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Habitat Selection by the Blanding's Turtle (*Emydoidea blandingii*) on a Protected Island in Georgian Bay, Lake Huron

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Abstract. – A key step in generating effective recovery strategies for species at risk is to identify habitat used under a variety of geographic settings. In part attributable to habitat loss and degradation, the Blanding's turtle (*Emydoidea blandingii*) is considered at risk across most of its range. Because little information for this species exists for the many islands of Georgian Bay, the world's largest freshwater archipelago, we conducted an intensive study on the habitat use of 12 turtles (6 males, 6 females) on a protected island. We used a combination of radio tracking and GPS loggers to determine habitat use during the active seasons of 2011 and 2012. We used aerial imagery to quantify available habitat and used compositional analyses to determine habitat selection. Both sexes used vernal pools and wet forest to move between habitat patches. Females used inland wetlands early in the year and coastal wetlands during the nesting season, whereas males maintained extensive use of inland wetlands during the entire active season. An effective conservation strategy for Blanding's turtles in Georgian Bay must include protection of inland and coastal wetlands, in addition to the surrounding upland matrix and connecting corridors.

Key Words. – Blanding's turtle; *Emydoidea blandingii*; habitat use; radio tracking; Georgian Bay

Effective conservation strategies for species at risk rely on accurate identification of critical habitat, such as areas that individuals use for reproduction, feeding, and hibernation. For a semi-aquatic species such as the Blanding's turtle (*Emydoidea blandingii*), this task is particularly important because of their extensive use of both aquatic and terrestrial habitat (Ernst and Lovich 2009). For instance, females are known to migrate long distances to their upland nesting sites (Ernst and Lovich 2009; Edge et al. 2010). These migrations can increase the risk of road mortality, which can lead to population declines because of low juvenile recruitment rates, delayed sexual maturity, and long lifespan (Congdon et al. 1993; Marchand and Litvaitis 2004; Steen and Gibbs 2004; Dowling et al. 2010). Overall, habitat loss, degradation, and fragmentation have led to Blanding's turtles being designated as a species at risk in 17 of the 18 provincial or state jurisdictions throughout their range (NatureServe 2009). To effectively conserve this species at risk, habitat use studies are required to identify and protect habitat from further alterations.

Blanding's turtles are ectotherms and regulate their metabolic needs through their behavior, which may require use of diverse habitats throughout the active season (Congdon 1989; Huey 1991; Beaudry et al. 2009). The active season can be divided into ''behavioral seasons'' (pre-nesting, nesting, and post-nesting), and it is important to determine habitat use during each season, because they are associated with unique behaviors or activities that require different habitats (Rasmussen and Litzgus 2010). According to the reproductive-strategies hypothesis (Morreale et al. 1984; Gibbons et al. 1990), males are expected to be more active during the pre-nesting season while searching for mates, whereas females are expected to be more active during the nesting season while making nesting migrations. The difference in activity patterns between males and females may lead to differences in habitat use. Additionally, it may be necessary to examine habitat selection at multiple spatial scales to account for the biology of a species and an individual's arbitrary use of habitats (Johnson 1980). Habitat selection can occur at 3 scales: first-order selection can be defined as selection of the population range, second-order selection is defined as the individual's home range, and third-order selection is defined as an individual's location (Johnson 1980). Therefore, it is important to determine habitat selection by both males and females during all behavioral seasons and at multiple scales, to fully identify habitat requirements for this species.

Within Canada, there are 2 isolated Blanding's turtle populations that encompass 20% of their global range, one centered on the Great Lakes and the other in Nova Scotia (Government of Canada 2009). Within the Great Lakes region, Georgian Bay, Lake Huron, is recognized as the largest freshwater archipelago in the world and most of its habitats are still in relatively pristine condition (Cvetkovic and Chow-Fraser 2011). The Georgian Bay archipelago is designated a World Biosphere Reserve by UNESCO and contains over 30,000 islands. However, this area is under increasing threat because road expansion and cottage and residential

