native wildlife. In southern New England, USA, forest succession has reduced the amount of early successional habitat on the landscape making the creation of such habitat a management priority in the region. However, questions remain regarding the impacts of the creation of early successional habitat on certain species, especially those that are associated with late successional habitats. We conducted a radio-telemetry study of Spotted Turtles (*Clemmys guttata*) in Rhode Island, USA, for one year before, and one year after a 3-ha forest clear-cut in close proximity to wetlands known to contain a resident population of the species. The annual home range size of turtles was 18.5% larger post-cut, possibly due to changes in the distribution of resources and suitable habitat after the harvest. However, turtles exhibited fidelity to hibernacula and communal overwintering, despite nearby disturbance, and patterns of activity and habitat use were similar in both years and were generally consistent with those of other Spotted Turtle populations. Our results suggest that timber harvesting of this spatial scale and management approach may not have any short-term effects on the spatial ecology or habitat use of populations of Spotted Turtles, but further research is needed to understand longer-term effects. We strongly recommend that the timing of clear-cut harvesting be restricted to outside of the region-specific activity season of this species and that land managers avoid significant disturbance to wetlands containing Spotted Turtles, especially those containing hibernacula.**

Key Words.—conservation; endangered species; habitat management; spatial ecology; wildlife management

Introduction

Habitat alteration can be an important component of wildlife management (Russell et al. 1999; Degraaf et al. 2006). The maintenance or creation of early successional habitat via mowing, prescribed burns, and clear-cuts is commonly employed by natural resource managers to benefit native wildlife (Greenberg et al. 1994, Van Dyke et al. 2004), including some birds (Degraaf and Yamasaki 2003), mammals (Litvaitis 2001; Fuller and DeStefano 2003), and reptiles (Dovĉiak et al. 2013). In southern New England of the United States, the abandonment of agricultural fields that occurred in the first half of the 19th Century led to an increase in early successional habitat. The gradual process of forest succession that followed however, has greatly reduced the amount of early successional habitat on the landscape (Foster and Aber 2004; Buffum et al. 2011). State wildlife agencies and conservation groups have made the creation of early successional habitat a priority in the region because of its benefits to many species of wildlife including shrubland birds and particularly to the New England Cottontail (*Sylvilagus transitionalis*; Buffum et al. 2014; Fuller, S., and A. Tur. 2015. New England Cottontail Conservation Progress. New England Cottontail Executive Committee. Available at https://newenglandcottontail.org/sites/default/files/research_documents/NEC%202014%20Performance%20Report.pdf. [Accessed 15 November 2016]). However, questions remain regarding the effects of early successional habitat creation on certain species, especially those that are associated with mature, forested habitats.

Although several studies have reported impacts of timber harvesting on reptiles (Enge and Marion 1986; Todd and Andrews 2008; Moorman et al. 2011), including turtles (Currylow et al. 2012), to our knowledge none have focused on how freshwater turtles respond to forest clear-cutting. This may be less important for highly aquatic turtles that make only occasional upland movements, for example, to an open area to nest. However, some freshwater turtle species, including the Spotted Turtle (*Clemmys guttata*) and the Wood Turtle (*Glyptemys insculpta*), move frequently between ephemeral and permanent wetlands and are known to estivate terrestrially, with some Spotted Turtles spending as much as 30% of their time on land (Milam and Melvin 2001) and Wood Turtles as much as 40% of their time (Arvisais et al. 2004). Use of upland habitats by some forest and wetland-associated turtle species may make them vulnerable to forest alteration if habitat is destroyed or fragmented. Alternatively, the removal of the forest canopy for the creation of early successional habitat may create new microhabitats suitable for thermoregulation and nesting.

The Spotted Turtle is a species of increasing conservation concern. The International Union for the Conservation of Nature (IUCN) reviewed the species in 2013 and upgraded its status from Vulnerable to Endangered (van Dijk 2013). In five of the six New England states where it occurs, the Spotted Turtle has been designated with some type of conservation protection and the status of the species is currently under review by the U.S. Fish and Wildlife Service (USFWS) for federal listing under the U.S. Endangered Species Act (USFWS 2015). Spotted Turtles are relatively small (carapace length up to 142.5 mm) freshwater turtles that are native to the eastern United States and Great Lakes regions of North America. They occur in a variety of wetland types throughout their range and have sometimes been described as habitat generalists (Ernst and Lovich 2009). However, Spotted Turtles have also been shown to exhibit strong habitat selection based on the physical and biological conditions of their environment (Milam and Melvin 2001; Anthonysamy et al. 2014). This selection is detectable at multiple spatial scales and can vary with season and by sex (Litzgus and Mousseau 2004; Rasmussen and Litzgus 2010). Spotted Turtles are often described as semi-aquatic because they use both wetland and upland habitats. They spend the majority of their time in wetlands and depend on these habitats for overwintering, foraging, thermoregulation, and mating (Milam and Melvin 2001; Ernst and Lovitch 2009). Most individuals exhibit high fidelity to wetlands, often overwintering in the same hibernaculum each year (Litzgus et al. 1999; Ernst and Lovich 2009). Spotted Turtles use uplands for nesting and moving between wetlands, and both sexes spend extended periods of time in upland habitat estivating in shallow forms or underneath leaf litter during the warmest periods of the summer (Joyal et al. 2001; Gibbs et al. 2007). Thus, uplands are essential to this species and concern is raised when these habitats are to undergo significant alteration. In Rhode Island, USA, Spotted Turtles are a strongly forest-associated species (Scott Buchanan, unpubl. data), but the implications for the removal of forest surrounding wetlands where they occur is unknown.

