Herpetology Notes, volume 11: 137-145 (2018) (published online on 10 February 2018)

Can snapping turtles be used as an umbrella species for Blanding's turtles in Ontario, Canada?

Dominic Demers[1,*], Emily Hawkins[1], Annie Morin[2] and Gabriel Blouin-Demers[1]

Abstract. Surrogates are commonly used in conservation biology to protect as many species as possible with limited resources. Umbrella species are used under the assumption that protection of their habitat simultaneously protects less demanding species. The purpose of our study was to evaluate the potential use of snapping turtles (*Chelydra serpentina*, [Linnaeus, 1758]) as an umbrella species for Blanding's turtles (*Emydoidea blandingii*, [Holbrook, 1838]) in Ontario, Canada. We studied habitat selection and spatial overlap of both species at three spatial scales: provincial, population, and location based on sightings reported by the public and on radio-telemetry data. At the provincial and population scales, habitat selection was very similar for both species. Blanding's turtles have more specific habitat preferences than snapping turtles at the population and location scales. The entire Blanding's turtle provincial range is encompassed within the snapping turtle provincial range. Snapping turtles are more abundant and easier to detect than Blanding's turtles. Our study suggests that protection of snapping turtle habitat may also provide protection for Blanding's turtles.

Keywords: *Chelydra serpentina*; *Emydoidea blandingii*; multiple-scale habitat selection; spatial and niche overlap; precautionary principle; specialist; generalist

Introduction

Surrogates are used in conservation to detect or monitor environmental changes that are too difficult or too costly to assess directly (Barton et al., 2015). Surrogate species 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 and O' Doherty, 1999). Umbrella species have been studied to determine the type of habitat or size of an area to be protected (Caro and O' Doherty, 1999; Favreau et al., 2006). Flagship species, normally charismatic megafauna, are used to obtain resources for conservation since they garner 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, and face extinction as a likely consequence (Gibbons et al., 2000). Turtles are particularly sensitive to anthropogenic stressors due to their longevity, late sexual maturation, and naturally low rate of recruitment (Congdon et al., 1983, 1987, 1993; Araújo et al., 2006; Beaudry et al., 2008). Approximately 40% of the World's turtles are currently listed as threatened by the International Union for the Conservation of Nature (van Dijk et al., 2014).

The purpose of our study was to determine whether 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 currently listed as Special Concern under the Ontario Endangered Species Act and under the federal Species at Risk Act, while the Great Lakes/St. Lawrence population of Blanding's turtles is currently listed as Threatened under both aforementioned acts. Snapping turtles are aquatic habitat generalists (Paterson et al., 2012) that occur from Nova Scotia to

[1] Department of Biology, University of Ottawa, Ottawa, Ontario K1N 6N5, Canada
[2] Canadian Nuclear Laboratories, 286 Plant Road, Chalk River, Ontario K0J 1J0, Canada
* Corresponding author. E-mail: ddeme005@uottawa.ca

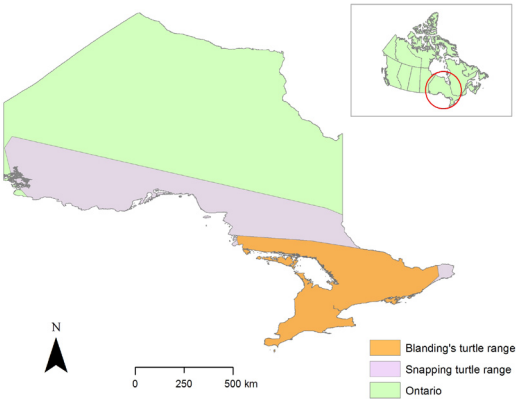

Figure 1. Blanding's and snapping turtle provincial ranges, Ontario, Canada. Note that the entire Blanding's turtle range is contained within the snapping turtle range.

southern Saskatchewan in Canada and south to Texas and Florida in the USA (SARPR, 2017). Blanding's turtles primarily reside in wetlands with abundant aquatic vegetation (Millar and Blouin-Demers, 2011) and occur around the Great Lakes from southwestern Québec to central Nebraska and to Ohio. There are also isolated populations in New York, Massachusetts, New Hampshire, Maine, and Nova Scotia (SARPR, 2017). Both Blanding's turtles (Millar and Blouin-Demers, 2011) and snapping turtles (Anderson, 1965; Obbard and Brooks, 1981) travel long distances on land to reach other wetlands.

