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Landscape composition weakly predicts wetland occupancy by Blanding's turtles (*Emydoidea blandingii* Holbrook, 1838)

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Abstract. Patterns of spatial occurrence in animals are largely a function of landscape composition and configuration. Studying habitat selection at the landscape scale allows the identification of habitat features that favour long-term survival of animal populations. We tested the hypothesis that wetland occupancy by Blanding's turtles, *Emydoidea blandingii*, in southern Québec, Canada is related to landscape composition. We conducted visual surveys at 110 wetlands to document occupancy and we measured landscape composition around surveyed wetlands. We used boosted regression trees (BRT) to model the probability of occurrence of Blanding's turtles based on land use, road density, and wetland size. Blanding's turtles were more likely to occupy wetlands with high wetland density in the surrounding landscape, but the BRT model did not fit the presence/absence data well. Therefore, we could not confidently predict wetland occupancy patterns from our six landscape composition variables. Blanding's turtles in our study area do not seem constrained to high quality sites: turtles occupy areas disturbed by agriculture in a slightly urbanised landscape. Management should focus on protecting sites of documented occurrence with an abundance of wetlands and sufficient suitable habitat to cover seasonal movement patterns.

Keywords. Blanding's turtle, boosted regression tree, *Emydoidea blandingii*, habitat selection, landscape composition, modelling, spatial occurrence

Introduction

In many animals, patterns of spatial occurrence largely depend on landscape composition and configuration (Berg, 2002; Guerry and Hunter, 2002; Mazerolle et al., 2005; Blevins and With, 2011; Morellet et al., 2011). For example, the probability of occurrence at breeding ponds of several frogs and salamanders is associated with forest and pond cover (Guerry and Hunter, 2002; Mazerolle et al., 2005), so occupancy of a breeding pond is influenced not only by the characteristics of the pond, but also by the surrounding landscape. At the landscape scale, animals select a range that provides the resources they need (e.g., breeding habitat and feeding sites; Johnson, 1980). Within this range, animals select specific habitat patches, but the general area must provide a minimum amount of suitable habitat if the population is to persist. Threats like habitat loss and road mortality can constrain animals to smaller geographical ranges or cause range contraction (Aldridge et al., 2008). In freshwater turtles, fragmentation of suitable habitat by roads increases collisions with vehicles and, by consequence, the probability of local population extirpation (Aresco, 2005; Gibbs and Steen, 2005; Beaudry et al., 2008).

We studied habitat selection at the landscape scale in Blanding's turtles, *Emydoidea blandingii* Holbrook, 1838, a semi-aquatic turtle considered endangered in Canada and at risk in 13 of the 18 Canadian and United States jurisdictions in which they occur (COSEWIC, 2016). Blanding's turtles inhabit a variety of wetlands, such as ponds, swamps, marshes, bogs, fens, and other shallow water habitats (Joyal et al., 2001; Grgurovic and Sievert, 2005; Edge et al., 2010; Millar and Blouin-Demers, 2011), and are mainly threatened by habitat loss and road mortality (COSEWIC, 2016). Previous studies of habitat selection at local scales consistently showed that Blanding's turtles select wetlands dominated by vegetation and avoid upland habitats as well as human disturbed areas (Edge et al., 2010; Millar and Blouin-Demers, 2012). Habitat modelling at a

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scale spanning multiple ecoregions showed that habitat suitability increases with wetland area and decreases with road density and cropland area (Millar and Blouin-Demers, 2012). Hence, wetland density, land use, and road density are likely important factors dictating the spatial patterns of Blanding's turtle occurrence at the landscape scale. Habitat selection studies focusing on Blanding's turtles have mainly identified elements preferred by the species at the microhabitat and home range scales (Beaudry et al., 2009; Edge et al., 2010; Millar and Blouin-Demers, 2011). Blanding's turtles can move long distances in aquatic or terrestrial habitats, and home range lengths of over 3 km have been recorded (Grgurovic and Sievert, 2005; Fortin et al., 2012). In addition to local factors, the landscape context should be considered when studying habitat selection, especially in vagile species like Blanding's turtles.