We investigated the potential impacts on a population of Spotted Turtles of a clear-cut timber harvest that took place within close proximity to a complex of wetlands in southern Rhode Island. We radio-tagged individuals in this population for one year prior to, and one year after, a clear-cut that was implemented to create early successional habitat for wildlife. Our objectives were to examine the effects of forest clear-cutting on Spotted Turtle spatial ecology, activity, and habitat use.

Materials and Methods

Study site.—Our study took place in Washington County, Rhode Island, USA. We have withheld specifics of the location out of concern for making this population of Spotted Turtles vulnerable to collection. Mean annual temperature in the area (Kingston, Rhode Island) is 10.5° C and mean annual precipitation is 134.3 cm (National Oceanic and Atmospheric Administration [NOAA] National Centers for Environmental Information. Available from http://www.ncdc.noaa.gov [Accessed 1 March 2016]). The study area consisted of an arrangement of mowed fields, upland forest, freshwater wetlands, and shrub-dominated habitats along a powerline right-of-way. Management was generally limited to trail maintenance, mowing, and seasonal deer hunting. Soils consist of predominantly fine, sandy loam (U.S. Department of Agriculture. 2016. Web Soil Survey. Available from http://websoilsurvey.sc.egov.usda.gov [Accessed 1 August 2016]). A mosaic of permanent and temporary wetlands were distributed throughout the site consisting of *Sphagnum* Bog, emergent shrub wetlands, and forested vernal pools. Adjacent second-growth forest consisted of an Oak-Maple overstory and a wetland-associated shrub understory (Appendix Table). The most common species of understory woody vegetation found throughout the study area in descending order of occurrence were Highbush Blueberry (*Vaccinium corymbosum*), Common Winterberry (*Ilex verticillata*), Sheep Laurel (*Kalmia angustifolia*), Coastal Sweetpepperbush (*Clethra alnifolia*), and Northern Bayberry (*Morela pensylvanica*).

Beginning in December of 2013 and concluding in February of 2014, while turtles were inactive in aquatic hibernacula, approximately 3 ha of mature forest was harvested to create early successional habitat using a Clear-cut with Reserves approach (Miller et al. 2006). The cut retained approximately eight residual trees per hectare to serve as seed trees and sources of food for wildlife. Large amounts of coarse woody debris were left on the ground to reduce deer browse and six large brush piles were created for wildlife habitat. No herbicides were applied after the cut and no rutting or erosion was observed after the cut. The shape of the cut was irregular and a buffer of at least 15.2 m (50 feet) was retained around all wetland habitat (Fig. 1 and 2).

Radiotelemetry and data collection.—We captured Spotted Turtles using baited hoop traps and by hand. We attached RI-2B 6g radio transmitters (Holohil Systems Ltd., Carp, Ontario, Canada) with waterproof putty epoxy to the right-posterior of the carapace. The combined mass of transmitter and epoxy averaged approximately 6% of body mass and did not exceed

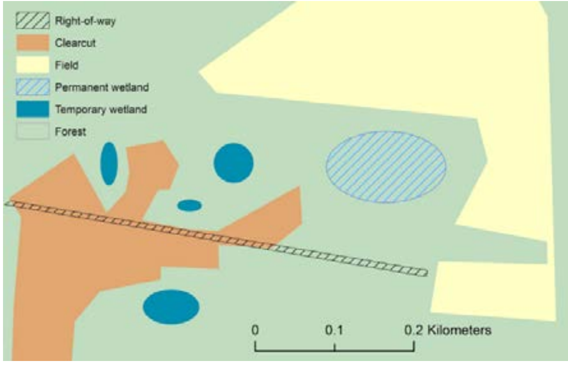

Figure 1. The study area in Washington County, Rhode Island, USA, showing the configuration of important features. All shapes are approximate.

Figure 2. Representative photograph of the clear-cut area in Washington County, Rhode Island, USA. Seed trees and coarse woody debris were purposefully left behind by the logger. (Photographed by Scott Buchanan).

8%. Following transmitter attachment, we released all individuals at their original points of capture. We used an ATS R410 receiver (Advanced Telemetry Systems, Isanti, Minnesota, USA) and a three-point Yagi antenna to track turtles. We recorded geographic coordinates (Universal Transverse Mercator; North American Datum of 1983) for each turtle radio-location using a Garmin Oregon 450 handheld global positioning system receiver (Garmin International Inc., Olathe, Kansas, USA). We conducted radio-telemetry for one season before (2013) and one season after (2014) the implementation of the clear-cut. We radio-tracked turtles approximately once every 5 d (mean = 5.35 ± 0.11 [SE] d, n = 655 intervals) between 1 April and 31 October, and less frequently in the early spring and late fall. We classified radio-locations into one of three categories based on the precision of the detection of the turtle. If we found a turtle and actually saw it, we classified the radio-location a Visual. If we obtained a signal and identified the location to a small area (a few square meters) without use of the telemetry antenna (i.e., using just the receiver), we classified the radio-location an Exact. If we obtained a signal and we estimated the location using the telemetry antenna, we considered the radio-location an Approximate, in which case we used triangulation to confirm that turtles were within wetlands.

We measured midline carapace length (mm) using analog calipers and we measured initial body weight (g) using a digital scale. We obtained daily maximum temperature (° C) and precipitation (mm) data for 1 April to 31 October in both years from a representative weather station (Kingston, Rhode Island; NOAA, National Centers for Environmental Information. *op. cit*.). We used these data to obtain annual means (for temperature) or sums (for precipitation) and we determined averages to compile weekly means over the course of the activity season. We conducted an initial forest inventory of the clear-cut area in October 2013 after the clear-cut area had been delineated but before logging operations began, and a second inventory after the logging was complete in October 2014. In both cases we assessed the vegetation at 56 locations along parallel transects spaced equal distances apart. We used 2 m^2 fixed area plots to record frequency of occurrence of understory vegetation, and variable area plots to measure diameter at breast height and density of overstory vegetation. We measured overstory tree canopy cover at each point using a spherical densiometer.

