Can Snapping turtles be used as an umbrella species for Blanding's turtles in Ontario?

By

Dominic Demers

Thesis submitted to the Department of Earth and Environmental Sciences in partial fulfillment of the requirements for the B.Sc. Honours degree in Environmental Science, specialization in Conservation and Biodiversity

University of Ottawa

Ottawa, Ontario

April 30, 2016

Supervisor: Dr. Gabriel Blouin-Demers

Abstract

Surrogates are commonly used in conservation biology to protect as many species as possible, with limited resources at hand. Umbrella species are used under the assumption that protection of their habitat simultaneously protects less spatially demanding species. The purpose of this study was to evaluate the potential use of Snapping turtles (*Chelydra serpentina*) as an umbrella species for Blanding's turtles (*Emydoidea blandingii*) in Ontario, Canada. Habitat selection and spatial overlap of both species was studied at three spatial scales: provincial, population, and location. Provincial scale habitat selection analyses were conducted using province-wide turtle observations. Population and location selection were studied at Chalk River Laboratories (CRL), Ontario. At the provincial scale, habitat composition of individual turtle ranges was very similar for both species. Habitat preferences at the population scale were also comparable for Blanding's and Snapping turtles: Marsh > Upland > Bog > Swamp > Lake. Logistic regression models showed that Blanding's turtles have more specific habitat preferences at the location scale. All analyses revealed that Snapping turtles have more general habitat selection than do Blanding's turtles. The entire Blanding's turtle provincial range is encompassed within the Snapping turtle provincial range. At the regional scale, the vast majority of the Blanding's turtle population range is confined within the Snapping turtle population range. Snapping turtles are more abundant and easier to detect and trap. This study suggests that protection of Snapping turtle habitat may provide biologically significant protection for Blanding's turtles.

Table of Contents

List of Tables

List of Figures

Introduction

Surrogates are used extensively in the field of ecology to detect or monitor environmental changes that are too difficult or costly to assess directly (Barton *et al*., 2015). Surrogates can be used as proxies for broader sets of species when there are too many species of concern (Wiens *et al*., 2008). There are many types of surrogate species, such as umbrella, flagship, and indicator species, and each type has a specific conservation purpose. Umbrella species are used under the assumption that the protection of their habitat simultaneously protects less spatially demanding species (Caro & O' Doherty, 1999). Umbrella species have been studied to determine the type of habitat or size of an area to be protected (Caro & O' Doherty, 1999; Favreau *et al*., 2006). Flagship species, normally charismatic large mega fauna, are utilized to obtain resources for conservation since they arouse public sympathy (Simberloff, 1998). Lastly, indicator species are proxies used to assess the health of an ecosystem.

Many reptiles are vulnerable to anthropogenic stressors, such as habitat loss, climate change, and environmental pollution; unfortunately, extinction is a likely consequence (Gibbons *et al*., 2000). Turtles are particularly sensitive to human impacts due to their longevity, late sexual maturation, and naturally low rate of hatchling recruitment (Congdon *et al*., 1983, 1987; Congdon, 1993; Araújo *et al*., 2006; Beaudry, De Maynadier & Hunter, 2008). Approximately 40% of the world's turtle species are currently listed as globally threatened by the International Union for Conservation of Nature (Rhodin *et al*., 2010).

The purpose of this study was to determine if Snapping turtles (*Chelydra serpentina*) can be used as an umbrella species for Blanding's turtles (*Emydoidea blandingii*) in the province of Ontario, Canada. Snapping turtles are Canada's largest freshwater turtle and are currently listed as Special Concern under the Ontario Endangered Species Act and under the federal Species at

Risk Act. Snapping turtles are aquatic habitat generalists (Paterson *et al*., 2012). Blanding's turtles primarily reside in wetlands with abundant aquatic vegetation (Millar & Blouin-Demers, 2011). However, Blanding's turtles often travel long distances on land to reach other wetlands and to find nesting sites (Millar & Blouin-Demers, 2011). The Great Lakes/St. Lawrence population of Blanding's turtles is currently listed as Threatened under the Ontario Endangered Species Act and under the federal Species at Risk Act.

The general criteria used to identify a potential umbrella species include: 1) well-known natural history and ecology; 2) spatial overlap with co-occurring species of concern; and 3) relative ease of sampling (Caro & O'Doherty, 1999; Fleishman *et al*., 2000; Seddon & Leech, 2008). This study addressed these three criteria to determine whether Snapping turtles could be used as a surrogate for Blanding's turtles. To gain further insight into Snapping and Blanding's turtle natural history and ecology, we compared their respective habitat selection across three spatial scales: provincial, population, and location. The first-order habitat selection can be defined as the selection of the geographical range (Johnson, 1980). In this study, Ontario-wide selection was determined and compared, but it is important to note that both species are found in other provinces and states. Within the geographical range, second-order or macrohabitat selection determines the home range of an individual. Third-order habitat selection pertains to the usage made of various habitat components within the home range (Johnson, 1980). Studying habitat selection at multiple scales provided a more comprehensive understanding of a species' habitat preferences. Strong selection at a large scale (i.e. provincial) does not imply strong selection at a smaller scale (i.e. home range). The other two general umbrella species criteria were assessed. We studied the overlap of Blanding's and Snapping turtles provincial and population ranges. We also compared the relative ease of sampling each species.

Methodology

Study site

This study was conducted on Canadian Nuclear Laboratories lands at Chalk River Laboratories (CRL, 38.7 km^2) in Chalk River, Ontario. Approximately 1% of the site houses infrastructure, while the rest is composed of wetlands, forests, lakes, and a network of gravel roads to access dispersed environmental monitoring stations.

