Can landscape composition predict movement patterns and site occupancy by Blanding's turtles?: A multiple scale study in Québec, Canada

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ABSTRACT

As habitat loss and fragmentation are major causes of decline in animal species, studying habitat requirements in these species is a key component of their recovery. I investigated the relationship between landscape composition and habitat use of Blanding's turtles, *Emydoidea blandingii*, a freshwater turtle threatened by habitat loss and road mortality on most of its Canadian range. In 2010, I conducted a radio-telemetry survey of 44 Blanding's turtles in southern Québec, Canada, and modelled their home range size from land cover proportions measured at many spatial scales. I also used data from a visual survey conducted in 2008 and 2009 to model wetland occupancy of the species at the landscape scale. Home range size of the Blanding's turtle was significantly correlated to landscape composition, and the proportions of agriculture, open water and anthropogenic lands had the strongest relationships with home range size. However, those relationships were weak and the models were unable to predict home range size accurately. At the landscape scale, land cover and road density poorly predicted probability of occurrence, and Blanding's turtles occupied wetlands in both disturbed and natural sites. Management of the species should focus on protecting sites of occurrence with high wetland density, low road density, and sufficient suitable habitat to cover their seasonal movement patterns.

RÉSUMÉ

La perte et la fragmentation des habitats étant des causes majeures du déclin des espèces animales, l'étude des besoins en matière d'habitat est une composante essentielle du rétablissement de ces espèces. J'ai étudié la relation entre la composition du paysage et l'utilisation de l'habitat chez la tortue mouchetée*, Emydoidea blandingii*, une tortue d'eau douce menacée par la perte d'habitat et la mortalité routière sur la majorité de son aire de distribution au Canada. En 2010, j'ai effectué le suivi télémétrique de 44 tortues mouchetées dans le sud du Québec, Canada, et j'ai modélisé la taille des domaines vitaux à partir des proportions de plusieurs types d'utilisation des terres, mesurées à plusieurs échelles spatiales. J'ai également utilisé des données provenant d'un inventaire visuel mené en 2008 et 2009 afin de modéliser l'occupation des milieux humides par l'espèce à l'échelle du paysage. La taille du domaine vital chez la tortue mouchetée était significativement corrélée à la composition du paysage et les proportions d'agriculture, d'eau libre et de zones anthropiques étaient les variables les plus fortement corrélées. Cependant, ces relations étaient faibles et les modèles se sont avérés incapables de prédire la taille du domaine vital avec précision. À l'échelle du paysage, l'utilisation des terres et la densité de routes prédisaient peu la probabilité de présence, et la tortue mouchetée occupait des milieux humides autant à des sites perturbés que naturels. La gestion de cette espèce devrait se concentrer sur la protection de sites ou l'espèce est présente et qui offrent une densité élevée de milieux humides, une faible densité de routes, ainsi qu'une quantité suffisante d'habitat propice afin de couvrir ses déplacements saisonniers.

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GENERAL INTRODUCTION

In a context of major human population expansion and constant increase in resource exploitation, natural landscapes undergo important changes. High human population densities are associated with species decline as a consequence of human activities (Kerr and Currie, 1995; McKee et al., 2004). Habitat modification, introduction of invasive species, and pollution are some of the many examples of threats to species caused by human activity.

Many countries have implemented legislation to protect declining species, and to ensure their survival and recovery. In Canada, the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) assesses the status of species and identifies threats, while the *Species at Risk Act* (SARA) provides protection on federal land to all species listed under the Act (SARA, 2003). A similar law applies in Québec, the *Loi sur les espèces menacées et vulnérables* (LEMV), which protects listed species on provincial land. Both legislations require the establishment of a recovery strategy (or plan) to ensure the persistence of listed species. As habitat loss and fragmentation are threats to many animal and plant species, those management plans describe their habitat requirements (Villard et al., 1999; Marchand and Litvaitis, 2004; Helm et al., 2006). For example, both legislations involve identification of critical habitat (or legal habitat), the habitat that will ultimately be protected under those laws. It is thus essential that habitat use of species at risk is well documented.

Spatial ecology

Fretwell (1972) described a habitat as a portion of land that a particular species is able to colonize and use for a living. A habitat can be divided into non-contiguous patches that offer different resources to a species. Habitat use refers both to the selection of suitable habitat patches and to the movement between those patches. Preference for resources, or habitat selection, is defined as the disproportional use of an element (food item, habitat type) compared to its availability (Johnson, 1980). Preferred resources are often dispersed in a heterogeneous environment and a species may need to use more than one habitat type to complete its life cycle, thus forcing animals to move between habitat patches. Reproductive migrations, shifts between summer and winter habitats, and natal dispersion of juveniles are all important causes of movement in animals (McCormick et al., 1998; Long et al., 2010).

In ecology, the concept of landscape implies an area comprising heterogeneously dispersed habitat patches and matrix elements (non-habitat: roads, fields, urban areas, etc.) (Wiens, 2002). Quality of a landscape can then be attributed to both matrix and patch features. Recent studies have suggested that landscape structural characteristics influence animal movement, probability of occurrence, species richness, and abundance (Bowne et al., 2006; Kindlmann and Burel, 2008; Reunanen et al., 2002). Landscape composition can therefore influence habitat use, and ultimately long-term survival of species.

Spatial scale is also important to consider in landscape ecology. Studying habitat use at many scales is necessary since behaviour at one scale does not necessarily predict the animal's behaviour at other scales (Nams and Bourgeois, 2004; Mayor et al., 2009). For example, when selecting a home range (macrohabitat), availability of habitat patches in the movement extent of the animal is important, and would not be considered if studying only the narrower selection of locations within the home-range (microhabitat) (Johnson, 1980; Mayor et al., 2009).

Blanding’s turtle

Blanding’s turtles are found in Canada and in the United States, and their global range is centered on the Great Lakes. The Canadian range (20% of the global range) is restricted to southern Ontario and the extreme southwest of Québec, with a disjunct population in Nova Scotia (Blanding’s Turtle Recovery Team, 2005; COSEWIC, 2005). The species is at risk in both Canada and Québec (SARA, 2003; LEMV), the Great Lakes population being threatened (COSEWIC 2005). Blanding’s turtles are long-lived; slow reproductive rates and delayed sexual maturity suggest a long-term reproductive success strategy, which makes the species very sensitive to additional adult mortality (Congdon et al., 1993; Joyal et al., 2000). The most important identified threats to the species are habitat loss, road mortality, and poaching (COSEWIC 2005).

The Blanding’s turtle is considered semi-aquatic, but it primarily inhabits wetlands such as forested swamps, ponds, marshes, bogs, fens, and other shallow water habitats (Ross and Anderson, 1990; Joyal et al., 2001; Grgurovic and Sievert, 2005; Edge et al., 2010; Millar and Blouin-Demers, 2011). They are associated with an organic substrate, abundant submergent and emergent aquatic vegetation like water-lillies (*Nymphaea spp.*), cattails (*Typha spp.*), and sedges (*Carex spp*.) (Ross and Anderson, 1990; Millar and Blouin-Demers, 2011). Edge et al. (2010) showed that Blanding’s turtles selected all wetland types over lotic and upland habitats at the home range scale. However, Blanding’s turtles commonly move long distances on land, mainly to reach other wetlands as well as nesting sites (Ross and Anderson, 1990; Joyal et al., 2001; Grgurovic and Sievert, 2005; Spetz, 2008; Edge et al., 2010; Congdon et al., 2011; Millar and Blouin-Demers, 2011). Nesting forays are an important part of upland habitat use in females, which often use anthropogenic sites to lay their eggs (Joyal et al., 2000; Joyal et al., 2001; Beaudry et al., 2010). For example, gravid females have been reported to move > 1 km on land to find a nesting site (Congdon et al., 1983; Ross and Anderson, 1990; Joyal et al., 2000). Long movements and use of terrestrial habitats make this turtle vulnerable to collision with vehicles, and to predation. Many indicators of movement capacities have been reported in descriptive studies, the most common ones being home range size and length. For Blanding's turtles, home range size ranges from 1 to 255 ha, with lengths ranging from 140 to 3200 m (Ross and Anderson, 1990; Hamernick, 2000; Grgurovic and Sievert, 2005; Millar and Blouin-Demers, 2011). Overall, large variations in movement patterns have been observed, with little explanation for such variation.

Objectives

The aim of my thesis was to provide information useful in the design of effective management strategies for Blanding's turtles. Habitat use of the Blanding's turtle has been studied in the past and basic information on movement patterns and habitat selection is available to conservation biologists. Because Blanding's turtles are mainly threatened by habitat loss, however, it is relevant to study their response towards changes in land use and human disturbance.

Chapter 1 was dedicated to movement patterns, and I investigated the effect of habitat composition on home range size. The home range of an animal represents the area it needs to complete its normal activities, so knowing how the home range is compressed or extended in certain habitat configurations can guide the identification of areas to be protected. In chapter 2, I looked at the spatial distribution of the Blanding's turtle at the landscape scale, and investigated the relationship between landscape composition and the probability of wetland occupancy. The geographical range of this species is quite limited in Québec, and its pattern of wetland occupancy could inform us on the physical characteristics of landscapes that favour their persistence.

CHAPTER 1

Landscape composition weakly affects home range size in Blanding's turtles (*Emydoidea blandingii*)

This chapter formed the basis for the following publication:

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ABSTRACT

Landscape composition and habitat quality influence the abundance, population structure, and movements of animals. Modelling how an animal interacts with elements of the landscape helps predict its response towards habitat loss and changes in land use. I tested the hypothesis that the extent of movements depends on landscape composition in a threatened freshwater turtle, *Emydoidea blandingii*. I measured habitat composition at multiple spatial scales, ranging from the home range to the landscape scale. I built multiple linear regression models to predict home range size from the proportions of five land uses, while controlling for intrinsic factors (sex, body size). Mean home range size was 29.7 ± 32.3 ha (from 2.8 to 130.5 ha), and landscape composition was significantly correlated with home range size. However, the models explained a low proportion of the observed variation in home range size, with R^2 ranging between 0.25 and 0.41, meaning that landscape composition was weakly linked to movement. My results also suggest that sex and body size are weakly correlated to home range size in Blanding's turtles. More research is needed to determine the factors driving movement in this species, and overall, I recommend cautious use of models predicting space use as a function of landscape composition in a conservation context.