Home range and habitat use.—We categorized all turtle radio-locations as occurring in either wetland or upland habitat. We calculated percentage wetland use by dividing the number of radio-locations that occurred in a wetland by the total number of radio-locations. For all upland radio-locations, we calculated the distance to the nearest wetland edge. The lack of consistent, precise radio-locations (particularly when turtles were in wetlands) made it impossible to calculate distance between radio-locations throughout the activity season, but did not preclude the calculation of home range size estimates. We estimated home range sizes using minimum convex polygons (MCPs). MCPs are widely used in home range analyses of reptiles and have been used in multiple studies of Spotted Turtles making them the most useful for comparison with other studies (Litzgus and Mousseau 2004; Row and Blouin-Demers 2006). We included Approximate radio-locations in the construction of MCPs, as these were the majority of locations because many turtles were located in the interior of a wetland and their precise location could not be determined. The majority of these points fell within the interiors of constructed polygons and did not influence MCP size. We also inspected all radio-locations for each turtle and manually removed points from the home range analysis that were ambiguous or erroneous due to transcription errors (n = 7 points).

We calculated overall home range size and overall percentage wetland use by combining all available data from both years. In addition, to examine both home range fidelity and potential differences pre- and post-clear-cut, we calculated annual home range size and annual percentage wetland use in 2013 and 2014 and compared these data between years. To maximize the comparability of these metrics between years, we also calculated constrained post-clear-cut values by constricting the radio-locations used to the range of dates when turtles were tracked in both years. We estimated annual home range percentage overlap between years to compare potential changes in resource use overall and between sexes. For all turtles tracked in both years, we divided the common area of both MCP polygons (one for each year) by the total merged area of both polygons. We used all available radio-locations to estimate annual home range overlap. We also determined all instances in which an individual used any of the area inside the delineation of the clear-cut, in a given year, by identifying all the instances in which an annual MCP (constrained MCP for post-cut) overlapped the area of the clear-cut.

Statistical analyses.—We assessed normality using Shapiro-Wilk tests and equality of variances using Levene's tests. All data were normally distributed and homoscedastic. We used paired *t*-tests to compare home range sizes and percentage use of wetlands pre- and post-clear-cut. We used an independent samples *t*-test to determine if home range sizes differed by sex pre-and post-clear-cut, using the difference between pre- and post-clear-cut MCP as the dependent variable. The paired *t*-tests and the independent samples *t*-test used observations only from individuals tracked in both years (n = 9), and the post clear-cut observations were constrained to the dates when turtles were tracked in the previous year. We compared overall home range size and annual home range percentage overlap between males and females using independent samples *t*-tests. We used linear regression to examine the relationships of body size (midline carapace length) and the number of radio-locations, and of body size and overall home range size. We compared overall percentage wetland use between sexes with an independent samples *t*-test. For descriptive statistics, we report means ± one standard error (SE), and we defined statistical significance as $P \leq 0.05$. We calculated MCPs and distance to nearest wetland using Geospatial Modeling Environment (version 0.7.3.0, www.spatialecology.com/gme [Accessed 15 January 2013]) and ArcGIS 10.2. All other statistical analyses were performed using R (R Core Team 2013).

Results

From 1 April to 31 October, mean daily maximum temperature was 21.5° C (range = 5.8–33.4° C) in 2013 and 21.0° C (range = 6.9–29.7° C) in 2014. Total precipitation was 69.3 cm in 2013, and 56.9 cm in 2014 (Appendix Figure). Basal area of trees in the clear-cut was 17.3 m^2/ha in 2013 prior to harvest, and 5.3 m^2/ha in 2014 after harvest (Appendix Table). Average canopy cover of the area was 76% in 2013, and 35% in 2014. Clear-cut border trees and a few remaining seed trees contributed to post-clear-cut estimates of canopy cover.

Radiotelemetry and data collection.—We tracked 12 turtles over the 2 y (six females, six males), nine of which (four females, five males) were tracked in both years (Table 1). We logged 712 radio-locations with a mean of 59.3 ± 5.1 radio-locations per individual. Tracking of individuals began in late May or early June in 2013, and March or April in 2014 (Table 2). We directly observed turtles in 24% of radio-locations (172/712), identified locations without visual observation (Exact) in 20% (143/712) of radio-locations, and estimated locations using triangulation (Approximate) for 56% of radio-locations. Approximate radio-locations occurred almost exclusively when turtles were in interior sections of a wetland.

Home range and habitat use.—Mean constrained annual home range was 18.5% larger post-cut (mean = 1.41 ± 0.21 ha, n = 12) than pre-cut (mean = 1.19 ± 0.27 ha, n = 9), but the difference was not significant (t = -2.02, df = 8, P = 0.078). The mean difference between pre- and post-cut constrained annual home range was larger for females (mean = -0.74 ± 0.31 ha, n = 4) than for males (mean = -0.09 ± 0.16 ha, n = 5), but this difference was not significant (t = 1.84, df = 4.7, P = 0.128). Between years, mean annual home range overlapped by 56.6% (± 3.2%, n = 5) for males, 29.9% (± 5.8%, n = 4) for females and 44.8% (± 6.1%, n = 9) for both sexes combined. Overlap between years by males was significantly higher than that of females (t = -2.86, df = 3.8, P = 0.048). Spotted Turtles exhibited a mean overall home range of 1.95 ha (± 0.26 ha, n = 12, range = 0.59–4.07 ha), and mean female home range size (2.04 ± 0.46 ha, n = 6) did not differ significantly from mean male home range size (1.85 ± 0.30 ha, n = 6; t = 0.362, df = 8.7, P = 0.73). We found no relationship between overall home range size and number of radio-locations (r^2 = 0.04, t = 0.61, P = 0.560), or between overall home range size and carapace length (r^2 = 0.01, t = 0.37, P = 0.720). One female (turtle C) moved outside of the study site in 2014, yielding an underestimate of home range size for that year as we were not allowed access to the adjacent property.