The criteria used to assess candidate umbrella species are: 1) well-known natural history and ecology; 2) spatial overlap with co-occurring species of concern; 3) relative ease of monitoring; and 4) moderate negative response to disturbance (Caro and O'Doherty, 1999; Fleishman et al., 2000; Seddon and Leech, 2008; Branton and Richardson, 2011). The most common umbrella species criterion is an extensive geographic range, and thus presumed co-occurrence with numerous other species of concern (Fleury et al., 1998; Simberloff, 1998; Caro and O'Doherty, 1999; Andelman and Fagan, 2000; Rowland et al., 2006). We addressed these criteria to determine whether snapping turtles could be used as an umbrella for Blanding's turtles. We compared habitat selection by the two species at three spatial scales: provincial, population, and location based on sightings reported by the public and on radio-telemetry data.

Materials and Methods

Study site.—We conducted the radio-telemetry portion of our study on Canadian Nuclear Laboratories lands (CNL, 38.7 km^2) in Chalk River, Ontario, Canada (Figures 2 and 3). Approximately 1% of the site is infrastructure, while the rest is composed of wetlands, forest, lakes, and a network of gravel roads.

Radio-telemetry.—We captured turtles with hoop nets baited with canned sardines or by hand. We fitted radio-transmitters (Holohil SI-2FT, 16 g, 24 mo battery life) on 21 Blanding's turtles and 13 snapping turtles (transmitters represented at most 5% of turtle mass). We attached the transmitters to the rear marginal scutes of the carapace with stainless steel bolts and nuts, and applied marine silicone to cover the bolts and transmitter edges to prevent snagging by plants. We released turtles at their site of capture within 24 hrs and relocated them every 3-4 days during the summers of 2014 and 2015. We recorded coordinates of each location with a GPS receiver (Garmin GPSMap 76, Olathe, Kansas, USA; accuracy of 2-5 m).

Habitat selection at the provincial scale.—We obtained observations for Blanding's turtles and snapping turtles reported by the public in Ontario from the Natural Heritage Information Centre (n = 11,629 and n = 12,125, respectively), and then created provincial ranges by tracing a minimum convex polygon (MCP)

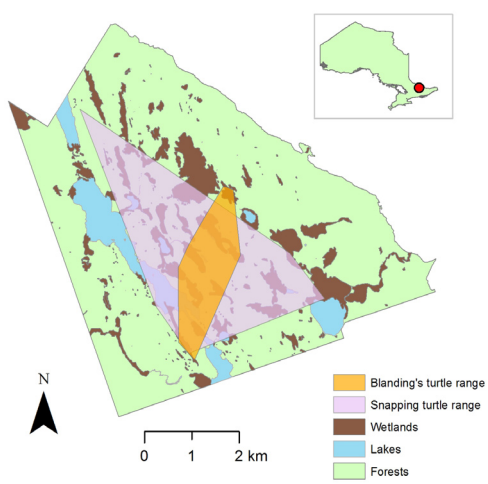

Figure 2. Blanding's and snapping turtle regional population ranges at Canadian Nuclear Laboratories, Chalk River, Ontario, Canada.

