Habitat selection at multiple spatial scales in Northern Map Turtles (*Graptemys geographica*)

M.-A. Carrière and G. Blouin-Demers

Abstract: Understanding habitat use of declining species is essential for their management and successful recovery. We examined habitat selection at multiple spatial scales by Northern Map Turtles (*Graptemys geographica* (Le Sueur, 1817)), a species at risk, in the St. Lawrence Islands National Park, Ontario, Canada. At the scale of the home range, Map Turtles generally avoided deep water (>2 m) and selected home ranges in waters <1 m deep. Importantly, turtles used home ranges with significantly more natural than developed shoreline. At the scale of the location, adult females used deep water more often and males preferred areas with surface cover. Management efforts should implement regulations concerning further shoreline development.

Résumé : La gestion et la récupération réussie des espèces en déclin nécessitent une compréhension de leur utilisation de l'habitat. Nous examinons la sélection de l'habitat à plusieurs échelles spatiales chez la tortue géographique (*Graptemys geographica* (Le Sueur, 1817)), une espèce vulnérable, dans le parc national des Îles-du-Saint-Laurent, Ontario, Canada. À l'échelle du domaine vital, les tortues géographiques évitent généralement les eaux profondes (>2 m) et choisissent des domaines vitaux dans des eaux de <1 m de profondeur. Ce qui est plus important, les tortues utilisent des domaines vitaux qui possèdent significativement plus de ligne de rivage naturelle que modifiée. À l'échelle du site, les femelles adultes utilisent les eaux profondes plus fréquemment et les mâles préfèrent les zones qui possèdent un couvert en surface. Les efforts de gestion devraient inclure la mise en vigueur de règlements concernant les modifications futures des rivages.

[Traduit par la Rédaction]

Introduction

Habitat destruction or modification is one of the leading causes of decline for all animals (Tear et al. 2005), including reptiles (Gibbons et al. 2000), and North America's freshwater habitats are facing threats from degradation, alterations, and land-use changes (Abell et al. 2000). Turtles are directly affected by aquatic habitat losses. In Canada, 8 of the 11 species of freshwater turtles (73%) are listed as species at risk by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Because conservation of declining species directly entails habitat management and protection, understanding the relationship between these animals and their habitat is often the first step towards recovery.

Habitat selection can be quantified at several spatial scales. First-order selection distinguishes the geographic range of the species, second-order selection determines the composition of home ranges within a landscape, and third-order selection is the selection of specific locations within the home range (Johnson 1980). Since these orders are inter-connected, habitat selection represents a hierarchical process. Habitat-selection pattern at one scale, however, is not necessarily a good predictor of the patterns at the other scales (McLoughlin et al. 2002; Morin et al. 2005). Differ-

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ences in selection pressures and limiting factors can sometimes lead to differing (Orians and Wittenberger 1991; Luck 2002) or conflicting (Compton et al. 2002) patterns of selection at different spatial scales. Therefore, key factors involved in habitat selection may not be detected from study of a single scale. When all elements of selection are examined at multiple scales, management actions will better reflect the needs of the species (Morin et al. 2005). Surprisingly, however, very few habitat-selection studies on reptiles have been conducted at multiple spatial scales (but see Compton et al. 2002; Row and Blouin-Demers 2006a). In this paper, we examine habitat selection at two spatial scales in Northern Map Turtles (Graptemys geographica (Le Sueur, 1817)), a species listed as special concern by COSEWIC, in the St. Lawrence Islands National Park, Ontario, Canada. The major threats identified for this species include habitat loss, increased human disturbance, and decline in turtles' molluscan prey (COSEWIC 2002).

Previous studies of habitat use in *Graptemys* sp. have shown that females use deeper, faster water farther from shore than males (Pluto and Bellis 1986; Jones 1996; Bodie and Semlitsch 2000). These studies, however, assessed habitat use by comparing capture locations or telemetry location between the sexes, without considering the influence of habitat availability, and the studies only considered a single spatial scale. We expected Map Turtles to use their habitat nonrandomly at both the microhabitat and macrohabitat scales. *Graptemys geographica* exhibits remarkable sexual size dimorphism. Females grow significantly faster and become significantly larger than males (Iverson 1988; Bulté and Blouin-Demers 2009). Therefore, we also expected habitat selection to differ between sexes at each scale. We expected all turtles to prefer relatively shallow water with macrophytes because these are ideal foraging areas (Vogt 1980), but because larger Map Turtles swim better (Pluto and Bellis 1986), we expected adult females to use deep water more.

