Spatial Ecology and Seasonal Activity of Blanding's Turtles (*Emydoidea blandingii*) in Ontario, Canada

CATHERINE S. MILLAR AND GABRIEL BLOUIN-DEMERS¹

Department of Biology, University of Ottawa, Ottawa, Ontario K1N 6N5 Canada

ABSTRACT.—Understanding the spatial ecology of species at risk is essential for conservation because this information forms the base from which management and recovery plans are delineated. We studied microhabitat selection and evaluated the effect of reproductive class on daily movement patterns, home ranges, and seasonal activity of Blanding's Turtles in the St. Lawrence Islands National Park, Ontario, Canada. We also consider the potential conservation/management ramifications of differences in habitat use between the reproductive classes. We monitored 38 Blanding's Turtles (20 males, 13 gravid females, and 5 nongravid females) from April 2008 to August 2009 via radiotelemetry. Reproductive class did not have a significant effect on the mean daily movement of turtles in May, July, and August. In June, however, gravid females moved significantly more (mean = 400 ± 49 m per day) than males (mean = 194 ± 22 m per day). Reproductive class also had a significant effect on turtle home-range size, although high individual variation was observed (range = 1.6–40.6 ha). Gravid females had significantly larger home ranges (mean = 20.3 ± 3.5 ha) did than both males (mean = 8.2 ± 1.8 ha) and nongravid females (mean = 7.3 ± 3.2 ha). At the microhabitat scale, Blanding's Turtles selected colder water with more submerged and floating vegetation and avoided open water. Our results highlight the importance of stratifying field observations and spatial data by reproductive class and time and including terrestrial habitat in home-range analyses of Blanding's Turtles.

When preparing management plans for species at risk, conservation practitioners need information on the habitat requirements of those species. Spatial ecology is the study of how landscape configuration influences the community and population dynamics of organisms (Collinge, 2001). Thus, empirical studies in spatial ecology link conservation biology research to practical mechanisms for species management and conservation planning (Collinge, 2001; Whitaker and Shine, 2003). Within the spatial ecology framework, various elements can be evaluated; these include movement patterns, home ranges, and habitat selection. By examining movement patterns, essential habitat types can be identified (i.e., nesting, mating, and overwintering sites), factors limiting distributions or abundance of species can be identified (i.e., spatial configuration of foraging sites in the landscape), and the effects of habitat management can be assessed (Rutherford and Gregory, 2003). In complement to movement patterns, home ranges enable researchers to estimate the size and shape of the area used by an animal, which allows for proper delineation of regions that need to be protected (Burt, 1943; Litzgus and Mousseau, 2004). Finally, habitat selection studies reveal specific habitat types that are used and needed by the species. All these elements, key to conservation, can be stratified by reproductive class, season, and the scale of analysis (Johnson, 1980; Litzgus and Mousseau, 2004; Edge et al., 2010).

For temperate-zone turtles at the northern periphery of their range, the active season (April to late October) (Arvisais et al., 2004; Litzgus and Mousseau, 2004) can be divided into four distinct periods: prenesting (April until late May), nesting (late May/early June until late June/early July), summer (early July until late August/early September), and prehibernation (September until late October). During this time, turtles must acquire energy, thermoregulate, and find refugia to minimize risk of predation (Congdon, 1989; Huey, 1991). In turtles, home-range size, movements, and activity often differ between the sexes (Morreale et al., 1984). Most studies have found that movement and activity are greater in males than in females (e.g., Pluto and Bellis, 1988; Rowe and Moll, 1991), whereas some studies have found the reverse (e.g., Ross and Anderson, 1990; Carrière et al., 2009), and a few found no difference (e.g., Jones, 1996; Carter et al., 1999; Hamernick, 2000). Only a few studies, however, have explored the differences in habitat use between males, nongravid females, and gravid females (Doody et al., 2002; Litzgus and Mousseau, 2004). The goal of this study is to examine differences in habitat use and movement patterns between male, nongravid female, and gravid female Blanding's Turtles. We also discuss the potential conservation/management ramifications of these differences.

The Blanding's Turtle, Emydoidea blandingii, is a mediumsized freshwater turtle that is considered at risk in 17 of the 18 state/provincial jurisdictions across its range (NatureServe, 2009). A large portion of its global range (\sim 20%) is contained within southern and south-central Ontario (COSEWIC, 2005), and the Great Lakes/St. Lawrence population is designated as threatened by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2005). The primary threat to Blanding's Turtles is habitat loss and degradation (Van Dam, 1993; Harding, 1997). Adult Blanding's Turtles use a variety of wetland habitats, including vernal pools, bogs, marshes, and impoundments dominated by cattails, water lilies, and duckweed (Rowe and Moll, 1991; Hartwig and Kiviat, 2007). In addition to aquatic habitats, terrestrial habitats are also used frequently as travel corridors between wetlands (Joyal et al., 2001) and for aestivation (Ross and Anderson, 1990; Joyal et al., 2001). Thus, upland habitats that are not fragmented by developments are essential (Grgurovic and Sievert, 2005).

Regional differences in temporal and spatial movement patterns and habitat use are apparent in Blanding's Turtles (Rowe and Moll, 1991; Hamernick, 2000; Piepgras and Lang, 2000; Edge et al., 2010). Sexual differences in movement are usually attributed to different reproductive strategies (Morreale et al., 1984; Ernst, 1986; Gibbons et al., 1990). Males tend to maximize their reproductive success by maximizing the number of eggs they are able to fertilize. Hence, increased movement should increase chances for copulation with several females and maximize fertilizations (Morreale et al., 1984; Parker, 1984; Ernst, 1986). Although Blanding's Turtles do not have a defined mating season, two studies report a high number of observed copulations prior to and following overwintering events (Newton and Herman, 2009; Edge et al., 2010). Thus, we expected that the distance moved by males in May, following overwintering, would be greater than that of females. On the other hand, gravid female turtles maximize their fitness by selecting optimal nesting sites. Blanding Turtle females are known to make long-distance journeys outside of their wetlands of origin to reach preferred nesting sites (Joyal et al., 2001). For this reason, we expected gravid females to move greater distances in June than would nongravid females and

¹Corresponding Author. E-mail: gblouin@uottawa.ca

TABLE 1. Variables used to quantify microhabitat for Blanding's Turtles on Grenadier Island, St-Lawrence Islands National Park, Ontario, Canada.