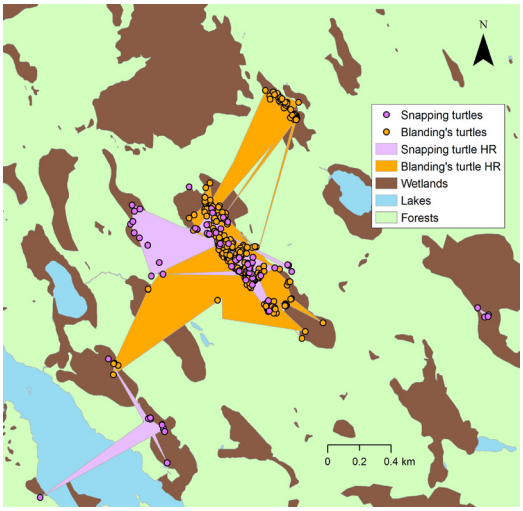

Figure 3. Location of individual Blanding's and snapping turtles and their associated characteristic hull polygon home ranges (HR) at Canadian Nuclear Laboratories, Chalk River, Ontario, Canada.

around all observations for each species (Figure 1). Based on the mean home range area for Blanding's turtles and snapping turtles (ca. 18 ha; Obbard and Brooks, 1981; Brown et al., 1994; Hamernick, 2000; Schuler and Thiel, 2008; Paisley et al., 2009; Edge et al., 2010; Millar and Blouin-Demers, 2011; Fortin et al., 2012; Paterson et al., 2012; Christensen and Chow-Fraser, 2014; Hasler et al., 2015), we traced buffers around turtle observations to approximate the area they could have used. This allowed us to determine habitat preferences for both species at the provincial scale. The buffer (500 m) was determined by the diameter of a circle with the same area as the mean Blanding's and snapping turtle home range, thus encompassing the area around an observation that an individual could use. To reduce clustering of points and overrepresentation of highly sampled regions, we selected a subset of observations separated by at least two buffers (1 km) with the command ecospat.occ.desaggragetion from ecospat R package (n = 2,007 for Blanding's turtles, n = 4,727 for snapping turtles; Thomasson and Blouin-Demers, 2015). We obtained land cover from the Ontario Land Cover Dataset (OMNR, 1998; Table 1) to conduct compositional analyses with the AdehabitatHS package in R 3.4.2 (R Core Team, 2015). Compositional analyses consider the proportional habitat use of individuals and estimate habitat preferences based on MANOVA/MANCOVA linear models (Aebischer et al., 1993). For each species, we compared the habitat composition around turtle observations to that of provincial species ranges (Aebischer et al., 1993).

Habitat selection at the population scale.—We determined population ranges by tracing MCP around all the radio-telemetry locations of each species (Figure 2). To delineate individual home ranges, we employed 95% characteristic hull polygons (CHP) (n = 19 for Blanding's turtles, n = 11 for snapping turtles; Downs and Horner, 2009; Figure 3). We derived CHP with the "maptools" and "adehabitatHR" packages in R version 3.4.2. We conducted compositional analyses by comparing habitat composition of home ranges to that of the population range for each species.

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	Forest clear-cuts and burns; includes new cutovers, new burns, and old cutovers and burns.

Habitat selection at the location scale.—We conducted compositional analyses by comparing the habitat type of a turtle location to the habitat composition of its home range. To determine microhabitat selection, we associated a paired random location with each radio-telemetry location ($n = 306$ for Blanding's turtles, $n = 86$ for snapping turtles) by walking a random distance between 10 and 50 m (an approximation of Blanding's and snapping turtle daily movements) in a random direction (Millar and Blouin-Demers, 2011). Within a 1 m radius circle, we measured air and water temperature (thermometer), water depth (tape measure), emergent vegetation, floating vegetation, submerged vegetation, open water (visual estimate), and organic substrate (sampling substrate manually and estimating organic matter content). We included all 8 variables in a bidirectional stepwise matched-pair logistic regression.