Radiotelemetry

Turtles were captured using hoop nets baited with canned sardines or by hand during road surveys. In total, 27 Snapping turtles and 24 Blanding's turtles were captured. We fitted radiotransmitters on 21 Blanding's and 13 Snapping turtles (Holohil SI-2FT, weighing 16 g with 24 months of battery life). We attached the transmitters to the rear marginal scutes of the carapace with stainless steel bolts and nuts. We applied marine silicone to cover the bolts and transmitter edges to prevent them from tangling with aquatic plants. Not all turtles were fitted with transmitters. If the transmitter weight represented more than 5 % of a turtle's body mass, we did not attach a transmitter. Turtles were released at their site of capture within 24 hours and were relocated every 3-4 days during the summers of 2014 and 2015. Upon each relocation, the Universal Transverse Mercator (UTM) coordinates were recorded using a GPS (Garmin GPSMap 76, Olathe, Kansas, USA; accuracy of 2-5 m) and habitat features were assessed and recorded.

Habitat selection at the provincial scale

Ontario-wide observations for Blanding's and Snapping turtles were obtained from the Natural Heritage Information Center (n = 11,629 and n = 12,125, respectively). Provincial ranges were created by tracing a minimum convex polygon (MCP) around all points of a species, then intersecting this polygon with a polygon representing Ontario. To maintain independence for the habitat selection analysis, we selected the maximum number of non-overlapping points that were at least 2 km apart for Blanding's turtles and at least 1.5 km apart for Snapping turtles using the Create Random Points tool in ArcGIS. Buffers were created to encompass the approximate area used by each individual. The radii of the circular buffers corresponded to the highest published mean annual home range length divided by two for Blanding's turtles (ca. 1 km; Hamernick, 2000) and for Snapping turtles (ca. 750 m; Brown *et al*., 1994). Provincial land cover was obtained from the Ontario Land Cover Dataset (OMNR, 1998). We derived 11 classes of land cover (Table 1). These data were collected between 1991 and 1998 at a spatial resolution of 25 m. A compositional analysis was conducted in R 3.2.2 (R Development Core Team, 2015) to determine Snapping and Blanding's turtle habitat use (habitat composition of buffers) versus habitat availability (habitat composition of population ranges) in Ontario (Aebischer *et al*., 1993). The null hypothesis of this statistical test is that turtles use habitats randomly. If habitat were not used randomly, the program produced a matrix that ranked the habitats in order of preference. Pairwise comparisons determined whether or not the ranks significantly differed. Individuals were the sampling units.

Habitat selection at the population scale

Population ranges were determined by tracing MCPs around all the points of a species within the CRL property. Kernel density estimators were employed to study habitat usage. These kernels are non-parametric estimators which produce a distribution that estimates the likelihood of finding the animal at any particular location within its home range (Powell, 2000). The kernel smoothing factor was adjusted until the area of the 95% kernel equalled the area of the MCP (Row & Blouin-Demers, 2006a). Kernels were derived with the "ks", "maptools" and "adehabitatHS" packages in R version 3.2.2. A compositional analysis was conducted to determine Snapping and Blanding's turtle habitat use (home range composition) versus habitat availability (population range composition). Individuals were the sampling units.

Microhabitat selection at the location scale

A paired random plot was associated with each radiotelemetry location. The location of this random plot was determined by walking a random distance between 10 and 50 m (an approximation of Blanding's and Snapping turtle daily movements), in a direction between 0° and 360° that was randomly generated (Millar & Blouin-Demers, 2011). In the paired design, each turtle location was compared to its paired random location to control for variations in environmental conditions and to ensure that the random locations were available to the individual (Row & Blouin-Demers, 2006b).

We assessed biological and physical habitat features at each relocation. Within a 1 m radius circle, we studied vegetation and substrate composition, measured the air and water temperatures, and determined the water depth. In total, 28 variables were collected. Certain vegetation and substrate types were pooled together into biologically relevant variables. Other variables contained mostly null values; therefore, they were not included in the analysis. The process of combining variables together and eliminating "null" variables reduced the variable count from 28 to 8. The 8 variables used in the analysis were: air temperature (°C), water temperature (°C), water depth (cm), emergent vegetation (%), floating vegetation (%), submerged vegetation (%), open water (%), and organic substrate (%) (Table 2). The organic substrate variable was the combination of hummus, detritus, peat, and muck (Marchand & Litvaitis, 2004). We included 3 vegetation type variables in our analysis: emergents, floating, and submerged. The emergent plant variable included herbaceous emergents (narrow-leaved, robust, and broad-leaved) and woody emergents (low shrubs) (Edge & al., 2010; Millar & Blouin-Demers, 2011). The other variables consisted of physical ecosystem features: water depth (cm), open water (%), air temperature (°C), and water temperature (°C). Since there were a few missing water temperatures, group means were substituted (Snapping turtle mean = 20.3°C, 11% of total; Blanding's turtle mean = 22.2°C, 12% of total). Submerged vegetation values were always "low" at Snapping turtle relocations and random plots; therefore, this variable was not included in the Snapping turtle model.

Matched-paired logistic regressions were performed for both species using R version 3.2.2. The goal of any logistic model is to estimate the probability of a binary response based on many independent variables. The dependent variable is categorical and binary: presence or absence of a turtle (1 and 0, respectively). All 8 variables were included in a bidirectional stepwise logistic regression. The model with the lowest Akaike's Information Criterion (AIC) was selected (Millar & Blouin-Demers, 2011). The logistic regression odd ratios were converted into probabilities. The fit of the each model was evaluated using the likelihood ratio statistic (Hosmer and Lemeshow, 2000). Finally, a compositional analysis was conducted to determine

Snapping and Blanding’s turtle habitat use (relocation habitats) versus habitat availability (home range composition). Individuals were the sampling units.

Results

Habitat selection at the provincial scale

The Snapping turtle provincial range (429,000 km^2) was larger than the Blanding's turtle provincial range (159,000 km^2; Figure 1). The entire Blanding's turtle range is contained within the Snapping turtle range.

A parametric test was used to test for Blanding's turtle selection at the provincial scale. Habitats were ranked as indicated in Figure 2. Pairwise comparisons revealed that Forest was the preferred habitat, followed by Water and then Marsh. Peatland and Swamp were considered interchangeable at alpha = 0.05. All wetland types, Forest, and Water were used more than their respective availabilities (Table 3). Cropland was used less than its availability.