Materials and methods

We conducted this study in the St. Lawrence Islands National Park on the St. Lawrence River between Mallorytown and Rockport, Ontario, Canada. Fieldwork took place from April to September in 2005 and in 2006. The study area was approximately 11 km \times 4 km and surrounded Grenadier Island. The animals were cared for in accordance with the guidelines outlined in the *Guide to the Care and Use of Experimental Animals* published by the Canadian Council on Animal Care. Our procedures were approved by the Animal Care Committee at the University of Ottawa (protocol BL-179) and we obtained appropriate permits from Parks Canada and the Ontario Ministry of Natural Resources.

Radiotelemetry

We captured Map Turtles with basking traps and by snorkelling near areas of aggregation. We marked each turtle captured by drilling a unique combination of small holes in the marginal scutes of the carapace (excluding marginal scutes attached to the bridge). We determined sex by size, carapace shape, and preanal tail length. Juvenile females were identified as any female with a carapace length <20 cm. This criterion was based on the size of the smallest gravid female captured (21.8 cm, n = 75).

We selected 31 Map Turtles (12 adult females, 9 juvenile females, and 10 adult males) to be fitted with radio transmitters (Holohil SI-2FT: 16 g, battery life of 28 months; Holohil SI-2FT: 12 g, battery life of 18 months; or Holohil SB-2FT: 6 g, battery life of 12 months; Holohil Systems Ltd., Carp, Ontario, Canada). We included juvenile females that are the same size as adult males because it allowed us to disentangle the effect of size from the effect of gender on habitat selection. Transmitters were bolted 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 to aid in adhesion and to seal any openings where macrophytes could snag. Transmitters (including screws, nuts, and silicone) represented at most 5% of the turtle's body mass. Transmitters were removed from the turtles at the end of the study. Turtles were released at their site of capture the following day and tracked every 2-3 days by boat using a telemetry receiver and a directional antenna for the duration of the active season (late April to mid-September). At each location, the Universal Transverse Mercator (UTM) coordinates (3-dimensional differential receiver status, NAD83 datum) were recorded with a GPSmap72 (Garmin International Inc, Olathe, Kansas, USA) at an estimated accuracy of <3 m.

Home ranges

The minimum convex polygon (MCP) is a simple and commonly used home-range estimator. A MCP is calculated by creating the smallest possible convex polygon that encompasses all known locations for an individual. Although the MCP is an accurate home-range estimator for reptiles (Row and Blouin-Demers 2006b), it ignores patterns of selection within a home range (Powell 2000), making it less ideal for use in habitat-selection studies. Kernel home-range estimators are useful in habitat-selection studies because they quantify the intensity of use and form a great basis for quantitative analysis (Seaman and Powell 1996), but are impractical for estimating home-range size (Row and Blouin-Demers 2006b). Therefore, we followed the method suggested by Row and Blouin-Demers (2006b) and combined the MCP and kernel method to analyze habitat selection. We adjusted the smoothing factor of the kernel until the area of the 95% kernel (excluding land) was equal to the area of the MCP (excluding land). Kernels were calculated using the Animal Movement extension for ArcView version 2.0 (Hooge and Eichenlaub 2000).

Macrohabitat characterization

Macrohabitat was characterized using high-resolution digital aerial orthoimagery from NYS GIS Clearinghouse (2006). The orthoimagery was produced in 2003 at a 0.6 m pixel resolution in colour infrared. For improved accuracy, we referenced habitats seen in the orthoimagery to those of Google Earth (version 4.0.13). A nautical chart layer (NAD83, 1:25000 scale) from Fisheries and Oceans Canada was superimposed to classify depths. We used ArcMap version 9.0 (ESRI 2000) to classify the study area in five habitats: open reeds, matted marsh, shallow water (<1 m), intermediate water (1-2 m), and deep water (>2 m). We defined open reeds as sparse aquatic emergent vegetation that is present throughout the entire study season and matted marsh as dense aquatic vegetation with little to no open water between plants. Water depths obtained from the nautical chart layer were cross-referenced to turtle telemetry locations where depth had been measured in the field to ensure accuracy. We also classified shoreline type into natural or developed. Developed shoreline referred to any continuous expanse of shoreline >50 m that had a minimum of 50% noticeable, long-term habitat alteration, such as cleared land, lawns, landscaping, buildings, and roads (Traut and Hostetler 2003).