Spatial and niche overlap.—We calculated the extent of spatial overlap of both species' provincial, population, and home ranges with the phi correlation coefficient (Φ). The Φ is used to measure the strength of association between two binary variables; in this case the presence or absence of Blanding's turtles and of snapping turtles. We used four mutually exclusive combinations of these two binary variables to calculate Φ: (1) area mapped as range for Blanding's turtles, but not for snapping turtles; (2) area mapped as range for snapping turtles, but not for Blanding's turtles; (3) area mapped as range for both species; and (4) area not mapped as range for either species (Rowland et al., 2006). We calculated niche equivalency, similarity, and overlap with the ecospat R package and bioclimatic data (Broennimann et al., 2012; Cola et al., 2017).

Table 2. Mean percentage of habitat types available and used by Blanding's turtles ("B", $n = 2{,}007$) and snapping turtles ("S", $n = 4{,}727$) in Ontario, Canada.

Habitat type	% provincial range		% circular buffers	
	B	S	B	S
Water	7.1	11.5	10.3	10.5
Marsh	0.3	0.1	1.9	1.6
Swamp	1.8	0.7	3.7	5.4
Peatland	1.0	2.1	1.5	1.0
Forest	51.0	62.6	55.8	39.1
Urban	2.0	1.0	2.4	3.2
Cropland	27.8	10.9	12.2	30.3
Pasture	6.1	3.0	5.7	6.9
Rock	1.6	0.8	3.9	1.1
Alvar	0.5	0.2	1.6	0.4
CB	0.7	7.0	0.9	0.4

Results

Habitat selection at the provincial scale.—At the provincial scale, Blanding's turtles order of preference for habitats was: Forest > Water ≥ Marsh > Swamp ≥ Peatland > Alvar > Rock > Pasture > Cut & Burn > Urban > Cropland. Pairwise comparisons revealed that Forest was significantly preferred to other land-cover types. Water and Marsh were interchangeable, as were Swamp and Peatland. All wetland types, Forest, and Water were used more than their respective availabilities (Table 2). Cropland was used less than its availability.

For snapping turtles, the order of preference for habitats was: Forest > Cropland ≥ Swamp ≥ Marsh ≥ Pasture > Alvar > Water > Urban > Rock > Peatland > Cut & Burn. Pairwise comparisons revealed that Forest was the significantly preferred habitat, followed by Cropland, Swamp, Marsh, and Pasture, which were interchangeable. Marsh, Swamp, and Cropland were used more than their respective availabilities, whereas Peatland, Water, and Forest were used less than their respective availabilities (Table 2).

Habitat selection at the population scale.—At the population scale, Blanding's turtles and snapping turtles had the same order of preference for habitats: Marsh > Forest > Peatland ≥ Swamp > Water. For both species, pairwise comparisons revealed that Marsh was significantly preferred, followed by Forest. Peatland and Swamp were interchangeable. The mean MCP home range size for Blanding's turtles (13.2 ha) was larger than that of snapping turtles (4.0 ha; $W = 180$, $p < 0.001$). The mean CHP home range size for Blanding's turtles (7.5 ha) was also larger than that of snapping turtles (3.1 ha; $W = 167$, $p = 0.006$).

Habitat selection at the location scale.—At the location scale, Blanding's and snapping turtles' order of preference for habitats was the same: Marsh ≥ Peatland > Forest. Pairwise comparisons revealed that Marsh and Peatland were interchangeable. For both species, Marsh and Peatland were used more than they were available (Table 3).

For Blanding's turtle microhabitat selection, the best model was significant (log ratio = 23.87, $R^2 = 0.038$, $p < 0.001$; Table 4). Blanding's turtles selected warmer air temperatures, colder and deeper water, and preferred areas with abundant emergent and floating

Table 3. Mean percentage of habitat types available and used by Blanding's turtles ("B", $n = 19$) and snapping turtles ("S", $n = 11$) at Canadian Nuclear Laboratories, Chalk River, Ontario, Canada.