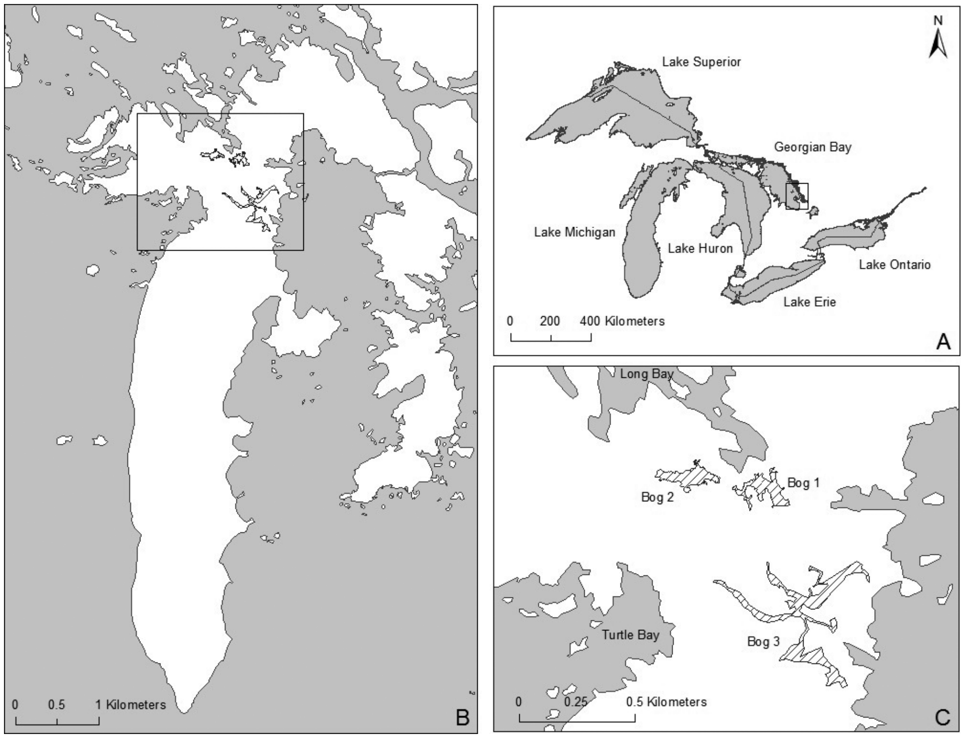

Figure 1. Map of the Great Lakes indicating the approximate location of our study site (A). Our study site is located on a protected island in southeastern Georgian Bay (B and C).

development along the shoreline are expected to increase (Walton and Villeneuve 1999; Niemi et al. 2007). With increasing human development, there is a pressing need to identify sensitive areas and ensure minimal habitat degradation and fragmentation (Walton and Villeneuve 1999). Even though this area is of great ecological significance, the subpopulation of Blanding's turtles living in this region has not yet been studied, which is an important information gap when developing conservation strategies. We cannot simply extrapolate information from previous studies to the Georgian Bay region because habitat selection differs among populations of Blanding's turtles in geographically distinct areas partly attributable to the variation in available habitat types. For example, a study in Maine, identified a population of Blanding's turtles that used wetlands within deciduous forest and with a high cover of sphagnum moss (Beaudry et al. 2009), whereas turtles in a study in New York used wetlands with shallow water depths and dense vegetation (Hartwig and Kiviat 2007). Millar and Blouin-Demers (2011) studied habitat use by Blanding's turtles in the St. Lawrence islands, which are within the Great Lakes basin, but extrapolating results to the Georgian Bay islands may be inappropriate because of different topography and, thus, a difference in available habitat types that originates from disparate bedrock type (Perera et al. 2000). The Georgian Bay islands have bedrock material of Canadian Shield (granitic rock with only a very thin layer of soil; Parks Canada 2010), whereas islands in the St. Lawrence are underlain by sedimentary rock (sandstone and limestone). Therefore, extrapolating information across geographic regions to determine Blanding's turtle habitat is often difficult and should not be done to develop effective management plans to protect the Blanding's turtles in the Georgian Bay archipelago.

The purpose of our study was to identify habitat selection and use by the subpopulation of Blanding's turtles living on a protected island in southeastern Georgian Bay. Based on the reproductive-strategies hypothesis, we predicted that 1) males and females would select different habitat types. We hypothesized that 2) habitat selection would differ between the sexes across pre-nesting, nesting, and post-nesting seasons attributable to differing requirements. Our study identified habitats required to sustain the study population and will enable the development of effective strategies for the islands of Georgian Bay to ensure that Blanding's turtles are adequately protected in an area under threat of development. Furthermore, we make general recommendations to enhance conservation of the Blanding's turtle in this region and identify areas for future research.

METHODS

Study Site. — Our study was carried out on a protected island in Georgian Bay, Lake Huron. The island contains 11 km^2 of pristine habitat characterized by Canadian Shield landscape and a mix of coniferous and hardwood forest (Fig. 1). We collected the majority of habitat data in situ when each turtle was individually radio

Table 1. Definitions of habitat types, following the Canadian National Wetlands Classification System (Warner and Rubec 1997) and additional classes to include all habitat types in the study area.

Habitat type	Brief description
Bog 1	An older bog that is at a more advanced stage of ecological succession. Dominated by *Sphagnum* mosses with shrubs and young trees. The presence of many pitcher (*Sarracenia purpurea)* and sundew (*Drosera* spp.) plants are indicative of the acidic water from decomposed peat and nitrogen limitation. The main source of water is through precipitation and snowmelt.
Bog 2	A younger bog in an earlier stage of ecological succession. A thin layer of peat is present, with many dead trees still standing to indicate it has been recently flooded. Only a few areas with pitcher plants (*Sarracenia purpurea)* indicate that the water may not be sufficiently acidic to support additional carnivorous plants. The main source of water is through precipitation and snowmelt.
Dry forest	Coniferous forest is dominated by needleleaf species such as white pine (*Pinus strobus*) and hemlock (*Tsuga* spp.). Hardwood forest is dominated by broadleaf species such as sugar maple (*Acer saccharum*) and beech (*Fagus* spp.).
Wet forest	A tree- or shrub-dominated wetland with highly decomposed peat that is not as wet as bogs or marshes. Also known as swamp.
Shallow-water wetlands	Transitional wetlands between bogs, fens, marshes, and swamps. They contain deep water and are beaver and vernal pools in this study area.
Rock	Rocky outcrops characteristic of the Canadian Shield.
Lake	Large body of water where the maximum depth is $>$ 5 m. Surface vegetation is confined to bays.
Marsh	Dominated by rushes, reeds, grasses, and sedges. Typically has shallow water which can fluctuate daily, seasonally, or annually.