Macrohabitat selection

To determine habitat selection at the macrohabitat scale. habitat types within the home range were compared with the habitat types available. For each individual, we used the composition of a circle centered on its hibernation site with a radius equal to the farthest recorded location a turtle was from that point as the available habitat (Row and Blouin-Demers 2006*a*). We calculated the percentage of open reeds (REEDS), matted marsh (MARSH), shallow water (SHALLOW), intermediate water (INTER), and deep water (DEEP) in the 95% kernel and in the circle of potentially available habitat for each individual. Because Map Turtles are highly aquatic, land was excluded. The proportions of the five habitat types sum to one, thus creating nonindependence. Log-ratio transformation is used to remove this linear dependency. If x_i is the proportion of use in *i* habitat and x_i is the proportion of available habitat, $y_i = \ln(x_i/x_i)$ renders y_i linearly independent (Aitchinson 1986). Because this transformation is equivalent to centering each observation on the log-transformed mean, the result is independent of the denominator chosen (x_j) (Aebischer et al. 1993). We used a MANOVA on the transformed data to test for nonrandom habitat selection with respect to reproductive class (adult female, juvenile female, and adult male). Wilks' λ was used as the test statistics for the group contrasts.

We analyzed preferences for habitat types with a compositional analysis (Aebischer et al. 1993). Compositional analysis considers the animal rather than the telemetry locations as the sample unit and therefore avoids the nonindependence problem of location data (Aebischer et al. 1993). A compositional analysis is based on pairwise differences (d = yU - yA) of the log-ratio transformations of the used (U) and available (A) habitat composition (y) for each animal. This analysis tests the null hypothesis that turtles use habitat types in proportion to their availability. When habitat use was found to be significantly nonrandom, we created a matrix comparing all possible habitat-type pairs and we ranked each habitat in order of use. We then used Student's t-test values in the ranking matrix to assess if the differences between the ranks of each habitat were significant. To avoid pseudoreplication and for comparison with selection at the microhabitat scale, each animal was represented by a single seasonal home range in the analysis even if monitored over 2 years. This resulted in data for 28 individuals (12 adult females, 9 juvenile females, and 7 adult males) being analyzed.

Developed or natural shoreline was analyzed separately from the other habitat types because it is measured as a straight-line distance, not as an area. The total length of each shoreline type was calculated in the 95% kernel and in the circle of available habitat for each individual. We then compared the percentage of use to the percentage of availability of each shoreline type using a compositional analysis as described above for the other habitat types.

Microhabitat selection based on land cover

We examined whether Map Turtles selected locations within their home range randomly. We used the composition of the 95% kernel as the habitat available to each individual. Using the land-cover information from the aerial orthoimagery, we calculated the percentage of open reeds (REEDS), matted marsh (MARSH), shallow water (SHALLOW), intermediate water (INTER), and deep water (DEEP) in the 95% kernel. Habitat use was the percentage of telemetry locations within each habitat type. We again analyzed preferences for habitat types with a compositional analysis (Aebischer et al. 1993).

Microhabitat characterization

Every time a turtle was located, we recorded the general habitat type (REEDS, MARSH, SHALLOW, INTER, DEEP). We also conducted a more detailed habitat characterization at every second location (to keep sampling manageable). We did not conduct habitat characterizations at locations where turtles were swimming, as these individuals may have been disturbed by our approach, and habitat used at these sites may not represent true choice. When a turtle was found basking, the aquatic habitat directly adjacent to its basking site was characterized. For the detailed characterization we quantified seven habitat variables (Table 1). These same variables were measured at paired random locations. We chose random locations by moving 400 m (the median distance moved by individuals between locations) from the turtle location in a randomly determined direction (by spinning a bearing dial on a compass). In the rare instances when random locations ended up on land, we spun the compass' bearing dial a second time. We characterized the random locations the same day as the location of the paired turtles to ensure that no temporal or environmental changes affected the measured variables.