The goal of this study was to test the hypothesis that wetland occupancy by Blanding's turtles depends on landscape composition around the wetland. The landscape context should be especially important for Blanding's turtles because this species typically uses many habitat patches throughout a season (Millar and Blouin-Demers, 2011; Fortin et al., 2012). We predicted that a wetland should have a higher probability of occupancy when surrounded with a high proportion of other wetlands because these are preferred habitats (Edge et al., 2010). High road density and high proportions of urban areas should have a negative effect on the probability of wetland occupancy because of more frequent encounters with vehicles, which increases mortality and risk of local extirpation. Additionally, human-modified land covers such as urban areas may replace the natural habitat types most suitable for Blanding's turtles. Studying habitat selection at the landscape scale will allow identification of landscape features that promote site occupancy, complementarily to large scale habitat selection modelling (Millar and Blouin-Demers, 2012) and habitat selection studies at the local scale (Edge et al., 2010; Fortin et al., 2012; Markle and Chow-Fraser, 2014).

Methods

Study area.—We conducted this study during the spring of 2008 in the extreme southwest of the province of Québec, Canada. The study area covered approximately 1500 km^2 and ranged from Breckenridge (Collines-de-l'Outaouais County) west to Fort-Coulonge (Pontiac County). The study area was located at the intersection of two physiographic regions: the St. Lawrence Lowlands and the Canadian Shield. The Ottawa River Valley, which marks the transition between those two regions, is characterised by important agricultural activity. In this region, mean road density was approximately 1 km/km^2, in addition to an extensive network of all-terrain vehicle trails. The northern part of the study area was located in the Canadian Shield and was mostly forested with low urbanisation and a more limited road network.

Wetland occupancy.—The study area was divided into 43 parcels of 8 km^2 and one to four wetlands were selected randomly within each parcel for a visit. A total of 110 wetlands were visited but, due to a lower concentration of wetlands, fewer wetlands were visited in the central part of the study area where most agriculture was concentrated. The visited wetlands (marshes, swamps, bogs, and other shallow water habitats) were considered potential habitat for Blanding's turtles. Visual surveys were conducted during sunny days at emergence from hibernation, from 1-15 May, when the probability of observing basking turtles is higher than at other times of the year (Millar and Blouin-Demers, 2011). Observers scanned the sites with binoculars or a spotting scope with the goal of covering the entire site in a single visit. The majority of wetlands were visited once (92), while 14 sites were visited twice, three sites visited thrice, and one site was visited four times; we stopped visiting wetlands once Blanding's turtles had been detected. Blanding's turtles were considered present at a site when at least one individual was observed. Additional Blanding's turtle observations in the database of the Ministère des Forêts, de la Faune et des Parcs du Québec (458 observations from 2008 to 2019) were used to corroborate the visual survey results.

Explanatory variables.—Wetlands were delineated with aerial photos at a scale of 5000:1. Land cover data for 2003 were obtained from the Institut de la statistique du Québec in raster format with a cell size of 50 m. Land cover was divided into five categories: open water (OW), wetlands (WET), forest (FOR), agriculture (AGRI), and anthropogenic land (ANTH), which included gravel pits, urban areas, and other disturbed sites. Road data (ROAD) were obtained from Open Street Maps (2019) and comprised both paved and unpaved roads. Wetland polygons were buffered in 100 m increments from 100 to 5000 m and the proportion of each land cover class (percent cover of the total buffer area) and road density (km per km^2) were correlated (point biserial correlation) with the probability of occupancy by Blanding's turtle for each buffer size (Fyson, 2020). Data for each landscape variable at the scale of maximum effect (the

buffer size with the highest correlation) were retained for model building. Variables were transformed to best fit a normal distribution (Table 1). Data manipulations were done using ArcMap 10.4.1 (ESRI, 2016) and Python 2.7.10 (Python Software Foundation, 2015).

