Herpetological Conservation and Biology 7(2):185-195.
Submitted: 17 January 2011; Accepted: 20 April 2012; Published 10 September 2012.

HABITAT USE AND MOVEMENT PATTERNS OF BLANDING'S TURTLES (*EMYDOIDEA BLANDINGII*) IN MINNESOTA, USA: A LANDSCAPE APPROACH TO SPECIES CONSERVATION

JEANINE M. REFSNIDER[1,2] AND MADELEINE H. LINCK[3]

[1]*Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota, 100 Ecology Building, St. Paul, Minnesota 55108, USA*
[2]*Department of Ecology, Evolution and Organismal Biology, Iowa State University, 253 Bessey Hall, Ames, Iowa 50011-1020, USA, e-mail: refsnij@iastate.edu*
[3]*Three Rivers Park District, 12615 County Rd. 9, Plymouth, Minnesota 55441-1248, USA*

***Abstract.*—A landscape-scale approach to species conservation is important for species in which land cover use varies both temporally and spatially. We used radio-telemetry to study habitat use and movement patterns of adult female Blanding's Turtles (*Emydoidea blandingii*) in the context of landscape composition, connectivity, and physiognomy over two years to inform management activities for the population. Throughout the year, Blanding's Turtles used a complex of wetlands differing in size and depth. Turtles traveled overland extensively during the nesting season, and exhibited frequent use of ephemeral wetlands while on nesting forays. In addition, they made numerous road crossings and many turtles nested along road edges, indicating that paved roads did not represent a barrier to nesting-related travel, and may represent an ecological trap to this population. By taking a landscape-level approach to studying habitat use and movement patterns, we demonstrated how this species used both aquatic and terrestrial cover types throughout the year, the distances traveled between different cover types during different seasons, and how connectivity between habitat patches may affect adult survival. We recommend that conservation efforts for Blanding's Turtle populations be implemented at the landscape level and: (1) encompass all land cover types used throughout the year; (2) maintain corridors for safe travel among these cover types; and (3) include sufficiently-large terrestrial buffer zones around wetlands such that the entire extent of females' nesting-related travel is enclosed.**

Key Words.—Blanding's Turtle; *Emydoidea blandingii*; ephemeral wetland; migration; nest-site selection; radio-telemetry; road mortality

INTRODUCTION

Freshwater turtles are a group of high conservation concern, with approximately 40% of the world's turtle species currently listed as globally Threatened by the IUCN (Rhodin et al. 2010). The decline of many freshwater turtle species is attributed to habitat loss and fragmentation (Turtle Conservation Fund 2002), but indirect effects (such as agricultural runoff) of land use practices also impact the wetland habitat used by freshwater turtles and contribute to species declines (reviewed in Bodie 2001). Although freshwater turtles generally spend the majority of their time in aquatic habitats, many species travel between wetlands (e.g., Bowne 2008; Roe and Georges 2008) and engage in overland travel to upland nesting areas (e.g., Carr 1952; Congdon et al. 1987). The use of both aquatic and upland habitat by freshwater turtles demonstrates that protection of wetland habitat alone is insufficient to conserve many populations of freshwater turtles. For example, while nesting-related travel accounts for only a small percentage of a female turtle's annual time budget, the risk of road mortality (Haxton 2000; Steen et al. 2006) and human exploitation (Suganuma et al. 1999) increases dramatically during nesting forays, and high mortality of adult females during nesting-related travel may skew population sex ratios (Steen and Gibbs 2004). Because road mortality is experienced only when turtles are traveling between more extensively used habitat patches, the problem involves both landscape composition and connectivity. The often extensive travel by freshwater turtles through a terrestrial matrix (e.g., Bowne 2008), and use of multiple wetland patches throughout the year (e.g., Joyal et al. 2001), suggests that effective conservation strategies should be undertaken at the landscape level. Indeed, in a review of terrestrial habitat use by 10 species of stream-dwelling freshwater turtles, Bodie (2001) found that a 150 m riparian zone was biologically critical to encompass the distances traveled by aquatic turtles during seasonal terrestrial migrations for nesting and over-wintering.

Conservationists are becoming increasingly aware of the importance of landscape-scale structure and processes in managing and conserving rare species (Simberloff 1988). While it is important to consider the composition of a landscape to ensure that all required habitat types are available to a species of concern, the connectivity of habitat patches and the distance between them (i.e., physiognomy) will also strongly influence the ability of an organism to access and use necessary habitat types. For example, including corridors in habitat conservation efforts can increase landscape connectivity and thereby facilitate movement between separated habitat patches (Wilson and Willis 1975). Conservation strategies that incorporate a population's entire landscape will be more effective (Joyal et al. 2001; Stokes et al. 2010), and will require less investment in management (e.g., Maehr 1990), than approaches focused only on specific habitat patches.

The importance of terrestrial habitat to primarily aquatic species is now recognized as a critical component of conservation and management strategies for wetland species (e.g., Gibbons 1970; Semlitsch 1981; Burke and Gibbons 1995; Palis 1997; Crawford and Semlitsch 2007). In some areas, the legal designation of buffer zones around wetlands has been an attempt to protect terrestrial habitat required by otherwise aquatic species such as salamanders and freshwater turtles (e.g., Klein and Freed 1989; Brown et al. 1990), as well as to minimize exogenous inputs such as siltation and run-off from agriculture and silviculture (e.g., Blackwell et al. 1999; Vesely and McComb 2002). However, in many cases, these buffer zones are insufficient to encompass the full extent of terrestrial habitat used by wetland species (e.g. Semlitsch 1998; Harper et al. 2008), leaving animals vulnerable to disturbance and pollution if they travel outside the buffer zone. The discrepancy between legally-designated protected areas and the habitat actually used by wetland species emphasizes the importance of accurately assessing the complete habitat requirements of species of concern, which can best be accomplished by taking a landscape-level approach to spatial analyses and management efforts.

