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Spatial Ecology of Blanding's Turtle in Central Minnesota

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Abstract. – We studied the movements, activity centers, and home ranges of Blanding's turtles (*Emydoidea blandingii*) in central Minnesota at the northwestern limit of the species' range. We monitored 46 turtles (15 males, 24 females, and 7 juveniles) via radio telemetry for two summers and an intervening winter (1996–97), and examined their records in a GIS database using ARCVIEW spatial analyses. Turtles were active from April through November, and spent the winter under ice in shallow water. Some males, females, and juveniles moved from overwintering marshes into summer wetlands, whereas others were sedentary and remained in the same wetland. Overall, males moved more often, but over shorter distances than did females. Females moved primarily during nesting. Males had the most activity centers, but these were small (1.7 ha) relative to those of females (2.1 ha). Male and female home ranges (7.8 ha) did not differ, but were larger than those of juveniles (5.9 ha). Juveniles had few activity centers, but these were large (2.6 ha). Several juveniles moved large distances relative to adults. Home ranges showed overlap among turtles. Individual turtles used the same areas from one season to the next. Most turtles resided in shrub swamps, and tended to remain longer and move farther in large vs. small swamps. Blanding's turtles in central Minnesota had large activity centers and home ranges in comparison to those studied elsewhere, and these features may be related to relatively low population density, patchy resources, and/or dispersed wetlands. The main conservation concern is the preservation of intact mosaics of upland and wetland habitats of sufficient size to support viable turtle populations.

Key Words. – Reptilia; Testudines; Emydidae; *Emydoidea blandingii*; turtle; ecology; radio telemetry; home range; activity centers; movements; Minnesota; USA

Among vertebrates that inhabit wetlands, freshwater turtles provide important ecological linkages between aquatic and terrestrial habitats (Bodie and Semlitsch, 2000). Because common boundaries of these habitats vary in time and space, long-lived turtle species are especially valuable subjects for the long-term studies necessary to fully understand the dynamics of wetland ecosystems (Congdon and Gibbons, 1996). In particular, understanding the temporal and spatial movements of turtles is a requisite for the effective conservation of habitats, of the resources within them, and of the turtles themselves (Gibbons et al., 1990). For example, many aquatic turtles utilize terrestrial habitats extensively, but do so only at certain times of year and/or when conditions are favorable (Burke and Gibbons, 1995; Tuberville et al., 1996). In addition, other factors which affect estimates of home ranges and activity patterns of freshwater turtles include age/size, sex, population density, locality, and methodology (Morreale et al., 1984; Stickel, 1989; Schubauer et al., 1990; Brown and Brooks, 1993; Brown et al., 1994; Edmonds, 1998).

Blanding's turtles (*Emydoidea blandingii*) utilize both upland and aquatic habitats to an unusual degree (Ernst et al., 1994; Congdon and Gibbons, 1996). Unlike most other freshwater turtles, females typically nest far afield, necessitating long-distance, overland movements and similar excursions back to wetlands by neonates upon emergence (Congdon et al., 1983; Butler and Graham, 1995; Linck and Moriarty, 1997). Furthermore, such movements are not necessarily restricted to nesting females and emerging hatchlings, but appear to be typical of adult males as well as juveniles throughout the year (Ross and Anderson, 1990; Pappas and Brecke, 1992; Linck and Moriarty, 1997). Widely spaced vernal pools, small wetlands, and permanent wetlands serve as important basking, feeding, breeding, and overwintering sites for this species in New England (Graham and Butler, 1993; Joyal, 1996) and Canada (Herman et al., 1994) and in the Minnesota populations studied to date (Pappas and Brecke, 1992; Dorff, 1995; Linck and Moriarty, 1997).

The species occupies diverse wetlands across its range, and utilizes habitats in distinctive ways in different locations. For example, in Illinois, Blanding's turtles overwintered in summer areas, whereas in Nova Scotia, individuals in a population moved long distances from summer locations to overwintering sites (Rowe and Moll, 1991; Herman et al., 1994). Consequently, regional differences in temporal and spatial movement patterns are apparent, and it is likely that such differences directly relate to conservation concerns at specific localities. In Minnesota, Blanding's turtle is listed as "threatened" (Coffin and Pfannmuller, 1988), a status likely to continue. The species reaches its northwestern limit in the state where it prefers wetlands with shallow water and aquatic vegetation (Oldfield and Moriarty, 1994). Little is known about the ecological factors which ultimately limit these populations, e.g., ability to overwinter, nesting success, hatchling survival, etc. To date, studies in Minnesota have focused on metropolitan areas, suburban communities, and river valleys where turtle habitats have been extensively altered (Dorff, 1995; Linck and Moriarty, 1997; Pappas et al., 2000). Although such studies are useful in formulating general conservation strategies, detailed investigations in undisturbed habitats are needed for management guidelines applicable elsewhere in the state.

In our view, turtle movements are vital indicators of habitat use. In order to protect diverse habitats together with corridors for safe travel, detailed information about habitat utilization is crucial, including age and sex specific patterns of activity and movement. We studied Blanding's turtles at their northwestern range limit in Minnesota: (1) to document movements, activity patterns, and home ranges of representative turtles, (2) to examine how these parameters differed among sex/age classes; (3) to determine which wetland and upland habitats were utilized throughout the year, and how habitats influenced turtle movements; and (4) to compare the spatial ecology of this population with studies of the species in other localities.

STUDY SITE

Camp Ripley is an Army National Guard Training Site located in Morrison County in central Minnesota, 16 km north of Little Falls. It is bounded on the north by the Crow Wing River and to the east by the Mississippi River, and covers 21,500 ha (53,000 acres). Adjacent private land, part of the Hay Creek wetland, 360 ha (900 acres) in size, was also included. The study area lies in the transition to the Coniferous-Hardwood Forest and Deciduous Forest-Woodland Zone (Tester, 1995). The landscape is developed on glacial moraines and is characterized by a steep knob and kettle topography with elevations of 340–470 m. Land alteration consists mainly of secondary roads and trails, as well as cleared fields for military training.

Wetlands are protected from military activities. The wetlands are extensive, consisting of many small lakes, potholes, beaver impoundments, and semi-permanent shallow marshes. Wetland types consist of inland shallow and deep fresh marshes, inland open water, and shrub swamps, based on USFWS Wetland Classification System. Emergent wetlands are shallow basin marshes, containing bulrush, reeds, grasses, and cattails. Shrub swamps consist mainly of alder and willow along with cattails and sedges, with large sections of floating bog (Minnesota DNR, 1993).

Upland habitat is characterized by extensive forest regions, open fields, and cleared training ranges and impact areas. Forest stands are a combination of fragmented and contiguous tracts of mixed hardwoods and conifers. Open fields are maintained by clear cutting, burning, and military training activities, and the resultant vegetation consists mainly of short grasses, small shrubs, and forbs. The soil types that offer favorable turtle nesting habitat are the Mahtomedi, Menahga, and Hubbard sands that occupy most of the training site and adjacent lands. Additional information on the study site appears in Piepgras (1998).

METHODS

Blanding's turtles were collected in aquatic hoop traps or by hand capture during road surveys, primarily in the nesting season. Turtles were measured and weighed, and the sex, age, reproductive status, time, and location of capture were recorded. Age was determined by counting annual growth on plastron scutes to 20 years of age; in this population, juveniles (based on the absence of secondary sex characteristics) were <210 mm in carapace length (CL) (Sajwaj et al., 1998). Average body sizes of adults at Camp Ripley area are larger than those in other studied populations; CL of males = 260 mm ($n = 23$) and of females = 245 mm ($n = 42$) (Sajwaj et al., 1998). Sex was determined by the presence of a plastral concavity and greater preanal tail length in males. Female reproductive status was determined by palpation. Each turtle was marked on the marginal scutes of the carapace (Cagle, 1939). A radio transmitter was affixed midway between the dorsal line and marginal scutes, using a fast drying (5 min) epoxy compound. Then, the turtle was released within 1–3 days at the point of capture.