Modelling.—We used boosted regression trees (BRTs) to determine the effects of landscape composition and wetland size on the probability of wetland occupancy by Blanding's turtles. The number of site visits (VISIT) was also included as a control variable. Tree complexity was set to 2, a suitable complexity for relatively small sample sizes (Elith et al., 2008). The learning rate was decreased from 0.005 to 0.0001 and then bag fractions of 0.5, 0.6, and 0.7 were tested to minimise cross-validation deviance, maximise training and cross-validation AUCs, and maximise the number of trees with a target of at least 1000 (Elith et al., 2008; Ruso et al., 2019). Finally, a final BRT model was built with the best parameters. The final BRT was evaluated on the relative influence of each variable, their partial dependence plots, the model's total and cross-validation (CV) deviance, and the training and cross-validation area under the receiver operating curve (AUC). Analyses were performed with the 'gbm' (Greenwell et al., 2019) and 'dismo' (Hijmans et al., 2017) packages in R 3.5.2 (R Core Team, 2018).

Results

We found Blanding's turtles at 15 of the 110 wetlands, with an additional five wetlands determined to be occupied based on subsequent surveys (2009 and 2010) by the Ministère des Forêts, de la Faune et des Parcs du Québec for a total of 20 occupied and 90 unoccupied wetlands. The probability of wetland occupancy by Blanding's turtles had the highest correlation with each of the land cover classes at buffer sizes ranging from 600 to 3200 m and with road density at 100 m (Fig. 1). Forest was the dominant land cover at all retained scales (58-73% cover), followed by agriculture (9-27%), wetlands (7-15%), open water (2-5%), and anthropogenic land (1-2%). Road density in the 100 m buffers varied from 0 to 6.1 km/km^2 (mean of 1.4 km/km^2).

The final BRT model (Table 2) ranked wetland cover as the most important predictor of the probability of wetland occupancy by Blanding's turtles (relative influence of 33.3%; Fig. 2), followed by wetland size (20.3%), agricultural land cover (19.4%), open water cover (10.8%), road density (7.3%), forest cover (6.9%), anthropogenic land cover (1.9%), and the number of site visits (0.0%). Partial dependence plots (Fig. 3) indicated that the proportion of wetland and of open water, as well as wetland size, positively influence the probability of occupancy by Blanding's turtles, while the proportion of agricultural land and road density negatively influence the probability of occupancy. The proportion of forest and of anthropogenic land in the surrounding landscape have little effect on the probability of wetland occupancy. Interactions between model variables were weak, with interaction strengths between 0.00 and 0.14 (mean 0.03) based on Friedman's H-statistic (Friedman and Popescu, 2008) (Table 2).

Table 1. Transformations used to reach normality for the included explanatory variables used to determine whether landscape composition affects wetland occupancy by Banding's turtles.

Variable	Transformation
Open water proportion (%)	x^0.1
Wetland proportion (%)	Square root
Forest proportion (%)	Squared
Anthropogenic land proportion (%)	None
Agriculture proportion (%)	Square root
Road density (km/km^2)	None
Area (ha)	Log10
Number of visits	None

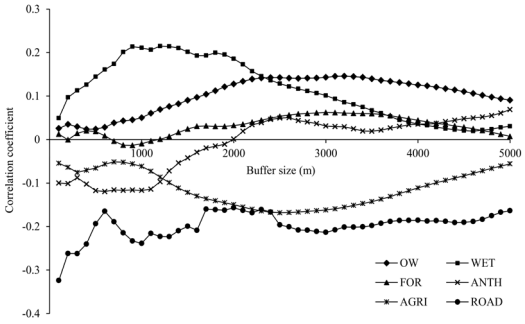

Figure 1. Correlation (point biserial) between the landscape composition variables for a given buffer size and Blanding's turtle occupancy. Buffer sizes were constructed at 100 m intervals from 100 to 5000 m. OW = open water proportion; WET = wetland proportion; FOR = forest proportion; ANTH = anthropogenic land proportion; AGRI = agricultural land proportion; ROAD = road density.