Table 1. Sex, initial weight (g), midline carapace length (CL), dates tracked, number of radio-locations, fate, minimum convex polygon (MCP) size, and percentage wetland use of Spotted Turtle (*Clemmys guttata*) individuals tracked in Washington County, Rhode Island, USA, 2013–2014.

Individual	Sex	Weight	CL (mm)	Dates tracked	Number of radio-locations	Fate	MCP (ha)	Percentage wetland use (%)
A	M	195	123.7	10 June 2013 – 11 November 2014	71	Tracked to hibernaculum	0.59	80.3
B	M	175	117.7	10 June 2013 – 11 November 2014	65	Tracked to hibernaculum	2.29	89.1
C	F	210	115.2	25 May 2013 – 23 September 2014	41	Moved outside study area	2.35	100
H	F	165	98.7	10 June 2013 – 11 November 2014	76	Tracked to hibernaculum	1.95	81.6
I	M	155	108.5	25 May 2013 – 11 November 2014	68	Tracked to hibernaculum	2.78	100
K	F	235	118.6	10 June 2013 – 11 November 2014	75	Transmitter failure	4.07	70.8
M	M	175	113.6	10 June 2013 – 30 September 2014	67	Died (unknown causes)	1.73	100
N	M	165	109.3	10 June 2013 – 11 November 2014	66	Tracked to hibernaculum	2.07	93.8
O	F	180	104.7	10 June 2013 – 11 November 2014	79	Tracked to hibernaculum	1.08	68.4
AC	F	183	102.9	1 April 2014 – 11 November 2014	34	Tracked to hibernaculum	1.84	73.5
AH	M	227	122.2	11 April 2014 – 11 November 2014	34	Tracked to hibernaculum	1.64	79.4
AN	F	203	104.2	18 April 2014 – 11 November 2014	36	Tracked to hibernaculum	1.00	77.8
Sum	—	—	—	—	712	—	—	—
Mean (SE)	—	189 (7.3)	111.6 (2.3)	—	59.3 (5.1)	—	1.95 (0.26)	84.6 (3.4)
Female mean (SE)	—	196 (10.2)	107.4 (3.1)	—	56.8 (8.9)	—	2.04 (0.46)	78.7 (4.7)
Male mean (SE)	—	182 (10.5)	115.8 (2.6)	—	61.8 (5.6)	—	1.85 (0.30)	90.4 (3.7)

Mean overall wetland use was 84.6% (± 3.4%, n = 12) and mean wetland use did not differ significantly (t = -1.95, df = 9.5, P = 0.079) between males (mean = 90.4 ± 3.7%, n = 6) and females (mean = 78.7 ± 4.7%, n = 6). Three turtles were found exclusively in wetlands. However, each of these individuals were radio-tracked in different, discontinuous wetlands, indicating that they too made terrestrial movements during the activity season. There was no significant difference (t = -0.994, df = 8, P = 0.35) in annual wetland use between 2013 (mean = 82.9 ± 5.8%, n = 9) and 2014 (mean = 83.2 ± 4.1%, n = 12), but persistent use of upland habitat occurred later in 2014 by approximately three weeks (Fig. 3).

Turtles moved from hibernacula in mid- to late-March and appeared to congregate in nearby vernal pools. Seven of 12 (58%) tracked turtles were found in the same small vernal pool (about 0.05 ha) in the same two-week period of May 2014 and as many as five turtles were found in the vernal pool on the same day. Annual home range overlapped with the clear-cut delineation in four of nine (44.4%) instances in 2013, and with the clear-cut in eight of 12 (66.7%) instances in 2014 (Fig. 4). There were only two confirmed observations (i.e., Visual or Exact) in 2013 (late July to mid-August) of individuals using the area of the clear-cut prior to cutting, and both involved estivation in which turtles were buried below vegetation and leaf litter. There were no confirmed observations of individuals in the clear-cut area in 2014, after the trees were harvested. Spotted Turtles found in uplands occurred a mean distance of 7.56 m (± 5.42 m, n = 107, range = 0.1–33.4 m) from the nearest wetland. Of these observations, 11% occurred at a distance greater than 15.2 m (50 feet) from the nearest wetland (the buffer distance mandated by state wetland regulations).

Turtles hibernated exclusively in wetlands. Several individuals exhibited fidelity to hibernacula and we observed the use of communal hibernacula in both years (Table 2). Of the six instances in which we tracked individuals to hibernacula in both years, four individuals (67%) used the same hibernaculum. Another individual

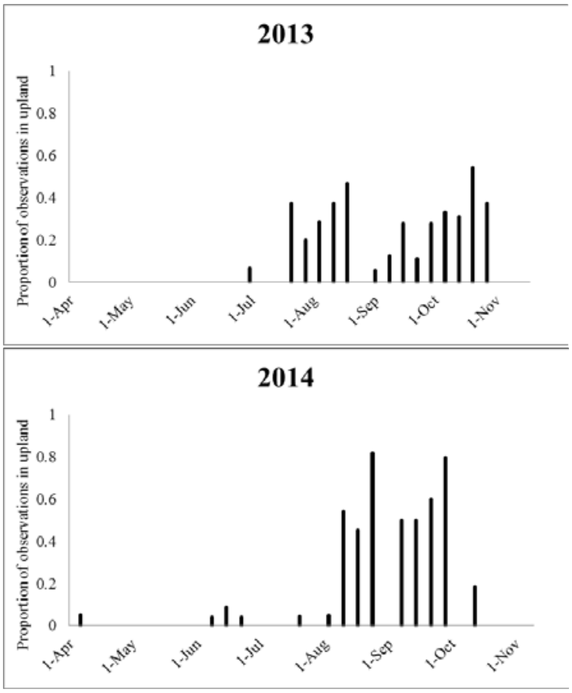

Figure 3. Proportion of radio-locations in upland habitat, calculated weekly, for Spotted Turtles (*Clemmys guttata*) tracked in Washington County, Rhode Island, USA, in 2013 and 2014.