During May through August in 1996 and in 1997, each radiotagged turtle was located 2–10 times a week. Locations were determined by either triangulation or observation, and plotted on aerial images and/or referenced with a GPS unit; these points were then incorporated into a GIS database. Spatial analysis was completed using ArcView 3.0a (ESRI, 1996) on coverages available at Camp Ripley.

Turtle movements were analyzed in the context of seasonal activities throughout the year. These consisted of overwintering movements and female-specific nesting movements. Overwintering movements were any intermarsh movements that occurred before May and after September. Females showed long overland movements to nest sites during mid-June and early July. Nesting movements were confined to movements 10 days prior and subsequent to nesting. Summer movements were divided into intermarsh movements between wetlands and daily movements within a wetland. Typically an intermarsh movement was followed by a period of residency in the new wetland before the turtle made another intermarsh movement. Thus, a characteristic spatial pattern would be one of limited daily movements within a wetland, punctuated by brief terrestrial forays between wetlands. Movements were calculated by measuring the straight-line distances between wetlands.

Daily movements were those in which a turtle was resident within a marsh for longer than 6 days. Straight-line distances were calculated by measuring the distance between the first location on subsequent dates. If dates were more than one day apart, the total distance moved was averaged by the number of intervening days to estimate daily movements. Meandering values for daily movements and for nesting movements were calculated by summing the actual distances traveled by a turtle, based on direct observations over variable time periods. This distance was measured and divided into the previously calculated straight-line daily distance to determine meandering ratio.

Winter locations were determined for 27 turtles in 1996–97; overwintering sites were located on foot and/or by air and marked for subsequent relocation. Any known radio location or capture point was considered part of the turtle's home range. Activity centers were considered any area in which the turtle spent seven or more days. Activity center sizes were estimated with the same method used to determine home ranges. In order to examine wetland effects, turtles that exhibited little movement were excluded from the analyses. These included any that had two or less activity centers in which one activity center comprised more than 50% of the home range, as well as any turtle that had multiple activity centers but a small home range (<6 ha).

For each turtle, locations were plotted on a GIS base map over which a 20 x 20 m grid was overlaid, and home ranges were calculated using the grid summation method (Kauffman, 1995). Two other methods for home range estimation were included to facilitate comparisons with previous studies. The adaptive kernel (AK) and minimum convex polygon (MCP) were obtained using CALHOME software (Kie et al., 1994; Lawson and Rodgers, 1997), with standard home range calculation techniques (White and Garrott, 1990) using 95% of all known data points and a 50 m cell size. Additional details on methodology is included in Piepgras (1998).

Differences in parameters were examined using non-parametric tests, i.e., the Mann-Whitney U test (MWU) and the Kruskal-Wallis test (KW); correlations were examined using Spearmans rank (SR) correlation coefficient. The significance level for all tests was alpha = 0.05.

RESULTS

We radiotracked 46 turtles (15 males, 24 females, and 7 juveniles) for periods of 10 to 15 months, which included two consecutive summers and the intervening winter. The records of 25 turtles (6 males, 13 females, and 6 juveniles) were included in the movement and home range analysis. These turtles had the most complete records and were followed for approximately the same time period, from May 1996 to August 1997. The timelines for these turtles are shown in Fig. 1.

Intermarsh Movements. — Females were most likely to be found moving in June or July, and again in September and October; earlier and later in the season movements by females were limited. In contrast, juveniles appeared to move either early or late in the season, on the basis of limited records. Males tended to move throughout the season, and more often, than did females or juveniles (Fig. 2).

The summer intermarsh movements of females between wetlands differed. Three females did not make any movements between wetlands during the the 58 weeks of study. Two of these remained in the same 18 ha wetland. The

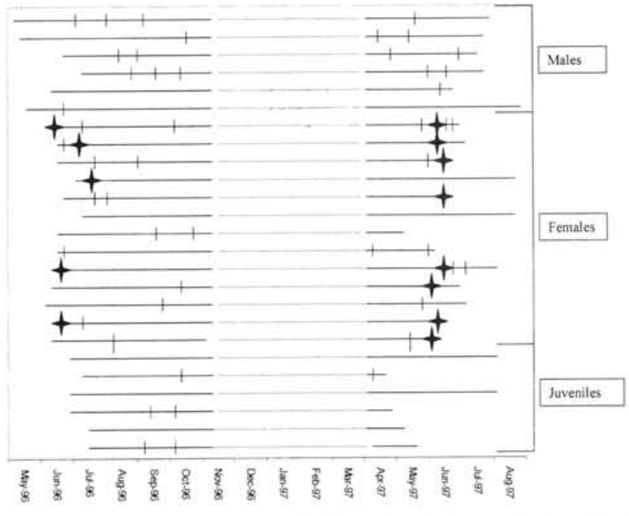

Figure 1. Timelines for 25 individual Blanding's turtles (vertical axis: 6 males [top] 13 females [middle], and 6 juveniles [bottom]) monitored at Camp Ripley during two summers and the intervening winter (horizontal axis: months, from May 1996 through August 1997). The record of each turtle is shown as a horizontal line for the months each was radiotracked. A vertical line on a record indicates an intermarsh movement; for each female, a dark star indicates nesting.

other 10 females moved 1–4 times over distances ranging from 77–2900 m (Table 1). On average, each female moved 2.1 times over an average distance of 543 m; average cumulative movement (number of moves x distance moved) totaled 1140 m. The movements of a female that used 6 different wetlands from June 1996 to June 1997, during which time she overwintered and also nested each year, are shown in Fig. 3.

Four of the 6 juveniles that we monitored never moved between wetlands. Three of these were located in the same 18 ha wetland as the two female non-movers mentioned above. On average, juveniles traveled less often, but farther than females. Two turtles each moved once, over an average cumulative distance of 607 m. In contrast to females and juveniles, every male we studied made at least one intermarsh movement. Six males moved 1–5 times over distances of

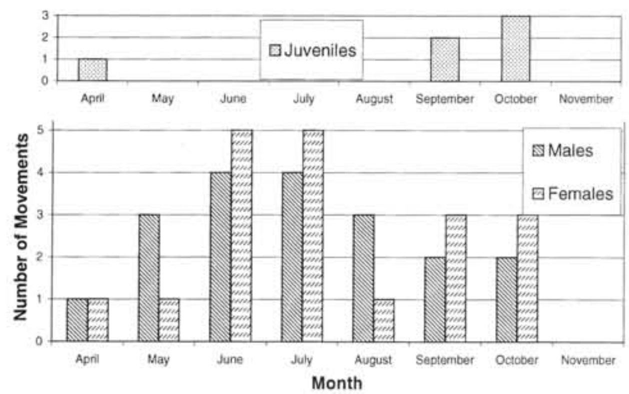

Figure 2. Seasonal pattern of intermarsh movements of Blanding's turtles at Camp Ripley during the active period from April through October (horizontal axis). The number of movements per month are shown for males and females (vertical axis, bottom) and for juveniles (vertical axis, top). Comparisons of age/sex classes are based on the combined records of 3 males, 3 females, and 3 juveniles whose records were matched for an activity season.

Table 1. Intermarsh movements, excluding nesting movements, for 25 Blanding's turtles (6 males; 13 females; 6 juveniles) monitored via radio-telemetry at Camp Ripley from May 1996 through August 1997. The number of moves, distance moved (m), and days between moves are shown. Three females and four juveniles shown below were not recorded moving from wetland residencies, whereas all of the males that were monitored moved at least once.