Variable	Classes ^a	Description		
%EMERG_VEG	Low Medium–low Medium–high	Percentage of area with emergent vegetation.		
%SUB_VEG	High Low Medium–low Medium–High Hist	Percentage of area with submerged vegetation.		
%FLOAT_VEG	High Low Medium–low Medium–high High	Percentage of area with floating vegetation.		
%OPEN_H2O	Low Medium–low Medium–high High	Percentage of area with open water. The area of open water within the sampling circle had to be continuous with an adjacent open water area of equal or greater width than 1 m, creating a clear passage way for turtles.		
H2O_DEPTH H2O_TEMP AIR_TEMP		Distance (cm) between the water surface and bottom. Water temperature (°C) one foot below the surface of the water. Air temperature (°C) 30 cm above the surface of the water.		

 a Low = 0–25%, medium–low = 26–50%, medium–high = 51–75%, high = 76–100%.

males. These greater distances moved and the forays outside of wetlands should also result in gravid females having larger home ranges.

Reptiles are ectothermic and must obtain heat from their environment. Because all physiological processes are temperature dependant, variation in the body temperature of reptiles greatly affects their development, physiology, and behavior (Dawson, 1975; Huey, 1982; Congdon, 1989; Peterson et al., 1993). Most reptiles have a narrow range of preferred body temperatures and thermoregulate by adjusting habitat selection, body posture, and timing of activity (Huey et al., 1989). In temperate regions, the task of thermoregulating can be particularly challenging because of the low average and high seasonal variability in environmental temperatures (Blouin-Demers and Weatherhead, 2001). Thus, with respect to microhabitat selection, we expected turtles to select sites of high thermal quality: sites with high solar radiation (as measured by air and water temperatures). We also expected turtles to select higher percentages of emergent vegetation and floating vegetation because Blanding's Turtles are wary and these cover types provide refuge (Hamernick, 2000; Sajwaj and Lang, 2000).

MATERIALS AND METHODS

Study Area.—We conducted this study from May 2008 to August 2009 on Grenadier Island in the Thousand Islands Ecosystem. Grenadier Island is located in the St. Lawrence River directly south of Mallorytown, Ontario, Canada. It is one of the largest islands (approximately 522 ha) in St. Lawrence Islands National Park and harbors several beaver ponds and wetlands that are used by Blanding's Turtles.

Radiotelemetry and Data Collection.—We captured Blanding's Turtles by hand, dip-net, and submerged hoop nets baited with canned sardines. We determined the sex of turtles by presence or absence of male secondary sexual characteristics (concave plastron and longer preanal tail length in males; Ernst and Lovich, 2009). We determined female reproductive status by palpation during the egg bearing period (May to early July). We fitted 38 Blanding's Turtles (20 males, 13 gravid females, and 5 nongravid females) with radio-transmitters (Holohil SI-2FT 17 g, battery life of 36 months). We bolted transmitters to the rear marginal scutes of the carapace using stainless steel screws, washers, and nuts. We used marine silicone to cover screws and transmitter edges, thus preventing detritus and macrophytes from catching on the transmitters. Transmitters (including screws, nuts, and silicone) represented at most 5% of the turtle's body mass and were removed at the end of the study. We released turtles at their site of capture the following morning, and we relocated each individual every 3–4 days in 2008 and every 1–2 days in 2009 with a telemetry receiver and a directional antenna. At each location, we recorded the Universal Transverse Mercator (UTM) coordinates (3D differential receiver status, NAD83 datum) using a GPSmap72 (Garmin International Inc., Olathe, KS) with an estimated accuracy of ≤ 6 m. We also noted the behavior of the turtles.

Movement Patterns.--We analyzed movement data from 13 individuals (four gravid females, three nongravid females, six males) (800 relocations) radio-tracked daily for four consecutive months during the 2009 active season (May to August). To calculate the distance moved between radio-locations, we used the Animal Movement Extension 2.0 (Hooge and Eichenlaub, 2000) in ArcGIS 3.2 (ESRI, 1995-2010). We measured movements as straight-line distances between relocations. If more than one day had elapsed between relocations, the daily distance moved was calculated by dividing the distance moved between relocations by the number of days elapsed since the last location. We also determined the total distance traveled in aquatic and terrestrial habitats by males, nongravid females, and gravid females in May, June, July, and August. To examine the effects of reproductive class and month on the daily distance moved by turtles, we used a two-way repeatedmeasures ANOVA. Movement data from 2008 were not used for statistical analyses of the daily distance moved because of the longer intervals between relocations.

Home Ranges.—We calculated the home range for each individual turtle using the 100% minimum convex polygon method (MCP). MCPs are calculated by creating the smallest possible convex polygon that encompasses all known locations for an individual. MCPs provide a robust estimate for maximum home-range size for herpetofauna (Row and Blouin-Demers, 2006) and are the most commonly used method to estimate animal home ranges (Powell, 2000). MCPs were calculated using Hawth's Tools (Beyer, 2004), an animal movement extension for ArcMAP 9.0 (ESRI, 1995–2010). We also determined the proportion of aquatic and terrestrial habitat in the home ranges of males, nongravid females, and gravid females.

To assess the robustness of our home-range estimates, we ran an asymptote analysis with the ABODE.mxt tool (Laver, 2005). Past studies have shown that the estimates of homerange area converge as the number of relocations increases, until the home-range estimate reaches an asymptote (Swihart and Slade, 1985; Seaman et al., 1999). Similar to Carrière et al. (2009), home-range area as a function of the number of successive relocations showed a series of plateaus, instead of asymptotes. These results suggest that, to obtain a robust estimate of home-range size for Blanding's Turtle, positional data from the entire active season are needed. Thus, we calculated home ranges only for individuals radio-tracked for at least three consecutive months during the active season (April to October) with at least 20 relocations per individual (mean = 40.3, range = 20–72). Home ranges were calculated for 37 Blanding's Turtles (20 males, 12 gravid females, 5 nongravid females) tracked in 2008 or in 2009. We examined the effect of reproductive class on home-range size using a oneway ANOVA.