Blanding's Turtle, *Emydoidea blandingii*, is an imperiled freshwater turtle of the northern United States and southern Canada. The species is listed as Endangered, Threatened, or of Special Concern in 15 of 18 states and provinces in which it currently occurs, and it has been extirpated from Connecticut and Rhode Island. The decline of Blanding's Turtle across its range is attributed primarily to habitat loss (Moriarty 2000) and high rates of nest predation (Linck and Moriarty 1997). Blanding's Turtles use a variety of wetland types throughout the year (Todd Sajwaj et al., unpubl. report), making the conservation of wetland complexes critical for this species (Joyal et al. 2001). Blanding's Turtles also commonly use the terrestrial matrix encompassing wetland complexes. Both sexes make overland journeys among wetlands throughout the active season (Rowe and Moll 1991; Herman et al. 1995) and long periods of terrestrial aestivation are common in some populations (Joyal et al. 2000). In addition, female Blanding's Turtles make particularly long overland journeys during the nesting season (Piepgras and Lang 2000). These nesting forays can last 17 d (Rowe and Moll 1991; Innes et al. 2008) and turtles may travel > 1 km during forays (Congdon et al. 1983; Piepgras and Lang 2000). Because Blanding's Turtles may use a combination of different wetland types annually, as well as upland nesting habitat and suitable habitat for traveling among these land cover types, they are vulnerable to threats that affect any of these individual components of the landscape.

We used a landscape ecology approach to study a population of Blanding's Turtles in a Minnesota reserve experiencing increasing habitat fragmentation as a result of expanding urban sprawl and road development. Previous research at the study site suggested that although suitable nesting habitat was available within the reserve, some Blanding's Turtles nevertheless bypassed this habitat and instead left the reserve to nest in private property adjacent to the reserve; such turtles had to cross paved roads to reach nesting habitat outside of the reserve. Residential development and road construction have expanded dramatically around the reserve since 2000, and the resulting human encroachment may result in road mortality of individual turtles attempting to travel into or out of the reserve, and/or relegate turtles from this population solely to within reserve boundaries. We therefore expected that while turtles from within the reserve would use nesting habitat both within and outside the reserve boundary, the paved roads bordering the reserve would present substantial mortality risk to individuals traveling into and out of the reserve.

Our specific objectives in conducting this study were to: (1) quantify landscape composition and determine which land cover types were used throughout the year; (2) examine the effects of decreasing habitat connectivity by determining the rate of road crossings by turtles moving in and out of the reserve; and (3) characterize physiognomy of habitat patches used during the nesting season. Overall, the goal of this study was to improve conservation efforts for Blanding's Turtles at the study site by identifying specific habitat features important to species persistence, determining when such features were used throughout the year to avoid disturbance to turtles, and assessing the threat that decreasing habitat connectivity due to increased road density poses to this population.

MATERIALS AND METHODS

We studied Blanding's Turtles at Murphy-Hanrehan Park Reserve, managed by Three Rivers Park District, in Scott County, Minnesota, USA. The Park Reserve is ~ 970 ha and is bordered by agricultural fields, pastures, residential developments, and golf courses. We defined the study site as a 6.22 km^2-area approximately centered around two large, shallow wetlands and a complex of smaller wetlands, and the site included 4.02 km^2 of Park Reserve land and 2.20 km^2 of adjacent private land (Fig. 1).

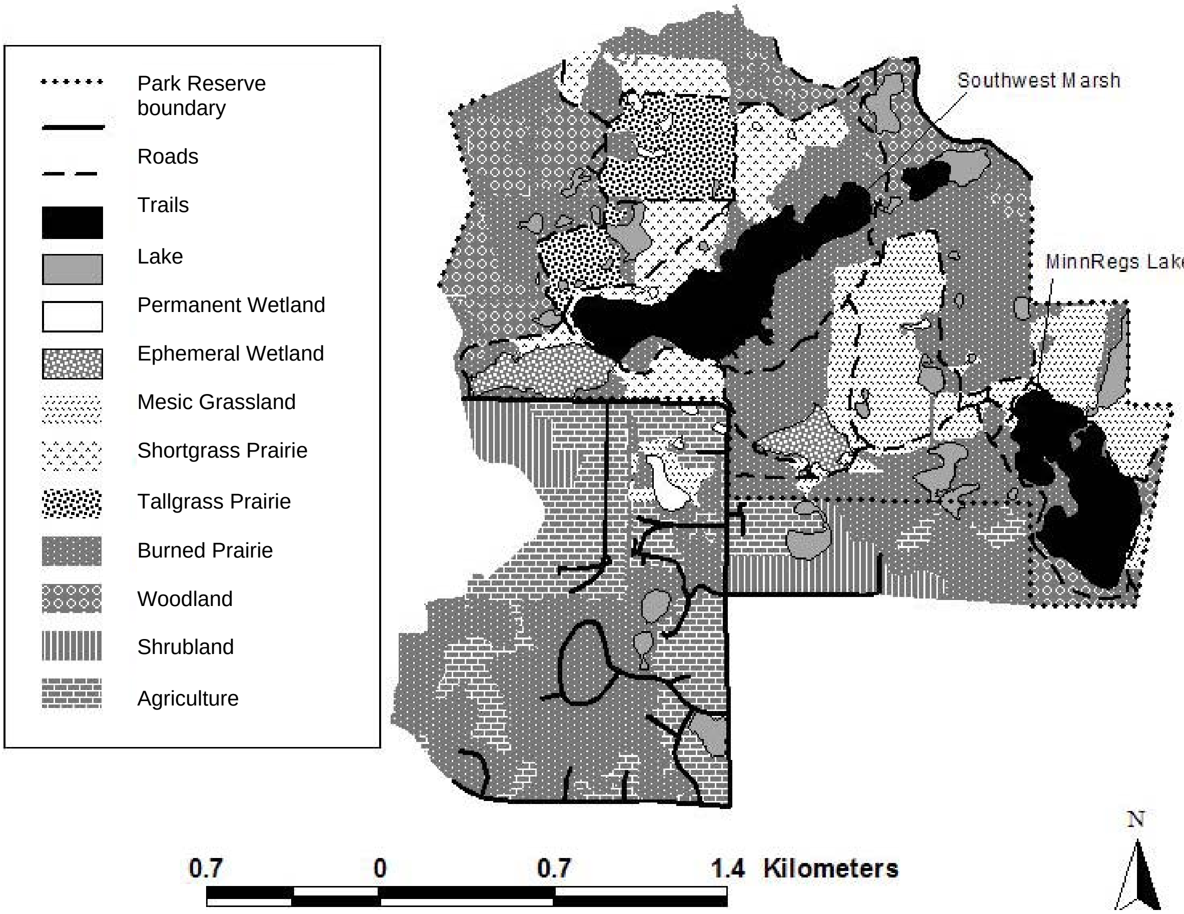

FIGURE 1. Land cover at Murphy-Hanrehan Park Reserve, Scott County, Minnesota. Land cover classification is shown for 2003, which was identical to 2004 except for Burned Prairie and Tallgrass Prairie. Park Reserve land is north of the park reserve boundary line; land south of the boundary is privately owned.