Turtle	Sex	Intermarsh Distance	No.	Days Between Moves
ABC	M	350, 780, 90, 185	4	27, 40, 245
ABO	M	868, 926, 116, 517	4	17, 47, 219
ABP	M	245, 471, 650, 233, 370	5	258, 67, 2, 7
BHJ	M	635	1	
BL	M	790	1	
WXY	M	629	1	
ABI	F	551	1	
ABK	F	281, 241	2	26
ABQ	F	0	0	
ADJ	F	1604	1	
ADL	F	0	0	
AN	F	114, 77, 207	3	59, 275
AP	F	594, 693	2	307
AQ	F	188, 684	2	16
JKL	F	0	0	
JNOP	F	210, 150, 202	3	256, 25
KLN	F	315	1	
NOP	F	230, 258	2	298
QTU	F	2900, 184, 1405, 327	4	92, 236, 3
ABL	J	0	0	
ABN	J	365	1	
ABT	J	0	0	
ABU	J	0	0	
ABV	J	0	0	
ACJ	J	850	1	

90–868 m (Table 1). On average, each male moved 2.6 times over an average distance of 491 m; average cumulative movement totaled 1278 m. For example, one male moved 5 times (an average of 394 m/move), while juveniles moved once (an average of 706 m). The movements of a male that used 5 different marshes from mid-July 1996 to late July 1997 and moved a total distance of at least 3300 m are shown in Fig. 4.

Males and juveniles did not differ in the size of intermarsh movements (MWU; $z = 0.24$, $p = 0.81$) but those of females differed from males and from juveniles (KW; $H = 5.05$, $p = 0.05$). With regard to the number of intermarsh movements, all three groups differed (KW; $H = 4.80$, $p = 0.05$).

Overwintering Movements. — Ten turtles made movements to and from overwintering sites, in October and November and in April, respectively (Table 2). Males averaged 1.3 moves, with a mean of 401 m. Females averaged 1.0 move, with a mean of 311 m. Juveniles averaged 1.3 moves, with a mean of 619 m. There were differences among groups in the distances moved (KW; $H = 8.77$, $p = 0.01$). Males and juveniles did not differ in the number of movements (MWU; $z = 0.00$, $p = 1.00$), but those of females differed from both (MWU; $z = 2.71$, $p = 0.02$). Females moved less and over shorter distances, relative to males and to juveniles.

Many of the turtles also tended to use familiar areas from one season to the next. In all, 12 of the 20 turtles that utilized more than one wetland used areas in 1997 that they had inhabited in 1996. In only one instance did a turtle (a juvenile) move to a new wetland and then return to its previous wetland in the same season.

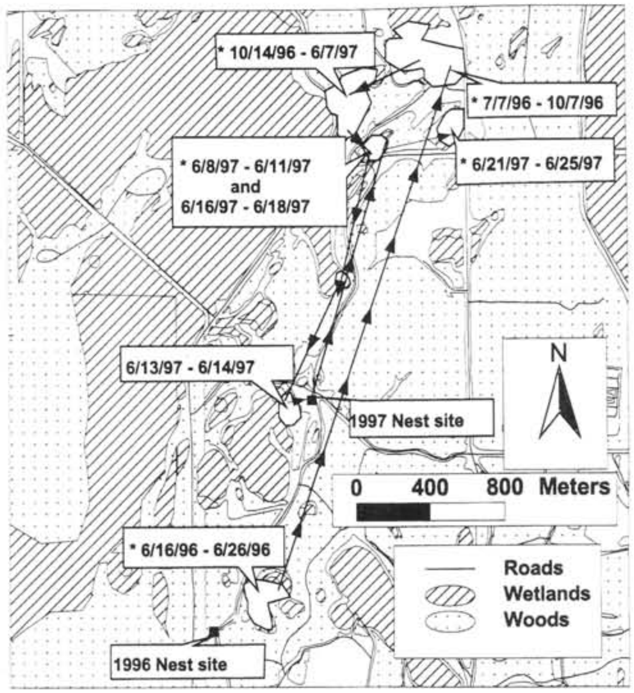

Figure 3. Movements and activity areas of an adult female Blanding's turtle (QTU) at Camp Ripley, monitored from June 1996 through June 1997, during two summers and an intervening winter. This female was initially found nesting in 1996, then moved to a nearby small wetland (bottom, center) for 10 days (activity center area shown as white area outlined in black superimposed on cross-hatched wetland) before making a long intermarsh movement (black line with directional arrows) to another wetland (top, right center) where she stayed for 3 months before shifting to a nearby wetland where she overwintered. This female used six different wetlands (as shown) during the year prior to nesting in mid-June 1997.

Nesting Movements. — Gravid females typically made long, meandering searches for a nest site. For example, a nesting female moved an estimated 1946 m over a 3-day period . The straight-line distance from start to finish, based on single locations each day, totaled 1609 m. The estimated meandering ratio for this female was 1.2 (1946 m / 1609 m) (Fig. 5). On average, the straight-line nesting distance for four turtles whose detailed movements were recorded in 1997 was 541 m vs. 931 m for the estimated actual nesting movement (Table 3). This tendency to meander characterized all of the observed females, but we only recorded detailed information for the four turtles listed. For 13 nests, the straight-line distance from the turtle's wetland to the nest ranged from 100 to 1609 m with a mean distance of 426 m. The estimated meandering distances for these females ranged from 170 to 1946 m, with a mean of 727 m, using a mean meandering ratio of 1.7 (Table 3).

Nesting was observed from 10 June to 11 July in 1996 and from 10 to 21 June in 1997. A nesting excursion lasted from 1 to 3 days. A turtle unable or unwilling to nest on a given night either moved a short distance back into a nearby wetland or buried itself by shaping a form in the substrate nearby on land until the following day when it resumed its nest search, typically in the afternoon.

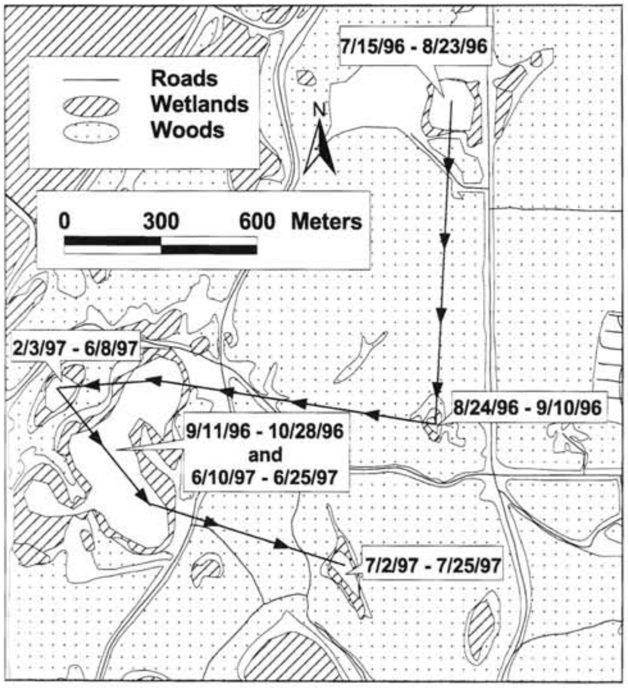

Figure 4. Movement and activity areas of an adult male Blanding's turtle (ABO) at Camp Ripley, monitored during two summers and an intervening winter, from mid-July 1996 until release in late July 1997. This male initially occupied an activity center (top, right: white area outlined in black superimposed on cross-hatched wetland) within a medium-sized wetland before making an intermarsh movement (black line with directional arrows) to a small wetland (center, right). He overwintered and spent the early summer in the next season (1997) in another wetland (center, left). This male used 5 different marshes and covered a distance >3300 m during the year it was radiotracked.

Daily Movements. — Turtles were active from mid-April to mid-November. In early April and late November, observations were intermittent. Throughout the study, most radiotagged turtles often spent weeks moving within a single wetland. Every turtle moved between relocation attempts during the activity season. We did not detect any inactive turtles (i.e., aestivated on land or in water) during the activity season (May–October).