Microhabitat Analysis.—We quantified habitat directly at the locations used by the turtles. Habitat was not quantified during nesting forays and, to keep sampling manageable, was only characterized at every second telemetry location. We quantified seven habitat variables within a 50-cm radius around each turtle location (Table 1). The percentage of open water, emergent vegetation, floating vegetation, and submerged vegetation was determined visually. Also, air temperature was measured using a mercury thermometer 30 cm above the surface of the water; water depth was measured using a meter stick; and water temperature was measured 15 cm below the surface of the water using a digital thermometer.

To measure habitat availability, a random location was immediately characterized after the turtle location to ensure that no temporal or environmental changes affected the measured variables. Random locations were identified by selecting a direction from the characterized turtle location at random and moving a distance of 40 m (an approximation of the daily distance moved by Blanding's Turtles during our pilot study in 2007). Such a distance ensures that the random location selected was available to the turtle.

To examine habitat selection within the turtles' home ranges, we used matched-pairs logistic regression. In the paired design, each turtle location is compared to its paired random location, thus controlling for changes in environmental conditions through time and ensuring that each random location was available to the individual being radio-tracked (Compton et al., 2002). We collected data on microhabitat use for 11 adult females and 12 adult males. Because of the small number of observations for each sex, data from both sexes were pooled. We ran univariate analyses for each habitat variable and selected variables with P-values less than 0.25 for subsequent multivariate analyses (Hosmer and Lemeshow, 2000). We fitted candidate models using a backward stepwise regression, and we selected the model with the lowest Akaike's Information Criterion (AIC) score (Boyce et al., 2002). Finally, we evaluated the fit of the each model using the likelihoodratio statistic (Hosmer and Lemeshow, 2000).

Statistical Analyses.—We performed all statistical analyses with JMP version 8.0 (SAS Institute Inc., Cary, NC, 2005–10) and R version 2.7.2 (R Development Core Team, Vienna, Austria, 2008). We report all means \pm SE, and we considered tests significant at $\alpha = 0.05$. Daily movement data and home-range estimates were log transformed to meet the assumptions of homogeneity of variance, normality, and sphericity.

RESULTS

We captured 91 Blanding's Turtles (51 males and 40 females) and radio-tracked 38 individuals for at least three consecutive months during the 2008–09 active seasons (1,589 relocations).

Movement Patterns.—Most terrestrial movements occurred in May and June (Fig. 1). In May, males and nongravid females traveled more than gravid females, but the distance traveled in



FIG. 1. Monthly averages of the total distance moved \pm SE in (A) terrestrial and (B) aquatic habitats by male (M), nongravid female (NGF), and gravid female (GF) Blanding's Turtles radio-tracked from May 2009 to August 2009 on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada.

terrestrial habitat was similar across all reproductive classes (Fig. 1). Gravid females traveled more than males and nongravid females in June and 21% of the total distance traveled by gravid females in June was in terrestrial habitat (Fig. 1). The total distance traveled by turtles in July and August was similar across all reproductive classes with males traveling only slightly more than females in August (Fig. 1).

A one-way ANOVA revealed that reproductive class had no effect on the annual mean daily distance moved ($R^2 = 0.07$, $F_{2,18} = 0.61$, P = 0.55). A two-way repeated-measures ANOVA revealed a significant interaction of month and reproductive class ($F_{6,30} = 2.533$, P = 0.042) on the monthly mean daily distance moved. Mauchly's test indicated that the assumption of sphericity was met ($\chi^2_5 = 9.08$, P = 0.11). Four separate ANOVAs testing for the effect of reproductive class on mean daily distance moved during each month revealed no significant effect of reproductive class in May ($R^2 = 0.22$, $F_{2,12} = 1.37$, P = 0.30), July ($R^2 = 0.17$, $F_{2,12} = 1.01$, P = 0.40), and August ($R^2 = 0.11$, $F_{2,12} = 0.64$, P = 0.55; Fig. 1). In June, however, reproductive class had a marginally significant effect ($R^2 = 0.44$, $F_{2,18} = 5.4$, P = 0.05). A Tukey-Kramer HSD test



Fig. 2. Monthly averages of the daily distance moved \pm SE by male (M), nongravid female (NGF), and gravid female (GF) Blanding's Turtles radio-tracked from May 2009 to August 2009 on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada. In June, reproductive classes with the same letters are not significantly different.

indicated that gravid females moved significantly more (mean = 400 ± 49 m per day) than did males (mean = 194 ± 22 m per day) (Fig. 2).

Sixteen nesting forays, defined here as movements to and from nesting areas, occurred between 4 and 25 June in 2008 and between 29 May and 27 June in 2009. Thirteen females were radio-tracked to their nesting sites, and four of the six gravid females in 2008 were also gravid in 2009. Furthermore, two nongravid females in 2008 were gravid in 2009. Nesting sites were located 150 to 1,850 m (mean of 919 \pm 129 m) from the wetland of origin. During these nesting forays, females traveled a total distance of 650 to 3,479 m (mean of 2,095 \pm 285 m) to and from nesting sites, staying up to 15 days around the nesting area before traveling back to their wetland of origin. Three communal nesting areas were used by six radio-tracked females in 2008 and 2009. One of these nesting sites had been identified previously by Petokas in 1986. Finally, one female successfully tracked to her nesting site in 2008 and 2009 used the same nesting site both years.

Home Ranges.—Home-range size varied between individuals, ranging from 1.6 to 40.6 ha with a mean of 12.0 ± 1.8 ha. The mean home-range size was 8.2 ± 1.8 ha ($11.1 \pm 3.2\%$ terrestrial) for males, 7.3 ± 3.2 ha ($15.9 \pm 10.1\%$ terrestrial) for nongravid females, and 20.3 ± 3.5 ha ($42.1 \pm 7.6\%$ terrestrial) for gravid females. A one-way ANOVA revealed that reproductive class had a significant effect on home-range area ($R^2 = 0.29$, $F_{2,36} = 8.21$, P = 0.0012). A Tukey-Kramer HSD test indicated that gravid females had significantly larger home ranges than did both males and nongravid females (Fig. 3). The larger home ranges of gravid females were largely a result of their greater use of terrestrial habitats.