Habitat Type	% Population Range		% Home Range		% Locations	
	B	S	B	S	B	S
Marsh	13.35	9.64	69.62	47.22	76.56	64.77
Peatland	3.74	3.96	9.1	20.63	18.11	21.21
Swamp	4.09	1.95	0.91	0	0	0
Water	7.88	13.8	0	4.43	0	0
Forest	70.94	70.65	20.38	27.72	5.33	14.02

vegetation. The probability of selection increased by 5% with a 1°C increase in air temperature, whereas that probability decreased by 5% with a 1°C increase in water temperature. An increase of 25 cm in water depth increased the probability of selection by 21%. Also, an increase of 25% in percent cover of emergent vegetation, floating vegetation, and open water increased the probability of selection by 35%, 47% and 33%, respectively. For snapping turtle microhabitat selection, the best model was significant (log ratio = 24.61, $R^2 = 0.133$, $p < 0.001$; Table 4). Snapping turtles selected colder air temperatures and areas with more open water. An increase of 1°C in air temperature decreased the probability of selection by 14%; an increase of 25% in percent cover of open water increased the probability of selection by 51%.

Spatial and niche overlap.—At the provincial scale, the extent of occurrence of snapping turtles (429,000 km^2) was much larger than the extent of occurrence of Blanding's turtles (159,000 km^2; Figure 1) and the latter was entirely contained within the former. The provincial ranges Φ was 0.5, which suggests a weak positive association. At the population scale, 93% of the Blanding's turtle population range was contained within the snapping turtle population range (Figure 2). The population ranges Φ was 0.7, representing a strong positive association. We found that 17% of the total Blanding's turtle home range area overlapped with snapping turtle home ranges, yielding a Φ of 0.3 or weak positive association. All Blanding's turtle home ranges overlapped with at least one snapping turtle home range. Only 2 snapping turtle home ranges did not overlap with Blanding's turtle home ranges.

Equivalency and similarity tests comparing Blanding's turtles and snapping turtles' niches were both significant ($p = 0.03$ in both cases). Schoener's D index of niche overlap showed a 58.5% overlap between Blanding's turtle and snapping turtle niches.

Discussion

Habitat selection at the provincial scale.—Compositional analyses revealed that Forest was the preferred habitat for both species at the provincial scale. Interestingly, Cropland and Pasture were ranked

Table 4. Coefficients and odds ratios for the paired-logistic regression models explaining microhabitat use by Blanding's and snapping turtles at Canadian Nuclear Laboratories, Chalk River, Ontario, Canada.

Model	Variable	Coefficient	SE	Increase	Odds ratio	95% CI[a]
Blanding's turtles	Air temperature	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 temperature	-0.047	0.028	1°C	0.95	(0.9,1.01)
Snapping turtles	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.

highly for snapping turtles, but not for Blanding's turtles. Snapping turtles are more widespread and easier to detect than Blanding's turtles (Browne and Hecnar, 2007), which could explain why there are more snapping turtle sightings in or near agricultural landscapes. Also, snapping turtles are known to be aquatic habitat generalists (Paterson et al., 2012) and to persist in urbanized water bodies such as irrigation canals (SARPR, 2017). Overall Blanding's turtles and snapping turtles select similar habitats at the provincial scale.

Habitat selection at the population scale.—Blanding's and snapping turtles have the same habitat preferences at the population scale. However, snapping turtle selection was more general (i.e. habitats were more interchangeable), which accords well with its more generalist nature. Our home range size estimates are in agreement with those reported in the literature: Blanding's turtles have larger home ranges than snapping turtles. Home ranges of umbrella species should be large to encompass sympatric species with smaller home ranges (Noss et al., 1996, Berger, 1997). In our case, however, the potential umbrella species (snapping turtle) has a smaller home range than the target species (Blanding's turtle), which is not ideal.