tracked and collected additional data at locations identified by GPS loggers. We identified 8 habitat types and classified wetlands using the Canadian National Wetlands Classification System (Warner and Rubec 1997) and created additional classes to include all habitat types in the study area (Table 1). We used ArcGIS 10 (ESRI, Redlands, CA) to digitize habitat types in orthophotos taken in the spring of 2008 (30-cm resolution) and ground truthed these aerial images. We used our resulting maps to calculate habitat areas. Also, we digitized and ground truthed *Sphagnum* mats and determined bathymetry of 2 bogs to characterize differences between these habitats. We calculated the number of *Sphagnum* mats and surface area of each mat in ArcGIS 10. We recorded depth measurements from a boat with a meter stick and collected associated GPS coordinates to input into ArcGIS 10 to create bathymetric maps. We used our resulting *Sphagnum* mat and bathymetric maps to determine percent total mat coverage, average mat size, and average depth of bog 1 and bog 2.

Turtle Movements. — Our study was carried out according to the *Guide to the Care and Use of Experimental Animals* (Canadian Council on Animal Care 1993). All of the turtles in this study were captured initially and radio tagged between 26 April and 31 May 2011. Six male and 6 female Blanding's turtles were caught opportunistically by hand, dip net, or in baited hoop nets. We identified the sex of each turtle using secondary morphological characteristics such as concavity of the plastron and position of the cloacal opening (Hamernick 2000; Innes et al. 2008). We weighed each turtle (Starfrit Digital Scale, accuracy $\pm$ 1 g) to ensure they were sufficiently large to carry the weight of the radio transmitter or the radio transmitter and GPS logger combination. The attachments were $<$ 5% of the turtle's body mass. We notched the scutes of each turtle with a unique code for later identification (Cagle 1939). Once the rear marginal scutes were cleaned, we attached AI-2F radio transmitters (Holohil Systems Ltd., Carp, ON, Canada, 19 g) with quick dry epoxy and plumber's epoxy. Additionally, 3 females were outfitted with GPS loggers in 2011, as were 2 females and 2 males in 2012 (Lotek Wireless, Newmarket, ON, Canada, 10 g; Telemetry Solutions, CA, 30 g). After tagging, we returned turtles within 24 hrs to the same locations where they had been caught.

We radio tracked turtles at least once per week from 31 May to 1 September in 2011 and from 1 May to 25 July in 2012. We used a 3-element Yagi antenna (Wildlife Materials International, Murphysboro, IL) and a Lotek Biotracker Receiver (Lotek Wireless, Newmarket, ON, Canada) to locate their positions during these weekly surveys. We conducted nesting surveys starting on 23 May 2012 until all tagged females were no longer gravid. Surveys commenced at 1700 hrs, and each gravid female was radio tracked. If females remained in the same location, the survey ended at 2400 hrs. If females remained active, we used a red light (to minimize disturbance) to identify a nesting site. When we located a turtle, the date, time of day, GPS location (Handheld Garmin, accuracy to within 6 m), and habitat type were recorded. We recaptured turtles with GPS loggers several times throughout the active season to download data (accuracy to within $\sim$ 10 m) and to recharge the devices. Also, we tracked during November 2011, February 2012, and February 2013 to determine hibernation locations.

Statistical Analyses. — We used compositional analyses to test for habitat selection (disproportionate habitat use) over the active season (Aebischer et al. 1993). Disproportionate use or habitat selection is defined as the use of a habitat type in greater proportion than its availability (Johnson 1980). This approach has been used in recent studies (Schmid et al. 2003; Rasmussen and Litzgus 2010) and provides three statistical advantages over previous habitat analyses such as the chi-square method (Carrière and Blouin-Demers 2010). First, the sample size is equal to the number of tagged turtles and not the number of radio locations; this avoids pseudoreplication and does not inflate the degrees of freedom, which would increase the chance for type I errors (Aebischer et al. 1993). Second, use of log ratios in compositional analyses avoids the unit sum constraint, which can lead to inappropriate conclusions because proportions will sum to one and habitats that are avoided will lead to an apparent selection for the remaining habitats. Finally, habitat selection can be determined for different groups of individuals. Even with this statistical approach and considering habitat selection at different spatial scales, the problem of arbitrary boundary selection still remains. This problem occurs because population-range size and home-range size must be calculated when using compositional analyses to determine habitat selection. Although this fundamental problem exists for all range-size estimation methods, we used the minimum convex polygon (MCP) method (Mohr 1947). This method is common for determining turtle ranges (Litzgus et al. 2004; Row and Blouin-Demers 2006; Rasmussen and Litzgus 2010; Millar and Blouin-Demers 2011), is an accurate estimator for reptile home ranges, and reduces the requirement for arbitrary choices involved in methods such as kernel estimation and selection of a smoothing factor (Row and Blouin-Demers 2006). Drawbacks to MCP include sensitivity to additional data points (i.e., as the number of location points increases, the estimated home-range size increases) and inclusion of large unused areas (Harris et al. 1990; White and Garrott 1990). These drawbacks were addressed by collecting the number of locations required for home-range stabilization (Harris et al. 1990) and combining the MCPs of all individual turtles to obtain the population range. In our study, we operationally defined second-order habitat availability as the population range and second-order habitat use as the individual home range. We defined third-order habitat availability as the MCP for individual turtles and third-order habitat use as the individual's locations.