INTRODUCTION

Large intraspecific variation in movement patterns is typical for many animal species. Commonly studied intrinsic factors that affect movement include sex and age, as well as reproductive status (Austin et al., 2004; Blouin-Demers et al., 2007; Kapfer et al., 2008; Millar and Blouin-Demers, 2011; van Beest et al., 2011). Availability of food and cover are primordial habitat characteristics that animals select for, and can also drive movement patterns (Noyce and Garshelis, 2011). Factors influencing movements are numerous and do not affect all animal species the same way. Targeting the main factors that affect movement in a species is a key element to evaluate its habitat requirements to include in management plans. Studying spatial and temporal movement patterns is a step towards describing a species' ecological needs, and ultimately leads to documented recommendations for its protection. For example, many studies investigating the effect of roads on animal movement suggest mitigation measures to reduce road mortality in developed landscapes (Andrews and Gibbons, 2005; Beaudry et al., 2008). Movement patterns are often used to identify seasonal habitats, evaluate the area required by an animal (home range), recognize potential threats to a species, etc. Specific ecological needs can be identified either for different groups within a population or for populations living in different environments. Among all determinants of animal movement, this study focuses on the spatial distribution of resources and matrix elements in a complex landscape.

In many recent studies, authors investigated how landscape structural characteristics influence animal movements (Reunanen et al., 2002; Bowne et al., 2006; Kindlmann and Burel, 2008). For example, some reptile and mammal species had larger home ranges in disturbed habitats (Collins and Barrett, 1997; Kapfer et al., 2010) and covered longer distances in search of high quality habitat patches (Bowne et al., 2006). Long movements caused by habitat loss combined with habitat fragmentation by roads can have serious consequences on vagile animals, as they become more susceptible to collision with vehicles (Aresco, 2005; Fahrig and Rytwinski, 2009). In highly degraded or fragmented landscapes, animals can also be constrained to the few remaining habitat patches and thus move shorter distances (Ahlers et al., 2010; Row et al., 2012). Given this, it is primordial that habitat requirements determined for conservation purposes take movement into account.

Objectives

Previous studies on Blanding's turtles have been mostly descriptive and concentrated on a single population in one landscape (Beaudry et al., 2009; Edge et al., 2010; Millar and Blouin-Demers, 2011). There is now a need to study the animal's behaviour towards changes in habitat quality and availability. The aim of this study was to determine the effects of landscape composition on movements in the Blanding's turtle, using a gradient of landscape characteristics. The relationship will be examined at many spatial scales to identify the extent at which each landscape component affects movement. Larger scales were also considered because habitat quality in the vicinity of the home range of an animal can facilitate or impede its movements. Modelling this relationship will allow predictions of movement from simple measures of landscape composition. The resulting models could then be applied to presence/absence data to determine the extent of protection that is required. Habitat models are also powerful tools to determine habitat requirements in different landscapes, and to evaluate the consequences of habitat loss.

I hypothesized that the inter-individual variation in movement patterns is caused by variation in landscape composition; individuals in poor quality habitats need to cover larger areas to fulfill their ecological needs. Because wetlands are considered to be preferred habitats for Blanding's turtles (Edge et al., 2010), I predicted that they should move longer distances in landscapes poor in wetlands. Presence of anthropogenic activity should also increase movement extent, because it reduces the proportion of suitable habitat. The study area has not undergone major development, so we did not consider the possibility that turtles were constrained to isolated habitat patches.

METHODOLOGY

Study sites

I conducted this study from April to September 2010, in the extreme southwest of the province of Québec, Canada. The global study area ranged from the Gatineau Park in Collines-de-l'Outaouais County, west to Clarendon, located in Pontiac County. This area encompassed five study sites located along the North shore of the Ottawa River. The study sites ranged from approximately 60 to 130 km^2 and were chosen to represent a gradient of landscape characteristics (Figure 1-1). Those sites were visited in 2007 and 2008 for a Blanding's turtle survey conducted by Nature Conservancy of Canada (NCC) and were identified as priority conservation areas for the species, supported by many observations of Blanding's turtles (Dubois, 2009).

Three sites out of five, referred here as Clarendon, Bristol, and Shawville, were located in the Ottawa River Valley, making the transition between the Saint-Lawrence Lowlands and the Canadian Shield, and were characterized by a mixed forest cover. Those sites generally showed low elevation and high wetland density (mainly marshes, swamps, and ponds). Clarendon and Bristol were partially located on NCC protected lands, Clarendon being mostly composed of forested areas and abandoned fields. This site had relatively low human disturbance, except from a few crops surrounding NCC's lands. Bristol showed more human activity, such as crops, an active mine, and a wood mill. Shawville was entirely located on unprotected lands, and was characterized by intense agriculture as well as more urbanized and industrial areas. Two other sites, Eardley-Masham and Gatineau Park West, were located in conservation areas of the

Gatineau Park. Eardley-Masham was clearly located in the Canadian Shield, with a high proportion of mixed forest cover, high elevation and low wetland density (mainly bogs and fens). The Gatineau Park West area was located at the limit of the Park, in the Ottawa River Valley, and was mainly composed of one large marsh surrounded by forest, fields and active mines (outside the boundaries of the Park).

Capture and telemetry

In spring, Blanding's turtles were captured by hand or using baited hoop nets. They were given a unique ID using notches on the marginal scutes of the carapace. Then, the carapace and plastron lengths were measured using a calliper. The sex was determined from the plastron concavity. In total, 44 turtles (22 females, 19 of them being gravid; 22 males) were equipped with radio-transmitters (model # AI-2F, 33 g, 36 months, Holohil Systems, Ontario, Canada) that were fixed to the rear carapace margin with two screws. The transmitter and screws did not exceed 5% of the animal's mass. The turtles were distributed in the five study sites as following: 9 for Clarendon, Bristol and Shawville, 11 in Eardley-Masham, and 6 in Gatineau Park West.

The telemetry tracking took place from early May to the end of September 2010, corresponding to the active season in the study area. The turtles were located with a receiver (Lotek Wireless, # SRX 400A, Ontario, Canada; Communication Specialists, # R-1000, California, USA) coupled with a three-element folding Yagi antenna (Advanced Telemetry Systems, Minnesota, USA). From May to August, the turtles were located every 2-4 days, and once a week in September. The turtles were located either directly to the animal or using triangulation. All coordinates (triangulation stations and animal locations) were recorded with a GPS (Garmin # GPSMap 60CSx, Kansas, USA). In the case of triangulation, the turtle locations were calculated using the software Locate III (Pacer Computing, Nova Scotia, Canada).

This protocol was accepted by the University of Ottawa (protocol # BL-253), and permits were obtained from Environment Canada (license # SARA-QR-2010-0154), the National Capital Commission (licenses # 9965 and # 11089) and the Ministère des Ressources Naturelles et de la Faune du Québec (licenses # 09042300707SF, # 10012103807SF and # CPA-FAUNE 2009-15).

Home ranges

All precise turtle locations were imported in ArcGIS 10 (ArcView, Environmental Systems Research Institute, California, USA). I also used triangulated turtle locations that had a precision under 30 m (see Telemetry validation, APPENDIX I). The dataset was randomly resampled using Hawth's tools (Hawthorne Beyer, Spatial Ecology) to get 34-35 locations per animal for the active season (May-September). To investigate the relationship between movement patterns and landscape composition, I chose the home range size (HRS) as the dependant variable (see Movement variables, APPENDIX I). The HRS of each animal was measured using minimum convex polygons (MCPs), as recommended for herpetofauna (Row and Blouin-Demers, 2006). HRS (ha) was log transformed to reach normal distribution as examined with Shapiro-Wilk test.

Landscape composition variables

I examined landscape composition by measuring the proportion of different land uses. I used standard tools from ArcGIS 10 to measure all landscape composition variables. Land use layers for the study area were obtained through the Base de données topographiques du Québec (BDTQ), Système d'information écoforestière (SIEF), Base de données des cultures assurées (BCDA, 2009) and Ducks Unlimited Canada (DUC, 2010). All the layers were in a vector format, at a scale of 1:20 000, except BCDA that had a scale of 1:50 000. The land use categories were first merged into 6 categories; 1) wetlands, including wetland and woody wetland from DUC, and wetlands from

BDTQ, 2) forest, from BDTQ, 3) agriculture, including BCDA, agriculture and agroforestry from SIEF, 4) open water, from BDTQ, 5) anthropogenic, including designated areas from BDTQ as well as gravel pits, disturbed sites from SIEF, and 6) other, corresponding to all the area that did not fall into the five other categories. Lands use categories were made independent from each other by removing overlaps from all layers.

The landscape variables were measured at eight spatial scales. The first scale was the MCP of each animal, and then I built buffers around the MCPs, with increasing radii of 250, 500, 1000, 1500, 2000, 3000 and 4000 m. The maximal buffer radius was chosen to include the Blanding's turtle largest home range length observed in this study as well as records from the literature (Ross and Anderson, 1990; Hamernick, 2000; Grgurovic and Sievert, 2005; Millar and Blouin-Demers, 2011). Because I started with turtle MCPs that had different sizes, the buffers in which I measured the landscape variables did not have a constant area. Consequently, all the variables were adjusted for area by dividing by the buffer area.

The landscape composition variables used were the proportions of the following land uses: wetland (WET), forest (FOR), agriculture (AGRI), open water (OW) and anthropogenic land (ANT). I did not include the category "other" as a variable because it did not represent a specific habitat type of interest. The Ottawa River was excluded from the "open water" category because it was not considered as a potential habitat for Blanding's turtles. None of the variables were normally distributed (Shapiro-Wilk test), and they were thus square root transformed to reach a distribution that was a close to normality as possible.

Modelling

I built models to predict the HRS of Blanding's turtles using multiple linear regressions. The predictors were all the landscape variables previously mentioned, in addition to sex (SEX) and plastron length (PL), a body size indicator. Those last two variables were included because other studies on reptiles have suggested they could influence movements (Blouin-Demers and Weatherhead, 2002; Blouin-Demers et al., 2007; Kapfer et al., 2010; Millar and Blouin-Demers, 2011). The distribution of plastron length was normal according to Shapiro-Wilk test.