A parametric test was also used to test for Snapping turtle selection at the provincial scale. Habitats were ranked as indicated in Figure 3. Pairwise comparisons revealed that Forest was the preferred habitat, followed by Cropland, Swamp, and Pasture, which were considered interchangeable at alpha = 0.05. Marsh held the fifth rank. Marsh, Swamp, and Cropland were used more than their respective availabilities, whereas Peatland, Water, and Forest were used less than their respective availabilities (Table 4).

The 11 habitat types were then ranked as a function of their percentage value within the circular buffers (Table 5). Both species had the same first 5 ranks:
Forest > Cropland > Water > Pasture > Swamp. In addition, the 3 types of wetlands had the same order of importance (Swamp > Marsh = Peatland) and approximately the same percentages.

Habitat selection at the population scale

At CRL, Blanding's and Snapping turtle population range sizes were 2.7 km^2 and 10.1 km^2, respectively. Overlap calculations revealed that 93% of the Blanding's turtle population range is contained within the Snapping turtle population range (Figure 4).

All Blanding's turtle individuals had their associated kernels (n = 19). Snapping turtle individual home ranges were represented by kernels (n = 6) or MCPs when there were insufficient location points to generate kernels (n = 6). Population kernels were generated for each species. The average individual home range size for Blanding's and Snapping turtles were 11.3 ha and 4.0 ha, respectively. A two-tailed t-test confirmed that they significantly differed in size ($p = 0.045$). At the individual home range level, 18% of Blanding's turtle home ranges were contained within Snapping turtles home ranges.

A parametric test was used to test for Blanding's turtle selection at the population scale. Habitats were ranked as Marsh > Upland > Bog > Swamp > Lake (Figure 5). Pairwise comparisons revealed that Marsh was the preferred habitat type. Upland and Bog were considered interchangeable, as were Bog and Swamp. Swamp, Lake, and Upland were used less than their respective availabilities (Table 6).

A randomization test was used to examine Snapping turtle selection at the population scale because of the presence of zeros in the matrix. Habitats were ranked as Marsh > Upland > Bog > Swamp > Lake (Figure 6). Pairwise comparisons revealed that Marsh, Upland, and Bog were considered interchangeable, as were Bog, Swamp, and Lake. Swamp, Lake, and Upland were used less than their respective availabilities (Table 7).

Microhabitat selection at the location scale

A non-parametric randomization test was used to examine Blanding's turtle selection at the location scale because of the presence of zeros in the matrix. Some habitat types were not available to all individuals; consequently, they were eliminated from the analysis. Lake was eliminated since it was not available within any home range, and Swamp was also eliminated as it was only available within one home range (Aebischer *et al*., 1993). Habitats were ranked as Marsh > Bog > Upland. Upland was used much less than it was available (Table 6). Pairwise comparisons revealed that Marsh was preferred over Upland (Figure 7). Marsh and Bog were considered interchangeable, as were Bog and Upland.

A randomization test was used to assess Snapping turtle selection at the location scale. Lake and Upland were eliminated because they were not used by any individual. Habitats were ranked as Marsh > Swamp > Bog. Marsh and Swamp were used much more than they were available, whereas Bog was used less than it was available (Table 7). Pairwise comparisons revealed that all habitats were interchangeable in terms of preference (Figure 8).

Blanding's turtle microhabitat data from 306 relocations, with the 306 corresponding random paired locations, were used for logistic regression analysis. The model with the lowest AIC value (AIC = 412.33) had the variables air temperature, water temperature, water depth, open water, emergent vegetation, and floating vegetation and was statistically significant (log ratio = 23.87, $R^2 = 0.038$, $p = 0.0006$). Based on the odds ratios, Blanding's turtles selected warmer air temperatures, colder and deeper water, and preferred areas with abundant emergent and floating vegetation (Table 8; Figure 9).

Snapping turtle microhabitat data from 86 relocations, with the 86 corresponding random paired locations, were used for logistic regression analysis. The model with the lowest AIC value

(AIC = 98.62) had the variables air temperature and open water and was statistically significant (log ratio = 24.61, $R^2 = 0.133$, $p < 0.0001$). Based on the odds ratios, Snapping turtles selected colder air temperatures and areas with more open water (Table 9; Figure 10).

Discussion

Habitat selection at the provincial scale

Compositional analyses showed that Forest was the preferred habitat for both species (Figures 1 and 2). Interestingly, Cropland and Pasture were highly ranked for Snapping turtles. Snapping turtles have a more widespread distribution than Blanding's turtles (Figure 1). They are also aquatic habitat generalists (Paterson *et al*., 2012) and can persist in urbanized water bodies such as irrigation canals (SARPR, 2016). The similar habitat composition within the circular buffers of both species provides convincing evidence that Blanding's and Snapping turtles select similar habitats at the provincial scale (Table 5).

Habitat selection at the population scale

Compositional analyses revealed that Blanding's and Snapping turtles possess the same habitat preference ranks at the population scale (Figures 5 and 6). However, Snapping turtle selection was more general (i.e. habitats were considered more interchangeable).

Microhabitat selection at the location scale

Marsh was the most important habitat for both species (Figure 7 and 8). Both species considered Marsh and Bog to be interchangeable. At CRL, we found that Blanding's turtles used Upland more than Snapping turtles. However, it is well known that Snapping turtles can migrate considerable distances overland (Anderson, 1965). Snapping turtles used all three wetlands interchangeably.

The logistic regression model which best predicted Blanding's turtle selection indicated that this species preferentially selected emergent and floating vegetation. The best model for

Snapping turtle selection showed that emergent and floating vegetation did not significantly increase the probability of selection. However, Paisley *et al*. (2009) noted that Snapping turtles used these two plant types disproportionately more than they were available. This suggests that both species select similar vegetation types. Furthermore, the Blanding's turtle logistic regression model had 6 variables, whereas the Snapping turtle model only had 2 variables. This implies that Blanding's turtles have more specific habitat selection than Snapping turtles.