Microhabitat Analysis and Behavior.—Microhabitat data from 187 turtle locations (76 female locations, 111 male locations), with the 187 corresponding random paired locations, were used for analysis. The model with the lowest AIC value (AIC = 231.751) had the variables H2O_TEMP, %FLOAT_VEG, %SUB_VEG, and %OPEN_H2O and was statistically significant (log ratio = 35.5, $R^2 = 0.091$, P < 0.0001) (Table 2). Based on the odd ratios, Blanding's Turtles selected colder waters where both floating and submerged vegetation are abundant. A 1°C increase in water temperature resulted in a 16% decrease in the probability of selection; a 25% increase in the probability of selection; a 25% increase in floating vegetation resulted in a

28% increase in the probability of selection; and a 25% increase in open water resulted in a 31% decrease in the probability of selection (Table 3, Fig. 4).

Pearson Chi-square analysis revealed a significant difference in behavior at telemetry location between reproductive classes $(\chi^2_{10,1561} = 64.36, P < 0.0001)$ and between months $(\chi^2_{15,1561} = 158.11, P < 0.0001)$. Turtles were most often found immobile underwater, usually under bog mats or floating vegetation (\geq 45%). Gravid females were located underwater less often than were nongravid females and males, and the frequency of underwater turtle observation was higher in August than any other month (Fig. 5). Furthermore, gravid females were found basking at the surface of the water and on land more often than males and nongravid females (Fig. 5). Basking behavior was most often observed in May, thereafter decreasing in frequency (Fig. 5).



FIG. 3. Average home-range size \pm SE of male (M), nongravid female (NGF), and gravid female (GF) Blanding's Turtles radio-tracked in 2008–09 on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada. Reproductive classes with the same letters are not significantly different.

TABLE 2. Matched paired-logistic regression models explaining microhabitat use by Blanding's Turtles on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada. The models with the lowest AIC scores and highest Akaike weights (ω) have more substantial support. The number of parameters (k) is also indicated.

Model	k	AIC	ΔΑΙϹ	ω
H2O_TEMP, H2O_OPEN, %FLOAT_VEG, %SUB_VEG, %EMERG_VEG	5	233.2741	1.5230	0.1809
H2O_TEMP, H2O_OPEN, %FLOAT_VEG, %SUB_VEG	4	231.7509	0.0000	0.3873
H ₂ O_TEMP, H ₂ O_OPEN, %FLOAT_VEG	3	231.7882	0.0373	0.3801
H_2O_TEMP , H_2O_OPEN	2	235.7767	4.0260	0.0517

DISCUSSION

Daily Movements.-The daily movements of Blanding's Turtles on Grenadier Island were almost three times longer than those documented in past studies (Table 4; Ross and Anderson, 1990; Rowe and Moll, 1991; Sajwaj et al., 1998; Piepgras and Lang, 2000; Innes et al., 2008; Edge et al., 2010). The higher annual mean daily movements of gravid females in our study could be associated with the inclusion of nesting forays in the movement analysis, because some studies removed nesting forays and other upland habitat movements from home-range calculation (Rowe and Moll, 1991). All three reproductive classes (males, gravid females, and nongravid females), however, had much higher than average daily movements. Interstudy differences could be attributed to difference in tracking patterns or local environmental factors. We found that differences in time between telemetry locations dramatically influenced the accuracy of daily movement estimates. In 2008, the average daily distance moved (DDM) by turtles in our study was 51 m per day, and turtles were radio-tracked 1-7 times per week. In 2009, however, when turtles were radio-tracked 5-7 times per week, the average DDM was 180 m per day. These results suggest that, to estimate the daily movement patterns of Blanding's Turtles properly, individuals must be radio-tracked every day of the week; otherwise researchers run the risk of grossly underestimating the daily movement of this species. This same pattern is evident in the literature; the highest observed DDM were obtained in studies where turtles were radio-tracked at least four times per week (Ross and Anderson, 1990; Edge et al., 2010).

We found that the effect of reproductive class on the DDM varied depending on the month. The significant interaction observed can be attributed to the significant difference in the DDM by gravid females, compared to males and nongravid females. Unsurprisingly, gravid females traveled longer distances daily during the nesting season than at any other time, and they traveled significantly more than did males and nongravid females. Furthermore, females spent a considerable amount of time around the nesting areas, spending up to 15 days around the nesting site before ovipositing and heading back to their wetland of origin. The upland corridors used to reach nesting sites are essential movement corridors, and one female seemed to exhibit high fidelity to these upland corridors. Finally, the use of wetlands adjacent to their nesting sites (staging areas) by this population of Blanding's Turtles suggests that protection of wetlands near known nesting sites would be an important consideration for land use planning.

Gravid female turtles frequent these aquatic habitats during nesting forays, possibly replenishing depleted energy reserves, hydrating, and protecting themselves from thermal stress and predators (Emrich, 1991).

Contrary to our expectation, male Blanding's Turtles did not move longer distances in May, immediately following overwintering, than did females. In May, Blanding's Turtles are still aggregated around overwintering sites (Newton and Herman, 2009; Edge et al., 2010), and these aggregations may decrease the benefit for males to travel farther and more frequently because they have access to several females ready to mate in a relatively confined area. Similar results were obtained in studies with Spotted, Yellow-Blotched Map, and Northern Map Turtles (Jones, 1996; Litzgus and Mousseau, 2004; Carrière et al., 2009). These turtle species aggregate annually around overwintering sites, and it appears that the seasonal movement patterns of aggregate breeders do not follow the predictions of the reproductive strategies hypothesis (Carter et al., 2000; Doody et al., 2002; Litzgus and Mousseau, 2004).