spent the winter in different locations within the same wetland. All turtles occupied hibernacula by 12 November in 2013 and by 28 October in 2014. Turtles remained in the uplands as late as 31 October in 2013 and as late as 14 October in 2014. Sites where turtles spent the winter were all associated with *Sphagnum* hummocks and/or the roots of woody shrubs. An untracked Spotted Turtle was found dead in the adjacent mowed field on 28 October 2014, suggesting use of the field at some time of the year. The turtle was decomposed, so it was not clear how long the turtle had been dead, but the shell remnants were found in many pieces suggesting that it had been crushed.

Discussion

Home range and movements.—The duration and timing of the activity season was consistent with other observations of Spotted Turtles at the northern portion of their range (Haxton and Berrill 2001; Beaudry et al. 2009; but see Milam and Melvin 2001). Surface activity began in mid- to late-March and ceased in late October or early November, after which turtles entered wetland hibernacula. Overlap of annual MCPs with the delineation of the clear-cut in both years suggests that turtles used the area both before and after the cut took place. Spotted turtle home range size was nearly 20% larger post-clear-cut, but lack of a statistical difference precludes a clear interpretation of this result, particularly given our relatively small sample size. Habitat alteration can cause wildlife to travel greater distances to locate necessary resources, which for turtles may include food items, mates, thermoregulatory habitat, nesting habitat, and overwintering habitat (Compton et al. 2002; Baldwin et al. 2004). However, the creation of early-successional habitat (such as a clear-cut) could also create new opportunities for thermoregulation and nesting, thereby reducing the distance required to locate

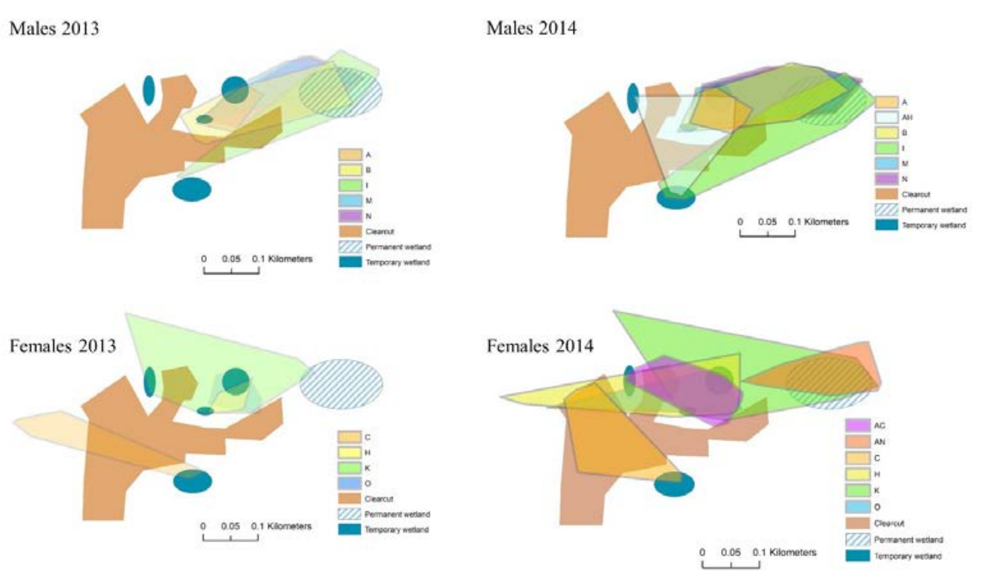

Figure 4. Annual home range estimates (MCPs derived from all available data) for each sex of Spotted Turtles (*Clemmys guttata*) before (2013) and after (2014) the clear-cut in Washington County, Rhode Island, USA. In the legend, letters represent individual turtles and the labeled areas represent simplified habitat features.

Table 2. Dates Spotted Turtles (*Clemmys guttata*) were tracked in 2013 (Year 1) and 2014 (Year 2) with number of radio-locations in parentheses, minimum convex polygon (MCP) estimates in ha in 2013 and 2014, constrained minimum convex polygon (CMCP) estimates in ha in 2014, percentage annual home range overlap, percentage wetland use (WU) in 2013 and 2014, and percentage constrained wetland use (CWU) in 2014 in Washington County, Rhode Island, USA, 2013–2014. An asterisk indicates an individual that exhibited hibernaculum site fidelity in consecutive years. Individuals sharing superscript numbers indicates communal hibernation in the winter beginning that year.

