Habitat Use and Movements of Radiotagged Blanding's Turtles (*Emydoidea blandingii*) in a Suburban Landscape

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ABSTRACT. – The greater Chicago metropolitan area may represent the best chance for the survival of Blanding's turtles (*Emydoidea blandingii*) in Illinois, where the species is listed as threatened. However, decades of urban and suburban development have resulted in habitats that are small and isolated such that they may not be adequate for the year-round needs of Blanding's turtles. With the development of management recommendations in mind, we conducted a radiotelemetry study from 1996 to 1998 in two local forest preserves in suburban Chicago to provide information on habitat use and movements of Blanding's turtles. Radiotelemetry observations for 24 individuals (14 males and 10 females) showed that during late summer when natural wetlands were rapidly drying Blanding's turtles were often found on dry land or migrating to bordering residential ponds. However, we found no evidence of extensive movements beyond the periphery of the preserves or into other nearby natural areas. No mortality as a result of vehicular traffic was observed throughout the study. Our findings indicated that Blanding's turtles in suburban Chicago are isolated and may be subject to inbreeding and hazardous environmental conditions, such as droughts. The persistence of Blanding's turtles in suburban Chicago are isolated and may be subject to inbreeding and hazardous environmental conditions, such as droughts. The persistence of Blanding's turtles in suburban Chicago are isolated and may be subject to inbreeding and hazardous environmental conditions, such as droughts. The persistence of Blanding's turtles in suburban Chicago are isolated and may be subject to inbreeding and hazardous environmental conditions, such as droughts. The persistence of Blanding's turtles in suburban Chicago may depend on management interventions that make permanent water available year-round.

KEY WORDS. – Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; radiotelemetry; habitat fragmentation; wildlife managment; conservation; population isolation; habitat use; suburban landscape; Illinois; USA

Once common throughout the northern two-thirds of Illinois (Garman, 1892), Blanding's turtle (*Emydoidea blandingii*) has been recently listed as threatened in the state (Redmer and Kruse, 1998), presumably as a result of habitat loss. Blanding's turtle depends on wetland habitats for its survival, inhabiting shallow vegetated waters and associated upland areas throughout its range in North America, which is centered in the Great Lakes region with disjunct populations also occurring in New England and Nova Scotia (Smith, 1961; McCoy, 1973; Ernst et al., 1994). Since European settlement, however, Illinois has lost over 90% of its original wetland habitats (Sullivan, 1999). Consequently, Blanding's turtles in Illinois have experienced a dramatic decline in abundance (Redmer and Kruse, 1999).

The greater Chicago metropolitan area (GCMA) may represent the best chance of survival for Blanding's turtles in Illinois. The GCMA, which consists of six counties in northeastern Illinois, retains a greater percentage of its original wetland habitats than other regions within the historic range of the Blanding's turtle in Illinois (White, 1978). More than one-third of Illinois' dedicated nature preserves occur in the GCMA (White, 1978). Most remaining wetlands, however, are small, degraded remnants surrounded by intense urban or suburban development. Thus, the species' persistence in Illinois may depend on how it responds to habitats that are small and isolated. Using radiotelemetry, we assessed the habitat use and movements of adult Blanding's turtles inhabiting two small and isolated forest preserves in suburban Chicago from 1996 to 1998. Based on the information gained from this study, we make management recommendations for the development of conservation strategies for Blanding's turtles in suburban Chicago.

METHODS

Study Sites. - Blanding's turtles were studied in Pratts Wayne Woods (PWW; 619 ha) and West Chicago Prairie (WCP; 123 ha), small and isolated forest preserves located about 3 km apart in northwestern DuPage County in northeastern Illinois in the suburbs of Wayne and West Chicago, respectively, approximately 50 km from downtown Chicago (Fig. 1). The suburban landscape surrounding WCP consists of industrial parks, train yards, residential housing, and commercial roads, while the landscape surrounding PWW consists of agricultural fields, horse stables, railroad tracks, and residential housing and roads. Recreational crushed limestone paths transect both PWW and WCP and attract diverse human activities, such as walking, jogging, biking, and horseback riding. A county-wide survey of forest preserves and other natural areas conducted by the Forest Preserve District of DuPage County concluded

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Figure 1. Map of DuPage County, northeastern Illinois, with locations of forest preserves (gray areas), including the two study sites, Pratts Wayne Woods and West Chicago Prairie (circled). In general, white areas represent suburban development.

that Blanding's turtles in the region were most common in PWW and WCP (Ludwig et al., 1992).