Home Ranges.-In comparison with several other studies, the Grenadier Island population exhibited intermediate homerange sizes (Table 5). The large variation in home-range size estimates among studies can be attributed to several factors, such as methodological differences, turtle age and reproductive class, sample size, and most important local habitat composition (Cagle, 1944; Bury, 1979). Unlike past studies (Hamernick, 2000; Edge, 2010), we observed a significant difference between the sexes in home-range size. Pooling of nongravid females with gravid females for home-range analysis in previous studies could be responsible for these conflicting results. The significantly larger home ranges of gravid females can be explained by the inclusion of longdistance nesting forays in home-range calculations. Interestingly, several past studies on Blanding's Turtles excluded nesting forays and other terrestrial movements from homerange analysis (Ross and Anderson, 1990; Rowe and Moll, 1991; Innes et al., 2008). Although studying activity centers within a home range might reveal information about a turtle's daily activity patterns, all terrestrial movements should be included in home-range analysis. Nesting is a normal activity for a gravid female turtle; and because the home range of an animal is, by definition, the area within which an individual moves when performing its normal activities, nesting excursions should be included in home-range estimation (Burt, 1943).

Microhabitat Selection and Behavior.—During the active season, Blanding's Turtle habitat consisted of muck substrate, water depths of 1–220 cm, cattails, sedges, grasses (predominantly wild rice), water lilies, swamp loosestrife, and various

TABLE 3. Coefficients and odds ratios for the paired-logistic regression model explaining microhabitat use by Blanding's Turtles on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada.

Variables	Coefficients	SE	Increase	Odds ratio	95% CI ^a
H2O_TEMP	-0.171	0.072	1°C	0.84	(0.73, 0.97)
%SUB_VEG	0.532	0.433	25% (1 level)	1.7	(0.73, 3.97)
%FLOAT_VEG	0.246	0.102	25% (1 level)	1.28	(1.05, 1.56)
%OPEN_H2O	-0.365	0.104	25% (1 level)	0.69	(0.57, 0.85)

^a 95% CI from odds ratios.



Fig. 4. Frequency of observed data (histograms) and predicted probability of selection as the percentage of floating vegetation, percentage of submerged vegetation, percentage of open water, and water temperature increases for Blanding's Turtles (1 = turtle locations, 0 = random locations) followed by radio-telemetry on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada.

submerged vegetation. This is consistent with past studies showing that Blanding's Turtles inhabit productive, clean, shallow waters with abundant aquatic vegetation and soft muddy bottoms over firm substrates (Ernst et al., 1994). Microhabitat analysis revealed that Blanding's turtles on Grenadier Island favored colder water with abundant floating and submerged aquatic vegetation and avoided open water. The wetland complex on Grenadier Island is relatively homogenous and remains largely undisturbed by human activities; thus, the lower predictive power of the model could be because little selection is needed in such a high-quality homogenous habitat (Edge et al., 2010).

Blanding's Turtles may select for areas with greater densities of filamentous algae, submerged vegetation, and floating vegetation because they provide food and cover from predators (Ross and Lovich, 1992; Hartwig and Kiviat, 2007). Floating vegetation, submerged vegetation, and filamentous algae are known to harbor high densities of macroinvertebrates (Evans et al., 1999; Gaston, 1999; Yozzo and Diaz, 1999), which are a primary food for Blanding's Turtles (Lagler, 1943). Because Blanding's Turtles spent most (>70%) of their time underwater (Fig. 4), it is unsurprising that selection occurred for water column properties (e.g., floating vegetation, submerged vegetation, and water temperature).

Similar to the Blanding's Turtles in Minnesota (Hamernick, 2000), Blanding's Turtles on Grenadier Island did avoid some habitat types, most notably open water. The lack of basking sites and refuge from predators in open water could potentially make this habitat unattractive to turtles. Furthermore, open water typically lacks the abundance of potential food sources



FIG. 5. Blanding's Turtle behavior exhibited at relocation points (N = 1566) in 2008 and 2009 on Grenadier Island, St. Lawrence Islands National Park, Ontario, Canada. Behavior is stratified by (I) reproductive class and (II) month. Behaviors described as "other" include copulating (N = 3), captured in hoop net (N = 6), or climbing a beaver lodge (N = 4).

and complex structural characteristics that habitats with more vegetative biomass contain.

Finally, we expected Blanding's Turtles to select for warmer shallower water because of their thermoregulatory needs. Contrary to our expectation, Blanding's Turtles selected sites with colder water. As the active season progresses, water levels fall, and surface water temperatures dramatically increase. During the hot summer months, turtles may select colder water to maintain their body temperatures within an optimal range that maximizes performance and fitness (Christian and Tracy, 1981; Huey and Kingsolver, 1989).

Interestingly, gravid females were more often found basking on floating vegetation and at the surface of the water than males and nongravid females. Basking behavior is often presumed to function in thermoregulation (Boyer, 1965; Crawford et al., 1983; Bulté and Blouin-Demers, 2011), and this trend could be a result of the higher energetic needs of gravid females (Congdon, 1989). Furthermore, accurate thermoregulation may have high reproductive benefits for adult females, such as speeding follicular development (Sarkar et al., 1996). In a study on the Yellow Margined Box Turtle (*Cuora flavomarginata*), Chen and Lue (2008) found evidence that gravid females maintained significantly higher shell temperatures during the nesting season (May to July). Following the nesting season, however, there were no significant differences in shell temperatures between males and females (Chen and Lue, 2008). Bulté and Blouin-Demers (2010) and Carrière et al. (2009) also found that gravid female Northern Map (*Graptemys geographica*) and Painted (*Chrysemys picta*) Turtles spent more time basking than males prior to and during the nesting season (May and June).

In summary, reproductive class and season influenced the behavior and spatial ecology of Blanding's Turtles. Thus, management plans should take into account these two effects. It is not enough to separate males from females; gravid females must be separated from nongravid females. Furthermore, to meet the goal of conservation and management of this species, movements associated with nesting should be considered.

TABLE 4. Review of literature on the mean daily distance moved (DDM) by male (M), nongravid female (NGF), and gravid female (GF) Blanding's Turtles.