Adaptation of umbrella species: specialists or generalists

Analyses at the three spatial scales revealed that Snapping turtles have more general habitat selection than do Blanding's turtles. It has been suggested that species with specialized resource requirements (i.e. specialists) may be more suitable umbrella species than generalists (Ozaki *et al*., 2006; Roberge *et al*., 2008). However, habitat specialists may be too specialized, thus the protection of their habitat may not protect other species (Seddon & Leech, 2008). While conducting a meta-analysis of 15 umbrella species studies, Branton & Richardson (2011) found that differences in co-occurring species richness and abundance were not consistently related to whether an umbrella species was a generalist or specialist. Therefore, we cannot omit the possibility that habitat generalists such as Snapping turtles can be adequate umbrella species.

Spatial overlap

An umbrella species' protection is transferable throughout its range; umbrellas with a large geographic range provide widespread protection for other species (Caro and O'Doherty, 1999). At the provincial scale, the entire Blanding's turtle range was contained within the Snapping turtle range (Figure 1). At CRL, 93% of the Blanding's population range overlapped with the

Snapping turtle population range (Figure 4). Although the overlap was not 100% at CRL, we suspect that the Snapping turtle population range was vastly underestimated. The focus of our field seasons was on capturing and studying Blanding's turtles, since CRL's wildlife management efforts were geared towards protecting threatened species. We invested much less time and effort into assessing Snapping turtles, thus we do not fully appreciate their spatial distribution at CRL. We concluded that there is significant overlap between Snapping and Blanding's turtle provincial and population ranges.

At CRL, we set traps in 15 wetland and lake locations. Blanding's and Snapping turtles were successfully trapped in 3 and 10 locations, respectively. In the 3 wetlands where Blanding's turtles were captured, Snapping turtles were captured as well. Our trapping results demonstrate that Snapping turtles are probably present wherever Blanding's turtles are located.

Relative ease of monitoring

Monitoring is an important umbrella species criterion to consider. It is much more feasible to implement a surrogate approach if the umbrella species can be easily monitored. Monitoring umbrella species is facilitated if its population size is large (Caro and O'Doherty, 1999).
At CRL, adult-sub-adult population estimates for Blanding's and Snapping turtles were determined with capture-re-capture data and a corrected Petersen-Lincoln model. The estimated Snapping turtle population (53 ± 15 individuals) was larger than the estimated Blanding's turtle population (25 ± 4 individuals).

A turtle population study conducted in Point Pelee National Park also demonstrated that Snapping turtles were probably much more abundant than Blanding's turtles (Browne & Hecnar, 2007). During their 2001-2002 field season, Browne & Hecnar captured 421 Snapping turtles and 85 Blanding's turtles in total, including recaptures. Their catch per effort (total amount of individual turtle captures, excluding recaptures, divided by the amount of trap days) was greater for Snapping turtles (0.1) than for Blanding's turtles (0.01). Browne & Hecnar employed a variety of trapping methods, including hoop nets, basking traps, wire cage live traps, and hand captures, to reduce potential bias. This provides strong evidence that Snapping turtles are more abundant and that they are easier to detect.

Precautionary principle

The Endangered Species Act (2007) explicitly recognizes the precautionary principle. Although many interpretations of this principle exist, the ESA recognizes the definition proposed by the international Convention on Biological Diversity: "Where there is a threat of significant reduction or loss of biological diversity, lack of full scientific certainty should not be used as a reason for postponing measures to avoid or minimize such a threat." This principle can certainly be applied to turtle conservation. Blanding's turtles are significantly threatened by many anthropogenic stressors (Gibbons *et al*., 2000). We lack the scientific certainty of knowing the full extent of their critical habitats. Therefore, measures to avoid and minimize these threats should be implemented. One of these measures consists of protecting more habitat than necessary to ensure complete protection of Blanding's turtle critical habitats; this could be achieved by protecting all Snapping turtle habitat.

Principle 15 of the Rio Declaration on Environment and Development (UN, 1992) states that environmental degradation prevention measures should be "cost-effective". Snapping turtles are more abundant and easier to capture than Blanding's turtles; for that reason, Snapping turtles have the potential of being a cost-effective umbrella species.

Conclusion

We can reasonably formulate two propositions based on the results of this study: 1) Blanding's and Snapping turtles select very similar habitats; and 2) the majority of Blanding's turtle habitats are most likely used by Snapping turtles. In accordance with syllogism logical argumentation, we can establish the following conclusion: by protecting all Snapping turtle habitat, it appears that all Blanding's turtle habitat will also be protected. Further analyses are required to affirm this conclusion, including a spatial overlap analysis at the provincial scale.

Acknowledgements

I would like to thank Dr. Gabriel Blouin-Demers for supporting and mentoring me through this research project. His expertise and efficiency were extremely helpful and appreciated. I would also like the thank Emily Hawkins for sharing her contagious passion for wildlife over two stimulating field work seasons. Thank you Annie Morin at Canada Nuclear Laboratories for supporting my turtle tracking adventures. Thank you so much to René and William at the Geographic, Statistical and Government Information Centre, University of Ottawa, for assisting me with GIS spatial analyses.

Tables

Table 1. Descriptions of the grouped land cover classes used for compositional analysis.

Land cover classes	Descriptions
Marsh	Includes all freshwater coastal and inland marshes.
Peatland	Includes all bogs and fens (i.e. peatlands).
Swamp	Includes deciduous and conifer swamps.
Water	Includes all water bodies that are not categorised as wetlands (i.e. rivers, streams, and lakes).
Forest	Forested areas with greater than 30% forest canopy closure. Includes dense coniferous forests, dense deciduous forests, mixed mainly coniferous forest, mixed mainly deciduous forests, sparse coniferous forest, dense deciduous forests, and mature conifer plantations.
Urban	Clearings for human settlement and economic activity.
Cropland	Row crops, hay, and open soil in areas of agricultural land use.
Pasture	Open grassland with sparse shrubs mapped in agricultural areas; includes orchards.
Rock	Clearings for mining activity, aggregate quarries, and bedrock outcrops.
Alvar	Homogeneous areas of dry grassland growing on thin soils over a limestone substrate.
Cut & Burn (CB)	Forest clear-cuts and burns; includes new cutovers, new burns, and old cutovers and burns.