Table 2. Pearson's correlation coefficient (top right) and Friedman's H-statistic (bottom left) between the explanatory variables in the BRT used to determine whether landscape composition affects wetland occupancy by Blanding's turtles. Asterisk (*) denotes significance ($P < 0.05$). OW = open water proportion; WET = wetland proportion; FOR = forest proportion; ANTH = anthropogenic land proportion; AGRI = agricultural land proportion; ROAD = road density; AREA = wetland area; VISIT = number of visits.

OW	0.06	-0.06	0.13	-0.36*	0.07	0.03	-0.19*
0.067	**WET**	0.18	-0.22*	-0.29*	-0.09	0.34*	0.12
0.031	0.041	**FOR**	-0.12	-0.83*	0.00	-0.12	0.00
0.014	0.010	0.072	**ANTH**	0.10	0.39*	-0.03	-0.11
0.011	0.018	0.031	0.011	**AGRI**	-0.08	0.10	0.05
0.054	0.050	0.025	0.031	0.140	**ROAD**	-0.17	-0.01
0.034	0.061	0.009	0.005	0.020	0.031	**AREA**	0.17
0.000	0.000	0.000	0.000	0.001	0.000	0.001	**VISIT**

Discussion

We tested the hypothesis that landscape composition plays a role in the spatial distribution of Blanding's turtles. Unsurprisingly, the probability of presence of Blanding's turtles was primarily related to a high proportion of wetlands, which is the preferred habitat of the species (Edge et al., 2010; Millar and Blouin-Demers, 2011), in the surrounding landscape. Wetland size, the second most influential variable, was also important in dictating the probability of presence of Blanding's turtles. Blanding's turtles were more likely to be found in larger wetlands; however, this could be the result of larger wetlands supporting a larger population of turtles which would increase the probability of detection. Agricultural land cover, which reduces nesting success of Blanding's turtles (Mui et al., 2016), in the surrounding landscape decreased the probability of presence of Blanding's turtles and was the third most influential variable in the BRT model. It is, however, important to note that the relative importance of the explanatory variables is affected by collinearity, which further complicates the interpretation of the model as some variables have strong and significant correlations (Table 2). For example, forest cover and agricultural land cover are strongly correlated (Pearson's correlation coefficient of -0.83) which might cause an underestimation in the importance of one variable in favour of an overestimation of the other.

The BRT model did not perform very well, with a cross-validation AUC score of 0.639 and a cross-validation percentage of deviance explained (calculated as 1 – CV deviance/total deviance) of 1.58% (Table 3). Compared with an AUC score of 0.852 for the training data, this also suggested model overfitting. Overfitting of BRT models, however, does not necessarily compromise their accuracy (Elith et al., 2008). All variables included in the model showed high variability, indicating that landscape composition differed across the sites, and both wetland cover and wetland area differed significantly between sites where Blanding's turtles were present and absent (Supplemental Table 1).

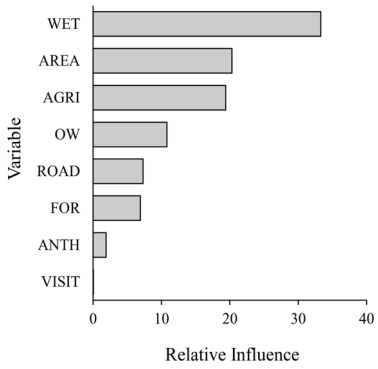

Figure 2. Relative influence (based on a total of 100) of the BRT model's explanatory variables on the probability of occupancy of Blanding's turtles. OW = open water proportion; WET = wetland proportion; FOR = forest proportion; ANTH = anthropogenic land proportion; AGRI = agricultural land proportion; ROAD = road density; AREA = wetland area; VISIT = number of visits.