We used two-way ANOVAs with sex and season as factors to determine effects on habitat selection, as well as the interaction between sex and season. We divided the active season into three behavioral seasons: pre-nesting (between the first sighting of a basking turtle and the first observed female to begin the nesting migration); nesting (from the first observed female to begin the nesting migration to the last female returning from nesting); and post-nesting (from the last female returning from nesting and the end of our field season; Table 2).

Table 2. Dates of pre-nesting, nesting, and post-nesting behavioral seasons.

Year	Pre-nesting	Nesting	Post-nesting
2011	27 Ap–31 May	1 Jun–12 Jul	13 July–1 Sep
2012	1 May–22 May	23 May–30 Jun	1 July–19 Sep

Weather differences between the two years provided a natural opportunity to examine changes in habitat selection. Temperature, rainfall, and snowmelt are important factors when considering habitat selection because they impact the drying of vernal pools. An early spring with little precipitation can indicate early drying of vernal pools, which may impact secondary productivity (Brooks 2004). Therefore, we calculated habitat selection during 2011 and 2012 separately to examine differences between years. We used weather data from Environment Canada's (2012) national climate data and information archive.

All statistical analyses were carried out in JMP version 10 (SAS Institute, Inc., Toronto, ON, Canada), and significance of tests was accepted at $\alpha = 0.05$. Although compositional analyses allow for the ranking of all possible habitat types according to selection, we only report the top 1 or 2 habitat types selected because results associated with lower rankings do not necessarily lead to ecologically meaningful interpretations.

RESULTS

Through ground truthing, we determined that there were 8 main habitat types used by the tagged Blanding's turtles on the protected island: bog 1, bog 2, dry forest, wet forest (swamp), shallow-water wetlands (beaver pools and vernal pools), rock, lake, and marsh (Table 1). Although the presence of Blanding's turtles was confirmed also in bog 3 (Fig. 1C), no tagged turtles used this habitat. The two bogs were determined to be ecologically different and, thus, were treated as 2 separate habitat types. Bog 1 was further along in ecological succession and had *Sphagnum* mats with a significantly larger surface area than did bog 2 (281 vs. 43 m^2; Mann-Whitney U-test, $Z = 3.16, p = 0.0016$) and provided more total coverage (38% vs. 30%; Fig. 2). Additionally, bog 1 was significantly shallower than was bog 2 (54.5 vs. 85.8 cm; Mann-Whitney U-test, $Z = 6.46$, $p < 0.0001$), with a maximum depth of 139 cm compared with 147 cm. These differences were deemed to be ecologically relevant because water depth and vegetation structure are variables that may affect the amount of time turtles spend swimming, basking, and feeding in a wetland (Sexton 1995; Black 2000 as cited in Marchand and Litvaitis 2004).

The amount of snow covering the ground was lower in 2012 than in 2011 in January (8.00 vs. 3.65 cm) and February (8.90 vs. 1.10 cm; Table 3). Coincident with lower snowfall, temperatures were also consistently warmer in 2012 than in 2011 (Table 3).

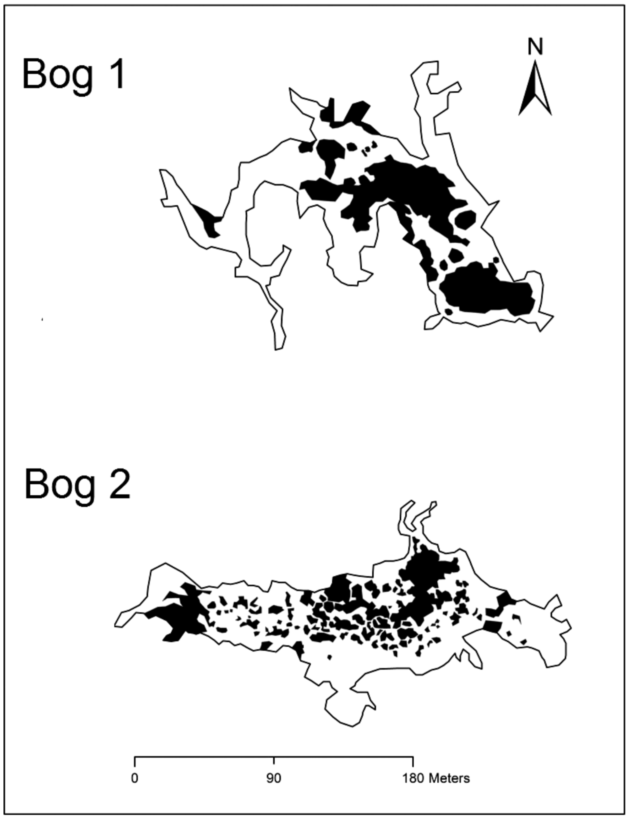

Figure 2. Comparison of size and cover of *Sphagnum* spp. mats in bogs 1 and 2.