Table 2. Variables used to quantify microhabitat for Blanding's and Snapping turtles at CRL, Ontario, Canada.

Variable	Classes[a]	Description
Emergent veg	Low Medium-low Medium-high High	Percentage of area with emergent vegetation.
Submerged veg	Low Medium-low Medium-high High	Percentage of area with submerged vegetation.
Floating veg	Low Medium-low Medium-high High	Percentage of area with floating vegetation.
Open water	Low Medium-low Medium-high High	Percentage of area with open water.
Organic substrate	Low Medium-low Medium-high High	Percentage of the substrate that was organic (i.e. hummus, detritus, peat, and muck).
Water depth		Distance (cm) between the water surface and bottom.
Water temp		Water temperature (°C) a few cm below the surface of the water.
Air temp		Air temperature (°C) a few cm above the surface of the water.

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

Table 3. Mean percentage of habitat types available and used by Blanding's turtles in Ontario, Canada (n = 1,392).

Habitat type	% provincial range	% circular buffers	% point locations
Water	7	12 ± 0.5	9
Marsh	0.3	1 ± 0.2	2
Swamp	2	4 ± 0.2	4
Peatland	1	1 ± 0.1	2
Forest	51	55 ± 1	48
Urban	2	2 ± 0.3	4
Cropland	28	13 ± 1	17
Pasture	6	6 ± 0.3	8
Rock	2	3 ± 0.3	4
Alvar	0.5	1 ± 0.2	1
CB	1	1 ± 0.1	1

Table 4. Mean percentage of habitat types available and used by Snapping turtles in Ontario, Canada (n = 3,425).

Habitat type	% provincial range	% circular buffers	% point locations
Water	12	10 ± 0.3	11
Marsh	0.1	1 ± 0.1	2
Swamp	1	5 ± 0.2	6
Peatland	2	1 ± 0.1	1
Forest	63	40 ± 0.5	36
Urban	1	3 ± 0.2	3
Cropland	11	31 ± 0.5	31
Pasture	3	7 ± 0.2	7
Rock	1	1 ± 0.1	1
Alvar	0.2	0.5 ± 0.1	0.5
CB	7	0.5 ± 0.1	1

Table 5. Habitat composition of circular buffers for Snapping and Blanding's turtles in Ontario, Canada. Habitats are ranked based on decreasing mean percentage value.

Rank	Blanding's turtle habitat (%)	Snapping turtle habitat (%)
1	Forest (55)	Forest (40)
2	Crop (13)	Crop (31)
3	Water (12)	Water (10)
4	Pasture (6)	Pasture (7)
5	Swamp (4)	Swamp (5)
6	Rock (3)	Urban (3)
7	Urban (2)	Marsh = Peat = Rock[a] (1)
8	Alvar = CB = Marsh = Peat[a] (1)	Alvar = CB[a] (0.5)

[a] These habitats have the same ranking.

Table 6. Mean percentage of habitat types available and used by Blanding's turtles at CRL, Ontario, Canada (n = 19).

Habitat Type	% Population Range	% Home Range	% Locations
Marsh	4.68	65.09 ± 24.44	82.63 ± 7.42
Bog	0.75	9.34 ± 4.56	15.34 ± 7.42
Swamp	0.59	0.53 ± 0.51	0.79 ± 0.77
Lake	5.64	0	0
Upland	88.34	27.98 ± 2.42	1.24 ± 0.67

Table 7. Mean percent of habitat types available and used by Snapping turtles at CRL, Ontario, Canada (n = 12).

Habitat Type	% Population Range	% Home Range	% Locations
Marsh	11.05	47.01 ± 9.15	71 ± 13.1
Bog	8.33	18.09 ± 10.46	16.67 ± 11.74
Swamp	3.5	0.21 ± 0.21	4.08 ± 2.42
Lake	4.76	4.06 ± 4.43	0
Upland	72.35	30.26 ± 5.43	0

Table 8. Coefficients and odds ratios for the paired-logistic regression model explaining microhabitat use by Blanding's turtles at CRL, Ontario, Canada.

Variable	Coefficient	SE	Increase	Odds ratio	95% CI[a]
Air temp	0.052	0.028	1°C	1.05	(1.0,1.11)
Water depth	0.238	0.132	25 cm	1.27	(0.98, 1.64)
Emergent vegetation	0.424	0.164	25%	1.53	(1.11, 2.11)
Floating vegetation	0.644	0.291	25%	1.9	(1.08, 3.37)
Open water	0.405	0.148	25%	1.5	(1.12, 2.0)
Water temp	-0.047	0.028	1°C	0.95	(0.9,1.01)

[a] 95% CI from odds ratios.

Table 9. Coefficients and odds ratios for the paired-logistic regression model explaining microhabitat use by Snapping turtles at CRL, Ontario, Canada.

Variable	Coefficient	SE	Increase	Odds ratio	95% CI[a]
Air temperature	-0.178	0.124	1°C	0.84	(0.66,1.07)
Open water	0.719	0.186	25%	2.05	(1.42, 2.95)

[a] 95% CI from odds ratios.