Both PWW and WCP contain an assortment of wetland habitats, including marshes, ponds, bottomland woods, sedge meadows, and wet prairies. Three small artificial lakes (total 15.4 ha) are present in PWW. No development has occurred at WCP, which hosts over 500 native plant species. Conversely, PWW has undergone considerable changes to its landscape, having been excavated for sand and gravel and farmed prior to becoming dedicated as a forest preserve. Marshes in both PWW and WCP are dominated by cattails (Typha sp.) and bulrush (Scirpus sp.) and bordered by sedge meadows that gently grade into wet prairies in some areas. The lakes in PWW are bordered by limestone slabs and paths, while ponds are bordered by cattails and sedges. Three permanent ponds occur in residential areas that are adjacent to WCP and are bordered by well-maintained turf grasses. Except for two marshes, all other natural wetland habitats in WCP typically dry up at least once during the summer. Dam building activities by beavers (Castor canadensis) in PWW help to maintain water levels throughout the year.

Capture and Radiotelemetry. — Blanding's turtles were captured as part of a capture-recapture study from 1994 to 1998 (for details see Rubin, 2000). From 1996 through 1998 all captured adult Blanding's turtles (n=26) were radiotagged using 35–40 g radio transmitters (Model HLPM 3180,

Wildlife Materials, Carbondale, Illinois). Radiotransmitters were attached to each turtle by drilling two small holes in the marginal scutes and then inserting two stainless steel screws and bolting down the transmitter with nylon lock nuts. Based on movement patterns, high survival rates, and the observation of gravid radiotagged females, this method of radiotransmitter attachment did not appear to hinder movement, survival, or reproduction. Radiotransmitters had a life-expectancy of approximately 450 days and were replaced annually when possible.

Using a hand-held Yagi antenna connected to a portable RB-4 receiver (Custom Electronics, Urbana, Illinois), radiotagged turtles were located on foot once daily 3–6 days a week from mid-May through September 1996 to 1998 and once a month throughout the rest of the year. All locations were recorded with submeter accuracy using a Trimble 4000SE Series Global Positioning System (Trimble Navigation Limited, Sunnyvale, California). At each GPS location, date, time, habitat type, and turtle activity were recorded. Nesting activity was not investigated because gravid females were removed from PWW and WCP, from a few days to several weeks, to facilitate a captive propagation program.

Establishment of Periods. — The summer hydrology in the GCMA is typically bimodal, with wet conditions occurring most often in May and June and drier conditions prevailing in July through September. Thus, wetlands are

 Table 1. Number of radiotagged Blanding's turtles followed in

 Pratts Wayne Woods (PWW) and West Chicago Prairie (WCP) in

 1997 and 1998 during early and late summer periods.

Year	WCP	(n = 14)	PWW $(n = 10)$		
	early summer	late summer	early summer	late summer	
1997	11	14	7	7	
1998	8	9	3	4	

typically less available during the later summer months as water levels decline due to a lack of precipitation and evaporation. To assess how Blanding's turtles respond to annual declines in natural wetland availability, habitat and movement data were divided into separate periods for early summer (15 May to 15 July) and late summer (16 July to 30 September) and compared.

Habitat Use. - Based on aerial photographs and observations, habitat boundaries were delineated and digitized using a Geographic Information System. Habitat types were classified based on hydrologic conditions. Areas having similar hydrologic conditions were grouped together in a coarse categorization of habitat types and were classified as: 1) Natural Wetland - natural areas inundated with water, including marshes (open water areas dominated by emergent vegetation), flooded timber (bottomland woodlot with standing water), sedge meadows, and wet prairies, 2) Artificial Lake - well-defined deep and sparsely vegetated artificial open water area with wave-washed shores (PWW only), 3) Residential Pond - well-defined deep and sparsely vegetated open water area on private property bordering WCP, and 4) Dry Land - natural areas not inundated with water, including evaporated wetland habitats.