We categorized the area within the study site into eleven habitat, or land cover, types, which were mapped using a combination of 2004 aerial photos and ground-truthing, and digitized using GIS software (ESRI, Redlands, California, USA). Terrestrial cover types were divided into the following categories: Shrubland, Mesic Grassland, Woodland, Residential, and Agricultural (corn or soybean fields). Three prairie categories were also defined as follows: Shortgrass Prairie was typically former pasture land currently returning to prairie; Tallgrass Prairie was dominated by *Andropogon gerardii* and had not been burned more recently than spring of the previous year; and tallgrass prairie that had been burned in spring of the current year was designated as Burned Prairie. Importantly, due to the burn regime maintained at the study site, certain sections of prairie were characterized as Tallgrass Prairie in one year and Burned Prairie in another.

Aquatic cover types were categorized as Lakes, Permanent Wetlands, or Ephemeral Wetlands. Permanent Wetlands were those categorized as Palustrine by the National Wetlands Inventory (NWI; Cowardin et al. 1979) and were verified by ground-truthing. Ephemeral Wetlands were small, shallow depressions in prairies or pastures that contained standing water during the spring and early summer, but dried up by mid-summer and remained dry until the following spring. These wetlands were not classified by the NWI, but were located and mapped during systematic ground surveys in early spring 2004. The percentage of the study site made up by each land cover type varied from 0.6% (Ephemeral Wetland) to 38.9% (Woodland; Table 1).

We captured Blanding's Turtles in early spring, either using dipnets from canoes, or by hand as they traveled overland between overwintering and spring wetlands. We marked all turtles by filing a unique combination of notches in the marginal scutes (adapted from Cagle 1939). We glued radio transmitters (R2030, Advanced Telemetry Systems, Isanti, Minnesota, USA) to the costal scutes of 21 adult female turtles using 5-minute epoxy. Transmitters plus glue weighed approximately 26 g, which amounted to a maximum of 1.8% of a turtle's body mass, and no negative effects of transmitter placement (such as difficulty swimming or walking) were observed. We released turtles within 24 h

TABLE 1. Percentage of radio-locations of adult female Blanding's Turtles (*Emydoidea blandingii*) in each land cover type during five seasons at Murphy-Hanrehan Park Reserve, Scott County, Minnesota in 2003 and 2004 (years pooled). The percentage of the total study site made up by each land cover type was the same in 2003 and 2004 for all land cover types except Tallgrass and Burned Prairie, which differed between years due to the prescribed burn regime in the Park Reserve.

	% of radio-locations in each land cover type					% of study site
	Spring	Nesting	Summer	Fall	Winter	
Shrubland	0	1.2	0	0	0	8.0
Mesic Grassland	0	0	0.2	0	0	2.2
Woodland	0	1.2	0	0	0	38.9
Residential	0	8.1	0.2	0	0	13.4
Agricultural	0	0.2	0	0	0	4.0
Shortgrass Prairie	0	8.1	0.4	0	0	9.7
Tallgrass Prairie	0	2.6	0	0	0	6.8 (2003) 6.5 (2004)
Burned Prairie	0	8.4	0.4	0	0	4.2 (2003) 4.5 (2004)
Lake	80.2	29.1	75.8	83.5	78.6	8.5
Permanent Wetland	9.9	12.4	18.8	16.5	21.4	3.6
Ephemeral Wetland	9.9	28.6	4.1	0	0	0.6
Total # locations	81	419	463	115	28	

at the site of capture. Additional Blanding's Turtles that we observed incidentally during the course of this study were also captured and marked, but we did not fit them with radio-transmitters.

We radio-tracked turtles 3–4 times weekly during April and May in 2003 and 2004. Each time a turtle was located, we recorded the activity of the turtle (e.g., traveling, sheltering under vegetation, nesting), weather conditions, time of day, and land cover type. Beginning in June of both years (i.e., the nesting season), we tracked females daily until they began their nesting foray, during which time we tracked them 2–3 times daily until they ended their nesting foray. This intensive tracking ensured that the nests of radio-tracked turtles could be located. We defined nesting forays *a posteriori* as the period during which a female, who had previously been observed for at least a week in the same wetland, left that wetland, nested, and returned to a wetland, after which she was observed to remain in that wetland for at least a week.

We mapped the locations of all radio-tracked turtles and nest sites using aerial photographs in GIS software. We divided the year into five seasons: Spring (April-May), Nesting (June), Summer (July-August), Fall (September-October), and Winter (November-March). Because the frequency of radio-tracking differed among seasons (e.g., we tracked turtles only once during the Winter season to locate each individual's hibernaculum, while we tracked individuals daily during the Nesting season to locate nests), we converted the total number of locations in each land cover type into the proportion of the total radio-locations per season observed in each land cover type. We used analysis of variance (α 0.05) with female identity as a random effect to compare the mean number of wetlands used, number of inter-wetland movements made, number of road crossings, and total terrestrial distance traveled among seasons. We conducted statistical analyses using SAS 9.2 (SAS Institute, Cary, North Carolina, USA).

RESULTS

We collected 1,106 radio-locations of 21 adult female Blanding's Turtles in 2003 and 2004. Three of these females we tracked in 2003 only, nine we tracked in 2004 only, and nine we tracked during both years. We combined data from both years for all analyses, but we included only the last location obtained per day in cases where an individual was radio-tracked multiple times in one day.