Females and juveniles moved similar straight-line daily distances (MWU; $z = 0.17$, $p = 0.87$). Females moved an average of 45 m (range = 6–142 m/day); juveniles moved an average of 45 m (range = 1–123 m/day). Males moved less on a daily basis than either females or juveniles (MWU; $z = 3.74$, $p = 0.00$). The average distance moved was 26 m (range = 1–133 m/day). Meandering values, similar to those for the nesting movements, were calculated to account for the error in straight-line daily distances. Data from 13 of the 25 turtles (3 males, 7 females, and 3 juveniles), in which three or more locations a day had been gathered, were used to estimate how far a turtle may have actually moved from day to day, i.e., the actual distance transversed (Table 4).

On this basis, females moved the most; the average estimated movement was 109 m/day. The daily movements of juveniles were similar to those of females, moving an average of 92 m/ day. Males moved the least on a daily basis, moving an average of 45 m/day. The estimated meandering

Table 2. Overwintering movements (m) made before May and after September by 10 radiotagged Blanding's turtles (3 males, 4 females, and 3 juveniles) at Camp Ripley during 1996 and 1997.

Turtle	Sex	Distance	Month
BL	M	265, 545	April, October
BHJ	M	635	April
ABO	M	159	October
ADJ	F	134	October
QTU	F	232	October
JKL	F	365	October
AP	F	516	April
ABV	J	683, 870	April, October
AVN	J	364	October
ACJ	J	561	October

daily distance of males, females, and juveniles differed (KW; $H = 24.8$, $p = 0.01$) as well as the meandering ratios among these groups (KW; $H = 9.1$, $p = 0.01$).

Activity Centers and Home Ranges. — Among females, activity centers and home ranges differed. The number of activity centers were related to the movement patterns of the individual females. For the 13 females, the number of activity centers ranged from 1 to 6 with a mean of 3.1. The areal extent of the activity centers ranged from 0.3 to 6.6 ha with a mean of 2.1 ha. The home range estimates for the females ranged from 3.9 to 18.7 ha with a mean of 7.9 ha. A typical activity center and home range estimate for female ABI is shown in Fig. 6. Her first activity center was 1.8 ha that she inhabited for 10 days. She then moved 551 m southeast to her second 3.5 ha activity center where she stayed for 56 weeks. Her total home range was 6.2 ha.

Juveniles had the fewest activity centers, but these were larger than those of either males or females. Juveniles averaged 2.0 activity centers, ranging from 0.4 to 6.9 ha,

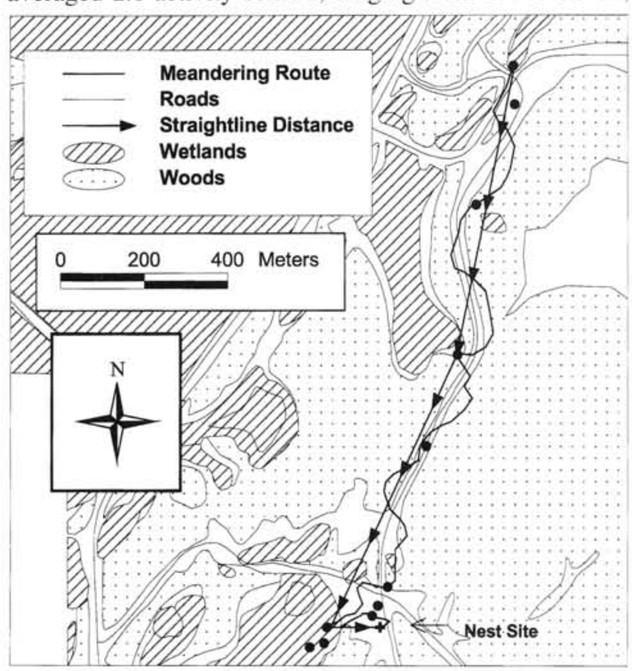

Figure 5. Nesting movements of a radiotagged female Blanding's turtle (QTU) at Camp Ripley in 1997. Observed meandering route is shown from the home wetland (top, right) to nest site (bold cross), over a 3-day period (bottom, center). Straight-line distances between locations on consecutive days shown with arrows.

Table 3. Nesting movements of radiotagged Blanding's turtles at Camp Ripley in 1997. Straight-line distances, estimated meandering distances, duration of travel, and calculated meandering ratios (straight-line distance/meandering distance) for four females are shown.

Turtle	Date		Calculated Straightline Distance (m)	Estimated Meandering Distance (m)	Duration (Hrs)		Meandering Ratio
ABI	11-Jun-97		25	356	4.0		14.3
	12-Jun-97		56	167	2.0		3.0
	13-Jun-97		171	232	2.5		1.4
		Total Distance	251	755		Mean Ratio	3.0
AQ	12-Jun-97		8	63	1.5		8.3
	13-Jun-97		81	180	2.0		2.2
	14-Jun-97		22	177	2.5		8.0
		Total Distance	111	420		Mean Ratio	3.8
JKL	11-Jun-97		112	325	3.0		2.9
	12-Jun-97		10	130	2.0		12.7
	13-Jun-97		71	147	1.5		2.1
		Total Distance	193	602		Mean Ratio	3.1
QTU	12-Jun-97		710	770	4.5		1.1
	13-Jun-97		752	877	2.0		1.2
	14-Jun-97		147	299	4.0		2.0
		Total Distance	1609	1946		Mean Ratio	1.2
		Total Mean Distance	541	931		Total Mean Ratio	1.7

with a mean size of 2.6 ha. Juvenile home range estimates ranged from 2.9 to 10.4 ha, with a mean of 5.9 ha.

Males had the greatest number of activity centers but these were smaller than those of females or juveniles. The number of activity centers for the six males ranged between 2 to 6, with a mean of 3.8. The areal extent of their activity centers ranged from 0.1 to 6.9 ha with a mean size of 1.7 ha. Male home range estimates were similar to females, ranging from 3.4 to 14.2 ha with a mean of 7.8 ha. Overall, turtles that moved often had more activity centers and larger home ranges (Fig. 7).

The activity centers and home ranges for each turtle are listed in Table 5. The size (KW; H = 5.5, $p = 0.04$) and number (KW; H = 5.70, $p = 0.001$) of activity centers for the three groups differed. Male and female home ranges did not differ (MWU; z = 0.13, $p = 0.89$), but juvenile home ranges

Table 4. Daily movements of radiotagged Blanding's turtles within resident wetlands during 1996 and 1997 at Camp Ripley. The straight-line distances (m), estimated meandering distances (m), and meandering ratios (straight-line distance/meandering distance) are shown for 3 males, 7 females, and 3 juveniles.