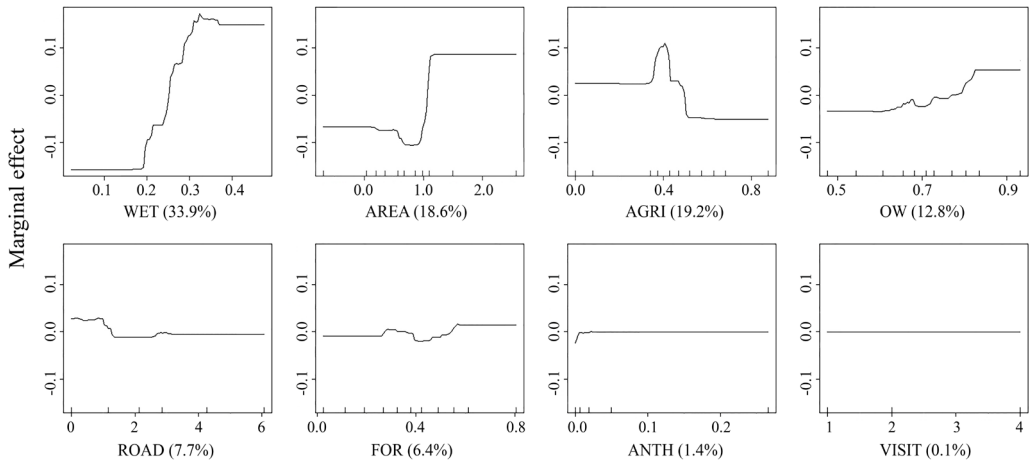

Figure 3. Partial dependence plots showing the marginal effects of the explanatory variables on wetland occupancy by Blanding's turtles, as determined by the BRT model. Relative influence is included in brackets beside the variable. OW = open water proportion; WET = wetland proportion; FOR = forest proportion; ANTH = anthropogenic land proportion; AGRI = agricultural land proportion; ROAD = road density; AREA = wetland area; VISIT = number of visits.

We were unable to examine the whole range of possible values for the proportions of our five habitat types (0 to 100%), which could have impaired the ability of the model to predict the probability of wetland occupancy by Blanding's turtles (Eigenbrod et al., 2011). Although the range of proportions was broad for most of the habitat types, the proportions of wetland, open water, and anthropogenic land were more restricted (Supplemental Table 1). At the spatial scales examined, it is impossible to obtain a full gradient for land use categories such as open water and wetland, and this limitation is inherent to studies at large spatial scales.

Wetland occupancy was estimated from presence/absence data at sites that were usually visited only once. Therefore, it was not possible to account for the probability of detection, which can be low for small populations and for cryptic species (Refsnider et al., 2011) such as Blanding's turtles. There remains the possibility that turtles were not detected at many sites; however, our BRT model ranked the number of site visits very low, suggesting that the difference in detection probability between one and four site visits was minimal. The lack of effect of the number of site visits may be explained by the small number of sites visited multiple times (18 in total, three visited thrice, and one visited four times). Failure to detect a species in occupied habitat patches can bias models investigating the relationship between an animal and its habitat (Guerry and Hunter, 2002; Mazerolle et al., 2005). In our case, underestimation of the probability of turtle occurrence at sampled wetlands could bias both parameter estimation and direction of the relationship between spatial distribution of the species and landscape composition. For this reason, techniques like environmental DNA surveying could

Table 3. Summary of the boosted regression tree (BRT) model used to evaluate whether landscape composition affects wetland occupancy by Blanding's turtles. Model performance is evaluated based on cross-validation (CV) deviance and cross-validation area under the receiver operating curve.

Tree complexity	Learning rate	Bag fraction	Final # trees	Total deviance	Residual deviance	CV deviance (SE)	Training AUC	CV AUC (SE)
2	0.0001	0.5	3700	0.948	0.873	0.933 (0.014)	0.852	0.639 (0.065)

be implemented to increase detection probability and improve accuracy of occupancy data (Lacoursière-Roussel et al., 2016; Fyson, 2020).