Habitat use.—Some use of terrestrial cover types was observed in Summer (2% of locations), but the majority (98%) of Summer locations was in aquatic cover types and most of these (76%) were in Lakes (Fig. 2a). During Fall, Winter, and Spring, all turtle locations were in aquatic cover types, and the majority of these (83%, 78%, and 80%, respectively) was in Lakes (Table 1).

All but one turtle spent Fall and the subsequent Winter in the same wetland (which was not necessarily the wetland in which they had spent the previous Summer); thus, most turtles appear to have moved into their Winter wetland in late Summer and remained there throughout hibernation. Although most (80%) Winter locations were in Lakes, individual hibernacula within Lakes were not generally in the deepest portion of Lakes, but instead tended to be in shallower areas near shorelines, often characterized by extensive emergent vegetation (Fig. 3a). The remaining (20%) Winter locations were in shallow, Permanent Wetlands. Most Spring locations were in Lakes (80%), but some use of Permanent (10%) and Ephemeral Wetlands (10%) also occurred. Turtles embarked on nesting forays from the wetland in which they were located at the end of the Spring season.

In contrast to the rest of the year, land cover type use during the Nesting season was more varied (Fig. 2b). The majority (70%) of locations during the Nesting season was in aquatic cover types, with 29%, 12%, and 29% of all Nesting season locations in Lakes, Permanent Wetlands, and Ephemeral Wetlands, respectively. Terrestrial cover types used were primarily Burned Prairie (28% of Nesting season locations that were in terrestrial cover types), Shortgrass Prairie (27%), and Residential (27%), with a few additional radio-locations in Tallgrass Prairie (9%), Woodland (4%), Shrubland (4%), and Agricultural land (1%). While engaged in nesting forays, females used an average of 1.2 Ephemeral Wetlands and 0.7 Permanent Wetlands. When we analyzed time spent in different cover types during nesting forays (i.e., nesting foray-days), females spent all or part of 4.9 (49%) nesting foray-days in Ephemeral Wetlands and 1.2 (10%) nesting foray-days in Permanent Wetlands.

Road shoulders and trail edges were the most commonly used land cover types for nest construction, followed by Burned Prairie (Fig. 3b). Eight nests (30.8%) were constructed in gravel road shoulders and an additional five nests (19.3%) were constructed in Shortgrass Prairie at the edge of recreational trails. Turtles that nested in road shoulders or in trail edges made nesting attempts for an average of two days before successfully completing a nest, compared to turtles that nested in more "natural" cover types (i.e., Burned and Shortgrass Prairies), none of which we observed making unsuccessful nesting attempts. Overall, 69% of nests were constructed in highly modified cover types including road shoulders, trail edges, residential areas, or agricultural fields.

Movement patterns.—Individual females used more total wetlands ($F_{4,59}$ = 42.53, P < 0.001), made more inter-wetland movements ($F_{4,59}$ = 31.87, P < 0.001), made more road crossings ($F_{4,59}$ = 12.45, P < 0.001), and traveled a greater total terrestrial distance ($F_{4,59}$ = 46.51, P < 0.001) during the Nesting season than any other season (Table 2). Minimal inter-wetland travel occurred during Fall when eight turtles moved 64 m between the same Summer and Winter wetlands. Similarly, three turtles made inter-wetland movements in Spring when they traveled 37 m from a Winter to an adjacent Spring wetland. We did not observe inter-wetland movement during Winter.

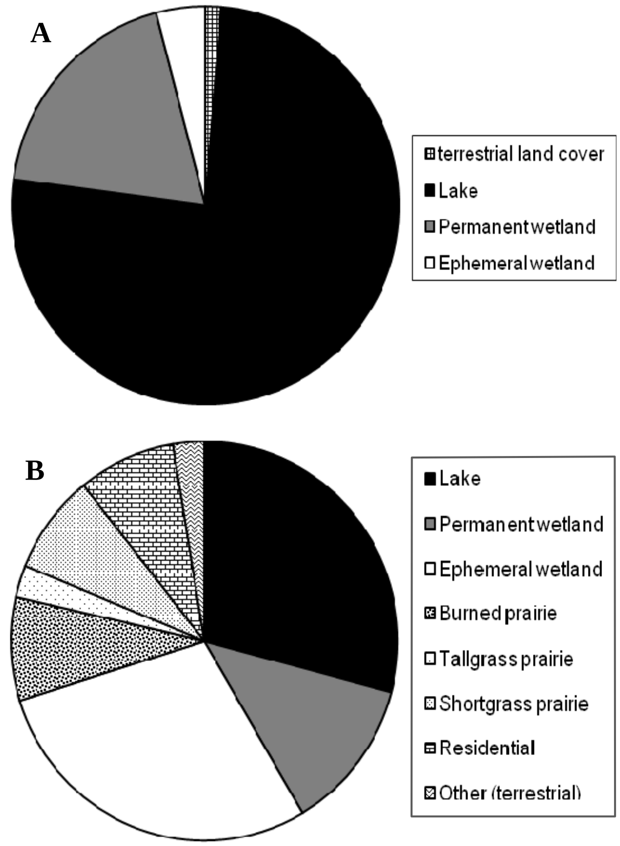

FIGURE 2. Proportion of radio-locations of Blanding's Turtles (*Emydoidea blandingii*) in each land cover type at Murphy-Hanrehan Park Reserve, Scott County, Minnesota, in 2003 and 2004. A: locations during Summer (July–August; n = 463); B: locations during the Nesting season (June; n = 419).

Nesting forays began on 9 June in 2003 and 3 June in 2004, and ended on 29 June in 2003 and 2 July in 2004. Mean duration of nesting forays was 10.2 d. Turtles made unsuccessful nesting attempts on an average of 0.8 d before successfully completing a nest, spent an average of 6.2 d on nesting forays before the day on which they completed nesting, and returned to a wetland within a mean of 3.0 d after nesting.