Habitat selection at the location scale.—Marsh and Peatland were the most important habitats for both species. We found that both species used Forest to migrate overland to reach other wetlands (Anderson, 1965; Obbard and Brooks, 1981; Millar and Blouin-Demers, 2011). Blanding's turtles preferentially selected emergent and floating vegetation at the location scale, whereas these two types of vegetation did not significantly increase the probability of selection for snapping turtles. Interestingly, Paisley et al. (2009) noted that snapping turtles used these two plant types disproportionately more than they were available. Both species may thus select similar vegetation types. Furthermore, the microhabitat selection model for Blanding's turtles retained six variables, whereas only two variables were retained in the snapping turtle model. This implies that Blanding's turtles have more specific habitat requirements than snapping turtles.

Spatial and niche overlap.—Umbrella species with large geographic ranges 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, and there was a weak positive association between the two species. At the population scale, 93% of the Blanding's turtle population range overlapped with the snapping turtle population range, and there was a strong positive association between the two species. Our spatial analyses revealed that snapping turtles have much larger geographic and population ranges than do Blanding's turtles, and that these snapping turtle ranges encompass the vast majority of Blanding's turtle habitat. Furthermore, Blanding's turtles and snapping turtles' niches are largely overlapping and thus very similar. This provides evidence that snapping turtles can serve as an adequate umbrella species for Blanding's turtles despite the fact that their home range is smaller.

Adaptation of umbrella species: specialists or generalists.—Analyses at the three spatial scales revealed that snapping turtles have more general habitat preferences than Blanding's turtles. Habitat specialists may be more suitable umbrella species than habitat generalists since their area requirements may be larger (Caro and O'Doherty, 1999; Andelman and Fagan, 2000). Habitat specialists may be too specialized, however, thus the protection of their habitat may not protect other co-occurring species' habitat fully (Seddon and Leech, 2008). While conducting a meta-analysis of 15 umbrella species studies, Branton and 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 a specialist. Therefore, habitat generalists such as snapping turtles can probably be adequate umbrella species.

Relative ease of monitoring.—It is much more practical to implement a surrogate species approach if the umbrella species can be easily monitored. Umbrella species with larger population sizes are easier to monitor (Caro and O'Doherty, 1999). Although the exact population sizes of Blanding's and snapping turtles are unknown, there is evidence indicating that snapping turtles are more numerous. The population size of adult snapping turtles in Canada is unknown, but it is in the thousands (COSEWIC, 2008). The size of the Blanding's Turtle Great Lakes / St. Lawrence population is estimated to be less than 10,000 individuals and 1,000 reproducing individuals (Environment Canada, 2016). Snapping turtle population density ranges from 1-75 adults/ha (Galbraith et al., 1988), while Blanding's turtle population density ranges from 0.02-57 adults/ha (van Dijk and Rhodin, 2011).

Results from our field study and of other similar studies also suggest that snapping turtles are more

abundant than Blanding's turtles. At CNL, we determined adult-sub-adult population estimates for Blanding's and snapping turtles with capture-mark-recapture data. The estimated snapping turtle population (53 ± 15 individuals) was twice the size of the estimated Blanding's turtle population (25 ± 4 individuals). In a field study at Point Pelee National Park, 421 snapping turtles and 85 Blanding's turtles were captured in total, including recaptures (Browne and Hecnar, 2007). The catch per unit effort was an order of magnitude greater for snapping turtles than for Blanding's turtles. Thus, snapping turtles are more abundant and probably easier to detect and monitor.

Precautionary principle.—The Endangered Species Act (ESA, 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." Blanding's turtles are significantly threatened by many anthropogenic stressors. Habitat loss, fragmentation, and road mortality are contributing to Blanding's turtle population decline (Environment Canada, 2016). The full extent of their critical habitat is unknown. Therefore, measures to avoid and minimize the threats to the species should be implemented. To ensure Blanding's turtle protection, snapping turtle habitat could be used to develop and implement mitigation measures for the protection of both species.