		Mean daily distance moved $(m/day) \pm SE(N)$			
Reference Location		М	NGF	GF	
Current study Edge et al., 2010 Innes et al., 2008 ^a Sajwaj et al., 1998 Rowe and Moll, 1991 ^b Ross and Anderson, 1990 ^c	Ontario Ontario New Hampshire Minnesota Illinois Wisconsin	$\begin{array}{r} 199.42 \pm 9.76 \ (9) \\ 83.5 \pm 39.9 \ (5) \\ 27.55 \pm 6.89 \ (4) \\ 22.75 \pm 8.34 \ (4) \\ 48.9 \pm 20.85 \ (4) \\ 48.4 \pm 8.99 \ (21) \end{array}$	$\begin{array}{r} 195.32\ \pm\ 15.57\ (4)\\ 91.0\ \pm\ 3\\ 30.08\ \pm\ 1\\ 41.75\ \pm\ 8\\ 32.4\ \pm\ 2\\ 95.1\ \pm\ 1\end{array}$	$\begin{array}{c} 249.50 \pm 16.96 \ (6) \\ 7.4 \ (16) \\ 4.15 \ (3) \\ .83 \ (4) \\ 2.66 \ (3) \\ 0.56 \ (56) \end{array}$	

^a The DDM was averaged over April-August to compare with other studies.

^b The DDM was only calculated within activity centers.

^c The minimum DDM was calculated.

TABLE 5. Review of Blanding's Turtle home-range sizes for males (M), nongravid females (NGF), and gravid females (GF).

			Mean home range size (ha) \pm SE (N)		
Reference	Location	Method	М	NGF	GF
Current study	Ontario	MCP	8.5 ± 1.7 (20)	7.3 ± 3.2 (5)	20.3 ± 3.5 (12)
Edge et al., 2010	Ontario	MCP	$57.1 \pm 15.3 (5)$	61.2 ± 30.4 (16)	
Schuler and Thiel, 2008	Wisconsin	MCP	26.1 (9)	20.7	(9)
Innes et al., 2008 ^a	New Hampshire	MCP		6.6	(3)
Innes et al., 2008 ^a	New Hampshire	MCP	3.7 (4)	1.5	(3)
Grgurovic and Sievert, 2005	Massachusetts	Fixed kernel (95%)	$27.5 \pm 0.10 (14)$	19.9 ± 0	.07 (27)
Hamernick, 2000	Minnesota	MCP	38.4	35.4	
Piepgras and Lang, 2000	Minnesota	MCP	94.9 ± 58.4 (8)	60.7 ± 1	2.6 (16)
Rowe and Moll, 1991 ^b	Illinois	MPM ^c	1.4 (4)	1.2	(3)
Ross and Anderson, 1990 ^b	Wisconsin	MPM ^c	0.76 ± 0.19 (2)	0.56 ± 0	.15 (4)

^aMedian values instead of averages.

^bMeasure of activity center size: excludes nesting forays and long distance movements.

^cMPM is equivalent to the MCP method.

Collectively, our results suggest that nesting excursions are primarily responsible for the differences observed between the reproductive classes in activity, movements, and home-range size and composition in Blanding's Turtles.

Acknowledgments.—Funding for this study was provided by the Natural Sciences and Engineering Research Council of Canada, the University of Ottawa, and St. Lawrence Islands National Park. N. Reshke, G. Picard, A. Dupoué, J. Graham, K. Bellehumeur, L. Colson, and R. Pringadi assisted with fieldwork. The work was conducted under the Parks Canada Agency research and collection permit SLI2009-3334 and the Ontario Ministry of Natural Resources Wildlife Scientific Collector's authorization 1051309, and within the guidelines for requisite animal care protocols at the University of Ottawa (protocol BL-221).

LITERATURE CITED

- ARVISAIS, M., E. LÉVESQUE, J.-C. BOURGEOIS, C. DAIGLE, D. MASSE, AND J. JUTRAS. 2004. Habitat selection by the Wood Turtle (*Clemmys insculpta*) at the northern limit of its range. Canadian Journal of Zoology 82:391–398.
- BEYER, H. L. 2004. Hawth's analysis tools for ARCGIS. In G. Blouin-Demers and P. J. Weatherhead (eds.), Thermal Ecology of Black Rat Snakes (*Elaphe obsoleta*) in a Thermally Challenging Environment. Ecology 82:3025–3043.
- BLOUIN-DEMERS, G., AND P. J. WEATHERHEAD. 2001. Thermal ecology of Black Rat Snakes (*Elaphe obsoleta*) in a thermally challenging environment. Ecology 82:3025–3043.
- BOYCE, M. S., P. R. VERNER, S. E. NIELSEN, AND F. K. A. SCHMIEGELOW. 2002. Evaluating resource selection functions. Ecological Modelling 157:281–300.
- BOYER, D. R. 1965. Ecology of the basking habit in turtles. Ecology 46:99–118.
- BULTÉ, G., AND G. BLOUIN-DEMERS. 2010. Implications of extreme sexual size dimorphism for thermoregulation in a freshwater turtle. Oecologia 162:313–322.

- BURT, W. H. 1943. Territoriality and home range as applied to mammals. Journal of Mammalogy 24:346–352.
- BURY, R. B. 1979. Population ecology of freshwater turtles. *In* M. Harless and H. Morelock (eds.), Turtles: Perspectives and Research, pp. 571–602. John Wiley and Sons, New York.
- CAGLE, F. R. 1944. Home range, homing behavior and migration in turtles. Miscellaneous Publications of the Museum of Zoology, University of Michigan 61:1–34.
- CARRIÈRE, M. A., G. BULTÉ, AND G. BLOUIN-DEMERS. 2009. Spatial ecology of Northern Map Turtles (*Graptemys geographica*) in a lotic and a lentic habitat. Journal of Herpetology 43:597–604.
- CARTER, S. L., C. A. HAAS, AND J. C. MITCHELL 1999. Home range and habitat selection of bog turtles in southwestern Virginia. Journal of Wildlife Management 63:853–860.