The minimum distance traveled by females on nesting forays was obtained by summing the straight-line distances from one radio-location to the next throughout a female's nesting foray. The average minimum distance

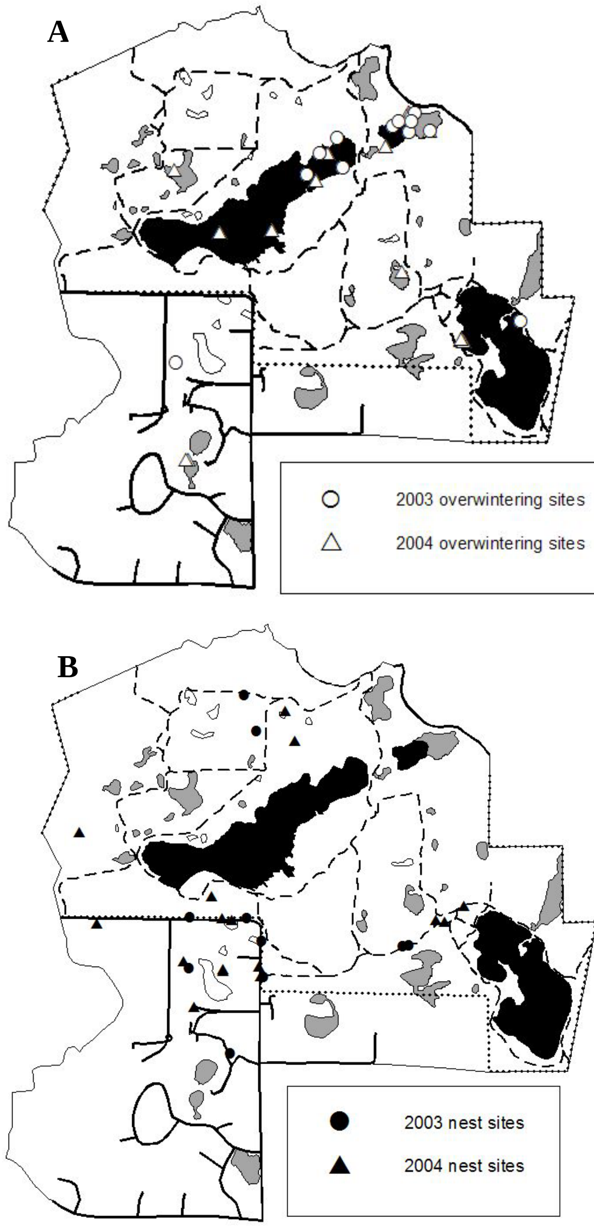

FIGURE 3. Overwintering (A) and nest sites (B) of radio-tracked adult female Blanding's Turtles (*Emydoidea blandingii*) at Murphy-Hanrehan Park Reserve, Scott County, Minnesota in 2003 and 2004. Circles = 2003 locations; triangles = 2004 locations. See Figure 1 for land cover types.

traveled was 1,851 m, and the average distance traveled per day was 193 m. Nests were constructed on average 196 m from the nearest permanent wetland, 514 m from the wetland exited by females when forays began, and 597 m from the wetland in which the female spent the remainder of the summer (see Fig. 3b).

Most (59%) turtles crossed a paved road at least once during their nesting foray, with an average of 2.4 road crossings per female. We captured and marked an additional seven adult females in and around the Park Reserve but they were not radio-tracked; we found three (42.8%) of these on paved roads during the Nesting season. One of these females was later found recently killed on a road, and crushed, shelled eggs found around this female indicated that she had been traveling to a nest site. This female represented 3.7% of all adult female Blanding's Turtles encountered during the two years of this study. No turtles were known to have crossed roads during Spring, Fall, or Winter, but 0.1 road crossing per individual occurred during Summer.

TABLE 2. Movements of radio-tracked adult female Blanding's Turtles (*Emydoidea blandingii*) during five seasons at Murphy-Hanrehan Park Reserve, Scott County, Minnesota in 2003 and 2004 (years pooled). Values are means ± 1 standard deviation.

	Spring	Nesting	Summer	Fall	Winter
Number of wetlands used	1.2 ± 0.4	2.8 ± 1.0	1.4 ± 0.5	1.3 ± 0.4	1 ± 0
Frequency of inter-wetland movements	0.7 ± 1.1	2.3 ± 1.5	0.5 ± 0.7	0.3 ± 0.5	0 ± 0
Number of crossings of paved roads	0 ± 0	2.4 ± 2.5	0.1 ± 0.3	0 ± 0	0 ± 0
Minimum terrestrial distance traveled (m)	23 ± 34.6	1171 ± 714.6	151 ± 373.0	30 ± 58.0	0 ± 0

Finally, fidelity to overwintering and nest sites was measured as the distance between an individual's overwintering or nest locations in successive years. We had overwintering locations for seven females in both 2003 and 2004; six of these seven females overwintered in the same wetland in both years of the study and four females overwintered within 40 m of their overwintering site from the previous year. The average distance between individuals' 2003 and 2004 overwintering sites was 94 ± 110 m (Fig. 4). Nest sites were known for six individuals in both 2003 and 2004, and these females nested from 48 to 360 m (mean 150 m) from their nest site the previous year (Fig. 4).

DISCUSSION

Our study examined the habitat use and movement patterns of Blanding's Turtles at the landscape scale. We determined which landscape patches were used at different times of the year, how landscape connectivity affected rates of road mortality, and the physiognomy of habitat patches used during the nesting season. Understanding how Blanding's Turtles used the landscape throughout the year can ensure that management activities, such as prescribed burnings and wetland drawdowns, are conducted at times of the year that will minimize effects on Blanding's Turtles. Early fall and late spring were times when adult turtles moved in and out of overwintering wetlands within the wetland complex, and turtles may be vulnerable to prescribed burning of the terrestrial matrix between wetlands during those times. Hatchling Blanding's Turtles also move overland during early fall and late spring (Linck and Gillette 2009); therefore, prescribed burns should be avoided during these times. In addition, turtles have entered their overwintering wetlands by early fall, where they remain until the following spring. Therefore, wetland draw-downs should not be conducted in fall to prevent turtles from being trapped in shallow water with insufficient time to move to a different wetland before the onset of winter.