Individual	2013	2014	2013 MCP	2014 MCP	2014 CMCP	Overlap (%)	2013 WU (%)	2014 WU (%)	2014 CWU (%)
A*	10 June – 12 November (34)	21 March – 19 October (37)	0.37	0.45	0.29	47.8	85.3	78.4	68
B	10 June – 31 October (29)	6 April – 11 November (36)[1]	1.77	1.71	1.66	57.2	78.6	97.2	96.3
C	25 May – 31 October (23)	25 April – 23 September (18)	1.05	1.47	1.47	27.4	100	100	100
H*	10 June – 20 November (36)1	21 March – 11 November (40)[2]	0.20	1.95	1.86	10.6	80.5	82.5	74.0
I	10 June – 20 November (31)	21 March – 11 November (37)	1.77	2.34	1.93	52.4	100	100	100
K	10 June – 11 November (37)1	21 March – 11 November (38)	2.67	3.55	3.06	53.0	55.5	86.1	82.6
M	10 June – 20 November (34)	21 March – 30 September (33)	0.99	1.70	1.70	58.4	100	100	100
N*	10 June – 7 November (32)	21 March – 11 November (34)1	1.51	1.88	1.32	67.2	90.3	97.1	95.2
O*	10 June – 20 November (39)	21 March – 11 November (40)	0.37	1.01	0.86	28.9	56.4	80	70.4
AC	—	1 April – 11 November (34)[2]	—	1.84	1.04	—	—	73.5	65.4
AH	—	11 April – 11 November (34)[2]	—	1.64	0.68	—	—	79.4	73.1
AN	—	18 April – 11 November (37)	—	1.00	1.00	—	—	77.8	73.1
Mean (SE)	—	—	1.19 (0.27)	1.71 (0.26)	1.41 (0.21)	44.8 (6.1)	82.9 (5.8)	87.7 (3.0)	83.2 (4.1)
Female mean (SE)	—	—	1.07 (0.56)	1.80 (0.38)	1.55 (0.34)	29.9 (8.7)	73.1 (10.7)	83.3 (3.8)	77.6 (5.0)
Male mean (SE)	—	—	1.28 (0.27)	1.62 (0.26)	1.26 (0.26)	56.6 (3.2)	90.8 (4.2)	92.0 (4.2)	88.8 (5.9)

these habitat types. Open areas including power line rights-of-way and recent clear-cuts have been used by Spotted Turtles for nesting (Litzgus and Mousseau 2004). Whether a habitat alteration serves to expand or reduce home range size probably depends on the proximity of the alteration to established home ranges as well as the nature of the alteration itself. Spotted Turtle home range size increased after disturbance in the form of flooding by Beaver (*Castor canadensis*) dams, but probably because the turtles were using newly available aquatic habitat (Yagi and Litzgus 2012); the flooding was interpreted as beneficial to this population of Spotted Turtles in Ontario.

We detected a difference in annual home range overlap between sexes. Male turtles exhibited greater overlap between years, suggesting a higher fidelity to specific sites. If males can reliably locate females for mating during early spring congregations, the additional distances a male must travel are potentially limited to those where it can find food, thermoregulatory habitat (e.g., for basking and estivation) and overwintering habitat. In addition to these types of movements, females must also locate nesting habitat. As a proportion of female Spotted Turtles in a population do not breed every year (Litzgus and Brooks 1998; Ernst and Lovich 2009), differences in reproductive condition between years may explain the observed differences in annual home range overlap in females. Alternatively, the clear-cut may have influenced female movements by altering habitat selection. The clear-cut could have created new areas that had potential to serve as nesting and thermoregulatory habitat. Females may have moved greater distances while seeking out these newly available sites. Determining the proximate effects of a given habitat alteration is difficult. Our inference is limited in this case due to insufficient information (e.g., reproductive condition of females), the lack of additional treatment and control sites, and the fact that our data are limited to one year before, and one year after the clear-cut.

Spotted Turtles exhibited smaller home range sizes at our study site in Rhode Island than those from populations of Spotted Turtles in Massachusetts (Milam and Melvin 2001), South Carolina (Litzgus and Mousseau 2004), and Ontario (Rasmussen and Litzgus 2010), but were larger or comparable to those of other studies (Ernst 1970; Wilson 1994; Graham 1995). Differences in home range size among studies are usually attributed to distribution and density of resources (i.e., food items, critical habitat, and mates) on the landscape. Intermediate home range sizes suggest a moderate density of resources at our study site. Males and females exhibited similar overall home range size. In turtles, males generally engage in larger movements during the mating season to locate mates, and females exhibit larger movements during the nesting season to locate nest sites (Morreale et al. 1984; Parker 1984). Movements of Spotted Turtles do not always follow this pattern, though. Early season congregations in Spotted Turtles appear to be common (Ernst 1967; Milam and Melvin 2001) and likely take place for breeding purposes (Litzgus and Mousseau 2004), thus limiting the distance that males must travel to actively search for mates. Larger home range sizes were observed for gravid females in South Carolina (Litzgus and Mousseau 2004), and results of other studies support the idea that gravid females exhibit larger home ranges because they must find appropriate nesting habitat (Haxton and Berrill 1999; Milam and Melvin 2001; but see Rasmussen and Litzgus 2010). The fact that we did not observe a difference in home range size between sexes may be due to an absence of gravid females, or the fact that appropriate nesting habitat existed in close proximity to wetlands used throughout the activity season. We suspect that, among populations, the location and configuration of appropriate nesting habitat plays a large role in the home range sizes of females.

***Habitat use*.**—Turtles used wetlands with much greater frequency than uplands. Most likely, the majority of observations of upland use were associated with summer estivation, possibly influenced by water levels in ephemeral wetlands (Milam and Melvin 2001; Rasmussen and Litzgus 2010). Vernal pools in the area dry in late June through late July, and increased use of upland areas may reflect decreases in available wetland area. Overall wetland use was consistent between years, but the shift from wetland use to persistent use of uplands occurred about three weeks later in 2014. Total precipitation was greater in 2013 though (69.3 cm in 2013 versus 56.9 cm in 2014), and data from a different study confirms that 2014 was a drier year in small wetlands state-wide (Scott Buchanan, unpubl. data). Thus, the timing of wetland drying does not explain the difference in timing of upland use between years, which remains unexplained. Future studies should investigate what factors influence the shift between wetland use and upland use for this species.