Conclusion

The habitats preferred by snapping turtles include the habitats preferred by Blanding's turtles. The provincial range of snapping turtles also includes the provincial range of Blanding's turtles. It is therefore reasonable to conclude that by protecting all snapping turtle habitat in Ontario, all or the majority of Blanding's turtle habitat within the province should also be protected. Snapping turtles could also be an ideal umbrella species for other sympatric species (i.e. freshwater turtles and wetland species at risk). Further investigations should be pursued to incorporate the most sympatric species under the protection of the snapping turtle's "umbrella".

Acknowledgments. We are grateful to Canadian Nuclear Laboratories for supporting and funding this project. We are also grateful to Environment and Climate Change Canada for their financial support through their Interdepartmental Recovery Fund program. We would like to thank R. Duplain at the Geographic, Statistical and Government Information Centre, University of Ottawa, for assisting with GIS spatial analyses. All animals were handled according to the guidelines of the Canadian Council on Animal Care and the University of Ottawa Animal Care Committee (protocol # BL-284) as well as with all necessary permits (SARA-2014-0275 and SARA-OR-2015-0301).

References

Aebischer, N.J., Robertson, P.A., Kenward, R.E. (1993): Compositional analysis of habitat use from animal radio-tracking data. Ecology **74**: 1313−1325.

Andelman, S.J., Fagan, W.F. (2000): Umbrella and flagships: efficient conservation surrogates or expensive mistakes? Proceedings of the National Academy of Sciences of the United States of America **97**: 5954−5959.

Anderson, P. (1965): The reptiles of Missouri. Columbia, USA. University of Missouri Press.

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.

Broennimann, O., Fitzpatrick, M.C., Pearman, P.B., Petitpierre, B., Pellissier, L., Yoccoz, N.G., Thuiller, W., Fortin, M., Randin, C., Zimmermann, N.E., Graham, C.H., Guisan, A. (2012): Measuring ecological niche overlap from occurrence and spatial environmental data. Global Ecology and Biogeography **21**: 481–497.

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.

Christensen, R.J., Chow-Fraser, P. (2014): Use of GPS loggers to enhance radio-tracking studies of semi-aquatic freshwater turtles. Herpetological Conservation and Biology **9**: 18−28.

Cola, V.D., Broennimann, O., Petitpierre, B., Breiner, F.T., D'Amen, M., Randin, C., Engler, R., Pottier, J., Pio D., Dubuis, A., Pellissier, L., Mateo, R.G., Hordijk, W., Salamin, N., Guisan, A. (2017): ecospat: an R package to support spatial analyses and

modeling of species niches and distributions. Ecography **40**: 774–787.

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.

Congdon, J.D., Breitenbach, G.L., van Loben Sels, R.C., Tinkle, D.W. (1987): Reproduction and nesting ecology of snapping turtles (*Chelydra serpentina*) in Southeastern Michigan. Herpetologica **43**: 39–54.

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

COSEWIC (2008): COSEWIC assessment and status report on the snapping turtle *Chelydra serpentina* in Canada. Committee on the Status of Endangered Wildlife in Canada. p. 34.

Downs, J.A., Horner, M.W. (2009): A characteristic-hull based method for home range estimation. Transactions in GIS **13**: 527–537.Edge, C.B., Steinberg, B.D., Brooks, R.J., Litzgus, J.D. (2010): Habitat selection by Blanding's turtles (*Emydoidea blandingii*) in A relatively pristine landscape. Écoscience **17**: 90–99.

ESA (2007): Endangered Species Act, S.O. 2007, Chapter 6. Available at: https://www.ontario.ca/laws/statute/07e06. Accessed on 10 February 2017.

Environment Canada (2016): Recovery strategy for the Blanding's turtle *(Emydoidea blandingii*), Great Lakes / St. Lawrence population, in Canada [Proposed]. Species at Risk Act Recovery Strategy Series. p. iv.