General Use of Habitat. — Blanding's turtles spent the majority of time during the pre-nesting and post-nesting seasons in their resident wetlands. We define a turtle's resident wetland as the wetland habitat where the majority of the active season is spent. In our study, bogs 1 and 2 served as resident wetlands and hibernacula (Fig. 1C). Three males and 4 females used bog 1 as their resident wetland, whereas 3 males and 2 females used bog 2 as their resident wetland. When traveling between resident wetlands, turtles primarily used beaver ponds or shallow-water wetlands. During the pre-nesting season, females appeared to remain in their resident wetlands, whereas some males left their resident wetlands to use vernal pools. During the nesting season, females used forest, wet forest, and vernal pools to travel to and from the staging area (Long Bay; Fig. 1C) and nesting area. During this time, 2 males remained in their resident wetland; 3 males used both bogs; and 1 male used the coastal marsh in Turtle Bay (Fig. 1C). During post-nesting, all turtles returned and remained in their resident wetlands until hibernation. Only 2 females hibernated in bog 2 compared with the majority of turtles that hibernated in bog 1.

Second-Order Habitat Selection. — During pre-nesting seasons, females selected bog 1 (Fig. 3a, f) in both years and shallow-water wetlands in 2012 (Fig. 3i–j). By comparison, males selected bog 2 during the pre-nesting season in both years (Fig. 4b, h) and shallow-water wetlands in 2011 (Fig. 4c–f). Although we observed males using shallow-water wetlands (vernal pools) in 2012, these did not appear to be selected.

There were some year-to-year differences with respect to habitat selection by females during the nesting seasons. In 2011, females selected shallow-water wetlands (Fig. 3b, d–e), whereas in 2012 (23 May to 30 June), they selected both wet forest and dry forest (Fig. 3g–h). Although wet forests were selected in both years (Fig. 3c, g), only dry forest was selected in 2012 (Fig. 3g) when weather conditions were exceptionally dry. Overall, males appeared to use resident wetlands primarily. Analysis of variance indicated a significant effect of season for selection of marsh ($F_{5,25} = 34.8$, $p < 0.0001$) and wet forest ($F_{5,25} = 8.3$, $p = 0.0017$) during 2011 and a significant interaction between sex and season for selection of marsh ($F_{5,25} = 14.3$, $p < 0.0001$) and wet forest ($F_{5,25} = 4.9$, $p = 0.0154$). A Tukey HSD post hoc test indicated that females selected marsh ($p < 0.0001$), rock ($p < 0.0001$), and wet forest ($p = 0.0273$) significantly

Table 3. Comparison of temperature, total rain, and snow cover from January to March in 2011 and 2012. All data obtained from Environment Canada's (2012) national climate data and information archive for the closest station (~ 5 km) to our study site (Midland Water Pollution Control Plant).

		Temperature (°C)				
Month	Year	Maximum	Mean	Minimum	Total rain (mm)	Total snow cover (cm)
Jan	2011	−4.28	−8.72	−13.17	0.00	8.00
	2012	0.68	−3.59	−7.85	0.23	3.65
	p-value[a]	0.0105	0.0087	0.0154	NS	NS
Feb	2011	−1.50	−6.06	−10.63	0.00	8.90
	2012	2.60	−1.80	−6.20	0.00	1.10
	p-value[a]	NS	0.0712	0.0313	—	NS
Mar	2011	2.41	−1.99	−6.39	1.22	—
	2012	12.57	6.94	1.29	1.21	—
	p-value[a]	0.0050	0.0011	0.0003	NS	—

[a] *p*-values correspond to paired *t*-tests comparing 2011 and 2012 data; NS = not significant ($p > 0.05$). Because of non-normality of data, total rain and total snow cover for January were analyzed with a Wilcoxon matched-pairs signed-rank test.