Turtle	Sex	Date	Calculated Straightline Distance	Meandering Distance	Meandering Ratio
ABC	M	7-Jun-96	18	23	1.3
		24-Jun-96	15	20	1.4
		6-Jul-96	21	38	1.8
		16-Jun-96	9	19	2.2
BHJ	M	9-Jul-96	15	27	1.8
WXY	M	15-Jul-96	125	197	1.6
ABQ	F	16-Jun-97	8	13	1.7
		9-Jul-97	13	24	1.8
ADJ	F	13-Jun-96	42	45	1.1
		16-Jul-96	31	34	1.1
ADL	F	24-Jul-96	11	30	2.6
		25-Jul-96	18	63	3.5
		10-Sep-96	7	27	3.7
		9-Jul-97	3	26	7.4
AN	F	17-Jun-96	63	80	1.3
		20-Jun-96	72	136	1.9
		12-Jun-97	102	229	2.2
AP	F	16-Jun-96	175	222	1.3
		18-Jun-96	59	83	1.4
		24-Jun-96	240	450	1.9
		12-Jun-97	72	168	2.4
		13-Jun-97	36	94	2.6
JKL	F	13-Jun-96	93	204	2.2
NOP	F	12-Jun-97	76	119	1.6
		13-Jun-97	21	82	3.9
ABL	J	16-Jun-97	58	99	1.7
		9-Jul-97	44	101	2.3
ABT	J	10-Sep-97	64	118	1.8
ABU	J	9-Jul-97	6	13	2.3

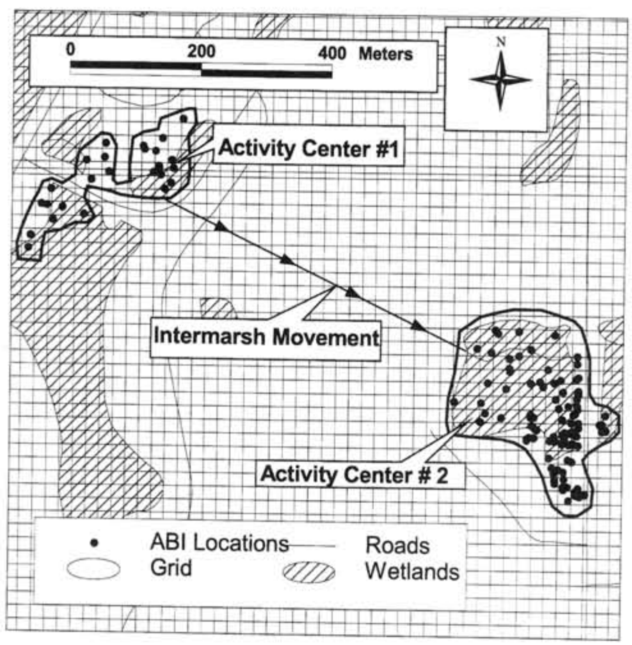

Figure 6. Activity centers and home range as determined by the grid summation method for an adult female Blanding's turtle (ABI) at Camp Ripley monitored from June 1996 to July 1997. This female had an initial activity center (dark line bounding specific locations indicated as black dots) that included parts of 3 separate wetlands (two small ones, top left; large marsh, left center) and totaled 1.8 ha. She then moved (black line with directional arrows) to another wetland where she remained. This activity center was 3.5 ha, encompassing a medium-sized wetland and a corner of an adjacent one to the east, as well as upland habitat to the southeast. The home range area was 6.2 ha, a typical size for females in this population.

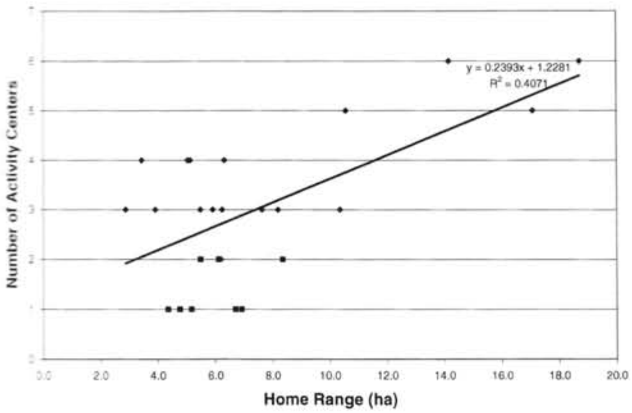

Figure 7. Relationship of the number of activity centers (vertical axis) as a function of home range size (horizontal axis, in hectares) for 25 Blanding's turtles (6 males, 13 females, 6 juveniles) at Camp Ripley during 1996–97. Squares indicate individuals that had two or fewer activity centers or had multiple activity centers and a home range less than 6 ha. Activity center number increased as home range size increased.

were smaller in comparison (MWU; z = 2.91, $p = 0.05$). As noted above in the section on intermarsh movements, some turtles were sedentary. Some males, females, and juveniles had two or fewer activity centers or had multiple activity centers and a home range of less than 6 ha (Fig. 7). Turtles that moved more often had more activity centers and larger home ranges. Activity center size increased with increasing home range size; turtles with activity centers >2.0 ha had home ranges >6 ha. Turtles that moved the longest distances had 5-6 activity centers and home ranges that exceeded 10 ha (Fig. 7).

During the two summers of our study, some turtles used familiar areas from year to year, whereas others did not. Of the 25 turtles, 12 utilized activity centers in 1997 that they had used in 1996. There was extensive overlap of home ranges among all of the turtles. Males, females, and juveniles were often found in the same areas and utilized the same wetlands at the same time as each other. Among 16 turtles living in the same general area, every individual turtle's home range overlapped a minimum of 3 other turtles, with some overlapping as many as 5 or 6 other turtles.

Wetland Effects. — The type of wetland inhabited by a turtle affected how long it resided there. At Camp Ripley, wetland types were: inland fresh marshes, inland open water, and shrub swamps. The turtles that we monitored resided in shrub swamps for extended periods. For 33 periods of residency that extended for over 50 days, 29 occupancies were in shrub swamps (Fig. 8). Overall, turtles spent more time in shrub swamps than in other habitats. For example, one male resided a total of 79 days in other wetlands, but inhabited shrub swamps for 130 days.

Wetland size also affected the length of residency, and consequently, the frequency of movements between wetlands. As the shrub swamp size increased, so did the period of residency (Fig. 9). For example, one male spent 26 and 67 days in the same 3.6 ha shrub swamp over the two activity seasons, but spent 114 days in a different 7.9 ha shrub swamp. One female spent 59 days in an 8.0 ha wetland and 124 days in a 371 ha wetland. One juvenile spent 24 days in a 3.6 ha wetland and 98 days in an 8.0 ha wetland.

Table 5. Size and number of activity centers, mean activity center size (ha), and home range, calculated by the grid summation method (GS; see text for explanation) for radiotagged Blanding's turtles at Camp Ripley (6 males, 13 females, and 6 juveniles). Mean home range size (ha) is shown for each group.

Turtle	Sex	Start	Finish	Days	Activity Centers (ha)	No. of Activity Centers	Mean Activity Center	Home Range (ha)
ABC	M	6-Mar-96	3-Jul-97	395	0.3, 0.04, 0.3, 0.5	4	0.3	3.4
ABO	M	15-Jul-96	25-Jul-97	375	1.5, 0.4, 3.1, 1.2, 2.4, 1.2	6	1.6	14.2
ABP	M	15-Jul-96	29-Jul-97	379	2.2, 0.3, 4.6, 0.4, 1.3	5	1.8	10.6
BHJ	M	23-May-96	2-Sep-97	467	0.6, 6.9	2	6.9	8.4
BL	M	23-May-96	6-Jun-97	379	1.0, 0.4, 0.2, 0.5	4	0.5	5.0
WXY	M	22-Jun-96	8-Jul-97	381	4.2, 0.4	2	4.2	5.5
					Means =	3.8	2.6	7.8
ABI	F	10-Jun-96	6-Jul-97	391	1.8, 3.5	2	3.5	6.2
ABK	F	28-Jun-96	21-Jun-97	358	0.6, 1.6, 5.2, 4.2, 1.4, 3.0	6	2.7	18.7
ABQ	F	17-Jul-96	2-Sep-97	412	6.6	1	6.6	6.6
ADJ	F	13-Jun-96	2-May-97	323	1.4, 3.3, 1.5	3	2.1	8.2
ADL	F	5-Jul-96	2-Sep-97	424	4.3	1	4.3	5.2
AN	F	14-Jun-96	16-Jun-97	367	0.6, 1.6, 1.6, 0.4	4	1.1	5.1
AP	F	16-Jun-96	21-Jun-97	370	0.5, 2.8, 0.3, 0.7	4	1.1	6.3
AQ	F	16-Jun-96	15-Aug-97	425	2.0, 0.3, 0.9	3	1.1	5.9
JKL	F	13-Jun-96	6-Jul-97	388	2.4, 2.6, 2.0	3	2.3	7.6
JNOP	F	17-Jun-96	24-Jul-97	402	1.6, 1.5, 0.6	3	1.2	3.9
KLN	F	11-Jun-96	14-Jun-97	368	1.5, 4.1	2	4.1	6.1
NOP	F	12-Jun-96	15-Jun-97	368	1.9, 2.6, 0.7	3	1.7	5.5
QTU	F	17-Jun-96	25-Jun-97	373	0.4, 1.8, 1.7, 0.6, 0.6	5	1.0	17.1
					Means =	3.1	2.5	7.8
ABL	J	18-Jul-96	2-Sep-97	411	4.8	1	4.8	4.8
ABN	J	18-Jul-96	10-Jun-97	296	0.4, 0.8, 0.4	3	0.5	2.9
ABT	J	10-Aug-96	4-Jun-97	298	4.4	1	4.4	4.4
ABU	J	28-Jul-96	1-Sep-97	400	6.9	1	6.9	6.9
ABV	J	10-Aug-96	5-May-97	268	2.2, 1.4, 0.7	3	1.4	6.2
ACJ	J	8-Aug-96	7-Jun-97	303	1.8, 3.0, 4.0	3	2.9	10.4
					Means =	2.0	3.5	5.9