Habitat use was assessed using chi-square tests in conjunction with Bonferroni confidence intervals (Miller, 1981) as outlined by Neu et al. (1974). The chi-square tests were used to determine whether there was a significant difference between the observed and expected utilization of habitat types based upon availability in the early summer and late summer periods. Bonferroni confidence intervals were calculated to determine which habitat types were used more or less frequently than expected when a significant difference was detected between usage and availability. The number of observations was determined by pooling individuals and then calculating the percentage of radio locations occurring in a given habitat. The expected number of observations was determined by multiplying the proportion of a given habitat type in the study area during either the early or late summer period by the total number of radio locations occurring in that habitat.

Movements. — Movements were investigated by measuring daily movements and home ranges calculated using CalHome (Kie et al., 1994). Daily movements were defined as the straight-line distance between two radio locations on consecutive days. Home ranges were estimated using the 100% minimum convex polygon (MCP) approach (Mohr, 1947; Hayne, 1949). This method was chosen to include all movements, and thus estimate total area traveled. Ten radio locations were chosen as the minimum criterion for the estimation of home ranges. Linear regression was used to check for possible effects of the number of radio locations on home range size; no relationship was found ($r^2 = 0.008$, n = 63). Mann-Whitney *U*-tests were used to test for differences in home range size between periods (early and late summer) and sites (PWW and WCP).

RESULTS

As a result of insufficient data in 1996, analyses of habitat use and movements were based on information collected in 1997 and 1998 using a total of 10 radiotagged turtles (4 males and 6 females) in PWW and 14 radiotagged turtles (10 males and 4 females) in WCP (Table 1). The mean number of radio locations per individual recorded in PWW in early summer 1997 was 15.4 (\pm 1.6 SE) and in late summer 1997 was 38.4 (\pm 1.6 SE), while the mean in early summer 1998 was 14.3 (\pm 0.9 SE) and in late summer 1998 was 15.5 (\pm 1.0 SE). The mean number of radio locations recorded in WCP in early summer 1997 was 18.7 (\pm 1.3 SE) and in late summer 1997 was 36.2 (\pm 2.2 SE), while the mean in early summer 1998 was 16.7 (\pm 0.2 SE) and in late summer 1998 was 15.6 (\pm 0.3).

Habitat Use. — As expected, radiotagged turtles in PWW and WCP were frequently associated with natural wetlands and artificial aquatic habitats (Table 2). The use of

Table 2. Percentage of radio locations occurring in each habitat type in Pratts Wayne Woods and West Chicago Prairie during early and late summers of 1997 and 1998.

-		19	97			19	998	
Study Site	Early Summer		Late Summer		Early Summer		Late Summer	
Habitat Type	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Pratts Wayne Woods								
Natural wetland	100	90.1	141	54.9	62	91.2	58	89.2
Artificial lake	4	3.6	84	32.7	2	2.9	6	9.2
Dry land	7	6.3	32	12.4	4	5.9	1	1.5
Total	111	100.0	257	100.0	68	100.0	65	99.9
West Chicago Prairie								
Natural wetland	216	97.7	102	20.2	114	82.0	56	36.1
Residential pond	1	0.5	232	45.9	15	10.8	54	34.8
Dry land	4	1.8	171	33.9	10	7.2	45	29.0
Total	221	100.0	505	100.0	139	100.0	155	99.9

Table 3. Summary statistics of habitat use by radiotagged Blanding's turtles in Pratts Wayne Woods and West Chicago Prairie (> indicates habitat use was significantly [p < 0.05] greater than expected based on habitat availability, < indicates habitat use was significantly [p < 0.05] less than expected based on habitat availability, n/s indicates no significant difference between expected and observed use based on habitat availability).

	Prat	ts Wayne W	oods	West Chicago Prairie			
Period	Natural Wetland	Dry Land	Artificial Lake	Natural Wetland	Dry Land	Residential Pond	
Early summer, 1997	>	<	n/s	>	<	n/s	
Late summer, 1997	>	<	>	>	>	>	
Early summer, 1998	>	<	n/s	>	<	>	
Late summer, 1998	>	<	n/s	>	<	>	

natural wetland habitats was significantly greater than expected throughout the study (Table 3), but was lower in late summer than early summer in both preserves, especially in WCP (Table 2). The decline in the use of natural wetland habitats was associated with a decrease in habitat availability due to wetland drying. The percentage of available natural wetland habitats in WCP declined from 23.9% to 0.6% (a 97.5% reduction) in 1997 and 1998 (Table 4). A similar, but less dramatic, drying occurred in PWW, with the percentage of available natural wetland habitats declining from 16.7% to 9.8% (a 41.3% reduction) (Table 4).