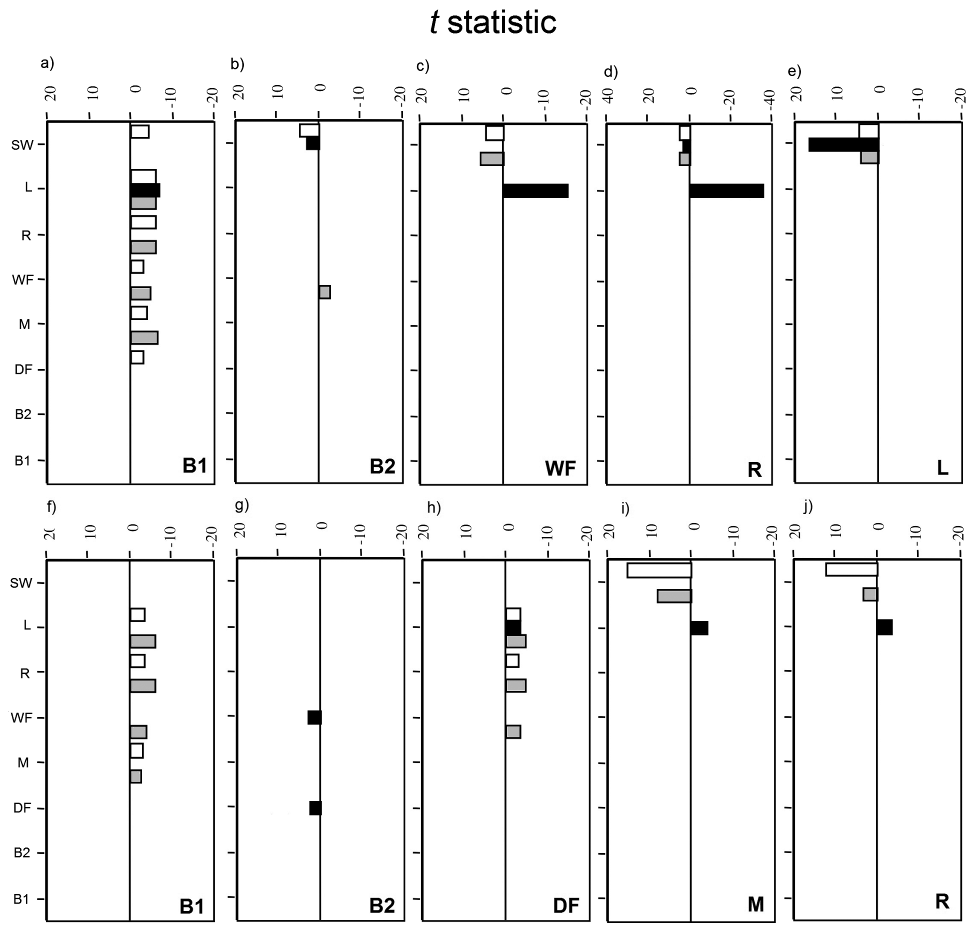

Figure 3. Results of compositional analyses for female Blanding's turtles in 2011 (panels a–e) and 2012 (panels f–j) for pre-nesting (hollow), nesting (black), and post-nesting (gray) seasons. Two-tailed 1-sample *t*-tests were used to determine significant differences in habitat usage. Only significant results are depicted ($\alpha < 0.05$). A positive *t*-value indicates significant selection for the corresponding habitat category along the *y*-axis, whereas a negative *t*-value indicates significant selection for the habitat category labelled on the bottom right of each panel. Habitat categories include SW = shallow water, L = lake, R = rock, WF = wet forest, M = marsh, DF = dry forest, B2 = bog 2, and B1 = bog 1.

more often during the nesting season compared with the pre-nesting season; they also selected marsh ($p < 0.0001$), rock ($p < 0.0001$), and wet forests ($p = 0.0193$) significantly more often during the nesting season compared to the post-nesting season. Additionally, females selected marsh ($p < 0.0005$) and rock ($p < 0.0016$) significantly more often during the nesting season than did males. During 2012, females also selected rock during the nesting season compared to the pre-nesting ($p = 0.0082$) and post-nesting ($p = 0.0036$) seasons. Based on these habitat selections, we suspected that nest sites would be found in marsh, wet forest, or rock habitats. The GPS logger located a female at 2100 hrs on an upland rocky outcrop on 14 June 2011, approximately 570 m from her resident wetland. In 2012, this female was observed successfully nesting 60 m from the 2011 location. The clutch was laid in soil that had accumulated in a crack in the bedrock. The GPS logger captured another female on an upland rocky outcrop on 10 June 2012 from 2200 hrs until 2400 hrs. Based on these observations, we confirmed females are using this rocky habitat for nesting.

During the post-nesting season, males selected bog 1 in both years (Fig. 4a–b, g–h). Males selected shallow-water wetlands and forest habitat in 2012 (Fig. 4i–k). Females selected bog 1 (Fig. 3a, f) and shallow-water wetlands (Fig. 3i–j). By November 2011, all turtles were found in their respective hibernation wetlands.

Third-Order Habitat Selection. — Third-order analyses determined habitats selected at the individual scale. Our data revealed that both sexes selected either bog 1 or bog 2 throughout the entire active season. For both males and females, use of the other habitat types was in proportion to their availability at this scale and not selected.

DISCUSSION

This is the first study to determine habitat selection by Blanding's turtles in the Georgian Bay archipelago. Consistent with our first hypothesis, we found that habitat selection differed for males and females. Supporting our second hypothesis, we found that males used different