Because the landscape variables were measured at eight spatial scales, they could not be all included as predictors in the same model (32 variables in total), because of my modest sample size (n ranged from 33 to 38). Therefore, I used univariate regressions to determine the spatial scale at which each variable influenced movement the most (see Spatial scale, APPENDIX I). It enabled me to reduce the number of predictors in the models and to determine the extent of influence for each landscape variable. For each variable, I chose the spatial scale that showed the highest correlation (Pearson's r) with HRS.

I then split the dataset into five subsets, each time excluding data from one study site (Clarendon, Bristol, Shawville, Eardley-Masham or Gatineau Park West). Each subset was used as a training set and the excluded data were subsequently used to test the model ability to predict HRS in this area.

I examined each training set for multicollinearity among the landscape composition variables, using both pairwise regressions between all variables and variance inflation factors (VIFs) for each variable (See Collinearity, APPENDIX I) (Smith et al., 2009). The VIFs were calculated using the "car" package in R. For each training set, I used multiple linear regressions to build models including all the predictors. I examined all the possible models, using the "MuMin" package in R.

I calculated the second order Akaike's Information Criterion (AICc) for each candidate model and model selection was based on ΔAICc and Akaike weights (Burnham and Anderson, 2002). All candidate models with a $\Delta AICc < 4$ were used to average the parameters of an averaged model, based on the relative weight of each candidate model. To validate the five averaged models, I first evaluated their fit of the training data by predicting HRS from the training data of each set. I then used simple linear regression to estimate the correlation between the observed (OBS) and the predicted (PR) HRS, with PR on the x axis and OBS on the y axis (Piñeiro et al., 2008). I then evaluated the ability of each averaged model to predict HRS from external data. I predicted HRS for the validation data initially excluded from each training set and estimated the correlation between predicted and observed HRS in the same way I did for the internal data. All the statistical analyses were performed with JMP 7 (SAS Institute Inc, North Carolina, USA) and R version 2.12.1 (R Development Core Team, Austria). The means are reported in the mean ± SD format and I considered tests significant at alpha = 0.05.

RESULTS

Landscape composition variables

I measured landscape composition variables at eight spatial scales. Pooling data from all spatial scales, the proportions of different land uses ranged from: 0.03 – 1 for wetland, 0 – 0.62 for agriculture, 0 – 0.94 for forest, 0 – 0.51 for open water, 0 – 0.34 for anthropogenic and 0 – 0.24 for other land uses. When looking at the correlation between HRS and landscape composition variables at their spatial scale of maximal influence on HRS, the correlation ranged from $| r | = 0.16 - 0.42$. The spatial scale at which the correlation was highest was used in further modelling analyses (Table 1-1). I used landscape composition variables measured at three spatial scales out of eight. The landscape composition variables used in modelling showed low inter-individual variability, meaning that the turtles used somewhat similar habitats across the study area (Table 1-2). The variability in plastron length was also low across the 44 turtles measured. The landscape composition variables that showed the largest variability were open water and anthropogenic land proportions. However, those two variables also showed the lowest mean values, meaning that open water and anthropogenic land accounted for a small portion of the surrounding landscape for a majority of turtles. I examined the five training sets for multicollinearity among the landscape composition variables and found VIFs = 1.42 – 31.98 and l r l = 0.01 – 0.95. Collinearity was strong between the proportions of forest and agriculture, but relatively weak among the other landscape composition variables. I included all five landscape composition variables in the multiple linear regressions models.

Modelling

I obtained between 14 and 44 candidate models with ΔAICc < 4 for each training set (see Candidate models, APPENDIX I), and candidate models for all the training sets had between 0 and 4 parameters. Only one candidate model did not include any parameter, and it suggested that HRS was better explained by a constant (y = c) than by a set of variables. Akaike weights of the candidate models for all the training sets ranged from 0.01 to 0.22. Akaike weights were generally low and similar among the candidate models of a training set, making it more appropriate to average a global model than to identify the best model from the lowest ΔAICc or highest Akaike weight. For each training set, I averaged a model from all candidate models (Table 1-3). The averaged models included all seven parameters used. Plastron length ranked as the less important variable across all models, while sex was the second less important variables in 4 models out of 5. Proportions of agriculture, open water and anthropogenic land appeared to be the three most important parameters. The proportion of agriculture at a scale of 3000 m around the MCP had a positive relationship with HRS. An increase in the proportion of open water at the MCP scale was associated with smaller home ranges. The same relationship was observed for the proportion of anthropogenic land at a scale of 3000 m around the MCP. The proportion of wetland ranked as the second and third less important variables in 4 models out of 5, and did not show a consistent relationship with HRS across all models. An increase in its proportion at a scale of 500 m around the MCP was associated with larger or smaller home ranges depending on the model examined. The proportion of forest showed high coefficients in many models, ranking in second or third place for 4 models out of five. It seemed that the proportion of forest at a scale of 4000 m around the MCP had a negative relationship with HRS in most cases, but one model showed larger home ranges with increasing forest proportion.

Pooling data from the five study areas, mean observed HRS was 29.7 ± 32.3 ha (from 2.8 to 130.5 ha). The five averaged models significantly predicted HRS from internal data, but the coefficients of determination (R^2) were low for all relationships (Table 1-3). Between 59 and 75 % of the variation in HRS remained unexplained by the averaged models. The five averaged models were also used to predict HRS on independent data, so each one predicted HRS for the turtles of the study site initially excluded. For each dataset, the relationship between observed and predicted HRS was examined, with data from 6 to 11 turtles per study site. Overall, correlation between predicted and observed HRS was low and was not significant for any of the five independent datasets examined ($R^2 = 0.00009 – 0.24$, $p = 0.319 - 0.980$; Table 1-4; Figure 1-2). A good predictive model should have a 1:1 linear fit when plotting observed values against predicted values, with the linear fit parameters ($mx + b$) being $m = 1$, and $b =0$ (Piñeiro et al., 2008). Compared to a 1:1 linear fit, the models showed deviation from 60 to 197 % for the slope. HRS from Gatineau Park West seemed to be best predicted by the corresponding averaged model, with $R^2 = 0.24$ between predicted and observed HRS. However, this relationship deviated a lot from the

1:1 linear fit, with parameters of m = 2.97 and b = -2.97, and provided the most biased estimates of HRS. Overall, the predictive power of the averaged models was low, and the models provided more or less biased HRS estimates depending on the model used.

DISCUSSION

Physical landscape characteristics have previously been shown to influence movement in many animal species (Reunanen et al., 2002; Bowne et al., 2006; Kindlmann and Burel, 2008). By modelling the relationship between movement and landscape composition, some researchers have successfully identified the effects of landscape modification and human activity on habitat use (Ahlers et al., 2010; Kapfer et al., 2010). For example, a study by Ahlers et al. (2010) in the USA suggested that muskrats (*Ondatra zibethicus*) located their home ranges linearly along available streams and could not move freely to upland habitat in the context of a landscape deeply modified by agriculture. This type of study is an important tool to evaluate the response of wildlife to landscapes modified by human activity.

In the current study, I attempted to model the relationship between landscape composition and HRS in Blanding's turtles using a gradient of landscape characteristics. HRS represents the area needed by an animal to complete its normal activities, and thus is a good indicator of habitat use, often used to identify critical habitat for species at risk. The models were validated on internal data and showed a poor fit to the data used to build them. Over 60% of the variability in HRS remained unexplained by the seven variables included in the models. The proportions of agriculture, open water and anthropogenic land seemed to have a stronger relationship with HRS than the other variables, but those relationships were weak. Moreover, the importance of each variable in predicting HRS varied a lot among the five models, even if over 75% of the training data were constant across the models. It is thus difficult to interpret the effect of each variable on HRS, especially for the variables that showed both positive and negative relationships with HRS depending on the model examined, which is the case for the proportions of wetland and forest. The prediction that animals in landscapes poor in wetlands should have large home ranges was not supported, neither was the positive effect of agriculture and human disturbance on HRS. Unsurprisingly, the models also failed at predicting HRS on independent data from an external study site. It is possible that the models overfitted the training datasets, which impaired their ability to predict HRS on external data. The main goal of predicting HRS on external data was to evaluate the potential of those models to be exported to other study areas. None of the five averaged models significantly predicted HRS on external data, and the prediction made by all of the models were largely biased. Therefore, these models cannot be used to predict habitat use of Blanding's turtles confidently.

Knowing that I was unable to relate movement of that species to landscape composition, there might be more important variables guiding the selection of a home range, at least in the area studied. Other physical attributes of the landscape that have not been studied here, such as configuration, fragmentation and connectivity, could also influence movement patterns (Bowne et al., 2006; Mitrovich et al., 2009).

A major issue I encountered was the low variability in landscape composition among the individuals. The range of proportions obtained for the five land use types was generally broad, except for anthropogenic land that varied between 0 and 11 %. However, the standard deviation was low for all variables, meaning that most of the turtles were using similar habitats, except for a few individuals that accounted for most of the variability. Because I was using sex categories (male, female) in modelling, turtles whose sex could not be determined were excluded from the analyses. Those were juvenile turtles with smaller body size, and their exclusion certainly reduced variability in plastron length. However, I had too few juvenile individuals to include them as a category. The low variability of the predictors used in modelling have also probably impaired the predictive power of the averaged models. Not being able to model the response of Blanding's turtles to the full potential range (0 to 100% cover) of any of the landscape composition variables is the main limitation of my study. Studying turtles in a landscape that had limited variation, especially in anthropogenic land covers, could have biased inferences of their response towards elements of the landscape (Eigenbrod et al., 2011). Future studies should attempt to examine the relationship between movement and landscape composition in heavily disturbed areas.

The selection of study sites for this study was based on a Blanding's turtle visual survey of the entire study area (Dubois 2009). Besides the study sites mentioned here, many other areas were surveyed, including more urban and agricultural zones. Blanding's turtle sightings were rare in disturbed landscapes, however, and the animals caught for the telemetry survey on which this study is based were generally found in areas with high wetland density and an extended forest matrix. This suggests that either Blanding's turtles select high quality habitats at a larger scale than what I considered here, or that Blanding's turtles have already disappeared from the more impacted sites. In both cases, all Blanding's turtles are currently using high-quality habitats, which limited my ability to detect an effect of landscape composition on movement. Further investigation is needed to determine the effect of landscape composition on the probability of presence of Blanding's turtles at larger spatial scales, which will be the main topic of Chapter 2.