Figures

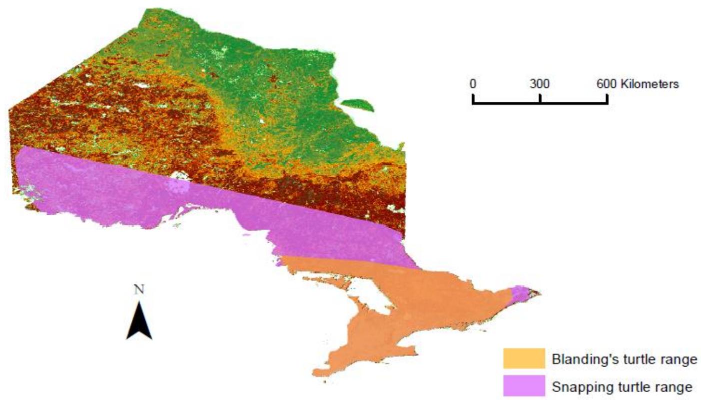

Figure 1. Blanding’s and Snapping turtle provincial ranges, Ontario, Canada.

Forest > Water > Marsh > Peatland > Swamp > Pasture > Alvar > Rock > CB > Urban > Cropland

Figure 2. Habitat rankings for provincial habitat selection of Ontario Blanding’s turtles (Parametric test, Wilk’s lambda = 0.190, $p < 0.001$). Decreasing preference is indicated from left to right. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

Forest > Cropland > Swamp > Pasture > Marsh > Alvar > Water > Urban > Rock > Peatland > CB

Figure 3. Habitat rankings for provincial habitat selection of Ontario Snapping turtles (Parametric test, Wilk’s lambda = 0.104, $p < 0.001$). Decreasing preference is indicated from left to right. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

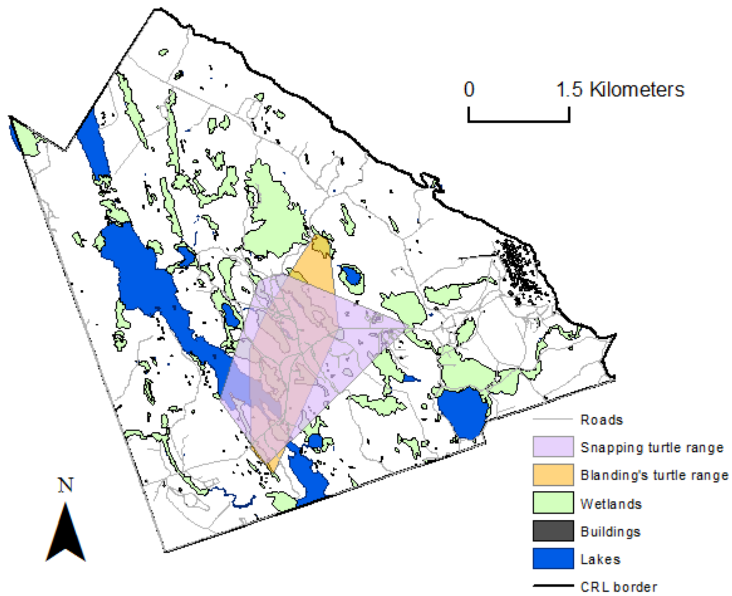

Figure 4. Blanding’s and Snapping turtle regional population ranges at CRL, Ontario, Canada.

Marsh > Upland > Bog > Swamp > Lake

Figure 5. Habitat rankings for population habitat selection of CRL Blanding’s turtles (Parametric test, Wilk’s lambda = 0.006, $p < 0.001$). Decreasing preference is indicated from left to right. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

Marsh > Upland > Bog > Swamp > Lake

Figure 6. Habitat rankings for population habitat selection of CRL Snapping turtles (Randomized test, Weighted mean lambda = 0.309, $p = 0.02$). Decreasing preference is indicated from left to right. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

Marsh > Bog > Upland

Figure 7. Habitat rankings for location habitat selection of CRL Blanding's turtles (Randomized test, Weighted mean lambda = 0.846, p = 0.046). Decreasing preference is indicated from left to right. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

Marsh > Swamp > Bog

Figure 8. Habitat rankings for location habitat selection of CRL Snapping turtles (Randomized test, Weighted mean lambda = 0.923, p = 0.968). Decreasing preference is indicated from left to right. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