Microhabitat selection based on detailed habitat characterization

To further examine habitat selection within the turtles' home ranges, we used matched-pairs logistic regression. This analysis is the most appropriate at this fine scale because it keeps paired data together. Pairing the data controls for changes in environmental conditions through time and ensures that the random locations are actually available to each individual (Compton et al. 2002). In the matched-pairs logistic regression, values for each random point are subtracted from the values of each paired-turtle location. A standard logistic regression with the constant term removed is then used to fit a response between presence and absence to the differences in habitat values between used and random locations. The resulting estimated coefficients, β_i , are interpreted the same way as with a standard logistic regression. An *n*-unit increase in the habitat variable results in an $e^{n\beta_i}$ increase in the odds ratio.

Another assumption of the logistic regression is that each observation is independent. Although using radiotelemetry as the sample unit causes pseudoreplication (Aebischer et al. 1993), it is difficult to avoid when few locations are taken for each individual. We collected detailed microhabitat-use data for 12 adult females, 9 juvenile females, and 7 adult males. Although it would have been better to fit models separately for each individual to allow such analyses. Since no individual represented a large proportion of the total locations (median = 3.2%, maximum = 5.1%), no individual had the opportunity to unduly bias the group means.

Map Turtles exhibit remarkable sexual size dimorphism. Since size dimorphism in a species may influence habitat use (Shine 1989), we constructed separate models for each reproductive class. Univariate analyses were run for each habitat variable. Variables with p values <0.25 were selected as candidates for subsequent multivariate analyses (Hosmer and Lemeshow 2000). Candidate models were fitted using a backward stepwise regression to select the most parsimonious model. The final model was selected based on the lowest Akaike's information criterion (AIC) score. Lastly, the fit of the model was evaluated using the likelihood-ratio statistic (Hosmer and Lemeshow 2000).

Statistical analyses

We performed compositional analyses using the computer program Resource Selection for Windows (Leban 1999). Matched-pairs logistic regressions were done in R version 2.4.0 (R Development Core Team 2006). All other statistical analyses were performed with JMP version 5.0.1 (SAS Institute Inc. 2002). We accepted significance of tests at $\alpha = 0.05$.

Variable	Description
DEPTH	Distance (m) from water surface to bottom
SHOREDIST	Distance (m) to nearest shore
WTMP	Temperature ($^{\circ}$ C) at water surface
% SURFCOV	Coverage (%) of floating or emergent aquatic vegetation in 1 m radius
% MACRO	Coverage (%) of submerged aquatic vegetation in 1 m radius
SUSBT	Categorical choices of silt, sand, gravel, or rock
TURBID	Water transparency in four categories of Formazin turbidity unit (FTU) values

Table 1. Habitat variables examined in the microhabitat analysis of Northern Map Turtles (*Graptemys geographica*) followed by radiotelemetry in the St. Lawrence River, Ontario, Canada.

Results

Macrohabitat selection

Map Turtles used their habitat nonrandomly at the scale of the home range ($\chi^2_{[4]} = 74.49$, p < 0.0001; Fig. 1). The ranking from the compositional analysis was SHALLOW > REEDS > MARSH > INTER > DEEP (Table 2). Deep water was used significantly less than all other habitat types and shallow water was used significantly more than intermediate water.

MANOVA revealed that adult males, juvenile females, and adult females use their habitat differently ($\lambda = 0.74$, $F_{[8]} = 3.2$, p = 0.002), so we analyzed each reproductive class separately. For each reproductive class, the habitat used was significantly different from the habitat available at the home-range scale (adult females: $\chi^2_{[4]} = 27.03$, p <0.0001; juvenile females: $\chi_{[4]}^2 = 29.47$, p < 0.0001; adult males: $\chi_{[4]}^2 = 21.14$, p < 0.0001). The overall ranking of habitats for adult females was SHALLOW > INTER > MARSH > REEDS > DEEP. No single habitat was preferred or avoided significantly relative to the next habitat variable in the ranking. For juvenile females, the ranking was a follows: SHALLOW > REEDS > INTER > MARSH > DEEP. DEEP was significantly less used than all other habitat types. The habitat ranking for adult males was REEDS > SHALLOW > MARSH > INTER > DEEP. Although no habitat type was significantly preferred or avoided relative to its adjacent habitat type in the ranking, deep water was used significantly less than all other habitats.