At present, I recommend that conservation strategies in the case of Blanding's turtles be based on descriptive studies of movement patterns and habitat selection at local scales, as well as habitat suitability modelling studies that provide insights on habitat requirements at very large spatial scales (Millar and Blouin Demers, 2012). A general caveat is that it seems likely that many species at risk have already declined to the point where they are now only occupying a fraction of their original distribution, most probably the highest quality patches, thus confounding efforts to define suitable habitat at intermediate and small spatial scales.

Table 1- 1. Correlation coefficients (Pearson’s r) of the landscape composition variables, at the spatial scale used in modelling, plotted against home range size of Blanding’s turtles (n = 44). Spatial scale is presented as MCP + the radius length added to build the buffer.

Variable	**r**	**Spatial scale**
Wetland proportion	0.20	MCP + 500 m
Forest proportion	- 0.26	MCP + 4000 m
Agriculture proportion	0.34	MCP + 3000 m
Open water proportion	- 0.42	MCP
Anthropogenic land proportion	- 0.16	MCP + 3000 m

Table 1- 2. Inter-individual variability of the predictors used to models home range size of the Blanding's turtles (n = 44). Landscape composition variables were measured at the spatial scale used to build the predictive models.

Variable	**Range (min - max)**	**Mean ± SD**
Plastron length (mm)	183 - 247	220.9 ± 12.5
Wetland proportion (%)	3.8 - 63.5	25.2 ± 2.2
Forest proportion (%)	27.3 - 82.3	59.1 ± 0.9
Agriculture proportion (%)	0.3 - 58.6	15.1 ± 3.9
Open water proportion (%)	0.0 - 51.5	5.5 ± 3.2
Anthropogenic land proportion (%)	0.0 - 11.4	1.7 ± 1.2

Table 1- 3. Parameter coefficients for five averaged multiple linear regressions models predicting home range size of Blanding's turtles (n = 33 - 38). Estimates of fit of the models on training data are presented with the corresponding coefficients of determination (R^2) and p-values (p). The name of the study site (CL =Clarendon, BR = Bristol, SH = Shawville, EM = Eardley-Masham, GPW = Gatineau Park West) here refers to the data excluded from each training set.

Parameter	**CL**	**BR**	**SH**	**EM**	**GPW**
Intercept	1.33	2.55	1.48	1.09	1.17
SEX	- 0.002	- 0.20	- 0.02	0.009	- 0.009
PL	0.0003	- 0.001	0.001	0.003	- 0.001
WET	0.14	- 0.02	- 0.04	- 0.05	0.14
FOR	- 0.08	- 1.24	- 0.43	- 0.21	0.26
AGRI	0.15	0.68	0.27	0.15	0.67
OW	- 0.89	- 0.06	- 0.78	- 1.23	- 0.26
ANT	- 0.08	- 3.84	- 0.22	- 0.43	- 0.25
R^2	0.25	0.41	0.25	0.34	0.25
p*	0.002	< 0.001	0.002	0.0004	0.002

* All relationships were significant at a 95% level.

Table 1- 4. Estimation of the predictive ability of the five averaged models predicting Blanding's turtles home range size from an independent dataset (n = 6 – 11). Coefficient of determination (R^2), p-value (p), and values for the slope and intercept of the linear fit are presented for each relationship between observed and predicted home range size. The name of the study site here refers to the dataset from that site.

Dataset	**R^2**	**p**	**m**	**b**
CL	0.02	0.708	0.40	0.95
BR	0.001	0.931	- 0.12	1.21
SH	0.00009	0.980	0.05	1.40
EM	0.03	0.609	0.23	0.91
GPW	0.24	0.319	2.97	- 2.97

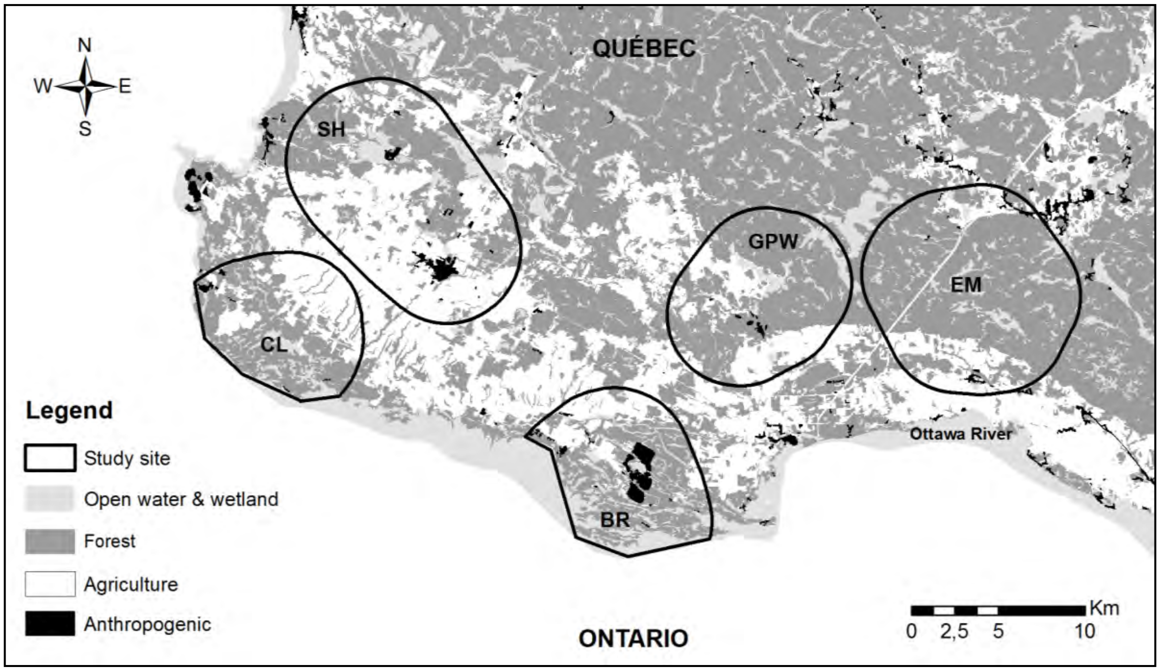

Figure 1- 1. Landscape characteristics of the Blanding's turtle study areas along the North shore of the Ottawa River, Québec, Canada. The maximal extent of the five sites are presented: Clarendon (CL), Shawville (SH), Bristol (BR), Gatineau Park West (GPW), and Earldey-Masham (EM).

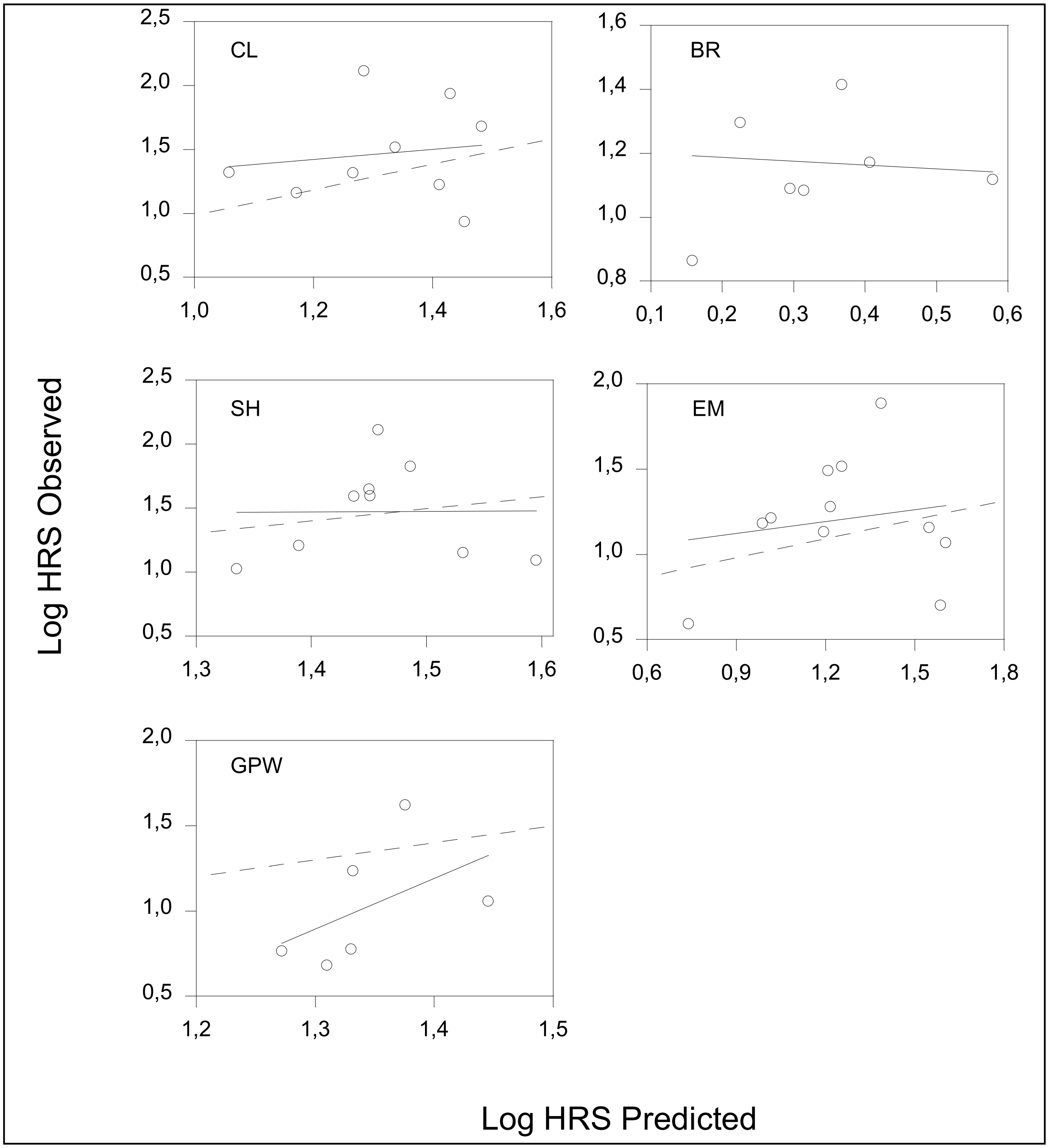

Figure 1- 2. Correlation plots of observed plotted against predicted home range size (both log transformed) of Blanding's turtles (n = 6 – 11). The linear fit for each plot (solid line) is compared to a 1:1 linear fit (dashed line) when in the extent of the axes. The name of the study site here refers to the dataset from that site.