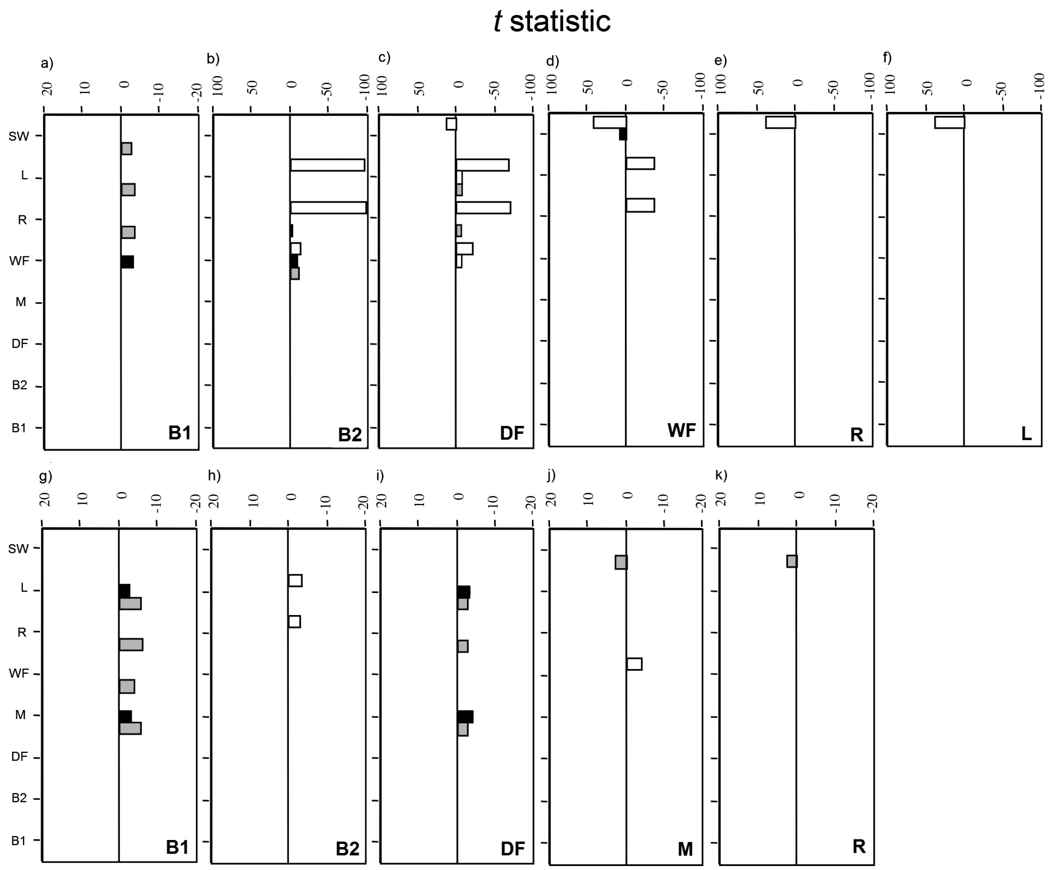

Figure 4. Results of compositional analyses for male Blanding's turtles in 2011 (panels a–f) and 2012 (panels g–k) for pre-nesting (hollow), nesting (black), and post-nesting (gray) seasons. For description, see Fig. 2.

habitat in the pre-nesting season compared with the remainder of the active season, whereas females traveled to access a variety of habitats during nesting. Also, we identified year-to-year differences in habitat selection by females during the nesting season that we attribute to differences in weather (amount of precipitation in the spring) and its effect on availability of wet forests.

In both years, males were found to initially use bog 2 prior to using bog 1 for most of the active season. This switch in usage may be attributable to several factors: 1) presence of females, 2) competition from other species of turtles, or 3) use of shallow water in the late summer. Selection of the shallower bog in this study differs from that in previous studies in Maine and the St. Lawrence islands (Beaudry et al. 2009; Millar and Blouin-Demers 2011) but is consistent with the preference for shallow, warm water by turtles in New York (Hartwig and Kiviat 2007). As expected, females remained in their resident wetland during the pre-nesting season, presumably to conserve energy in preparation for the nesting season (Congdon 1989; Millar and Blouin-Demers 2011). This finding was similar to that of Millar and Blouin-Demers (2011), who found that female Blanding's turtles did not make long-distance movements in spring and were found basking more often than males and non-gravid females, potentially because gravid females have higher energetic needs (Congdon 1989). Overall, selection of bog habitat by males and females during the pre-nesting season was similar to that of Blanding's turtles studied in Maine (Beaudry et al. 2009), Nova Scotia (Newton and Herman 2009), and a few turtles in Illinois (Rowe and Moll 1991; Table 4). Contrary to our results, however, Blanding's turtles in New York were found to be associated with wetlands with buttonbush cover (Hartwig and Kiviat 2007), whereas Blanding's turtles in Wisconsin were found to prefer ponds (Ross and Anderson 1990; Table 4). These variations in Blanding's turtle habitat selections across their geographic range highlight the importance of site-specific habitat studies, because results may not be transferable among locations.

We confirmed fidelity to resident bogs and nesting sites between years. All tagged turtles caught in either bog 1 or bog 2 during 2011 were found to emerge from the same bog in spring 2012. In addition, none of the turtles in our study used a third bog that was located only 300 m from bog 1 and 475 m from bog 2 (see Fig. 1). We confirmed lichen-filled cracks in bedrock as nesting sites and observed fidelity to this location. One female nested in 2011 and 2012 with both nests within a 30-m radius. A second female was also confirmed to

Table 4. Habitat use by Blanding's turtles in various locations during pre-nesting, nesting, and post-nesting seasons and hibernation.

Season	Study	Location	Habitat characteristics
Pre-nesting	Beaudry et al. (2009)	Maine	Bogs with deciduous forest, high sun exposure, and a high abundance of wood frog egg masses
	Hartwig and Kiviat (2007)	New York	Wetlands with buttonbush cover
	Newton and Herman (2009)	Nova Scotia	Wetlands dominated by sedges, sweet gale, and leatherleaf
	Ross and Anderson (1990)	Central Wisconsin	Preference for ponds compared with all other habitat types
	Rowe and Moll (1991)	Illinois	Majority of time spent in marsh and fen habitats
	Current study	Ontario	Males: bog 2 (2011, 2012) and shallow-water wetlands (2011) Females: bog 1 (2011, 2012) and shallow-water wetlands (2012)
Nesting	Standing et al. (1999)	Nova Scotia	Beaches and roadways
	Ross and Anderson (1990)	Central Wisconsin	Grasslands
	Current study	Ontario	Rocky outcrops (2011, 2012)
Post-nesting	Joyal et al. (2001)	Southern Maine	Forested swamps
	Current study	Ontario	Males: bog 1 (2011, 2012), shallow-water wetlands (2012) and forest (2012) Females: bog 1 (2011, 2012) and shallow-water wetlands (2011, 2012)
Hibernation	Ross and Anderson (1990)	Central Wisconsin	Deep ponds
	Joyal et al. (2001)	Southern Maine	70% of a population in Maine used permanent pools
	Standing et al. (1999); Newton and Herman (2009)	Nova Scotia	Backwaters, streams, seasonally isolated ponds, small but deep pools in a mixed forest, fens, and bogs
	Current study	Ontario	Males: bog 1 (2011–2012, 2012–2013) Females: bogs 1 and 2 (2011–2012, 2012–2013)