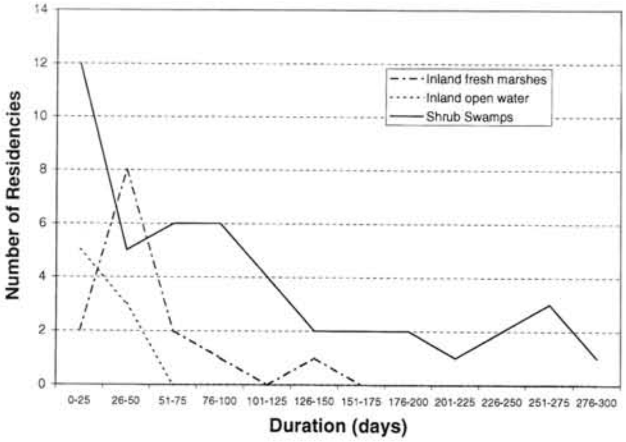

Figure 8. Effect of wetland type on the duration of residence. Blanding's turtles at Camp Ripley remained longer in shrub swamps, relative to time spent in marshes and in inland open water. Shrub swamps accounted for 29 of 33 periods of residency over 50 days.

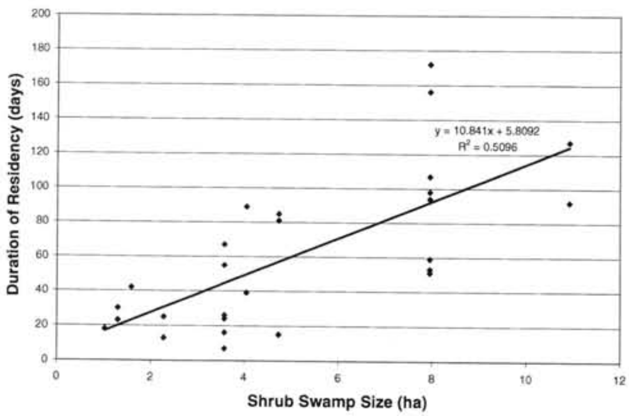

Figure 9. Effect of shrub swamp size on the duration of residence. Blanding's turtles at Camp Ripley remained longer in large vs. small shrub swamps. The length of residency increased as shrub swamp size increased.

The size of the inhabited wetland was also correlated with the size of daily movements, presumably by influencing how far a turtle moved. A very small wetland limited how far a turtle moved on a daily basis. As wetland size increased, this effect became less pronounced. Patterns of daily movements also depended on individual differences among turtles. One male resided in an 18.8 ha wetland from mid-September to late October with movements averaging 61 m a day. He resided in the wetland again from mid- to late June when he averaged 113 m a day. A juvenile showed a different, but similarly individual pattern of movement. It resided in the same 8.0 ha wetland from October to mid-November and again from mid-April to early June when it averaged 123 and 37 m a day, respectively.

DISCUSSION

Intermarsh Movements. — In our study, the seasonal movement patterns of females differed from those of males. Females moved most often in early summer. They moved relatively long distances between wetlands, most often during nesting. In contrast, males made intermarsh movements throughout the active season; consequently, peak periods of movement were not as evident (Fig. 2). Males moved between marshes more frequently and over shorter distances, relative to females or juveniles. Based on our limited data, some juveniles made overland trips of intermediate distance just prior to and after overwintering, whereas the majority of those monitored never moved between wetlands. These differing patterns are likely related to age/sex specific differences in life history, and will be discussed below in the section on activity centers and home range.

Wetland features also probably affected movements. In our study, turtles showed a preference for shrub swamps. These are discolored, highly vegetated, and organically rich eutrophic environments that normally provide greater secondary productivity for macro-invertebrates and tadpoles than more open clear-water bodies (Power et al., 1994). A wetland with continuous emergent vegetation supports a greater biomass than one that is only 10% vegetated (Congdon et al., 1986). A turtle in a shrub swamp was less likely to shift to a new wetland than was one living in open water habitat. Shrub swamps may also provide protection against predators, particularly for smaller turtles (Pappas and Brecke, 1992).

The intermarsh movements of Blanding's turtles at Camp Ripley generally were over greater distances and more frequent than those observed at several localities. Average intermarsh distances were smaller in Wisconsin (Ross, 1985) and in Illinois (Rowe and Moll, 1991). In addition, intermarsh movements were not common in an Illinois population (Rowe, 1987), whereas at Camp Ripley, most turtles moved between wetlands. On the other hand, the intermarsh movements observed by Joyal (1996) in Maine were greater, for the average distance moved by radiotagged turtles as well as the cumulative distance moved by a turtle over a single season.

Nesting Movements. — At Camp Ripley, nesting females moved average distances that were greater than those documented in Wisconsin (Ross, 1985), but smaller than those reported in most other studies (Congdon et al., 1983; Rowe and Moll, 1991; Joyal, 1996; Linck and Moriarty, 1997). The maximum nesting distances in these studies, including ours, ranged from 900 to 2025 m. The smaller mean nesting distances at Camp Ripley may be due to available nest sites adjacent to many of the numerous, small wetlands distributed throughout the habitat. Additionally, as females moved between wetlands, the apparent total distance a female moved to nest might seem smaller, particularly if it was not known in what wetland her journey started. Nesting distances at Camp Ripley were based on straight-line distances, and consequently underestimated the actual distance a female moved. The actual nesting movements, corrected to include meandering distances, were much larger than straight-line estimates, sometimes by as much as 7 times (Table 3). A majority of the nesting movements we observed appeared to be round trips, with the post-nesting female moving back to the area she occupied prior to nesting.

The onset of nesting at Camp Ripley was similar to that reported in Wisconsin (Ross, 1985), Minnesota (Linck and

Moriarty, 1997), and in Maine (Joyal, 1996), but later than that reported for other populations (Congdon et al., 1983; Rowe and Moll, 1991). Most nesting was completed by late June in sunny, exposed sites that facilitated hatching. Emergence occurred in late August and early September, before the onset of winter.

Seasonal Patterns and Overwintering Movements. — The turtles at Camp Ripley were active from mid-April to mid-November. Spring emergence was about two weeks later than in other southerly populations (Evermann and Clark, 1916; Rowe and Moll, 1991; Sexton, 1995). The onset of hibernation in the fall, during October and November, appears to coincide with dates reported elsewhere (Evermann and Clark, 1916; Kofron and Schreiber, 1985; Rowe and Moll, 1991). However, a population in Wisconsin (Ross, 1985) began overwintering as early as late September, earlier than we observed.