CHAPTER 2

Landscape composition weakly predicts wetland occupancy by Blanding’s turtles (*Emydoidea blandingii*)

This chapter formed the basis for the following publication:

*Fortin, G., G. Blouin-Demers & Y. Dubois. Landscape composition weakly predicts wetland occupancy by Blanding’s turtles (*Emydoidea blandingii*). Journal of Herpetology, in review.*

ABSTRACT

In many animal groups, patterns of spatial occurrence largely depend on landscape composition and configuration. Studying habitat selection at the landscape scale allows identification of habitat features that favour long-term survival of animal populations. I investigated the relationship between landscape composition and wetland occupancy for a population of Blanding's turtles, *Emydoidea blandingii*, over its geographical range in southern Québec. A visual survey was conducted to document occupancy, and I measured landscape composition at two spatial scales (1 and 3 km) around surveyed wetlands. I used logistic regression to model the probability of occurrence of the Blanding's turtle from land cover and road density. Models of wetland occupancy at both scales showed that Blanding's turtles were more likely to occupy areas with high wetland density. However, the models did not fit the presence/absence data well, and their explanatory power was low. Thus, I could not confidently explain the Blanding's turtle wetland occupancy patterns from the six landscape composition variables investigated. It seems this population of Blanding's turtles is not constrained to high quality sites, and that they use areas disturbed by agriculture, in a slightly urbanized landscape. Management of the species should focus on protecting sites of occurrence with an abundance of wetlands and sufficient suitable habitat to cover their seasonal movement patterns.

INTRODUCTION

Habitat selection studies are generally pursued with the goal of identifying important resources to animal species. Their principal contribution to wildlife conservation is to provide, from the perspective of each species, a definition of what constitutes suitable habitat. Johnson (1980) identified three main orders of habitat selection: first-order selection corresponds to the geographical range, second-order selection is the selection of a home range within this range, while third-order selection is the use of certain resources within the home range (microhabitat). To get a complete picture of a species' habitat requirements, habitat selection needs to be investigated at many spatial scales. Selection may be influenced by spatial structure and distribution of habitat components within a landscape (Mayor et al., 2009). Moreover, the selection process is hierarchical, since selection of resources at certain scale depends on previous acts of selection at larger scales.

In many animal groups, patterns of spatial occurrence largely depend on landscape composition and configuration (Berg, 2002; Guerry and Hunter Jr, 2002; Mazerolle et al., 2005; Blevins and With, 2011; Morellet et al., 2011). For example, many frogs and salamanders' probability of occurrence at breeding ponds is associated with forest and pond cover (Guerry and Hunter Jr, 2002; Mazerolle et al., 2005). In this case, selection of a breeding pond goes beyond the sole characteristics of the pond, and illustrates the importance of the landscape context. At the landscape scale, animals select for a geographical range that provides the resources they need, for example, breeding habitat and feeding sites. Within this range, they will select for habitat patches at different moments in their life cycle, but the general area must provide a minimum amount of suitable habitat if the species is to survive for the long-term. Habitat loss can constrain animals to smaller geographical ranges, while populations that face major threats like predation and road mortality might also experience range contraction through local extirpation (Aldridge et al., 2008).

In freshwater turtles, fragmentation of suitable habitat by roads increases vehicle collision, and probabilities of local extirpation (Aresco, 2005; Gibbs and Steen, 2005; Beaudry et al., 2008). Previous studies of habitat selection at local scales consistently showed that Blanding's turtles selected for wetlands dominated by vegetation, and avoided upland habitats as well as human disturbed areas (Hamernick, 2000; Edge et al., 2010; Millar and Blouin-Demers, 2011). Land use and road density could then be important factors dictating the spatial patterns of occurrence of Blanding's turtles at the landscape scale.

Objectives

Habitat selection studies focusing on Blanding's turtles have mainly identified elements preferred by the species at the microhabitat and home range scales (Hamernick, 2000; Beaudry et al., 2009; Edge et al., 2009; Edge et al., 2010; Millar and Blouin-Demers, 2011). The landscape context should be taken into account when studying habitat selection in this species at risk which is mainly threatened by habitat loss and road mortality. The goal of this study was to evaluate the effect of landscape composition on wetland occupancy by Blanding's turtles. Studying habitat selection at the landscape scale will allow identification of habitat features that promote site occupancy. It could also help identify suitable sites to survey or to protect, using simple information like land cover and road density.

I hypothesized that wetland occupancy by Blanding's turtles is affected by landscape composition. Because this species typically uses many habitat patches throughout a season, the quality of surrounding habitat within movement extent should be a determinant of the suitability of a site. I predicted that wetland occupancy would be higher at sites with a high proportion of wetlands because wetlands are considered preferred habitats for the species. High road density and high proportions of urban areas should have a negative effect on wetland occupancy due to more frequent encounters with vehicles, which increases mortality and risk of local extirpation.

METHODOLOGY

Study area

The field portion of this study was conducted by Nature Conservancy Canada in spring of 2008 and 2009 in the extreme southwest of the province of Québec, Canada. The study area covered approximately 1 800 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 Valley, which makes the transition between those two regions, is characterized by widespread agricultural activity. In this region, road density was approximately 4 km/km^2, and there was an extensive network of ATV trails and unpaved roads. The northern part of the study area was located in the Canadian Shield, and was mostly forested, with very low urbanization and a limited road network.

Visual surveys

The study area was divided into 43 parcels of 8 km^2 and 1 to 4 wetlands were selected within each parcel for a visit, for a total of 162 wetlands. The visited wetlands (marshes, swamps, bogs, and other shallow water habitats) were considered potential habitat for Blanding's turtles (Dubois et al. 2009). Visual surveys were conducted during sunny days at emergence from hibernation, from

1 to 15 May, when the probability of observing basking turtles is the highest. Observers walked shorelines or patrolled in canoe, and scanned the sites using binoculars or a telescope with the goal of covering the entire site in a single visit. Most of the sites were visited only once, but 16 sites were visited twice, and one site was visited thrice. Blanding's turtles were considered present at a site when a least one individual was observed.

Landscape composition variables

I measured landscape composition as the proportion of five land uses, as well as road density. I used standard tools from ArcGIS 10 (ArcView, Environmental Systems Research Institute, California, USA) to measure all landscape composition variables. Land use layers for the study area were obtained through the Base de données topographiques du Québec (BDTQ), Système d'information écoforestière (SIEF), Base de données des cultures assurées (BCDA), and Ducks Unlimited Canada (DUC). All the layers were in a vector format, at a scale of 1:20 000, except BCDA that had a scale of 1:50 000. The land use categories were first merged into 6 categories: 1) wetlands, including wetland and woody wetland from DUC, and wetlands from BDTQ, 2) forest, from BDTQ, 3) agriculture, including BCDA, agriculture and agroforestry from SIEF, 4) open water, from BDTQ, 5) anthropogenic, including designated areas from BDTQ as well as gravel pits, and disturbed sites from SIEF, and 6) other, corresponding to all the area that did not fall into the five other categories. Lands use categories were made independent from each other by removing overlaps from all layers. I obtained the road layer from the BDTQ, and it included all paved and unpaved roads as well as non-vehicular roads, including ATV trails, railroads, and abandoned roads.

I measured landscape composition at two spatial scales at the sites visited for the Blanding's turtle presence/absence survey. I built buffers with radii of 1 and 3 km around the visited locations (centroids of visited wetlands), corresponding approximately to the mean and largest home range lengths measured for the Outaouais population of Blanding's turtles. When buffers of recorded presence and absence of the species overlapped, the buffer was kept at the presence location only and the species was considered present.

The landscape composition variables used were the proportions of the following land uses: wetland (WET), forest (FOR), agriculture (AGRI), open water (OW), and anthropogenic land (ANT). I also included road density as a landscape composition variable. I did not include the category "other" as a variable because it did not represent a specific habitat type of interest. The Ottawa River was excluded from the "open water" category because it was not considered as a potential habitat for Blanding's turtles. Each of the variables was transformed to best fit a normal distribution (Table 2-1).

Modelling

To examine the relationship between landscape composition and presence of the Blanding's turtle, I built multiple logistic regression models to predict wetland occupancy. The predictors were all the landscape variables previously mentioned, and were measured at two spatial scales. I built a predictive model for each scale to examine the effect of landscape composition on wetland occupancy at intermediate and maximal movement extents of the species.

I examined each training set for multicollinearity among the landscape composition variables, using both pairwise regressions between all variables and variance inflation factors (VIFs) for each variable (See Collinearity, APPENDIX II) (Smith et al., 2009). The VIFs were calculated using the "car" package in R. For each dataset, I used multiple logistic regressions to build models including all the predictors. I examined all the possible models, using the "MuMin" package in R. I calculated the second order Akaike's Information Criterion (AICc) for each candidate model and model selection was based on ΔAICc and Akaike weights (Burnham and Anderson, 2002). I measured Nagelkerke's R-square for each candidate model, and considered it an indicator of their ability to predict wetland occupancy. All candidate models with a ΔAICc < 4 were used to average the parameters of an averaged model, based on the relative weight of each candidate model. To validate the two averaged models, I measured the coefficients of each predictor of an averaged model, as well as their corresponding standard error and 95% confidence interval. Those statistics indicate the uncertainty associated with each predictor's coefficient, large confidence intervals and standard errors suggesting poor predictive ability. All the statistical analyses were performed with JMP 7 (SAS Institute Inc, North Carolina, USA) and R version 2.12.1 (R Development Core Team, Austria).

RESULTS

After removing survey sites with overlapping 1 km or 3 km buffers, I measured landscape composition for 70 survey sites at a 1 km scale (16 occupied, 54 unoccupied), and for 22 sites at a 3 km scale (9 occupied, 13 unoccupied). For both spatial scales, the proportions of open water and anthropogenic lands were low (Table 2-2). Agriculture and forest were the dominant land use types at both scales. Overall, predictors showed high variability across the surveyed landscape, but there was little difference in landscape composition between the two spatial scales.