As natural wetland habitats in WCP became less available in late summer, the number of individual radiotagged turtles located on dry land and in residential ponds increased. For example, of 15 turtles in WCP on 6 August 1997, four were located on land, seven in residential ponds, and four in remaining wetland habitats, while 10 of 10 turtles on 5 June 1997 were located in natural wetland habitats. In accordance with these observations, the percentage of radio locations on dry land in WCP was significantly less than expected in the early summer periods of 1997 and 1998, and was significantly greater than expected in late summer 1997 (Table 3). Although the use of dry land in WCP was significantly less than expected in late summer 1998 (Table 4), the number of radio locations on dry land increased 21.8% (Table 2). Residential ponds, which comprised only 0.3% of the total study area, were used significantly greater than expected in late summer 1997 and early and late summer 1998 (Table 3).

Relative to WCP, natural wetland use in late summer in PWW was high (Table 2). The percentage of radio locations on dry land in PWW was significantly less than expected throughout the study (Table 3). Terrestrial use in PWW was typically associated with overland movements between aquatic areas. Use of artificial lake habitats in PWW in early summer 1997 and early and late summer 1998 was not significantly different from expected (Table 3). Use of artificial lake habitats in late summer 1997 was significantly greater than expected (Table 3), though this was because one turtle was repeatedly located in a single lake.

Movements. — Most movements were confined within preserve boundaries. However, one female and two male radiotagged turtles were observed crossing narrow lowtraffic roads that divided PWW. In addition, two radiotagged males used culverts to cross under railroad tracks along the boundaries of PWW. The only movement observed outside preserve boundaries in WCP was into bordering residential ponds. No mortality as a result of vehicular traffic was observed of radiotagged turtles or any other Blanding's turtles throughout the study.

There was no direct evidence of extensive overland movements outside PWW and WCP, although turtles safely crossed roads. All turtles that moved outside PWW and WCP eventually returned to the preserve. Although infrequent, turtles made extensive movements within preserve boundaries. The maximum daily straight-line distance recorded in PWW was 722 m by a non-nesting female and 882 m by a male. The maximum daily straight-line distance recorded in WCP was 882 m by a non-nesting female and 1.0 km by a male. Nesting excursions were not recorded, as gravid females were removed temporarily from the study site.

Table 5 provides mean home range sizes for PWW and WCP in early and late summer 1997 and 1998. Home range sizes in PWW were not significantly different between early and late summer in 1997 (U = 21.0, p =0.710, n = 14) and in 1998 (U = 3.0, p = 0.400, n = 7), whereas significant differences were detected between periods in WCP in 1997 (U = 23.0, p = 0.002, n = 25) and in 1998 (U = 2.0, p < 0.001, n = 17). Home range sizes were not significantly different between PWW and WCP

Table 4. Habitat area and the percent of the total area (availability) in West Chicago Prairie and Pratts Wayne Woods during early and late summers of 1997 and 1998.

		West Chicago Prairie				Pratts Wayne Woods			
	Early Summer		Late Summer		Early Summer		Late Summer		
Habitat Type	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	Area (ha)	Percent	
Natural wetland	35.5	23.9	0.9	0.6	101.4	16.7	59.8	9.8	
Residential pond	0.4	0.3	0.4	0.3					
Dry land	112.6	75.8	147.1	99.1	494.5	81.5	536.2	88.3	
Lake					11.01	1.8	11.0	1.8	
Total	148.5	100.0	148.4	100.0	607.0	100.0	607.0	99.9	

Table 5. Mean home range sizes (ha) of radiotagged Blanding's turtles in Pratts Wayne Woods (PWW) and West Chicago Prairie (WCP) during early and late summer periods, 1997 and 1998.