Hibernation and emergence dates appear to be heavily influenced by local weather. In central Minnesota, surface ice forms from early November to late December; ice sheets disappear from early April to mid-May. Activity under the ice during the winter months (December through March) was not observed at Camp Ripley, but has been reported in Indiana (Evermann and Clark, 1916) and in Michigan (Sexton, 1995). When turtles were monitored closely for brief periods (1–3 days) in the winter, no activity was detected. No movements (>2 m) were made by any turtle while it was under the ice, based on monthly monitoring of radiotagged individuals. Lack of winter activity has been previously reported in other northern populations (Ross, 1985; Rowe, 1987) whereas limited winter activity has been observed elsewhere (Conant, 1938; Kofron and Schreiber, 1985; Ernst et al., 1994). Other aquatic turtles have been shown to exhibit microhabitat shifts during the winter (Peterson, 1987; Meeks and Ultsch, 1990).

Movements to and from overwintering sites by turtles at Camp Ripley entailed movements over moderate distances, averaging from 300 to 620 m for males, females, and juveniles. Similar seasonal movements between overwintering sites and summer wetlands have been documented in some populations studied (Gibbons, 1968; Linck and Moriarty, 1997; Sexton, 1995). In other localities, Blanding's turtles reportedly overwinter primarily in summer wetlands (Ross and Anderson, 1990; Rowe and Moll, 1991; Joyal, 1996), as did some juveniles and adults in our study. In contrast, in Nova Scotia, well-defined overwintering movements along stream drainages typify the population (Power, 1989; Herman et al., 1994).

Daily Movements. — For aquatic turtles, Gibbons et al. (1990) defined daily movements as ones in which basic life requirements such as feeding, basking, predator avoidance, courtship, and mating are met. At Camp Ripley, daily movements were varied and unpredictable, both among turtles and within individuals. Care must be taken when comparing the movements of turtles inhabiting different wetlands in the same area. Daily movements were turtle dependent, but also showed a wetland effect. Small wetlands tended to limit turtle movement. On the other hand, the turtles living in large wetlands (>6 ha) typically utilized only a small part of the wetland on any given day or series of days.

The turtles that we studied did not show any signs of inactivity or dormancy during the summer months, although they were generally inactive at night. In addition, aestivation on land or in the water was not observed in this population. These results are in marked contrast with previous reports from other localities throughout the species' range (Gibbons, 1970; Ross, 1985; Linck and Moriarty, 1997; Joyal, 1996).

In our study, the average daily distance that male turtles moved was similar to values reported in other populations. Prior studies did not include data on juvenile movements. At Camp Ripley, juveniles moved only slightly smaller daily distances than did females. The longer daily movements of the females in our study may reflect increased activity associated with nesting, especially during June (when many such movements were recorded). Comparable daily distances of females were reported for a Wisconsin population; in that study, the authors attributed aquatic movements in part to reproductive activity (Ross and Anderson, 1990). If this were the case in that study, the daily distances moved by females in the Wisconsin study would be shorter than those we documented for females at Camp Ripley. Shorter daily movements throughout the activity period were also characteristic of adult females in a population in Illinois (Rowe and Moll, 1991).

Activity Centers and Home Ranges. — At Camp Ripley, the activity centers and home ranges of turtles were characterized by a number of features that distinguished this population from those studied elsewhere. Age/sex class differences were apparent, a feature not well-documented previously. Males had the greatest number of activity centers, but these were smaller than those of females and juveniles. Home range estimates for males and females were nearly equivalent, but were larger than the estimate for juveniles. Juveniles had the fewest activity centers, but these were larger than those of either males or females that we monitored. Movements between marshes by juveniles occurred early and/or late in the season, and likely provided routes to and from suitable overwintering sites in the vicinity of summer wetlands.

Resources related to reproduction are important factors affecting space use in turtles, and differences in the sexual strategies between males and females should be reflected in patterns of activity and space use (Morreale et al., 1984; Brown and Brooks, 1993). For males, reproductive success is dependent on maximizing encounters with females, particularly those that result in successful matings. Thus, males may actively search for sedentary females, moving more frequently over shorter distances. Importantly, such movements would be expected to be more random than would directed movements associated with nesting or overwintering. In our study, the patterns of activity and space use exhibited by males suggest that an important component of these movements was related to mate searching. At Camp

Ripley, mating was noted in the fall as well as in the spring. In addition, there was a distinct difference in the thermal ecology of males vs. females in late summer and fall. Whereas females tended to thermoregulate often, males tended not to thermoregulate during this period (Sajwaj and Lang, 2000).

Females moved between wetlands before and after nesting, apparently using nearby wetlands as staging areas for long distance excursions. The tendency of females to thermoregulate more than males in late summer and fall is likely related to egg production for the subsequent nesting season (Sajwaj and Lang, 2000). An alternate explanation for these sex differences in movements and activity is that energetic requirements of males were greater than those of females, based on a body size difference, i.e., males larger than females. However, the lack of strong sexual size dimorphism in this as well as in other populations of Blanding's turtles provides little support for an energetic explanation of sex differences (Sajwaj et al., 1998; Pappas et al., 2000).

In addition, within an age/sex class, individual turtles showed distinctly different patterns of movement and uses of space. For example, a number of turtles, including females and juveniles, that inhabited an 18 ha marsh remained in the same wetland throughout the entire study period, extending over two activity seasons and the intervening winter. In contrast, other individuals exhibited extensive movements among different wetlands which were utilized as separate summer and winter habitats during this same period. Finally, most turtles that made long-distance intermarsh movements consistently returned to certain well-defined activity centers within the wetlands they had inhabited previously. Joyal (1996) documented individual variation in movement patterns and habitat use among adult Blanding's turtles in Maine, and noted that one male did not travel for the length of the study.

Three spatial estimators (grid summation, minimum convex polygon, and adaptive kernel) were used to determine the areal extent of the activity centers and the home ranges of the turtles in our study. Of these, the grid summation method was judged to be the best estimate of the actual areas utilized by an individual turtle (Piepgras, 1998). This method may underestimate slightly its actual home range because activity centers were connected by the shortest straight-line distance between them, resulting in a narrow corridor of overland movement (Fig. 6). This discrepancy could be rectified by incorporating a corridor wide enough (ca. 40 m) to accommodate the meandering routes that were typical of the turtles that we observed closely. The minimum convex polygon method and the adaptive kernel method both tend to greatly overestimate the actual areas used by the turtles; both methods incorporate large blocks of terrestrial habitat never frequented by the turtle. These methods have been criticized for overestimating the actual areas used by the turtles (White and Garrott, 1990; O'Connor et al., 1994; Kaufmann, 1995; Edmonds, 1998).

Overall, the turtles at Camp Ripley moved greater distances and moved more often than Blanding's turtles studied elsewhere. Using the grid summation method, the turtles in our study had large activity centers and large home ranges (Table 5). However, direct comparisons of our results with those from other studies were confounded by the different methodologies used to estimate these parameters. For example, the mean home range size of turtles at Camp Ripley was 7.4 ha, using the grid summation method. Using the minimum convex polygon (MCP) method, the population in Illinois had a mean home range size of 9.5 ha (Rowe, 1987). If the home ranges at Camp Ripley were calculated with the same method as those in Illinois, the mean home range in our study would be approximately 31 ha, over a three-fold increase. Using the same method (MCP), the mean length of home ranges at Camp Ripley was 906 m vs. 489 m for turtles in a Wisconsin population (Ross and Anderson, 1990). Estimates of activity centers and home ranges of Blanding's turtles for various populations, including summary values for our study, are shown in Table 6.