Estimation of the probability of occurrence can be a useful conservation tool to target important habitats for protection, for example when designating critical habitat for species at risk like the Blanding's turtle. Our results do not currently allow confident identification of potential habitats for Blanding's turtles at the landscape scale because of the relatively poor fit of the BRT model to the data. Presence of the species at both natural and disturbed sites could reflect progressive transformation of the landscape at sites of historical occurrence. The study area, however, is only slightly urbanised and it is possible that more intensive urbanisation is detrimental to Blanding's turtles (Millar and Blouin-Demers, 2012). Also important to note is that, although we did not find a strong link between landscape composition and occupancy, we did not test whether landscape composition affected Blanding's turtle abundance. The intensity of human disturbance in the study area may be high enough to affect abundance, but not occupancy, because abundance and occupancy can be affected by similar variables but at differing magnitudes (Dibner et al., 2017). Blanding's turtles often rely on anthropogenic sites (road shoulders, quarries, etc.) to provide suitable nesting habitat, which could partially explain their presence at disturbed sites (Beaudry et al., 2010). Moreover, development of the road network in the study area is relatively recent compared to the extreme longevity of the species, and only a few roads likely have a high enough traffic volume that could potentially result in the extirpation of a population within a relatively short period of time. Hence, the full effect of road mortality on Blanding's turtles might not yet be apparent with occupancy data. Habitat loss being a major threat to this species, management plans should focus on protecting sites of occurrence with abundant wetlands and sufficient suitable habitat to cover seasonal movement patterns (Fortin et al., 2012).

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References

Alderidge, C.L., Nielsen, S.E., Beyer, H.L., Boyce, M.S., Connelly, J.W., Knick, S.T., Schroeder, M.A. (2008): Range-wide patterns of greater sage-grouse persistence. Diversity and Distributions **14**: 983–994.

Aresco, M.J. (2005): The effect of sex-specific terrestrial movements and roads on the sex ratio of freshwater turtles. Biological Conservation **123**: 37–44.

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

Beaudry, F., Demaynadier, P.G., Hunter Jr., M.L. (2009): Seasonally dynamic habitat use by spotted (*Clemmys guttata*) and Blanding's turtles (*Emydoidea blandingii*) in Maine. Journal of Herpetology **43**: 636–645.

Beaudry, F., Demaynadier, P.G., Hunter Jr., M.L. (2010): Nesting movements and the use of anthropogenic nesting sites by spotted turtles (*Clemmys guttata*) and Blanding's turtles (*Emydoidea blandingii*). Herpetological Conservation and Biology **5**: 1–8.

Berg, Å. (2002): Composition and diversity of bird communities in Swedish farmland–forest mosaic landscapes. Bird Study **49**: 153–165.

Blevins, E., With, K.A. (2011): Landscape context matters: local habitat and landscape effects on the abundance and patch occupancy of collared lizards in managed grasslands. Landscape Ecology **26**: 837–850.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (2016): COSEWIC assessment and status report on the Blanding's Turtle *Emydoidea blandingii*, Nova Scotia population and Great Lakes/St. Lawrence population, in Canada. Available at: https://wildlife-species.canada.ca/species-risk-registry/virtual_sara/files/cosewic/sr_Blanding%E2%80%99s%20Turtle_2016_e.pdf Accessed on 24 October 2018.

Dibner, R.R., Doak, D.F., Murphy, M. (2017): Discrepancies in occupancy and abundance approaches to identifying and protecting habitat for an at-risk species. Ecology and Evolution **7**: 5692–5702.

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.

Eigenbrod, F., Hecnar, S.J., Fahrig, L. (2011): Sub-optimal study design has major impacts on landscape-scale inference. Biological Conservation **144**: 298–305.

Elith, J., Leathwick, J.R., Hastie, T. (2008): A working guide to boosted regression trees. Journal of Animal Ecology **77**: 802–813.

ESRI (2016): ArcGIS, version 10.4.1. Redlands, California, USA, Environmental Systems Research Institute.