Compositional analysis revealed that shoreline types were used nonrandomly at the scale of the home range ($\chi^2_{[1]} = 16.7$, p < 0.0001; Fig. 2). Natural shorelines were significantly preferred over developed shorelines (Table 3). When each reproductive class was analyzed separately, a significant difference in shoreline selection was only found for adult females ($\chi^2_{[1]} = 11.6$, p < 0.0001) and juvenile females ($\chi^2_{[1]} = 6.95$, p = 0.01), both of which used natural shorelines more than developed shorelines.

Microhabitat selection based on land cover

We used the same individuals and locations in both the macrohabitat and microhabitat analyses to allow direct comparison between scales. The three reproductive classes selected general habitat types differently within their home range based on MANOVA ($\lambda = 0.37$, $F_{[8]} = 3.6$, p = 0.003). Habitat used was significantly different from the habitat available in the home range (adult females: $\chi^2_{[4]} = 83.78$,

Fig. 1. Percentage (mean ± 1 SE) of the five macrohabitat types within the 95% kernel home ranges and the available habitat for all Northern Map Turtles (*Graptemys geographica*) (n = 28) tracked in the St. Lawrence River, Ontario, Canada.



p < 0.0001, juvenile females: $\chi^2_{[4]} = 50.48$, p < 0.0001, adult males: $\chi^2_{[4]} = 32.19$, p < 0.0001). Adult females and juvenile females had the same overall ranking of habitat types: SHALLOW > INTER > REEDS > DEEP > MARSH. The ranking for adult males was similar, except for MARSH > DEEP. Both adult and juvenile females used MARSH significantly less than all other habitat types. All three reproductive classes used SHALLOW significantly more than INTER.

Microhabitat selection based on detailed habitat characterization

We characterized the habitat at 314 turtle locations (138 adult females, 96 juvenile females, and 80 adult males). The model with the lowest AIC value for both adult females and juvenile females had the same two variables (SHOREDIST + DEPTH) and was significant for both adult (AIC = 86.3, LR₂ = 13.4, p = 0.001) and juvenile (AIC = 58.7, LR₂ = 10.5, p = 0.005) females. The best model for adult males also had two variables (DEPTH +

Table 2. Matrices of Student's *t* values and associated *p* values comparing between-pairs of habitat types (REEDS, MARSH, SHALLOW, INTER, DEEP) in the 95% kernel for 28 Northern Map Turtles (*Graptemys geographica*) in the St. Lawrence River, Ontario, Canada.

	REEDS		MARSH		SHALLOW		INTER		DEEP		
	t	р	t	р	t	р	t	р	t	р	Rank
REEDS			0.25	0.82	-0.34	0.73	0.26	0.80	5.17	< 0.0001*	2
MARSH					-1.30	0.20	0.08	0.94	9.51	< 0.0001*	3
SHALLOW							2.73	0.01*	16.58	< 0.0001*	1
INTER									16.84	< 0.0001*	4
DEEP											5

Note: Preference rankings are in the order of most (1) to least (5) preferred. Refer to the text for descriptions of the habitat types. *Denotes significant difference.

Fig. 2. Percentage (mean ± 1 SE) of the two shoreline types measured in the 95% kernel home ranges and the available habitat for all Northern Map Turtles (*Graptemys geographica*) (n = 28) tracked in the St. Lawrence River, Ontario, Canada.



SURFCOV) (AIC = 23.8, LR₂ = 35.6, p < 0.001), but differed from the female model. As SHOREDIST was a significant (p = 0.0008) candidate variable for model building in adult males, we added this variable to the adult male model to allow for a better comparison between the classes. The AIC difference between the two models was 1.3, and because this difference is <2, it indicated that both models had a similar level of support (Burnham and Anderson 2002). The new model remained significant (LR₃ = 36.3, p < 0.001) and the addition of a variable did not elicit much change in the coefficients. We did not add SURFCOV to the female models, as this variable was not a significant candidate (p > 0.25) at the univariate stage.

Adult male Map Turtles had a strong preference for shallow water (Fig. 3C): based on the odds ratios (Table 4), a 1 m increase in depth resulted in a 75% decrease in selection. Juvenile females also used areas of shallow water (Fig. 3B): a 1 m increase in depth resulted in a 33% decrease of selection (Table 4). Although adult females used **Table 3.** Matrices of Student's *t* values and associated *p* values comparing shoreline types (natural or developed) in the 95% kernels for 28 Northern Map Turtles (*Graptemys geographica*) followed by radiotelemetry in the St. Lawrence River, Ontario, Canada.