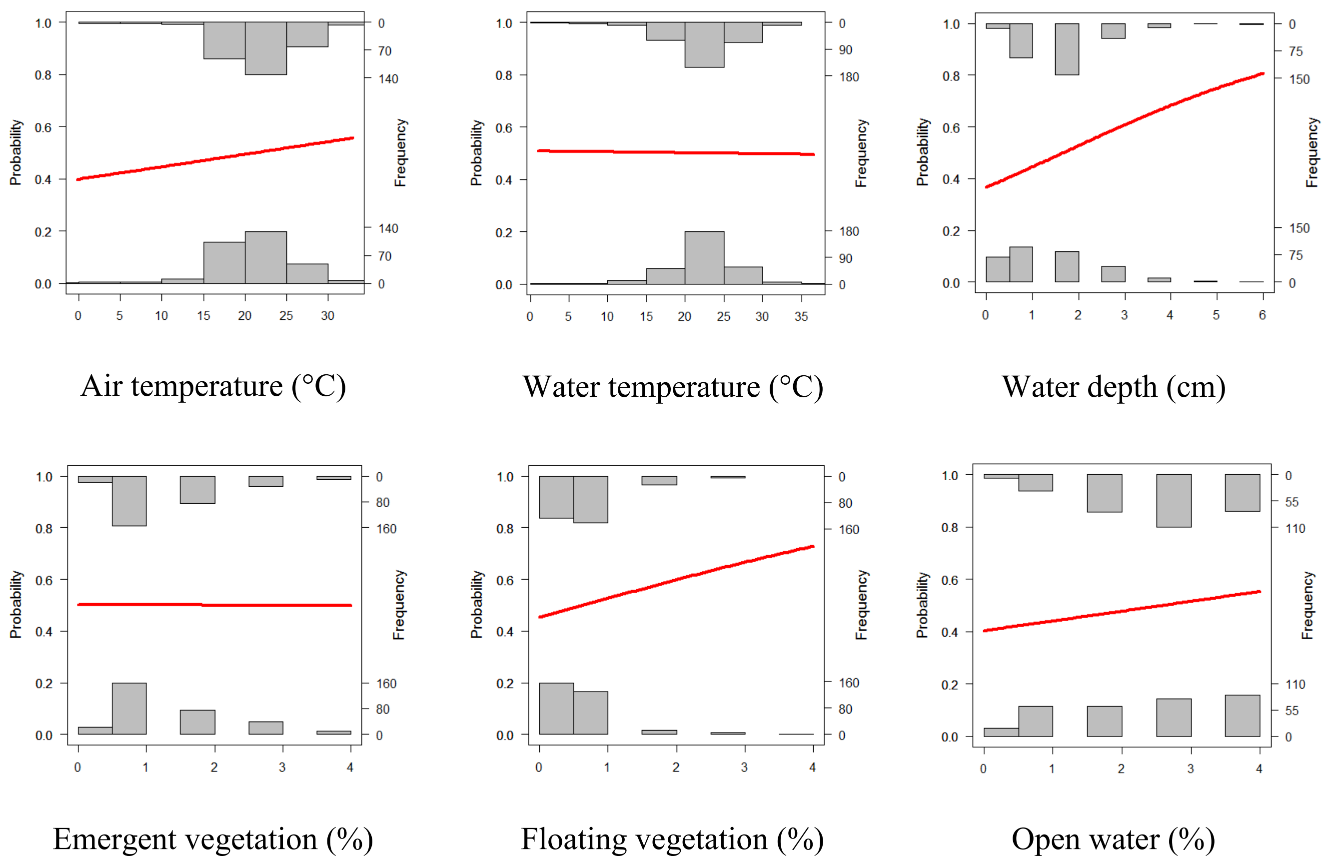

Figure 9. Frequency of observed data (histograms) and predicted probability of selection as air temperature, water temperature, water depth, percentage of emergent vegetation, percentage of floating vegetation, and percentage of open water increase for Blanding's turtles (1 = turtle locations, 0 = random locations) followed by radio-telemetry at CRL, Ontario, Canada. A 1°C increase in air temperature resulted in a 5% increase in the probability of selection; a 1°C increase in water temperature resulted in a 5% decrease in the probability of selection; a 25 cm increase in water depth resulted in a 21% increase in the probability of selection; a 25% increase in emergent vegetation resulted in a 35% increase in the probability of selection; a 25% increase in floating vegetation resulted in a 47% increase in the probability of selection; and a 25% increase in open water resulted in a 33% increase in the probability of selection.

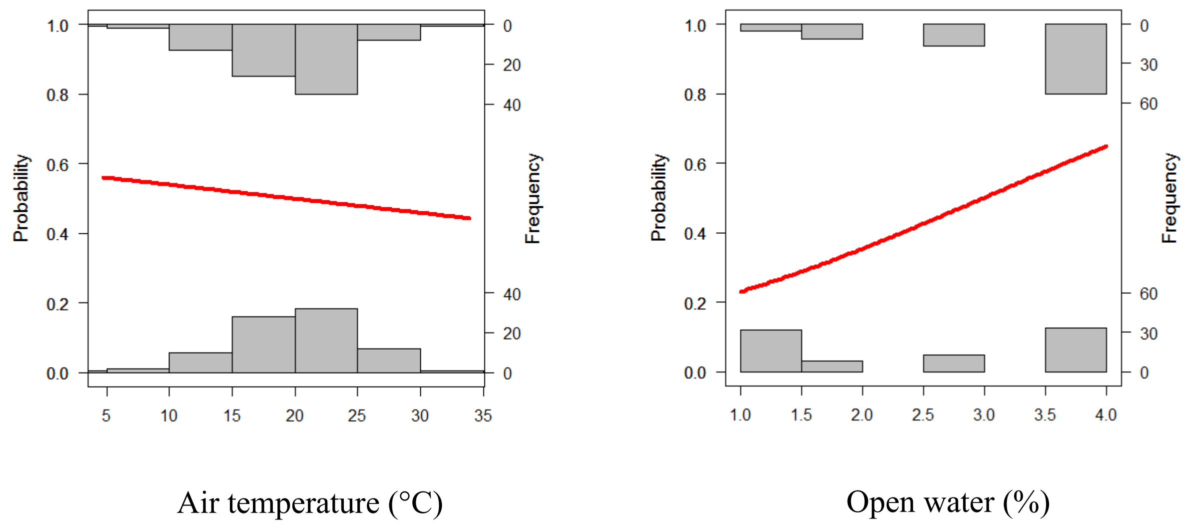

Figure 10. Frequency of observed data (histograms) and predicted probability of selection as air temperature and percentage of open water increase for Snapping turtles (1 = turtle locations, 0 = random locations) followed by radio-telemetry at CRL, Ontario, Canada. A 1°C increase in air temperature resulted in a 14% decrease in the probability of selection; a 25% increase in open water resulted in a 51% increase in the probability of selection.

Literature Cited

Aebischer, N.J., Robertson, P.A. & Kenward, R.E. (1993) Compositional analysis of habitat use from animal radio-tracking data. Nicholas J. Aebischer, Peter A. Robertson, Robert E. Kenward, 74, 1313–1325.

Anderson, P. (1965) The reptiles of Missouri. University of Missouri Press, Columbia, 6-6.

Araújo, M. B., Thuiller, W. & Pearson, R. G. (2006) Climate warming and the decline of amphibians and reptiles in Europe. Journal of Biogeography, 33, 1712–1728.

Barton, P.S., Pierson, J.C., Westgate, M.J., Lane, P.W. & Lindenmayer, D.B. (2015) Learning from clinical medicine to improve the use of surrogates in ecology. Oikos, 124, 391-398.

Beaudry, F., DeMaynadier, P. G. & Hunter, M. L. (2008) Identifying road mortality threat at multiple spatial scales for semi-aquatic turtles. Biological Conservation, 141, 2550–2563.

Berger, J. (1997) Population constraints associated with the use of black rhinos as an umbrella species for desert herbivores. Conservation Biology, 11, 69–78.