I examined collinearity in each dataset, and found VIFs = 1.30- 8.07 and l r l= 0.03 – 0.75 at a 1 km scale, and VIFs = 1.61 – 15.93 and l r l= 0.12 – 0.92 at a 3 km scale. For both spatial scales, the proportion of agriculture was strongly correlated to the proportions of forest and open water. The proportion of forest also showed high correlation with the proportion of open water at the 3 km scale. Other variables showed weak collinearity with VIFs under 5, and correlation was generally higher at the 3 km scale. I included all six landscape composition variables in the models predicting wetland occupancy of the Blanding's turtle.

At a 1 km scale, the full model had many significant terms. There was a significantly positive relationship between the probability of presence of Blanding's turtles and the proportions of forest ($X^2_{5,\,70} = 5.45$, $p = 0.02$) and wetland ($X^2_{5,\,70} = 8.69$, $p = 0.003$), and a significantly negative relationship with the proportion of agriculture ($X^2_{5,\,70} = 5.33$, $p = 0.02$) and road density ($X^2_{5,\,70} = 4.70$, $p = 0.03$). For the 3 km scale dataset, none of these relationships were significant.

Modelling

For the 1 km scale dataset, I obtained 11 candidate models with $\Delta AICc < 4$, and the models had between 1 to 4 parameters (Table 2-3). Nagelkerke's pseudo R^2 ranged from 0.09 to 0.15. The 3 km scale dataset showed similar results, with 13 candidate models that had between 0 to 3 parameters (Table 2-4). At this scale, one candidate model did not include any parameter, suggesting that wetland occupancy was better explained by a constant ($y = c$) than by the selected predictors. Nagelkerke's pseudo R^2 ranged from 0.00 to 0.19. For both datasets, Akaike weights were generally low, thus I averaged a model from all candidate models of each dataset.

Both averaged models included all 6 predictors originally selected. At a 1 km scale, the most important parameter was the proportion of wetland, which showed a positive relationship with wetland occupancy. Road density ranked as the second most important variable, and had a negative relationship with wetland occupancy. Results were different at a 3 km scale, with the three most important predictors of the average models being, in order, the proportions of forest, wetland, and anthropogenic land. All three parameters showed a positive relationship with wetland occupancy, suggesting that Blanding's turtles are likely to use natural sites as well as human disturbed sites.

For both datasets, all parameter coefficients had large standard errors and confidence intervals, meaning that the averaged models could not precisely predict wetland occupancy from the landscape composition variables used. This is most probably linked to the low values of Nagelkerke's pseudo R^2 obtained for the candidate models used in model averaging.

DISCUSSION

Many studies on amphibians and reptiles conclude that habitat features drive patterns of distribution and abundance at both local and landscape scales (Guerry and Hunter Jr, 2002; Mazerolle et al., 2005; Blevins and With, 2011; Millar and Blouin Demers, 2012). While every species has particular requirements in terms of habitat, it has become possible to determine the global distribution of a species at the landscape scale, and even to locate core areas of activity within a landscape. This enables researchers and wildlife managers to identify physical elements necessary to survival and persistence of wildlife species.

With this study, I tried to evaluate the role played by landscape composition on the spatial distribution of Blanding's turtles. At both spatial scales examined, the presence of the species seemed to be related to high a proportion of wetlands, which is the preferred habitat type of the species (Edge et al., 2010; Millar and Blouin-Demers, 2011). The candidate models did not fit the presence/absence data well, however, and the predictions made from the two averaged models had very low precision (high standard errors and large confidence intervals). Thus, I could not explain well the Blanding's turtle wetland occupancy patterns from the six landscape composition variables investigated.

When looking at the full models, however, an intriguing result was that the probability of presence of Blanding's turtles was significantly lower at sites with high road density. The probability of presence was also significantly higher at sites with high proportions of wetland and forest, which are the main natural habitat features used by Blanding's turtles. Less fragmented, natural sites thus appear to promote Blanding's turtle occupancy. These results should be confirmed in other areas to confirm that they are biologically significant in addition to being statistically significant.

A limitation of this study was the small number of sites that were spatially independent from each other after applying buffers of 1 km and 3 km. After removing overlapping buffers, data from 70 surveyed sites were available for the 1 km scale model, and only 22 sites remained for the 3 km scale model. Since I used a total of six variables to model wetland occupancy, a larger number of observation locations would have been preferable, especially in the case of the 3 km scale model.

Another limitation is that I was not able to examine the whole range of possible values for the proportions of five habitat types (0 to 100%), which could have impaired the model's ability to predict wetland occupancy by the Blanding's turtle (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, especially at a 3 km scale. I thus recommend adding study sites to complete the environmental gradient of landscape composition, including heavily disturbed sites and pristine landscapes with high wetland density. At such large spatial scales, however, it seems unlikely to obtain a full gradient for land cover categories such as open water and wetland, and this limitation is inherent to studies at large spatial scales.

The main limitation of the survey method was that wetland occupancy was estimated from presence/absence data at sites that were usually visited only once. Thus, it was not possible to account for the probability of detection, which can be low for small populations and for cryptic species such as the Blanding's turtle. Moreover, it has been shown that failure to detect a species in occupied habitat patches can bias models investigating the relationship between an animal and its habitat (Guerry and Hunter Jr, 2002; Mazerolle et al., 2005). In this case, underestimation of the Blanding's turtle probability of occurrence at sampling locations could bias both parameter estimation and direction of the relationship between spatial distribution of the species and landscape composition. Thus, I recommend careful interpretation of the predictions made by the averaged models at both the 1 km scale and the 3 km scale.

In chapter 1, I showed that landscape composition weakly affected the movement of Blanding's turtles within the study area. I suggested that the low variability in landscape composition observed in the vicinity of their home ranges might reflect a selection of high quality habitats at the landscape scale. In the current study, all variables investigated showed high variability, meaning that landscape composition was different across the sites surveyed. However, the sites where Blanding's turtles were detected only slightly differ from sites where they were absent, suggesting that probability of occurrence of the species is not driven by specific landscape characteristics. Blanding's turtles seemed to inhabit landscapes of variable composition within this study site, even if the landscape was generally dominated by agriculture and forest. Again, underestimation of the species' presence at the sites surveyed might also have impaired the model predictions.

Predictions of occurrence can be a useful conservation tool to target important habitats to protect. The results obtained here do not allow identification of potential habitats at the landscape scale. Presence of the species at natural sites and disturbed sites could reflect progressive transformation of the landscape at sites of historical occurrence. Blanding's turtles do not seem to have been already extirpated from all human exploited areas, and many sites where the species occurred were surrounded by crops. The study area represents the major part of the Blanding’s turtle distribution in Québec, and is very slightly urbanized. 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 the effect of road mortality on Blanding’s turtles population might currently be moderate. Because I was unable to predict presence/absence of Blanding’s turtles from landscape composition, conservation recommendations should be based on descriptive studies of local habitat selection and movement, which are currently the best information available in the literature. Habitat loss being a major threat to this species, managing plans should focus on protecting sites of occurrence with abundance of wetlands and sufficient suitable habitat to cover their seasonal movement patterns.

Table 2- 1. Transformations used to reach normality of the landscape composition variables measured at two spatial scales in the study of wetland occupancy by Blanding's turtles.

Variable	**Transformation**	
	Buffer 1 km	Buffer 3km
Agriculture proportion (%)	Square root	Square root
Forest proportion (%)	None	None
Open water proportion (%)	Square root	Square root
Anthropogenic land proportion (%)	Square root	Square root
Wetland proportion (%)	Square root	Square root
Road density (km/km2)	None	Log+1

Table 2- 2. Variability of the predictor variables at surveyed sites, used to model wetland occupancy by Blanding's turtles (1 km scale model, n = 70; 3 km scale model, n = 22).

Variable	**Range (min - max)**	**Mean ± SD**
1 km scale		
Wetland proportion (%)	0.0 - 42.6	12.6 ± 10.5
Forest proportion (%)	6.2 - 94.7	58.4 ± 19.3
Agriculture proportion (%)	0.0 - 84.7	19.0 ± 18.3
Open water proportion (%)	0.0 - 30.7	2.9 ± 5.0
Anthropogenic land proportion (%)	0.0 - 31.7	2.1 ± 5.6
Road density (km/km^2)	0.0 - 8.3	3.0 ± 1.9
3 km scale		
Wetland proportion (%)	1.9 - 22.3	9.8 ± 5.8
Forest proportion (%)	16.0 - 85.3	52.0 ± 20.5
Agriculture proportion (%)	0.0 - 70.6	30.0 ± 22.1
Open water proportion (%)	< 0.1 - 10.1	1.9 ± 2.2
Anthropogenic land proportion (%)	< 0.1 - 12.5	3.0 ± 3.6
Road density (km/km^2)	0.8 - 5.4	3.1 ± 1.3

Table 2- 3. Multiple logistic regression candidate models predicting wetland occupancy by Blanding's turtles at a 1 km scale (n = 70; 16 presences, 54 absences). Models are ranked according to second order Akaike Information Criterion (AICc, ΔAICc < 4), and the number of parameters (k), Akaike weights (w), and Nagelkerke pseudo R^2 (R^2) values are also presented.

Model name	**k**	**AICc**	**ΔAICc**	**w**	**R^2**
ROAD+WET	2	75.05	0.00	0.28	0.14
WET	1	76.69	1.64	0.12	0.09
ROAD+FOR+WET	3	77.11	2.06	0.10	0.15
ROAD+OW+WET	3	77.16	2.11	0.10	0.14
ROAD+ANT+WET	3	77.31	2.26	0.09	0.14
ROAD+AGRI+WET	3	77.37	2.32	0.09	0.14
FOR+WET	2	78.14	3.09	0.06	0.11
ANT+WET	2	78.49	3.44	0.05	0.10
ROAD+FOR+AGRI+WET	4	78.67	3.62	0.04	0.13
OW+WET	2	78.82	3.77	0.04	0.09
AGRI+WET	2	78.92	3.87	0.04	0.09

Table 2- 4. Multiple logistic regression candidate models predicting wetland occupancy by Blanding's turtles at a 3 km scale (n = 22; 9 presences, 13 absences). Models are ranked according to second order Akaike Information Criterion (AICc, ΔAICc < 4), and the number of parameters (k), Akaike weights (w), and Nagelkerke's pseudo R^2 (R^2) values are also presented.