- CHEN, T. H., AND K. Y. LUE. 2008. Thermal preference of the Yellow-Margined Box Turtle (*Cuora flavomarginata*) (Testudines: Geoemydidae) inhabiting a mesic lowland forest, northern Taiwan. Amphibia-Reptilia 29:513–522.
- CHRISTIAN, K. A., AND C. R. TRACY. 1981. The effect of the thermal environment on the ability of hatchling Galapagos land iguanas to avoid predation during dispersal. Oecologia 49:218–223.
- COLLINGE, S. K. 2001. Spatial ecology and biological conservation. Biological Conservation 100:1–2.
- COMPTON, B. W., J. M. RHYMER, AND M. MCCOLLOUGH. 2002. Habitat selection by Wood Turtles (*Clemmys insculpta*): an application of paired logistic regression. Ecology 83:833–843.
- CONGDON, J. D. 1989. Proximate and evolutionary constraints on energy relations in reptiles. Physiological Zoology 62:356–373.
- COSEWIC. 2005. COSEWIC Assessment and Update Status Report on the Blanding's Turtle *Emydoidea blandingii* in Canada. Committee on the Status of Endangered Wildlife in Canada, Ottawa.
- CRAWFORD, K. M., J. R. SPOTILA, AND E. A. STANDORA. 1983. Operative environmental temperatures and basking behavior of the turtle *Pseudemys scripta*. Ecology 64:989–999.
- DAWSON, W. R. 1975. On the physiological significance of the preferred body temperatures of reptiles. *In* D. M. Gates and R. B. Schmerl (eds.), Perspectives of Biophysical Ecology, pp. 443–473. Springer-Verlag, New York.
- DOODY, J. S., J. E. YOUNG, AND A. GEORGES. 2002. Sex differences in activity and movements in the Pig-Nosed Turtle, *Carettochelys insculpta*, in the wet-dry tropics of Australia. Copeia 2002:93–103.
- EDGE, C. B., B. D. STEINBERG, R. J. BROOKS, AND J. D. LITZGUS. 2010. Habitat selection by Blanding's Turtles (*Emydoidea blandingii*) in a relatively pristine landscape. Ecoscience 17:90–99.
- EMRICH, M. E. 1991. Blanding's Turtle (*Emydoidea blandingii*) Nesting Behavior and Response to an Artificial Nest Habitat. Unpubl. master's thesis, Bard College, Annandale, NY.
- ERNST, C. H. 1986. Ecology of the turtle, *Sternotherus odoratus*, in southeastern Pennsylvania. Journal of Herpetology 20:341–352.
- ERNST, C. H., AND J. E. LOVICH. 2009. Turtles of the United States and Canada. 2nd ed. John Hopkins University Press, Baltimore, MD.
- ERNST, C. H., R. W. BARBOUR, AND J. E. LOVICH. 1994. Turtles of the United States and Canada. Smithsonian Institution Press, Washington, DC.
- ESRI. 1995–2010. ArcGIS Desktop Evaluation Edition 9.3. Environmental Systems Research Institute, Redlands, CA.
- EVANS, D. L., W. J. STREEVER, AND T. L. CRISMAN. 1999. Natural flatwoods marshes and created freshwater marshes of Florida: factors influencing aquatic invertebrate distribution and comparisons between natural and created marsh communities. *In* D. P. Batzer, R. B. Rader, and S. A. Wissinger (eds.), Invertebrates in Freshwater Wetlands of North America, pp. 81–104. John Wiley and Sons, New York.
- GASTON, G. R. 1999. Bayous of the northern Gulf of Mexico: distribution and trophic ecology of invertebrates. *In* D. P. Batzer, R. B. Rader, and S. A. Wissinger (eds.), Invertebrates in Freshwater Wetlands of North America, pp. 919–947. John Wiley and Sons, New York.
- GIBBONS, J. W., J. L. GREENE, AND J. D. CONGDON. 1990. Temporal and spatial movement patterns of sliders and other turtles. *In J. W.* Gibbons (ed.), Life History and Ecology of the Slider Turtle, pp. 201–215. Smithsonian Institution Press, Washington, DC.