Upland areas surrounding wetlands, often termed buffer zones or core terrestrial habitat, are important for ensuring the protection of wetland fauna that use both habitat types. Use of upland areas appears to be variable among populations of Spotted Turtles. In 12 instances (approximately 11% of upland radio-locations), turtles in our study were found in upland areas beyond the protected buffer of 50 ft (15.2 m) required for Perimeter Wetlands (pond area > 0.10 ha [0.25 ac] and standing water for ≥ 6 mo/y) under the Rhode Island Fresh Water Wetlands Act (Rhode Island Department of Environmental Management 1998). In addition, there were many instances in which individuals moved from one wetland to another, and in doing so used upland habitat outside of the regulatory buffer zone. In our study population, current Rhode Island regulations would not be adequate to ensure that upland habitat used by Spotted Turtles was protected from development projects or other activities that would result in the destruction or fragmentation of upland habitat. In Massachusetts, > 90% of Spotted Turtles nested or estivated outside the 30 and 60 m upland buffer zones (for palustrine and permanently flowing wetlands, respectively) stipulated by Massachusetts wetlands regulations at the time of study (Milam and Melvin 2001). In Ontario, one population of Spotted Turtles nested 2–139 m from a wetland (Rasmussen and Litzgus 2010). In contrast, individuals in another population in

Ontario were described as rarely observed farther than 2 m from a wetland except in instances of nesting or movements between areas (Haxton and Berrill 1999); the study did not quantify these distances. A review of aquatic turtle nesting data estimated that a core area of 127 m surrounding wetlands would be required to protect 95% of Spotted Turtle nests (Steen et al. 2012). Our results and those of other studies of Spotted Turtle habitat use suggest that protection of upland habitat around wetlands is important to ensure that habitat used for nesting, thermoregulation, and movement between sites is not compromised.

Spotted turtles hibernate in wetlands, hibernate communally, and show fidelity to overwintering sites (Litzgus et al. 1999; Ernst and Lovich 2009). Most (66%) of the individuals tracked to hibernacula in both years exhibited fidelity to hibernacula. This level of fidelity is comparable to other studies of Spotted Turtles at undisturbed sites in Ontario (Haxton and Berrill 1999; Litzgus et al. 1999; Rasmussen and Litzgus 2010), and suggests that turtles were able to navigate to and from specific wetlands, even after the dramatic alterations to our study site associated with the clear-cut. Wetland habitat is critical to this species and, from the perspective of conservation, the protection of wetlands containing Spotted Turtle hibernacula is of preeminent importance.

Management implications.—Overall, our observations should be considered descriptive. Our data are limited to one year before, and one year after the clear-cut at only one study site. Multiple years of data collection, both before and after the cut, would have improved our ability to gauge the direct influence of the clear-cut by establishing interannual variation for the ecological parameters of interest under both conditions. In addition, monitoring populations at control sites that did not undergo a clear-cut would have been helpful in establishing inter-population variation in home range size and timing of upland use (Currylow et al. 2012). We did however document potential effects of the clear-cut; marginally larger home range sizes in 2014 could have come as a result of the clear-cut. Whether home range sizes were larger for positive (e.g., new opportunities for nesting or thermoregulation) or negative (e.g., more area needed to obtain resources) reasons for this population of Spotted Turtles remains an open question. Nonetheless, our data suggest that timber harvesting of this intensity (i.e., percentage of forest removal and management practices carried out) and spatial scale may be compatible with maintaining populations of Spotted Turtles, even when the harvest takes place in close proximity to wetlands where the species occurs. However, the spatial configuration of the clear-cut relative to wetland habitat is probably an important factor to consider. Although the clear-cut did come very close to several wetlands containing Spotted Turtles, the continuity of forest north of the rights-of-way (where turtles spent the majority of their time) remained largely intact and no wetlands were completely fragmented. A larger cut or a cut that completely fragmented individual wetlands may have had a more dramatic effect on turtle movements. In addition, the availability of longer-hydroperiod wetlands at our study site may have ameliorated some of the effects of the clear-cut. The study site contains several vernal pools, which dry nearly every year, and one permanent wetland on the site and another just off-site. Permanent wetlands in the area of the study provide refugia for turtles as vernal pools dry, probably reducing the need for long-term estivation in upland sites, as has been documented in other populations (Litzgus and Brooks 2000; Beaudry et al. 2009). Thus, a clear-cut similar to this one is probably less likely to impact Spotted Turtle populations where turtles are able to move from ephemeral into permanent wetlands during the hottest and driest parts of the activity season.

To our knowledge, this is the first study to investigate responses of Spotted Turtles to creation of early successional habitat. Given that more than 3,300 ha of early successional habitat was created for New England Cottontail in six northeast states in 2013 and 2014 (Fuller and Tur, *op. cit.*), we are encouraged that we did not detect major impacts of this activity on the turtle population in our study. However, we strongly recommend that the spatial arrangement and hydroperiods of wetlands near a proposed clear-cut area be investigated prior to commencement of operations and that the entire harvesting process take place during months when turtles remain in or near wetland hibernacula. In the Northeast, this would generally be between mid-November and early March, but may vary depending on weather conditions in a given year. Additionally, care must be given to avoid any significant disturbance to wetlands that contain Spotted Turtles at any point in the year, especially those containing hibernacula.

Spotted Turtles are a species of increasing conservation concern. Habitat destruction and modification, vehicular mortality (i.e., automobiles and agricultural equipment), and personal and commercial collection are considered the greatest threats to the species (Ernst and Lovich 2009; van Dijk 2013). An improved understanding of how early successional habitat creation affects populations of Spotted Turtles will allow resource managers to identify instances in which the implementation of the practice is consistent with the site-specific conservation goals for the species.