	19	97	1998		
Site	Early summer	Late summer	Early summer	Late summer	
PWW	$9.8 \pm 5.6 \text{ SE}$	$4.0 \pm 1.9 \text{ SE}$	$1.2 \pm 0.6 \text{ SE}$	$2.7 \pm 0.7 \text{ SE}$	
	(n = 7)	(n = 7)	(n = 3)	(n = 4)	
WCP	3.1 ± 0.8 SE	0.8 ± 0.3 SE	$4.0 \pm 1.1 \text{ SE}$	$0.1 \pm 0.1 \text{ SE}$	
	(n = 11)	(n = 14)	(n = 8)	(n = 9)	

in early summer in 1997 (U = 38.0, p = 1.00, n = 18) and in 1998 (U = 5.0, p = 0.194, n = 11). In late summer, however, home range sizes in PWW and WCP were marginally different in 1997 (U = 25.0, p = 0.079, n = 21) and significantly different in 1998 (U = 0.00, p = 0.003, n = 13).

DISCUSSION

In an apparent response to the lack of natural wetland habitats in late summer, Blanding's turtles in WCP were located more often on land or in nearby residential ponds. The lack of natural wetland habitats also appeared to be associated with sedentary behavior as indicated by small home range size estimates. Although PWW was five times larger in size than WCP, home range size estimates in early summer when water levels were highest were not significantly larger than estimates in WCP. Late summer home range size estimates in WCP, however, were significantly smaller in size than in PWW. Furthermore, home range size estimates in WCP were significantly smaller in late summer than in early summer, while no differences were detected between periods in PWW.

In contrast to WCP, Blanding's turtles in PWW in late summer were located more often in natural wetland habitats than on dry land or in artificial lakes, although natural wetlands were used less often than in early summer. Blanding's turtles in PWW were also less sedentary and when located on land were usually traveling between wetland habitats. This disparity in the behavior of Blanding's turtles in late summer in PWW and WCP appears to be associated with differences in the availability of natural wetland habitats. Nearly 60 ha of natural wetland habitats were available in PWW in late summer, while less than 1 ha was available in WCP.

Although adult mortality has been found to be low in the studied populations (Rubin, 2000), the lack of available wetland habitat has the potential to create a catastrophic situation for Blanding's turtles in PWW and WCP. To illustrate, in east-central Minnesota, Blanding's turtle mortality was found to be extremely high after a wetland drawdown (5 of 10 radiotagged turtles died and 20 others were found dead) (Hall and Cuthbert, 2000). These deaths were attributed to predation, road mortality, and winterkill. Due to their low thermal tolerance (Hutchinson et al., 1966), heat stress may be an additional cause of mortality to Blanding's turtles during periods of drought. Secondary effects of prolonged reduced activity (i.e., aestivation) on foraging, reproductive output, and growth rate may also negatively affect population stability. We believe the use of dry land would have been much greater in PWW and WCP if artificial lakes and residential ponds were not available to Blanding's turtles. Thus, artificial lakes and residential ponds were important as aquatic refugia to Blanding's turtles in late summer and may have prevented increased rates of mortality.

The finding that Blanding's turtles did not apparently migrate to other local wetlands despite an extensive forest preserve system in DuPage County (Fig. 1) suggests that suburban development deters migration, which may have important implications for the persistence of Blanding's turles in suburban Chicago. First, a lack of movement beyond preserve boundaries may result in the concentration of individuals into limited refugia (if refugia exist), which may have catastrophic results including the rapid spread of disease and increased susceptibility to predators. Second, a lack of movement between local populations in suburban Chicago may result in the loss of genetic variability through genetic drift (Rubin, 2000). The loss of genetic variation may increase the probability of population extinction through a decline in fecundity and viability (i.e., inbreeding depression) (Lacy, 1987; Ralls et al., 1988; Meffe and Carroll, 1994; Frankham, 1995).

The lack of adequate wetland habitats, isolation, and possible increases in adult mortality appear to be among the immediate threats to the persistence of Blanding's turtles in PWW, WCP, and possibly elsewhere in suburban Chicago. Thus, the persistence of Blanding's turtles in suburban Chicago may depend upon providing safe access to adequate wetland habitat year-round. We recommend that sufficient and widely-spaced aquatic refugia be maintained (possibly through the active pumping of water) on-site in forest preserves and other protected natural areas where Blanding's turtles are known to exist in suburban Chicago. Moreover, we recommend that potential local aquatic refugia, such as residential ponds and artificial lakes, be protected and maintained for Blanding's turtles (see Ross and Anderson, 1991; Pappas and Brecke, 1992; Power et al., 1994; Herman, 1999; McMaster and Herman, 2000). Terrestrial corridors should also be established to encourage and provide a means for safe migration in an otherwise hostile suburban landscape.

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