Model name	**k**	**AICc**	**ΔAICc**	**w**	**R^2**
Presence ~ 1	0	35.83	0.00	0.22	0.00
ROAD	1	37.27	1.44	0.11	0.04
FOR	1	37.34	1.52	0.10	0.04
ROAD+WET	2	37.47	1.64	0.10	0.13
WET	1	37.67	1.84	0.09	0.03
OW	1	37.95	2.13	0.07	0.02
AGRI	1	38.04	2.21	0.07	0.02
ANT	1	38.48	2.65	0.06	0.00
FOR+ROAD	2	38.58	2.76	0.05	0.10
ROAD+AGRI	2	39.36	3.54	0.04	0.07
FOR+AGRI+ANT	3	39.40	3.57	0.04	0.19
FOR+ANT	2	39.60	3.78	0.03	0.06
FOR+AGRI	2	39.72	3.89	0.03	0.06

Table 2- 5. Parameter coefficients for two logistic regression models predicting wetland occupancy by Blanding's turtles (1 km scale model, n = 70; 3 km scale model, n = 22). Standard error (SE) and 95% confidence intervals (95% CI) are also presented for each parameter.

Parameter	**Coefficient**	**SE**	**95%CI**
1 km scale			
Intercept	0.09	0.26	- 0.41 ; 0.60
WET	0.88	0.33	0.23 ; 1.53
FOR	0.05	0.18	- 0.31 ; 0.40
AGRI	0.01	0.13	- 0.24 ; 0.26
OW	0.03	0.18	- 0.33 ; 0.39
ANT	-0.004	0.17	- 0.34 ; 0.33
ROAD	-0.33	0.30	- 0.92 ; 0.27
3 km scale			
Intercept	0.20	0.91	- 1.63 ; 2.02
WET	0.28	0.81	- 1.35 ; 1.91
FOR	0.32	0.96	- 1.60 ; 2.24
AGRI	0.08	0.64	- 1.21 ; 1.37
OW	0.08	0.51	- 0.97 ; 1.14
ANT	0.15	0.72	- 1.31 ; 1.61
ROAD	-0.04	0.07	- 0.19 ; 0.12

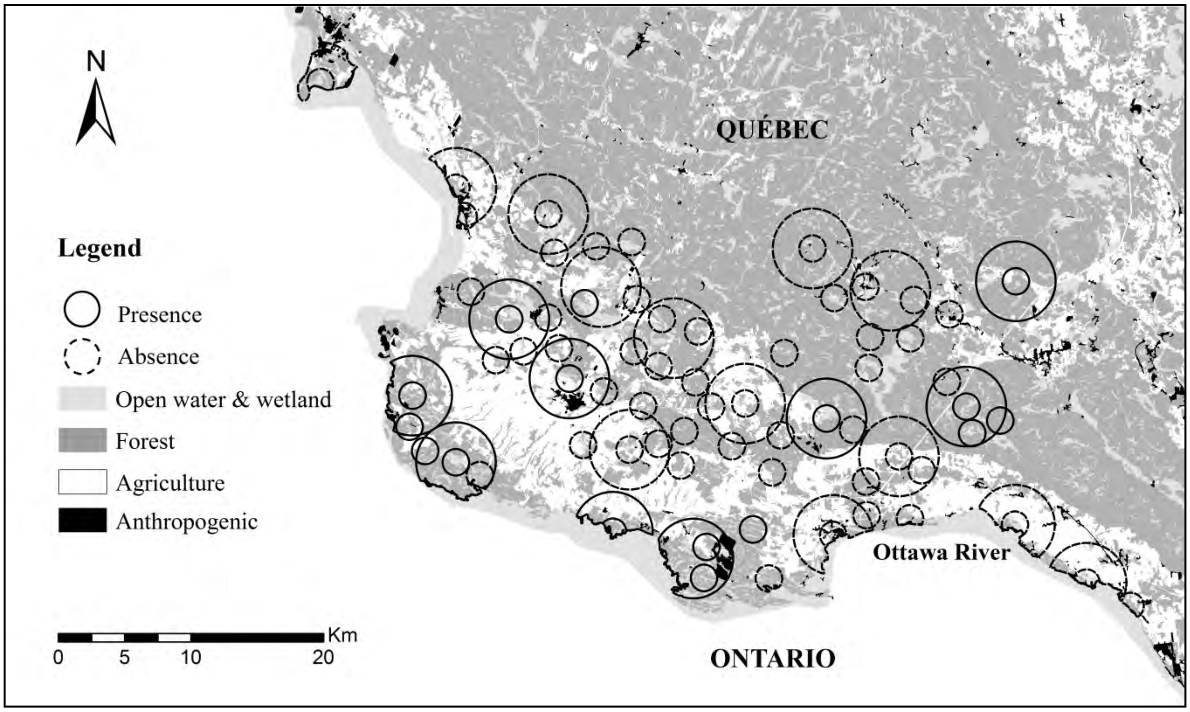

Figure 2- 1. Map of southern Québec, Canada, showing land cover at survey sites, where landscape composition was measured within radii of 1 and 3 km (circle) at sites of Blanding's turtle presence (solid) and absence (dashed).

APPENDIX I

Complementary results for telemetry validation and movement modelling in Blanding's turtles

Telemetry validation

The turtle locations were obtained through direct localization of the animal or using triangulation. To measure the accuracy of triangulation, each of the six observers did pairs of locations, a pair including a triangulation followed by the direct localization for the same animal. For each pair, I measured the precision of the triangulation (distance between true animal location and triangulated location) and the distance from the animal (mean distance between triangulation stations and true animal location). I performed a one-way ANOVA to test the effect of the observer on triangulation precision and used regression to model the relationship between distance from the animal (independent variable) and triangulation precision. The equation was used to estimate the precision of all other triangulated locations, using the mean distance between the triangulation stations and the triangulated turtle location as the independent variable.

I used a total of 135 pairs of locations to validate triangulation accuracy, each observer having between 20-27 pairs of locations. There was no significant effect of the observer on the triangulation precision ($R^2 = 0.04$, $F_{5,129} = 1.09$, $p = 0.37$). The relationship between distance to the animal and triangulation precision was significantly positive and the pooled data were best fitted by a second-degree polynomial curve ($r = 0.81$, $p < 0.001$). Its equation ($y = 0.001\, x^2 + 0.206\, x + 0.822$) was used to estimate the precision of 817 triangulated turtle locations. I discarded 94 triangulated locations that had a precision > 30 m (90% quantile = 31.96 m).

Movement variables

Because I wished to model the effect of landscape composition on movement patterns, I first considered four possible independent variables: home range size (HRS; ha), home range length

(HRL; m), mean distance moved (MM; m), and total distance moved (TM; m). Using a sample of 34-35 locations for the active season (May-September), the HRS of each animal was measured with minimum convex polygons (Row and Blouin-Demers, 2006). HRL was measured as the longest distance between two locations of the home range. MM and TM were measured using distances between successive locations for each animal. Those analyses were performed in Arc GIS 10, using Hawth's tools (Hawthorne Beyer, Spatial Ecology). The four variables were log transformed to reach a normal distribution, as examined by the Shapiro-Wilk test. I built a correlation matrix with the four movement variables to determine if many dependent variables were needed to model the Blanding's turtle movements.

The range and mean for each movement variable are shown in Table A1-1. The correlation was very high between all four movement variables, and ranged from $r = 0.72$ -0.99 (Figure A1-1). Those relationships were all significant, with p-value < 0.001 in all cases. These high correlations suggest that the movement variables chosen bring similar information on movement patterns. Therefore, HRS was chosen as the only dependant variables used in modelling, and had correlation coefficients ranging from $r = 0.82$ - 0.87 with the other movement variables.

Spatial scale

The landscape composition variables used were the proportion of the following land uses: wetland (WET), forest (FOR), agriculture (AGRI), open water (OW), and anthropogenic lands (ANT). These variables were measured at eight spatial scales, ranging from the MCP to MCP 4000 (buffer of 4000 m around the MCP). To reduce the number of variables in the models, I needed to choose one specific spatial scale for each variable. The choice was based on the correlation between the landscape composition variable and HRS. For each variable, the correlation between the variables and HRS was measured at all spatial scales using linear regression. For each variable, coefficients of correlation (Pearson's r) were then plotted against spatial scale to examine the spatial extent of effect for each variable. The highest correlation guided the choice of the spatial scale used in further modelling analyses. However, some of the plots of HRS against landscape composition showed a large number of null values on the x axis, with correlation driven only by a few points. When selecting a spatial scale for each variable, I excluded plots of HRS against landscape composition that had lower than 10 positive values on the x axis. This was done on the whole dataset.

The correlation between landscape variables and HRS varied greatly with spatial scale, ranging from l r l = < 0.008 – 0.42 (Figure A1-2). The general pattern observed was higher correlation at small spatial scales, decrease in correlation at intermediate scales, followed by a more or less important increase in correlation for large spatial scales. The maximal correlation was observed either at very small (MCP – MCP 500) or very large spatial scales (MCP 3000 – MCP 4000). For the proportion of agriculture, the plot of HRS against agriculture proportion showing the highest r was excluded because it had too few positive values on the x axis. Consequently, the second highest value of r guided the choice of the spatial scale

Collinearity

Collinearity is a common problem encountered in model selection and it can bias estimated model parameters and mask certain predictor effects (Freckleton, 2011). Thus, I tested each training set separately, and the whole dataset for multicollinearity among the landscape variables. As recommended by Smith et al. (2009), I ran pairwise regressions between all landscape variables and measured variance inflation factors (VIFs) while including all predictors used to model home range size (Burnham and Anderson, 2002). I used the "car" package in R to measure VIFs.