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.

Fleury, S.A., Mock, P.J., O'Leary, J.F. (1998): Is the California Gnatcatcher a good umbrella species? Western Birds **29**: 453–467.

Fortin, G., Blouin-Demers, G., Dubois,Y. (2012): Landscape composition weakly affects home range size in Blanding's turtles (*Emydoidea blandingii*). Écoscience **19**: 191–197.

Galbraith, D.A., Bishop, C.A., Brooks, R.J., Simser, W.L., Lampman, K.P. (1988): Factors affecting the density of populations of common snapping turtles (*Chelydra serpentina serpentina*). Canadian Journal of Zoology **66**: 1233–1240.

Gibbons, J.W., Scott, D.E., Ryan, T.J., 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. Nongame Wildlife Program, Minnesota Department of Natural Resources, p. 7.

Hasler, C.T., Robinson, K., Stow, N., Taylor, S.R. (2015): Population size and spatial ecology of Blanding's turtle (*Emydoidea blandingii*) in South March Highlands, Ottawa, Ontario, Canada. Canadian Journal of Zoology **93**: 509–514.

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.

Noss, R.F., Quigley, H.B., Hornocker, M.G., Merrill, T., Paquet, P.C. (1996): Conservation biology and carnivore conservation in the Rocky Mountains. Conservation Biology **10**: 949−963.

Obbard, M.E., Brooks, R.J. (1981): A radio-telemetry and mark-recapture study of activity in the common snapping turtle, *Chelydra serpentina*. Copeia **3**: 630–637.

OMNR (1998): Ontario Ministry of Natural Resources, Ontario landcover database, remote-sensing image, Peterborough, Ontario.

Paisley, R.N., Wetzel, J.F., Nelson, J.S., Stetzer, C., Hamernick, M.G., Anderson, B.P. (2009): Survival and spatial ecology of the snapping turtle, *Chelydra serpentina* , on the Upper Mississippi River. Canadian Field-Naturalist **123**: 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. Canadian Journal of Zoology **90**: 139–149.

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

R Core Team (2015): R: A language and environment for statistical computing. R Foundation for Statistical Comuputing, Austria.

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

Rowland, M.M., Wisdom, M.J., Suring, L.H., Meinke, C.W. (2006): Greater sage-grouse as an umbrella species for sagebrush-associated vertebrates. Biological Conservation **129**: 323–335.

SARPR (2017): Species at Risk Public Registry, Species Profile: Blanding's and snapping turtle. Available at: http://www.registrelep-sararegistry.gc.ca/species/default_e.cfm. Accessed on 1 July 2017.

Schuler, M., Thiel, R.P. (2008): Annual vs. multiple-year home range sizes of individual Blanding's turtles, *Emydoidea blandingii*, in central Wisconsin. Canadian Field-Naturalist **122**: 61–64.

Seddon, P.J., 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.

Thomasson, V., Blouin-Demers, G. (2015): Using habitat suitability models considering biotic interactions to inform critical habitat delineation: an example with the eastern hog-nosed snake (*Heterodon platirhinos*) in Ontario, Canada. Canadian Wildlife Biology and Management **4**: 1–17.

van Dijk, P.P., Iverson, J.B., Rhodin, A.G.J., Shaffer, H.B., Bour, R. (2014): Turtles of the World, 7th Edition: annotated checklist of taxonomy, synonymy, distribution with maps, and conservation status. Chelonian Research Monographs **5**: 329–479.

van Dijk, P.P., Rhodin, A.G.J. (2011): *Emydoidea blandingii*. (errata version published in 2016): The IUCN Red List of Threatened

Species 2011. Available at: http://dx.doi.org/10.2305/IUCN.UK.2011-1.RLTS.T7709A12843518.en. Accessed on 10 February 2017.

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.

Accepted by Anamarija Zagar