	Natural		Develop	ed	
	t	р	t	р	Rank
Natural			4.69	0.0001*	1
Developed					2

*Denotes significant difference.

areas of shallow water, use of deeper water was more frequent than in the other classes (Fig. 3A): a 1 m increase in depth only resulted in a 12% decrease in selection (Table 4). All three classes showed a preference for areas close to shore (Figs. 4A–4C), with juvenile females and adult males both decreasing selection by 18% when distance from shore increased by 50 m. In adult females, a 50 m increase in distance from shore resulted in a 26% decrease in probability of selection. Adult males also demonstrated a strong preference for areas with surface cover (Fig. 5). As surface cover increased by 10%, adult males increased their probability of selection by 35%.

Discussion

Hierarchical habitat selection

Map turtles use their habitat nonrandomly at both microand macro-habitat scales. Home-range selection (macrohabitat scale) was nonrandom, and Map Turtles primarily had their home ranges in shallow waters. Map Turtles used all tested variables with greater frequency than expected from their availability, except for deep water (>2 m) that was avoided. Although there was a significant difference in habitat selection between reproductive classes, final habitat rankings remained quite similar. Adult males do appear to select areas with open reeds more strongly than females. Turtles, especially females, also had home ranges with more natural shorelines.

At the microhabitat scale, we found that Map Turtles select areas of shallow water near shore. However, the probability of selection differed between the three reproductive classes studied. Although adult females chose areas near shore, they also selected areas that had deeper water. Juvenile females and adult males stayed in shallow water. In

Fig. 3. Frequency of observed data (histograms) and predicted probability of selection as depth increases for (A) adult female, (B) juvenile female, and (C) adult male Northern Map Turtles (*Graptemys geographica*) (1 = habitat used by turtle; 0 = habitat available) followed by radiotelemetry in the St. Lawrence River, Ontario, Canada.



Table 4. Coefficients and odds ratios for the best models explaining microhabitat use by adult female, juvenile female, and adult male Northern Map Turtles (*Graptemys geographica*) in the St. Lawrence River, Ontario, Canada.

Variable	Coefficient	SE	Increase	Odds ratio	95% CI*
Adult females					
DEPTH	-0.127	0.12	1 m	0.88	0.7, 1.1
SHOREDIST	-0.006	0.003	50 m	0.74	0.55, 0.99
Juvenile females					
DEPTH	-0.399	0.236	1 m	0.67	0.43, 1.1
SHOREDIST	-0.004	0.003	50 m	0.82	0.61, 1.1
Adult males					
DEPTH	-1.37	0.945	1 m	0.25	0.04, 1.62
SHOREDIST	-0.004	0.005	50 m	0.82	0.5, 1.34
% SURFCOV	0.03	0.02	10%	1.35	0.91, 1.99

Note: For descriptions of each variable see Table 1.

*95% confidence interval from odds ratios.

fact, adult males strongly preferred shallow water and were never found in waters deeper than 2.4 m. Juvenile females also preferred shallow water but were found in areas as deep as 6.5 m. Although the probability of selection by adult males and juvenile females was the same for distance to shore, adult males were never found more than 230 m from shore, whereas juvenile females were found as far as 482 m from shore. Adult males also showed strong preference for areas with surface cover such as lily pads or other floating vegetation. Aquatic plants provide animals with important cover and food resources (Radomski and Goeman 2001). Because adult males are much smaller than adult females, it is possible that they are using surface cover to hide from predators. Because males are mostly insectivorous (White and Moll 1992; Lindeman 2006), however, aquatic vegetation likely provides areas with abundant food resources, whereas adult females, who are molluscivorous (White and Moll 1992; Lindeman 2006), can easily find their prey in open water (Bulté et al. 2008).

Both swimming ability, as influenced by body size, and diet have been implicated to explain differences in habitat use between the sexes in Graptemys sp. (Pluto and Bellis 1986; Jones 1996; Lindeman 2003). Juvenile females are intermediate in body size and diet; they overlap in body size with adult males and are more similar to adult females in diet (Bulté et al. 2008). Lindeman (2003) suggested that if habitat use between adult females and juvenile females are the most similar, one could infer that the differences in habitat use are related to diet rather than to swimming ability. Otherwise, if habitat use between juvenile females and adult males are most similar, swimming ability may be driving the observed differences. Although juvenile females appeared most similar to adult females in their habitat use, lack of significance in ranking orders at the macrohabitat scale and their intermediate levels in probability of selection at the microhabitat scale could not completely support the idea that differences in diet explain the difference in habitat use. Hence, although diet likely plays a role in habitat selection, swimming ability cannot be ruled out (Carrière et al. 2009).