- GRGUROVIC, M., AND P. R. SIEVERT. 2005. Movement patterns of Blanding's Turtles (*Emydoidea Blangingii*) in the suburban landscape of eastern Massachusetts. Urban Ecosystems 8:203–213.
- HAMERNICK, M. G. 2000. Home ranges and habitat selection of Blanding's Turtles (*Emydoidea blandingii*) at the Weaver Dunes, Minnesota. Final report submitted to the Nongame Wildlife Program, Minnesota Department of Natural Resources.
- HARDING, J. H. 1997. Amphibians and Reptiles of the Great Lakes Region. University of Michigan Press, Ann Arbor.
- HARTWIG, T. S., AND E. KIVIAT. 2007. Microhabitat association of Blanding's Turtles in natural and constructed wetlands in southeastern New York. Journal of Wildlife Management 71:576–582.
- HOOGE, P. N., AND B. EICHENLAUB. 2000. Animal movement extension to ArcView 2.0. Alaska Science Center—Biological Science Office, U.S. Geological Survey, Anchorage, AK.
- HOSMER, D. W., AND S. LEMESHOW. 2000. Applied Logistic Regression. 2nd ed. John Wiley and Sons, New York.
- HUEY, R. B. 1982. Temperature, physiology, and the ecology of reptiles. In C. Gans and F. H. Pough (eds.), Biology of the Reptilia. Vol. 12, pp. 25–91. Academic Press, New York.
- . 1991. Physiological consequences of habitat selection. American Naturalist 137:S91–S115.
- HUEY, R. B., AND J. G. KINGSOLVER. 1989. Evolution of thermal sensitivity of ectotherm performance. Trends in Ecology and Evolution 4:131–135.
- HUEY, R. B., C. R. PETERSON, S. J. ARNOLD, AND W. P. PORTER. 1989. Hot rocks and not-so-hot rocks: retreat-site selection by garter snakes and its thermal consequences. Ecology 70:931–944.
- INNES, R. J., K. J. BABBIT, AND J. J. KANTER. 2008. Home range and movement of Blanding's Turtles (*Emydoidea blandingii*) in New Hampshire. Northeastern Naturalist 15:431–444.
- JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.
- JONES, R. L. 1996. Home range and seasonal movements of the turtle Graptemys flavimaculata. Journal of Herpetology 30:376–385.
- 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.
- LAGLER, K. F. 1943. Food habits and economic relations of the turtles of Michigan with special reference to fish management. American Midland Naturalist 29:257–312.
- LAVER, P. 2005. Abode: kernel home range estimation for ArcGIS, using VBA and ArcObjects. User manual, Beta version 2, 62 pp.
- LITZGUS, J. D., AND T. A. MOUSSEAU. 2004. Home range and seasonal activity of Southern Spotted Turtles (*Clemmys guttata*): implications for management. Copeia 2004:804–817.
- MORREALE, S. J., J. W. GIBBONS, AND J. D. CONGDON. 1984. Significance of activity and movement in the Yellow-Bellied Slider Turtle (*Pseudemys scripta*). Canadian Journal of Zoology 62:1038–1042.
- NATURESERVE. NatureServe explorer [Internet]. Version 7.1. Arlington (VA): NatureServe; 2009 [cited 20 May 2010]. Available from: http://www.natureserve.org/explorer.
- NEWTON, E. J., AND T. B. HERMAN. 2009. Habitat, movements, and behavior of overwintering Blanding's Turtles (*Emydoidea blandingii*) in Nova Scotia. Canadian Journal of Zoology 87:299–309.
- PARKER, W. S. 1984. Immigration and dispersal of the Slider Turtles *Pseudemys scripta* in Mississippi farm ponds. American Midland Naturalist 112:280–293.
- PETERSON, C. R., A. R. GIBSON, AND M. E. DORCAS. 1993. Snake thermal ecology: the causes and consequences of body temperature variation. *In* R. A. Seigel and J. T. Collins (eds.), Snakes: Ecology and Behavior, pp. 241–314. Mc-Graw-Hill, New York.

- PETOKAS, P. J. 1986. Patterns of Reproduction and Growth in the Freshwater Turtle, *Emydoidea blandingii*. Unpubl. Ph.D. diss., University of New York, Binghamton.
- PIEPGRAS, S. A., AND J. W. LANG. 2000. Spatial ecology of Blanding's Turtle in central Minnesota. Chelonian Conservation and Biology 3:589–601.
- PLUTO, T. G., AND E. D. BELLIS. 1988. Seasonal and annual movements of Riverine Map Turtles, *Graptemys geographica*. Journal of Herpetology 22:152–158.
- POWELL, R. A. 2000. Animal home ranges and territories and home range estimators. *In* L. Boitani and T. Fuller (eds.), Research in Animal Ecology: Controversies and Consequences, pp. 65–110. Columbia University Press, New York.
- Ross, D. A., AND R. K. ANDERSON. 1990. Habitat use, movements, and nesting of *Emydoidea blandingii* in Central Wisconsin. Journal of Herpetology 24:6–12.
- Ross, D. A., AND J. E. LOVICH. 1992. Does the color pattern of two species of turtles imitate duckweed? Journal of the Pennsylvania Academy of Science 66:39–42.
- Row, J. R., AND G. BLOUIN-DEMERS. 2006. Kernels are not accurate estimators of home range size for herpetofauna. Copeia 2006:797–802.
- ROWE, J. W., AND E. O. MOLL. 1991. A radiotelemetric study of activity and movements of the Blanding's Turtle (*Emydoidea blandingii*) in northeastern Illinois. Journal of Herpetology 25:178–185.
- RUTHERFORD, P. L., AND P. T. GREGORY. 2003. Habitat use and movement patterns of Northern Alligator Lizards (*Elgaria coerulea*) and Western Skinks (*Eumeces skiltonianus*) in southeastern British Columbia. Journal of Herpetology 37:98–106.
- SAJWAJ, T. D., AND J. W. LANG. 2000. Thermal ecology of Blanding's Turtle in central Minnesota. Chelonian Conservation and Biology 3:626–636.
- SAJWAJ, T. D., S. A. PIEPGRAS, AND J. W. LANG. 1998. Blanding's Turtles (*Emydoidea blandingii*) at Camp Ridley: critical habitats, population status, and management guidelines. Report submitted to the Nongame Wildlife Program, Minnesota Department of Natural Resources, Little Falls, MN.
- SARKAR, S. N., K. SARKAR, P. DAS, AND B. R. MAITI. 1996. Photothermal effects on ovarian growth and function in the Soft-Shelled Turtle *Lissemys punctata punctata*. Journal of Experimental Zoology 274:41–55.
- SCHULER, M., AND R. P. THIEL. 2008. Annual vs. multiple-year home range sizes of individual Blanding's Turtles, *Emydoidea blandingii*, in central Wisconsin. Canadian Field-Naturalist 122:61–64.
- SEAMAN, D. E., B. GRIFFITH, AND R. A. POWELL. 1999. Effects of sample size on kernel home range estimates. Journal of Wildlife Management 63:739–747.
- SWIHART, R. K., AND N. K. SLADE. 1985. Influence of sampling interval on estimates of home range size. Journal of Wildlife Management 49:1019–1025.
- VAN DAM, B. 1993. Element Stewardship Abstract for *Emydoidea* blandingii (Holbrock) Blanding's Turtle. Michigan Natural Features Inventory, Lansing.
- WHITAKER, P. B., AND R. SHINE. 2003. A radiotelemetric study of movements and shelter-site selection by free-ranging Brownsnakes (*Pseudonaja textilis*, Elapidae). Herpetological Monographs 17:130– 144.
- YOZZO, D. J., AND R. J. DIAZ. 1999. Tidal freshwater wetlands: invertebrate diversity, ecology, and functional significance. *In D.* P. Batzer, R. B. Rader, and S. A. Wissinger (eds.), Invertebrates in Freshwater Wetlands of North America, pp. 889–918. John Wiley and Sons, New York.

Accepted: 22 October 2010.