The movement patterns exhibited by turtles in this study illustrate the importance of landscape connectivity to this species. Turtles regularly traveled between lakes and small permanent wetlands, particularly in spring and fall; separation of these wetland types by roads is known to increase mortality (Haxton 2000; Steen and Gibbs 2004; Steen et al. 2006). During the June nesting seasons, turtles additionally exhibited extensive use of small, isolated, ephemeral wetlands, illustrating the importance of this cover type to the conservation of the study population. Ephemeral Wetlands comprised a small fraction of the study site (0.63%), but were used more than any other land cover type by Blanding's Turtles on nesting forays. Females either spent the night in Ephemeral Wetlands, or used them as refuges during the day when they were not actively traveling or searching for a nest site. Ephemeral Wetlands likely provide food, protection against predation, and refuge from high afternoon temperatures to turtles on nesting forays. The presence of ephemeral wetlands along travel routes may also improve a female's chances of successfully nesting by serving as re-hydration sites. Turtles in this and other populations (Standing et al. 1999; Joyal et al. 2000) commonly attempted to nest over several consecutive days before successfully completing a nest. The ability to use ephemeral wetlands as refuges along travel routes may be especially important in populations where turtles travel long distances and for many days before nesting, as seen here. The frequent use by nesting Blanding's Turtles of small isolated wetlands, especially ephemeral wetlands,

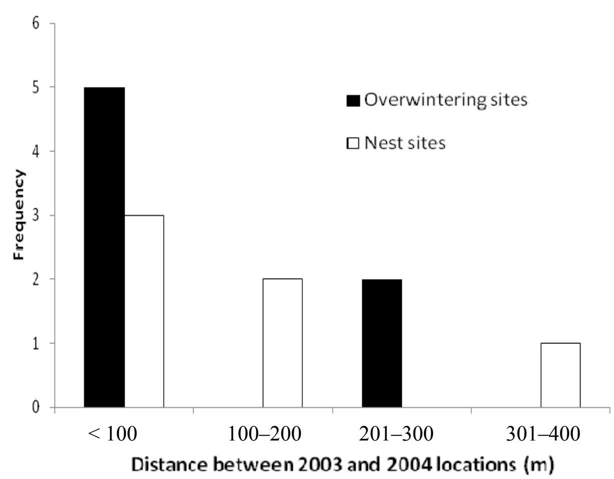

FIGURE 4. Distances between subsequent overwintering (n = 7) and nest sites (n = 6) of adult female Blanding's Turtles (*Emydoidea blandingii*) at Murphy-Hanrehan Park Reserve, Scott County, Minnesota, radio-tracked in both 2003 and 2004.

is a new demonstration of the importance of these habitat features, and suggests that small, isolated wetlands near nesting habitat may be important for the reproductive success of a population. Importantly, when designating protective buffer zones around wetland habitats, ephemeral wetlands should be included in the definition of wetlands (e.g., Semlitsch and Bodie 1998; Leibowitz 2003). Failure to protect a single important habitat component, even one that is used for only a short period of time, will negate conservation efforts elsewhere in an organism's landscape.

During the two years of this study, one instance of road mortality was observed, representing 3.7% of all females encountered during the study. Fifty-seven percent of turtles encountered during this study (both radio-tracked and non-tracked individuals) crossed paved roads during their nesting foray, and usually these turtles crossed roads at least once in each direction. This figure may overestimate the frequency of road crossing in the study population, as turtles that crossed roads were more likely to be encountered by the researchers; however, road mortality of females on nesting forays poses a significant threat to this population. Indeed, although Blanding's Turtles have high annual survivorship (Congdon et al. 1993), a decrease in adult survivorship by 3% annually due to road mortality could drive a population to extinction over time. Importantly, roads separating wetland complexes from upland nesting habitat do not inhibit turtle movement from wetlands to nesting habitat. Instead, some individuals traveled through habitat used by other turtles for nesting, crossed a paved road, and nested in highly modified cover types outside the Park Reserve. Blanding's Turtles in some areas are known to use artificial nesting habitat created by managers (e.g., Dowling et al. 2010). However, some turtles at our study site forego available nesting habitat near their wetland complex and instead travel to more distant habitat, despite having to make dangerous road crossings to reach such habitat. This tendency suggests that at our study site, the creation of artificial nesting habitat to entice Blanding's Turtles to remain within the safety of the Park Reserve throughout the year may not be successful. However, data from our study show that those turtles that did leave the Park Reserve to nest crossed a specific section of road along the southern park boundary. Where roads bisect a travel corridor used by many Blanding's Turtles, safety measures such as turtle tunnels could decrease road mortality, particularly of nesting females (e.g., Scott Jackson, unpubl. report).

Fifty percent of nests observed in this study were constructed in or along gravel road shoulders or trails. Turtles that nested in these areas generally made more nesting attempts, and spent more time digging the nest cavity (Jeanine Refsnider, unpubl. data), than turtles that nested elsewhere, suggesting that nest construction in roads and trails is more difficult than in more natural habitat types. Moreover, nests constructed along roads or in trails at this site are unlikely to hatch due to compaction by vehicles, horses, and hikers (Madeleine Linck, unpubl. data). Predation rates may also be higher along habitat edges such as roads than in less disturbed areas (e.g., Temple 1987; Miller et al. 1998), and females nesting along roads or in trails are vulnerable to being hit by vehicles (unpubl. data). The high use of roads and trails for nesting in this population, despite low hatching success and increased vulnerability of nesting females, suggests that roads may represent an ecological trap to Blanding's Turtles.

In an attempt to preserve upland habitat for primarily aquatic species, protective terrestrial buffer zones are sometimes designated around wetland habitats (e.g., Klein and Freed 1989; Brown et al. 1990). However, the width of buffer zones is often based on the requirements of relatively short-distance migrants, which may travel a given distance to an upland breeding site and then immediately return to the wetland from which they emerged (Semlitch 1998). At our study site, Blanding's Turtles are concentrated in a wetland complex in which wetlands are generally less than 75 m apart. The close proximity among wetlands meant that, as they used wetlands of differing characteristics throughout the year, Blanding's Turtles made only short-distance inter-wetland movements. For most of the year, therefore, a protective buffer of as little as 75 m around wetlands would protect both the aquatic and terrestrial cover types used by Blanding's Turtles. However, turtles traveled extensively during the nesting season, and these movements took them up to 600 m from the wetlands used during spring and summer. Such long-distance movements may have resulted at least in part from turtles searching for areas of recently-burned prairie, which shift from year to year, and would also explain the relatively low fidelity to nest sites in comparison to overwintering sites that we observed. Moreover, some females began nesting forays by exiting a spring basking wetland; then, after completing their nesting foray, they entered a different wetland, where they remained for the rest of the summer. This circuitous nesting movement has also been described in Blanding's Turtles in other populations (Rowe and Moll 1991; Joyal et al. 2000), and indicates that modest protective buffer zones around wetlands are unlikely to encompass the extent of terrestrial habitat required by Blanding's Turtles on nesting forays.