Habitat selection studies at multiple scales are important

Fig. 4. Frequency of observed data (histograms) and predicted probability of selection as distance to shore increases for (A) adult female, (B) juvenile female, and (C) male Northern Map Turtles (*Graptemys geographica*) (1 = habitat used by turtle; 0 = habitat available) followed by radiotelemetry in the St. Lawrence River, Ontario, Canada.



Fig. 5. Frequency of observed data (histograms) and predicted probability of selection as surface cover increases for adult male Northern Map Turtles (*Graptemys geographica*) (1 = habitat used by turtle; 0 = habitat available) in the St. Lawrence River, Ontario, Canada.



because different factors can influence habitat use at different scales, creating noncongruent patterns of selection (Wiens et al. 1987; Luck 2002; Morin et al. 2005). Habitatselection patterns in Map Turtles were similar between scales, but investigation of both scales allowed for a more detailed understanding of the selection process. Hierarchical scales of habitat selection probably represent a continuum, but separate examination of these levels facilitates interpretation (Wiens et al. 1987).

Conservation implications

Selection at both scales revealed a close association with natural shorelines in Map Turtles, especially females. At the microhabitat scale, all individuals demonstrated a tendency to stay near shore and adult males preferred areas with surface cover. This reflects the importance of conserving shore-line habitat for Map Turtles. Rocks and fallen trees along shorelines are commonly used as basking sites by Map Turtles (Vogt 1980; Pluto and Bellis 1986). Map Turtles aggregate to bask and it is not uncommon to find up to 30 individuals sharing a single site (M.-A. Carrière, personal observation). Removal of deadwood along a river has been shown to lower basking densities in *Graptemys* spp. (Lindeman 1999). Thus, loss of natural basking sites could result in detrimental effects on the turtle population.

Shorelines also provide essential nesting sites for adult female Map Turtles. Some shoreline development, such as retaining walls, rip rap, boathouses, and marinas, directly remove access to these indispensable nesting sites. Subtler shoreline developments, such as lawns to water edge, clearing of aquatic vegetation, and docks, can also have negative impacts on Map Turtles. These areas have substantially less emergent and floating vegetation than undeveloped shorelines (Radomski and Goeman 2001). Because adult male Map Turtles have a strong preference for areas with surface cover, conservation of such natural areas is of crucial importance. In addition, increases in human activity are also closely tied with developed shorelines (Radomski and Goeman 2001). Basking and nesting behaviours in *Graptemys* sp. are altered by human recreational activities: disturbances force females to increase the number of nesting attempts, resulting in more invested time and energy and a higher mortality risk (Moore and Seigel 2006).

A further concern of developed shorelines is the presence of motorized boats and roads near the shoreline. Motorized boat-induced mortality is a significant threat to Map Turtles (Bulté et al. 2010). In addition, female turtles use the gravel shoulders along roads as nesting sites (Steen et al. 2006). Road mortality is a significant threat to turtle populations (Gibbs and Shriver 2002; Aresco 2005) and populations of other long-lived reptiles (Row et al. 2007). Because turtles are long-lived, slow growing, experience late sexual maturity, and have high rates of mortality in eggs and hatchlings (Gibbons 1987), they are very sensitive to even slight increases in annual mortality rates (Brooks et al. 1991; Congdon et al. 1993; Gibbs and Shriver 2002; Bulté et al. 2010).

Evidence of site fidelity between years in adult female Map Turtles highlights the importance of conserving their habitat. Female Map Turtles are loyal to their home ranges between years. Despite severe habitat alteration and disturbances, some turtles (such as the Ornate Box Turtle, *Terrapene ornata* (Agassiz, 1857)) returned to the same areas to breed, nest, and feed (Doroff and Keith 1990; Bernstein et al. 2007). If adult turtles are unlikely to establish new areas of activity, increased development will result in greater disturbance. Species with high site fidelity are less adaptable to habitat loss and degradation (Warkentin and Hernández 1996). This further emphasises the need to protect natural shorelines.

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