Branton, M. & Richardson, J. S. (2011) Assessing the Value of the Umbrella-Species Concept for Conservation Planning with Meta-Analysis. Conservation Biology, 25, 9-20.

Brown, G.P., Bishop, C.A. & Brooks, R.J. (1994) Growth Rate, Reproductive Output, and Temperature Selection of Snapping Turtles in Habitats of Different Productivities. Journal of Herpetology, 28, 405-410.

Browne, C.L. & Hecnar, S.J. (2007) Species loss and shifting population structure of freshwater turtles despite habitat protection. Biological Conservation, 138, 421-429.

Caro, T.M. & O'Doherty, G. (1999) On the use of surrogate species in conservation biology. Conservation Biology, 13, 805–814.

Congdon, J. D., Breitenbach, G. L., Van Loben Sels, R. C. & Donald, W. (1987) Reproduction and nesting ecology of Snapping turtles (Chelydra serpentina) in Southeastern Michigan. Herpetologica, 43, 39–54.

Congdon, J. D., Dunham, A. & Van Loben Sels, E. R. C. (1993) Delayed sexual maturity and demographics of Blanding ' s turtles (Emydoidea blandingii) for Conservation: Implications and management of long-lived organisms. Conservation Biology, 7, 826-833.

Congdon, J. D., Tinkle, D. W., Breitenbach, G. L. & Van Loben Sels, R. C. (1983) Nesting ecology and hatching success in the turtle Emydoidea blandingi. Herpetologica, 39, 417-429.

Edge, C.B., Steinberg, B.D., Brooks, R.J. & Litzgus, J. D. (2010) Pristine landscape habitat selection by Blanding's turtles (Emydoidea blandingii) in a relatively pristine landscape. Écoscience, 17, 90–99.

Endangered Species Act (2007) S.O. 2007, Chapter 6.

Favreau, J.M., Drew, C.A., Hess, G.R., Rubino, M.J., Koch, F.H. & Eschelbach, K. A. (2006) Recommendations for assessing the effectiveness of surrogate species approaches. Biodiversity and Conservation, 15, 3949–3969.

Fleishman, E., Murphy, D.D. & Brussard, P.F. (2000). A new method for selection of umbrella species for conservation planning. Ecological Applications, 10, 569–579.

Gibbons, J. W., Scott, D. E., Travis, J. R., Buhlmann, K. A., Tuberville, T. D., Metts, B. S., Greene, J. L., Mills, T., Leiden, Y., Poppy, S. & Winne, C. T. (2000) The global decline of reptiles, déjà vu amphibians. Bioscience, 50, 653–666.

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.

Hosmer, D.W. & Lemeshow, S. (2000). Applied Logistic Regression. 2nd ed. John Wiley and Sons, New York.

Johnson, D.H. (1980) The comparison of usage and availability measurements for evaluating resource preference. Ecology, 61, 65-71.

Marchand, M.N., & Litvaitis, J.A. (2004) Effects of Habitat Features and Landscape Composition on the Population Structure of a Common Aquatic Turtle in a Region Undergoing Rapid Development. Conservation Biology 18, 758–767.

Millar, C. S. & Blouin-Demers, G. (2011) Spatial ecology and seasonal activity of Blanding's turtles (*Emydoidea blandingii*) in Ontario, Canada. Journal of Herpetology, 45, 370–378.

Ontario Ministry of Natural Resources (1998) Ontario Landcover Database, remote-sensing image, Peterborough, ON.

Ozaki, K., Isono, M., Kawahara, T., Iida, S., Kudo, T. & Fukuyama, K. (2006) A mechanistic approach to evaluation of umbrella species as conservation surrogates. Conservation Biology, 20, 1507–1515.

Paisley, R.N., Wetzel, J. F., Nelson, J. S., Stetzer, C. & Hamernick, M. G. (2009) Survival andspatial ecology of the snapping turtle, Chelydra serpentina , on the Upper Mississippi River. The Canadian Field Naturalist, 329–337.

Paterson, J.E., Steinberg, B.D. & Litzgus, J.D. (2012) Generally specialized or especially general? Habitat selection by Snapping Turtles (*Chelydra serpentina*) in central Ontario. Can. J. Zool., 90, 139-149.

Powell, R. A. (2000) Animal home ranges and territories and home range estimators. Pages 65–110 *in* L. Boitani & T. Fuller (eds.). Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press, New York, New York.

R Core Team (2015). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/.

Rhodin, A.G.J., van Dijk, P.P., Iverson, J.B. & Shaffer, H.B. (2010) Update: Annotated checklist of taxonomy, synonymy, distribution, and conservation status. Chelonian Research Monographs, 5, 85–164.

Roberge, J.M., Mikusinski, G. & Svensson, S. (2008) The white-backed woodpecker: umbrella species for forest conservation planning? Biodiversity and Conservation, 17, 2479–2494.

Row, J. R. & Blouin-Demers, G. (2006a) Kernels are not accurate estimators of home-range size for herpetofauna. Copeia, 4, 797–802.

Row, J.R. & Blouin-Demers, G. (2006b) Thermal quality influences habitat selection at multiple spatial scales in milksnakes. Écoscience, 13, 443-450.

Seddon, P. J., and Leech, T. (2008) Conservation short cut, or long and winding road? A critique of umbrella species criteria. Oryx, 42, 240–245.

Simberloff, D. (1998) Flagships, umbrellas, and keystones: is single-species management passé in the landscape era? Biological Conservation, 83, 247-257.

Species at Risk Public Registry (2016) Species Profile: Snapping Turtle. URL: http://www.registrelep-sararegistry.gc.ca/species/speciesDetails_e.cfm?sid=1033.

United Nations (1992) Rio Declaration on Environment and Development: Principle 15.

Wiens, J.A., Hayward, G.D., Holthausen, R.S. & Wisdom, M.J. (2008) Using surrogate species and groups for conservation planning and management. BioScience, 58, 241-252.