In general, conservation strategies for this species should encompass all land cover types used throughout the year, maintain corridors for safe travel among these cover types, and include sufficiently large terrestrial buffer zones around *all* wetlands such that the entire extent of females' nesting-related travel is enclosed. We can make several specific management recommendations based on our results. First, the timing of management activities such as prescribed burns and wetland draw downs should be planned such that effects on traveling or overwintering turtles are minimized. Second, road mortality of females on nesting forays is a serious threat and every effort should be made to minimize such mortality. For example, protective corridors such as turtle tunnels should be considered for sections of roads that are frequently crossed by turtles on nesting forays and to prevent roads from becoming ecological traps for nesting females. Finally, if protective buffer zones around wetlands are designated to conserve terrestrial habitat necessary for Blanding's Turtles, ephemeral wetlands should receive the same protection as permanent wetlands. Moreover, buffer zones around an entire wetland complex may provide more protection to this species than buffer zones around individual wetlands. Future research should attempt to determine the precise purpose of ephemeral and/or isolated wetlands used by female Blanding's Turtles on nesting forays, and how reproductive success is related to availability of such wetlands.

Acknowledgments.—Funding was provided by the Minnesota Department of Natural Resources - Natural Heritage and Nongame Wildlife Program and State Wildlife Grants, Three Rivers Park District, Minnesota Herpetological Society, and the James Ford Bell Museum of Natural History's Dayton-Wilkie Natural History Funds. Thanks to Carol Carter, Ron Refsnider, Maureen Refsnider, Paul Schlick, Alison Weier, and Three Rivers Park District technicians and volunteers for many hours of field assistance, and to Bonita Eliason, Joan Galli, and Larry Gillette for logistical and funding support. Andrew Simons, Paul Bolstad, Francesca Cuthbert, and Henry Streby provided valuable comments that greatly improved the manuscript. This research was conducted in accordance with Special Permit No. 11605 (Minnesota Department of Natural Resources) and Institutional Animal Care and Use Committee protocol #0312A54521 (University of Minnesota).

LITERATURE CITED

Blackwell, M.S.A., D.V. Hogan, and E. Maltby. 1999. The use of conventionally and alternatively located buffer zones for the removal of nitrate from diffuse agricultural run-off. Water Science and Technology 39:157–164.

Bodie, J.R. 2001. Stream and riparian management for freshwater turtles. Journal of Environmental Management 62:443–455.

Bowne, D.R. 2008. Terrestrial activity of *Chrysemys picta* in Northern Virginia. Copeia 2008:306–310.

Brown, M.T., J. Schaefer, and K. Brandt. 1990. Buffer zones for water, wetlands and wildlife in the east central Florida region. Center for Wetlands publication #89-07. University of Florida, Gainesville, Florida, USA. 202 p.

Burke, V.J., and J.W. Gibbons. 1995. Terrestrial buffer zones and wetland conservation: a case study of freshwater turtles in a Carolina Bay. Conservation Biology 9:1365–1369.

Cagle, F.R. 1939. A system of marking turtles for future identification. Copeia 1939:170–173.

Carr, A. 1952. Handbook of Turtles: The Turtles of the United States, Canada, and Baja California. Cornell University Press, Ithaca, New York, USA.

Congdon, J.D., G.L. Breitenbach, R.C. van Loben Sels, and D.W. Tinkle. 1987. Reproduction and nesting ecology of Snapping Turtles (*Chelydra serpentina*) in southeastern Michigan. Herpetologica 43:39–54.

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., D.W. Tinkle, G.L. Breitenbach, and R.C. van Loben Sels. 1983. Nesting ecology and hatching success in the turtle *Emydoidea blandingii*. Herpetologica 39:417–429.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service - Office of Biological Services Publication #79-31. U.S. Government Printing Office, Washington, D.C., USA. 103 p.

Crawford, J.A., and R.D. Semlitsch. 2007. Estimation of core terrestrial habitat for stream-breeding salamanders and delineation of riparian buffers for protection of biodiversity. Conservation Biology 21:152–158.

Dowling, Z., T. Hartwig, E. Kiviat, and F. Keesing. 2010. Experimental management of nesting habitat for Blanding's Turtle (*Emydoidea blandingii*). Ecological Restoration 28:154–159.

Gibbons, J.W. 1970. Terrestrial activity and the population dynamics of aquatic turtles. American Midland Naturalist 83:404–414.

Harper, E.B., T.A.G. Rittenhouse, and R.D. Semlitsch. 2008. Demographic consequences of terrestrial habitat loss for pool-breeding amphibians: predicting extinction risks associated with inadequate size of buffer zones. Conservation Biology 22:1205–1215.

Haxton, T. 2000. Road mortality of Snapping Turtles, *Chelydra serpentina*, in central Ontario during their nesting period. Canadian Field-Naturalist 114:106–110.

Herman, T.B., T.D. Power, and B.R. Eaton. 1995. Status of Blanding's Turtles, *Emydoidea blandingii*, in Nova Scotia, Canada. Canadian Field-Naturalist 109:182–191.

Innes, R.J., K.J. Babbitt, and J.J. Kanter. 2008. Home range and movement of Blanding's Turtles (*Emydoidea blandingii*) in New Hampshire. Northeastern Naturalist 15:431–444.

Joyal, L.A., M. McCollough, and M.L. Hunter, Jr. 2000. Population structure and reproductive ecology of Blanding's Turtle (*Emydoidea blandingii*) in Maine, near the northeastern edge of its range. Chelonian Conservation and Biology 3:580–588.

Joyal, L.A., M. McCollough, and M.L. Hunter, Jr. 2001. Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. Conservation Biology 15:1755–1762.