The home range of an animal is presumably related to the spatial and temporal distribution of key resources (Pettit et al., 1995). The large home ranges that we have reported here may be related to specific features of the wetland habitats at Camp Ripley that distinguish the region from wetland habitats elsewhere. These may include low population density, patchy resource availability, and extensive but dispersed marshes. It has been suggested that home range size varies inversely with the population density (Stickel,

Table 6. Comparison of Blanding's turtle activity centers and home ranges from this study with values reported for other populations. The three methods used in this study were grid summation (GS), minimum convex polygon (MCP), and adaptive kernel (AK). The minimum polygon method (MPM) used in two previous studies is equivalent to the minimum convex polygon method (MCP) used in this study. Of these, the grid summation method was judged to be the best estimate of the actual areas utilized by an individual turtle in this study.

		Activity Center		Home Range			
Location	Number and Sex	Area (ha)	Number	Area (ha)	Length (m)	Method	Reference
Minnesota	6M, 13F, 6J	1.5, 2.1, 2.6	3.8, 3.1, 2.0	7.8, 7.8, 5.9	208-2700 (835)	GS	This study
	6M, 13F, 6J	1.7, 4.8, 1.2	3.5, 2.7, 1.8	38.4, 35.4, 12.8	243-2987 (906	MCP	This study
	6M, 13F, 6J	3.5, 9.1, 4.2	3.5, 2.7, 1.9	53.4, 63.0, 15.1	292-3100 (985)	AK	This study
Wisconsin	2M, 6F	0.56	2.3	n/a	489	MPM**	Ross and Anderson, 1990
Wisconsin	1M, 1F, 1J	n/a	n/a	ca. 17.7	n/a	?	Thiel, 1997
Illinois	6M, 5F, 1J	0.6	3.1	1.3*	630-800	MPM**	Rowe and Moll, 1991
Maine	3M, 6F	0.03-0.94	2.8	0.91*	90-2050 (680)***	MPM**	Joyal, 1996
Nova Scotia	?	n/a	3	n/a	<1500	?	Herman et al., 1994

* denotes summed activity centers; ** MPM equivalent to MCP method; ***distance between activity centers

1989). In our study, the population density of Blanding's turtles was estimated to be between 0.47 and 1.45 turtles/ha (Sajwaj et al., 1998). This is significantly less than the 27.5 turtles/ha that Ross (1989) estimated in Wisconsin, the 8.8 and 10.0 turtles/ha reported by Congdon et al. (1986) in southern Michigan, or the 3.9 and 5.9 turtles/ha in Maine studied by Joyal (1996).

Another possible factor that distinguishes the movement patterns observed at Camp Ripley is resource availability. Turtles may require resources otherwise not available, resulting in movements to new wetlands. Turtles may be making intermarsh movements to locate food, nest, and/or mates, as well as suitable sites for overwintering (Gibbons et al., 1990). In habitats where these resources are dispersed relative to one another, such movements will be longer and/or more frequent. Turtles moving during the summer months are likely doing so for food and/or reproduction, whereas those moving earlier or later in the season are likely returning from or seeking sites for overwintering.

In areas where food resources are widely distributed, home ranges will be larger than in areas where resources are more concentrated. Temporally and spatially, the food resources available to the turtles at Camp Ripley are patchily distributed due in part to the short growing season and the consequent dependence upon locally available invertebrate and vertebrate prey. Thus, a patchy distribution of resources would lead to increased movements between wetlands to exploit locally abundant species; and this, in turn, would result in larger home ranges.

The availability of wetland habitats may also influence turtle movements. The wetlands at Camp Ripley are extensive, even though the 450 ha of habitat is primarily subdivided into series of small wetlands. In contrast, suitable wetland habitats at study sites in Illinois were limited to few relatively large 125 and 25 ha tracts (Rowe and Moll, 1991). The smaller the wetland, including examples at Camp Ripley, the more likely were turtles to move between adjacent wetlands. Thus, the differences between the Camp Ripley population and the Illinois and Wisconsin populations may be related to the relatively unfragmented and extensive habitat available in central Minnesota. At several locales near Minneapolis, Minnesota, Blanding's turtles living in large parks or reserves moved distances of 2000 to 3500 m during an activity season (Dorff, 1995; Linck and Moriarty, 1997). In another study on a military reservation in Massachusetts, turtles were documented moving 1600 m between wetlands (Butler, 1995). At a large contiguous site in Maine, Blanding's turtles moved an average of 2900 m in a season (Joyal, 1996).

In these studies as well as in our study, there were few obvious barriers that bounded or impeded movements among wetland habitats. Such barriers might include wetland degradation, extensive highway construction, and/or land development. Although these factors ultimately would likely have deleterious long-term effects on turtles, our recent study of Blanding's turtles in a rapidly developing resort region near Camp Ripley (the Brainerd/Baxter area) indicated that the movements of turtles among these wetlands did not differ appreciably from those documented here (Piepgras, 1998; Piepgras et al., 1998; Sajwaj et al., 1998). In Ontario, wood turtles (*Clemmys insculpta*) studied by Quinn and Tate (1991) have home ranges that were almost 6 times as large as wood turtles in Pennsylvania (Kaufmann, 1995), a difference attributed to extensive use of upland as well as riparian habitats in the Ontario population. In bog turtles (*Clemmys muhlenbergii*), regional differences in home range size are likely related to the distribution of wetlands (Carter et al., 1999). In other species, home ranges also vary with locality, but explanations for such intraspecific variation are elusive (Schubauer et al., 1990; Brown et al., 1994).

Blanding's turtles have often been classified as "semi-terrestrial" or "semi-aquatic" in general accounts (e.g., Pritchard, 1979; Ernst et al., 1994). Our observations indicate that the population at Camp Ripley is aquatic, and this description agrees with that of most previous workers (e.g., Kofron and Schreiber, 1985; Sexton, 1995). The overland movements we documented were short in duration, typically a day or two, and directed toward another wetland. Wetland residencies frequently extended for a month or more (Fig. 8). The percentage of time that these turtles spent on land ≤5%) was small relative to that spent in aquatic habitats during the active season, and was even less when calculated on an annual basis (Sajwaj et al., 1998; Sajwaj and Lang, 2000).

Blanding's turtles appear to be the most vagile aquatic turtles in North America. They tend to move longer distances and move more frequently than other common aquatic turtles occupying the same habitats, including painted turtles (*Chrysemys picta*) and snapping turtles (*Chelydra serpentina*). Relative to Blanding's turtles, snapping turtles and painted turtles inhabit much smaller areas (MacCulloch and Secoy, 1983; Brown et al., 1994; Ernst et al., 1994; Petit et al., 1995). Sliders (*Trachemys scripta*) are probably more similar to Blanding's turtles than to either of the other two species. Schubauer et al. (1990) showed that sliders had home ranges ranging from 0.6 to 103 ha., using the minimum convex polygon method for estimation. In our study, comparable values for Blanding's turtles were 1.7 to 119 ha.

The primary conservation concern for Blanding's turtles in central Minnesota is the preservation of intact mosaics of upland and wetland habitats. In particular, individual turtles rely on shrub swamps to provide sufficient resources for the active and inactive periods of the annual cycle. In addition, there must be suitable uplands nearby for nesting females, eggs, and hatchlings. Since home ranges at Camp Ripley were more than three times larger than those of populations elsewhere, adequate size is an important determinant of habitat suitability. For this purpose, the minimum convex polygon (MCP) method of calculating home range was a better estimator than the grid summation method because the MCP method incorporated intervening segments of upland between occupied wetlands. At Camp Ripley, a terrestrial buffer zone of 300 m around a complex of 15 wetlands inhabited by 16 monitored turtles would protect all known nest sites and travel corridors for this concentration of turtles (Piepgras, 1998). The major threats are likely habitat fragmentation, wetland degradation, and road mortality, all of which characterize Blanding's turtle populations elsewhere in Minnesota (Dorff, 1995; Linck and Moriarty, 1997).

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