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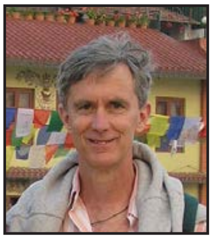

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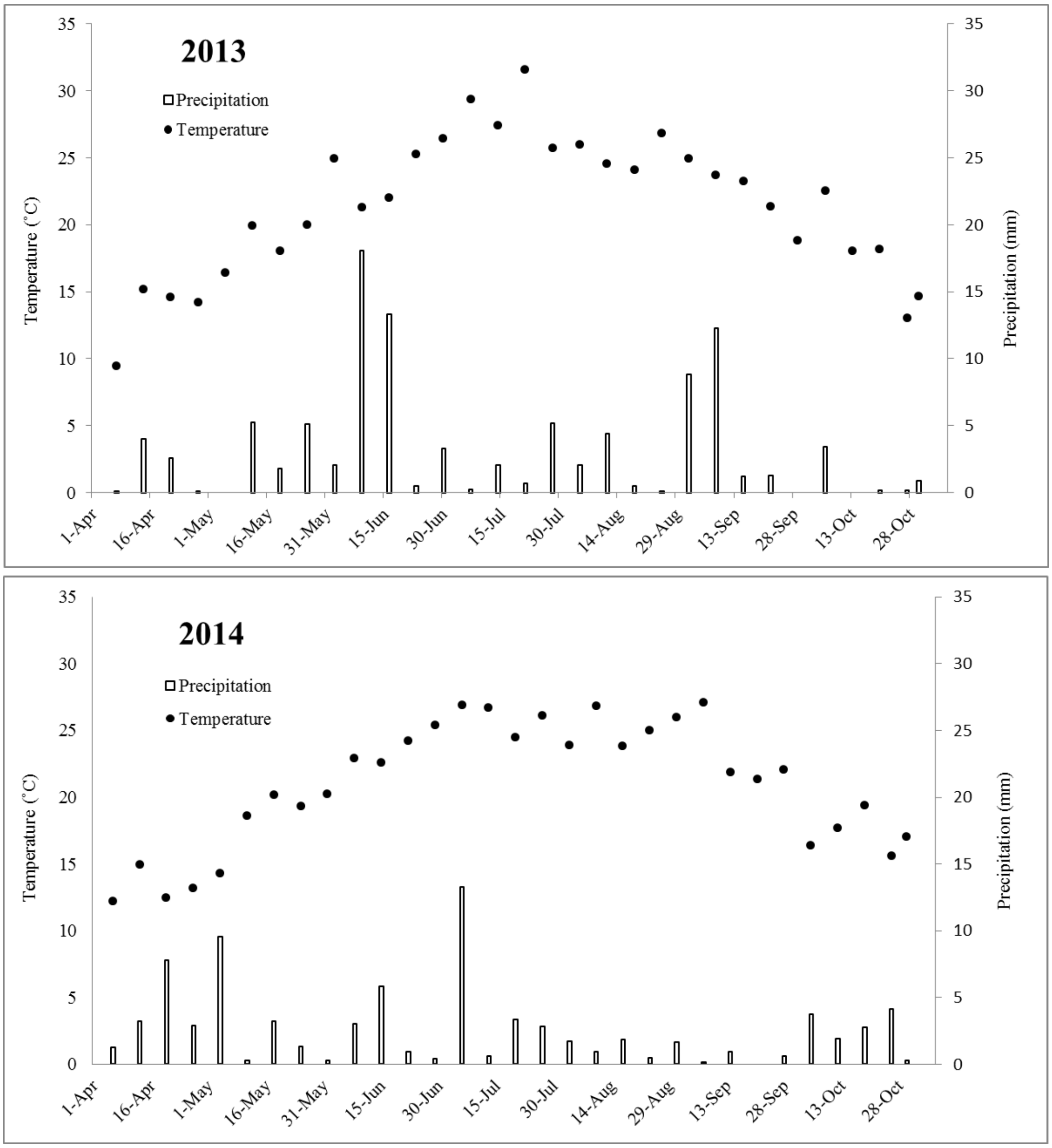
Appendix Table. Basal area estimates for all tree species before and after clear-cut, Washington County, Rhode Island, USA, 2013–2014. Estimates for 2014 include the trees on the perimeter of the clear-cut.

Species	2013 basal area (m^2 / hectare)	2014 basal area (m^2 / hectare)
Black Oak (*Quercus velutina*)	6.76	0.98
Red Maple (*Acer rubrum*)	4.14	1.15
White Oak (*Quercus alba*)	1.89	1.44
Northern Red Oak (*Quercus rubra*)	2.00	0.74
Eastern White Pine (*Pinus strobus*)	1.27	0.25
Scarlet Oak (*Quercus coccinea*)	0.04	0.25
Eastern Redcedar (*Juniperus virginiana*)	0.41	0.37
Bigtooth Aspen (*Populus grandidentata*)	0.25	0
Gray Birch (*Betula populifolia*)	0.12	0
Black Cherry (*Prunus serotina*)	0.12	0
Pitch Pine (*Pinus rigida*)	0.12	0.04
Swamp White Oak (*Quercus bicolor*)	0.08	0
Paper Birch (*Betula papyrifera*)	0.04	0
Sassafras (*Sassafras albidum*)	0	0.04
Sum	17.26	5.25
Mean (SE)	1.23 (0.53)	0.37 (0.13)



Appendix Figure. Weekly means for maximum temperature (° C) and precipitation (mm) Washington County, Rhode Island, USA, 2013 and 2014.