have nested in similar habitat in 2012. Similar nesting habitat has been confirmed in Georgian Bay for *Clemmys guttata* (Litzgus and Brooks 2000) and *Sternotherus odoratus* (Edmonds and Brooks 1996). Other studies on Blanding's turtles have found nests in grasslands (Ross and Anderson 1990) as well as beaches and along roadways (Standing et al. 1999; Table 4). Using GPS loggers in combination with radio tracking allowed us to obtain more detailed information on Blanding's turtle habitat use than would radio tracking alone (Christensen and Chow-Fraser 2014) and proved important in obtaining locations late at night when turtles were nesting.

Vernal pools are important temporary habitats and can provide a source of food, hydration, and shelter for turtles. Access to these pools by turtles may vary from year to year, however, depending on the amount and timing of precipitation, because pool depths respond quickly to precipitation (Brooks 2004). For example, in 2012, usage of these vernal pools during early May stopped when the pools dried up by 21 May. By comparison, the much wetter spring in 2011 provided access to vernal pools throughout the month of May. Similar findings of weather impacting the amount of wet habitat available to turtles occurred in Maine (Joyal et al. 2001). Also, we found females using dry forest during the nesting season, presumably because the wet habitats had been severely reduced or had become difficult to access in 2012. Therefore, interannual differences in weather patterns (e.g., reduced snowmelt and warmer winter temperatures in 2012) may influence usage of wet and dry habitats and should be investigated further, especially in light of predicted changes associated with global climate change in the region.

Also, differences in weather may affect the timing of nesting migrations for Blanding's turtles. Our field observations suggest that females use wet forest, vernal pools, and beaver pools as travel corridors to access the staging area in Long Bay (see Fig. 1). These temporary wet habitats can be important also for providing food, hydration, and shelter (Grgurovic and Sievert 2005), although our data did not allow for confirmation of their importance. Female Blanding's turtles spent a few days to a few weeks in the staging area (Long Bay) before making migrations to nest sites in upland areas. Although they used Long Bay as their staging area in both years, the nesting season started 8 days earlier and ended 12 days earlier in 2012 than in 2011. Warmer temperatures between January and March in 2012 may have accelerated female emergence from hibernation and led to earlier nesting migrations. This shift in timing may have consequences for the long-term viability of Blanding's turtle populations on this protected island because other freshwater turtles have been shown to be negatively affected by climate change because of the association of nesting with weather-related cues (Bowen et al. 2005).

After returning from nesting, females selected bog 1 during the post-nesting season. Similarly, males also selected bog 1 during the post-nesting season. Contrary to this, Blanding's turtles in Maine used forested swamps prior to hibernation, despite having access to more permanent pools (Joyal et al. 2001; Table 4). By November 2011, all tagged Blanding's turtles were found in their hibernation wetlands. Only 2 of 12 turtles hibernated in bog 1 compared with 10 of 12 turtles hibernating in bog 2. Also, hibernation in permanent wetlands was confirmed for Blanding's turtles in Wisconsin (Ross and Anderson 1990) and Maine (Joyal et al. 2001), whereas hibernation habitat varied in Nova Scotia (Standing et al. 1999; Newton and Herman 2009; Table 4). Determining hibernation sites is important for conservation planning, and research on microhabitat may determine key features in hibernacula.

It is noteworthy that one of the tagged males spent the majority of the active season in the lake on the west side of the island, approximately 900 m from the resident wetland (Turtle Bay; see Fig. 1). We recorded this behavior in both years and recorded the presence of 2 untagged Blanding's turtles in the same area. This behavior may aid in gene dispersal if a male mates with females from different resident wetlands. It is important to be aware of the turtles that travel long distances because they could be important for sustaining the population, and an effort should be made to identify and protect the habitat used as travel corridors.

Studying habitat selection is essential for conservation because it provides data for the design of effective management and conservation strategies. From previous habitat use studies across North America, it is evident that discrete populations of Blanding's turtles are using a variety of habitats. Research regarding the habitat selection of the Blanding's turtle is vital for the Georgian Bay population because there have been no previous studies conducted in this unique geographic region. Our results demonstrate the extent and differences in type of habitat that are necessary for this population of Blanding's turtles to carry out its life processes. Critical habitat types for both males and females included 1) upland and coastal wetlands for annual use; 2) vernal pools, beaver ponds, and wet forest to access and travel between wetlands; and 3) rocky outcrops for nesting sites.

Overall, we have identified differential habitat selection throughout the active season and between years, which has important implications for conservation of Blanding's turtles throughout their range. First, conservation plans should emphasize the protection of nesting habitats and identify and protect the common habitats used to travel throughout the landscape. Second, future research should focus on differences in precipitation from year to year and how they may affect the timing of migration and the use of temporary habitats. Third, we recommend using remote sensing and GIS techniques to create regional models of habitat suitability such that critical habitat for Blanding's turtles can be delineated and protected from future human disturbance. In conclusion, habitat types identified in our study can be used to guide the protection of other subpopulations of Blanding's turtles in this freshwater archipelago.

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