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.

Fyson, V. (2020): Does landscape composition affect wetland occupancy by Blanding's turtles (*Emydoidea blandingii*) in the National Capital Region? Unpublished MSc thesis, University of Ottawa, Ottawa, Canada.

Friedman, J.H., Popescu, B.E. (2008): Predictive learning via rule ensembles. The Annals of Applied Statistics **2**: 916–954.

Gibbs, J.P., Steen, D.A. (2005): Trends in sex ratios of turtles in the United States: Implications of road mortality. Conservation Biology **19**: 552–556.

Greenwell, B., Boehmke, B., Cunningham, J., GBM Developers. (2019): R package 'gbm'. Available at: http://cran.r-project.org/web/packages/gbm/index.html. Accessed on 5 December 2019.

Grgurovic, M., Sievert, P.R. (2005): Movement patterns of Blanding's turtles (*Emydoidea blandingii*) in the suburban landscape of eastern Massachusetts. Urban Ecosystems **8**: 203–213.

Guerry, A.D., Hunter Jr., M.L. (2002): Amphibian distributions in a landscape of forests and agriculture: an examination of landscape composition and configuration. Conservation Biology **16**: 745–754.

Hijmans, R.J., Phillips, S., Leathwick, J., Elith, J. (2017): R package 'dismo'. Available at: http://cran.r-project.org/web/packages/dismo/index.html. Accessed on 5 December 2019.

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

Joyal, L.A., McCollough, M., Hunter Jr., M.L. (2001): Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. Conservation Biology **15**: 1755–1762.

Lacoursière-Roussel, A., Dubois, Y., Normandeau, E., Bernatchez, L. (2016): Improving herpetological surveys in eastern North America using the environmental DNA method. Genome **59**: 991–1007.

Markle, C.E., Chow-Fraser, P. (2014): Habitat Selection by the Blanding's Turtle (*Emydoidea blandingii*) on a Protected Island in Georgian Bay, Lake Huron. Chelonian Conservation and Biology **13**: 216–226.

Mazerolle, M.J., Desrochers, A., Rochefort, L. (2005): Landscape characteristics influence pond occupancy by frogs after accounting for detectability. Ecological Applications **15**: 824–834.

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.

Millar, C.S., Blouin-Demers, G. (2012): Habitat suitability modelling for species at risk is sensitive to algorithm and scale: A case study of Blanding's turtle, *Emydoidea blandingii*, in Ontario, Canada. Journal for Nature Conservation **20**: 18–29.

Morellet, N., Van Moorter, B., Cargnelutti, B., Angibault, J.M., Lourtet, B., Merlet, J., et al. (2011): Landscape composition influences roe deer habitat selection at both home range and landscape scales. Landscape Ecology **26**: 999–1010.

Mui, A.B., Edge, C.B., Paterson, J.E., Caverhill, B., Johnson, B., Litzgus, J.D., He, Y. (2016): Nesting sites in agricultural landscapes may reduce the reproductive success of populations of Blanding's Turtles (*Emydoidea blandingii*). Canadian Journal of Zoology **94**: 61–67.

Python Software Foundation (2015): Python Language Reference, version 2.7. Python Software Foundation.

R Core Team (2017): R: A language and environment for statistical computing. Vienna, Austria, R Foundation for Statistical Computing.

Refsnider, J.M., Mitchell, T.S., Streby, H.M., Strickland, J.T., Warner, D.A., Janzen, F.J. (2011): A generalized method to determine detectability of rare and cryptic species using the ornate box turtle as a model. Wildlife Society Bulletin **35**: 93–100.

Ruso, G.E., Morrissey, C.A., Hogan, N.S., Sheedy, C., Gallant, M.J., Jardine, T.D. (2019): Detecting Amphibians in Agricultural Landscapes Using Environmental DNA Reveals the Importance of Wetland Condition. Environmental Toxicology and Chemistry **38**: 2750–2763.

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