Klein, K.C., and R. Freed. 1989. Implementing the Massachusetts Wetlands Protection Act: the local perspective. Pp. 499–507 *In* Wetlands: Concerns and Successes. Fisk, D.W. (Ed.). American Resources Association, Bethesda, Maryland, USA.

Leibowitz, S.G. 2003. Isolated wetlands and their functions: an ecological perspective. Wetlands 23:517–531.

Linck, M.H., and L.N. Gillette. 2009. Post-natal movements and overwintering sites of hatchling Blanding's Turtles, *Emydoidea blandingii*, in east-central Minnesota. Herpetological Review 40:411–414.

Linck, M.H., and J.J. Moriarty. 1997. The effects of habitat fragmentation on Blanding's Turtles in Minnesota. Pp. 30–37 *In* Minnesota's Amphibians and Reptiles: Their Conservation and Status. Proceedings of a Symposium. Moriarty, J., and D. Jones (Eds.). Serpent's Tale Natural History Book Distributors, Lanesboro, Minnesota, USA.

Maehr, D.S. 1990. The Florida Panther and private lands. Conservation Biology 4:167–170.

Miller, S.G., R.L. Knight, and C.K. Miller. 1998. Influence of recreational trails on breeding bird communities. Ecological Applications 8:162–169.

Moriarty, J.J. 2000. Blanding's Turtle workshop summary. Chelonian Conservation and Biology 3:555–556.

Palis, J.G. 1997. Breeding migration of *Ambystoma cingulatum* in Florida. Journal of Herpetology 31:71–78.

Piepgras, S.A., and J.W. Lang. 2000. Spatial ecology of Blanding's Turtles in Minnesota. Chelonian Conservation and Biology 3:589–601.

Rhodin, A.G.J., P.P. van Dijk, J.B. Iverson, and H.B. Shaffer. 2010. Turtles of the World, 2010 Update: Annotated checklist of taxonomy, synonymy, distribution, and conservation status. Chelonian Research Monographs 5:85–164.

Roe, J.H., and A. Georges. 2008. Maintenance of variable responses for coping with wetland drying in freshwater turtles. Ecology 89:485–494.

Rowe, J.W., and E.O. Moll. 1991. A radiotelemetric study of activity and movements of Blanding's Turtle (*Emydoidea blandingii*) in northeastern Illinois. Journal of Herpetology 25:178–185.

Semlitsch, R.D. 1981. Terrestrial activity and summer home range of the Mole Salamander (*Ambystoma talpoideum*). Canadian Journal of Zoology 59:315–322.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology 12:1113–1119.

Semlitsch, R.D., and J.R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129–1133.

Simberloff, D. 1988. The contribution of population and community biology to conservation science. Annual Review of Ecology and Systematics 19:473–511.

Standing, K.L., T.B. Herman, and I.P. Morrison. 1999. Nesting ecology of Blanding's Turtle (*Emydoidea blandingii*) in Nova Scotia, the northeastern limit of the species' range. Canadian Journal of Zoology 77:1609–1614.

Steen, D.A., M.J. Aresco, S.G. Beilke, B.W. Compton, E.P. Condon, C.K. Dodd, Jr., H. Forrester, J.W. Gibbons, J.L. Greene, G. Johnson, T.A. Langen, M.J. Oldham, D.N. Oxier, R.A. Saumure, F.W. Schueler, J.M. Sleeman, L.L. Smith, J.K. Tucker, and J.P. Gibbs. 2006. Relative vulnerability of female turtles to road mortality. Animal Conservation 9:269–273.

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

Stokes, E.J., S. Strindberg, P.C. Bakabana, P.W. Elkan, F.C. Iyenguet, B. Madzoké, G.A.F. Malanda, B.S. Mowawa, C. Moukoumbou, F.K. Ouakabadio, and H.J. Rainey. 2010. Monitoring great ape and elephant abundance at large spatial scales: measuring effectiveness of a conservation landscape. PLoS ONE 5:1–18.

Suganuma, H., N. Kamezaki, and A. Yusuf. 1999. Current status of nesting populations of the Hawksbill Turtle (*Eretmochelys imbricata*) in the Java Sea, Indonesia. Chelonian Conservation and Biology 3:337–343.

Temple, S.A. 1987. Predation on turtle nests increases near ecological edges. Copeia 1987:250–252.

Turtle Conservation Fund. 2002. A Global Action Plan for Conservation of Tortoises and Freshwater Turtles: Strategy and Funding Prospectus 2002–2007. Conservation International and Chelonian Research Foundation, Washington, D.C.

Vesely, D.G., and W.C. McComb. 2002. Salamander abundance and amphibian species richness in riparian buffer strips in the Oregon coast range. Forest Science 48:291–297.

Wilson, E.O., and E.O. Willis. 1975. Applied Biogeography. Pp. 522–534 *In* Ecology and Evolution of Communities. Cody, M.L., and J.M Diamond (Eds.). Harvard University Press, Cambridge, Massachusetts, USA.

JEANINE REFSNIDER is completing a Ph.D. in Ecology and Evolutionary Biology at Iowa State University. Her dissertation research explores the capacity for behavioral phenotypic plasticity to compensate for the effects of climate change on long-lived species, using the painted turtle (*Chrysemys picta*) as a model species. Jeanine completed a M.S. in Conservation Biology at the University of Minnesota and a B.A. in Biology at the University of Minnesota-Morris. She also studied nest-site choice and parental care in New Zealand's endemic tuatara (*Sphenodon* spp.) while on a Fulbright Fellowship at Victoria University of Wellington. (Photographed by Henry Streby)

MADELEINE LINCK works for Three Rivers Park District, Plymouth, Minnesota, as a Wildlife Technician where she has conducted long-term radio tracking and nesting studies of *Emydoidea blandingii* since 1992. She studied the nesting ecology *of Emydoidea blandingii* for her M.S. in Biology under Dr. Terry E. Graham at Worcester State College, Worcester, Massachusetts. Her current work involves the management and protection of several Park District turtle species, as well as, other wildlife such as Northern Leopard Frogs (*Lithobates pipiens*), Trumpeter Swans (*Cygnus buccinator*), and Purple Martins (*Progne subis*). (Photographed by Carol Carter)