Correlation among the landscape variables was examined for each training set, and showed correlation varying from l r l = 0.01 – 0.95. For the whole dataset, correlation varied from l r l = 0.02 – 0.85 (Figure A1-3). The highest correlation was found between proportions of forest and agriculture, and other variables showed low correlation. VIFs for the landscape composition variables ranged from 1.42 to 31.98 for the five separate training sets (Table A1-2), and from 1.50 to 16.63 when considering the whole dataset. Again, multicollinearity was a problem with forest and agriculture proportions, but other variables showed weak collinearity with VIFs < 5. Because of the strong relationship between proportions of forest and agriculture, it can be hard to distinguish the effect of those two variables on HRS. Being aware of that, I still included all the landscape composition variables in the models predicting HRS.

Candidate models

To model HRS of the Blanding's turtles, I used 7 predictors, being sex (SEX), plastron length (PL), and root squared transformed proportions of the following land uses: wetland, forest, agriculture, open water, and anthropogenic land. I used five different training sets to build models, each time excluding data from one study area. The models considered were those with ΔAICc < 4 (Burnham and Anderson, 2002). Statistical analyses were performed with the "MuMin" package in R. Tables A1-3 a-e show the candidate models used in model averaging.

Table A1- 1. Inter-individual variability of four movement variables measured in Blanding's turtles (n = 44).

Variable	**Range (min -max)**	**Mean ± SD**
Home range size (ha)	2.8 - 130.5	29.7 ± 32.3
Home range length (m)	345.9 - 3135.8	1085.2 ± 625.1
Mean move (m)	36.4 - 237.6	125.1 ± 47.4
Total move (m)	1239.0 - 8079.5	4250.7 ± 1611.7

Table A1- 2. Variance inflation factors for landscape composition variables used in multiple linear regressions to model home range size in the Blanding's turtles (n = 33 – 38). The name of the study site here refers to the data excluded of each training set.

Variable	CL	BR	SH	EM	GPW
WET	2.11	2.34	1.83	1.77	1.74
FOR	21.06	18.94	8.06	11.12	31.98
AGRI	16.23	17.95	6.23	11.58	24.22
OW	1.42	1.59	1.52	1.64	1.50
ANT	5.28	2.99	4.46	5.79	7.20

Table A1- 3. Multiple linear regressions candidate models explaining home range size in the Blanding's turtle. Models are ranked according to second order Akaike Information Criterion (AICc, ΔAICc < 4), and the number of parameters (k) and Akaike weights (w) are also presented.

Table A1-3a. Training set excluding Clarendon (n = 35).

Model	**k**	**AICc**	**ΔAICc**	**w**
OW	1	33.12	0.00	0.16
AGRI+OW	2	33.39	0.27	0.14
OW+WET	2	33.88	0.76	0.11
FOR+OW	2	34.70	1.59	0.07
ANT+OW	2	35.40	2.28	0.05
PL+OW	2	35.44	2.32	0.05
AGRI+ANT+OW	3	35.52	2.41	0.05
ANT+FOR+OW	3	35.58	2.46	0.05
AGRI+OW+WET	3	35.60	2.48	0.05
SEX+OW	2	35.64	2.52	0.04
AGRI+FOR+OW	3	35.82	2.70	0.04
PL+OW+WET	3	36.09	2.97	0.04
SEX+AGRI+OW	3	36.11	2.99	0.04
PL+AGRI+OW	3	36.12	3.00	0.04
FOR+OW+WET	3	36.17	3.06	0.03
ANT+OW+WET	3	36.22	3.10	0.03
SEX+OW+WET	3	36.52	3.40	0.03

Table A1-3b. Training set excluding Bristol (n = 35).

Model	**k**	**AICc**	**ΔAICc**	**w**
SEX+AGRI+ANT	3	27.82	0.00	0.22
SEX+ANT+FOR	3	28.44	0.61	0.16
SEX+AGRI+ANT+WET	4	30.04	2.22	0.07
SEX+AGRI+ANT+OW	4	30.06	2.24	0.07
ANT+FOR	2	30.28	2.46	0.07
SEX+AGRI+ANT+FOR	4	30.39	2.57	0.06
PL+SEX+AGRI+ANT	4	30.63	2.81	0.05
PL+SEX+ANT+FOR	4	30.85	3.02	0.05
SEX+ANT+FOR+OW	4	30.92	3.10	0.05
AGRI+ANT	2	31.14	3.31	0.04
PL+ANT+FOR	3	31.21	3.39	0.04
SEX+ANT+FOR+WET	4	31.33	3.51	0.04
AGRI+ANT+OW	3	31.58	3.75	0.03
ANT+FOR+OW	3	31.60	3.78	0.03

Table A1-3c. Training set excluding Shawville (n = 35).

Model	**k**	**AICc**	**ΔAICc**	**w**
AGRI+OW	2	34.23	0.00	0.13
OW	1	34.40	0.17	0.12
ANT+FOR+OW	3	35.39	1.16	0.07
PL+OW	2	35.67	1.44	0.06
FOR+OW	2	35.83	1.60	0.06
AGRI+OW+WET	3	35.84	1.62	0.06
ANT+OW	2	36.12	1.89	0.05
SEX+OW	2	36.40	2.17	0.04
AGRI+ANT+OW	3	36.42	2.19	0.04
SEX+AGRI+OW	3	36.45	2.22	0.04
PL+AGRI+OW	3	36.51	2.28	0.04
OW+WET	2	36.94	2.71	0.03
AGRI+FOR+OW	3	36.96	2.73	0.03
PL+SEX+OW	3	36.98	2.75	0.03
ANT+FOR	2	37.60	3.37	0.02
PL+FOR+OW	3	37.63	3.40	0.02
ANT+FOR+OW+WET	4	37.64	3.41	0.02
AGRI	1	37.90	3.67	0.02
SEX+ANT+FOR+OW	4	37.93	3.70	0.02
PL+ANT+OW	3	37.94	3.72	0.02
SEX+FOR+OW	3	38.12	3.89	0.02
PL+ANT+FOR+OW	4	38.23	4.00	0.02

Table A1-3d. Training set excluding Eardley-Masham, (n = 33).

Model	**k**	**AICc**	**ΔAICc**	**w**
ANT+OW	2	32.59	0.00	0.10
PL+OW	2	32.61	0.02	0.09
AGRI+OW	2	32.68	0.10	0.09
OW	1	32.72	0.13	0.09
ANT+FOR+OW	3	33.48	0.89	0.06
PL+ANT+OW	3	33.62	1.03	0.06
PL+AGRI+OW	3	33.98	1.40	0.05
AGRI+ANT+OW	3	34.31	1.72	0.04
ANT+OW+WET	3	34.36	1.77	0.04
FOR+OW	2	34.51	1.92	0.04
SEX+AGRI+OW	3	34.79	2.20	0.03
PL+FOR+OW	3	35.14	2.56	0.03
SEX+OW	2	35.16	2.57	0.03
SEX+ANT+OW	3	35.24	2.65	0.03
OW+WET	2	35.31	2.73	0.02
AGRI+FOR+OW	3	35.33	2.75	0.02
PL+SEX+OW	3	35.38	2.79	0.02
PL+OW+WET	3	35.38	2.80	0.02
AGRI+OW+WET	3	35.40	2.82	0.02
PL+ANT+FOR+OW	4	35.61	3.02	0.02
SEX+ANT+FOR+OW	4	35.81	3.23	0.02
ANT+FOR+OW+WET	4	35.94	3.35	0.02
AGRI+ANT+FOR+OW	4	35.97	3.38	0.02
PL+AGRI+ANT+OW	4	36.07	3.48	0.02
PL+ANT+OW+WET	4	36.18	3.59	0.02
AGRI+ANT+OW+WET	4	36.48	3.90	0.01

Table A1-3e. Training set excluding Gatineau Park West (n = 38).

Model	k	AICc	ΔAICc	w
AGRI+OW	2	37.11	0.00	0.07
AGRI	1	37.35	0.24	0.06
AGRI+FOR+OW	3	37.63	0.52	0.05
AGRI+FOR	2	37.73	0.63	0.05
AGRI+ANT	2	38.08	0.97	0.04
AGRI+ANT+OW	3	38.16	1.05	0.04
PL+AGRI	2	38.29	1.18	0.04
PL+AGRI+ANT	3	38.70	1.59	0.03
PL+AGRI+FOR	3	38.81	1.71	0.03
AGRI+WET	2	38.83	1.72	0.03
OW	1	38.96	1.85	0.03
OW+WET	2	39.06	1.96	0.03
WET	1	39.20	2.09	0.02
ANT+FOR	2	39.21	2.11	0.02
ANT+FOR+OW	3	39.23	2.13	0.02
AGRI+OW+WET	3	39.28	2.18	0.02
PL+AGRI+OW	3	39.44	2.33	0.02
SEX+AGRI	2	39.44	2.34	0.02
SEX+AGRI+FOR	3	39.57	2.46	0.02
PL+ANT+FOR	3	39.59	2.48	0.02
SEX+AGRI+OW	3	39.77	2.66	0.02
AGRI+ANT+WET	3	39.77	2.67	0.02
AGRI+FOR+WET	3	39.82	2.71	0.02
PL+AGRI+FOR+OW	4	40.13	3.02	0.02
ANT+FOR+WET	3	40.20	3.09	0.01
SEX+AGRI+ANT	3	40.21	3.10	0.01
FOR+OW	2	40.25	3.14	0.01
AGRI+FOR+OW+WET	4	40.28	3.17	0.01
ANT+OW	2	40.29	3.19	0.01

Model	k	AICc	ΔAICc	w
ANT+WET	2	40.34	3.23	0.01
SEX+AGRI+FOR+OW	4	40.35	3.25	0.01
PL+AGRI+ANT+OW	4	40.38	3.27	0.01
AGRI+ANT+FOR	3	40.39	3.28	0.01
AGRI+ANT+FOR+OW	4	40.45	3.35	0.01
ANT+OW+WET	3	40.46	3.36	0.01
PL+AGRI+WET	3	40.51	3.40	0.01
AGRI+ANT+OW+WET	4	40.53	3.42	0.01
SEX+WET	2	40.57	3.46	0.01
PL+SEX+AGRI	3	40.95	3.84	0.01
SEX+AGRI+ANT+OW	4	40.97	3.86	0.01
SEX+AGRI+WET	3	41.02	3.91	0.01
FOR+WET	2	41.05	3.94	0.01
Log HRS = 1	0	41.07	3.96	0.01
ANT+FOR+OW+WET	4	41.10	3.99	0.01

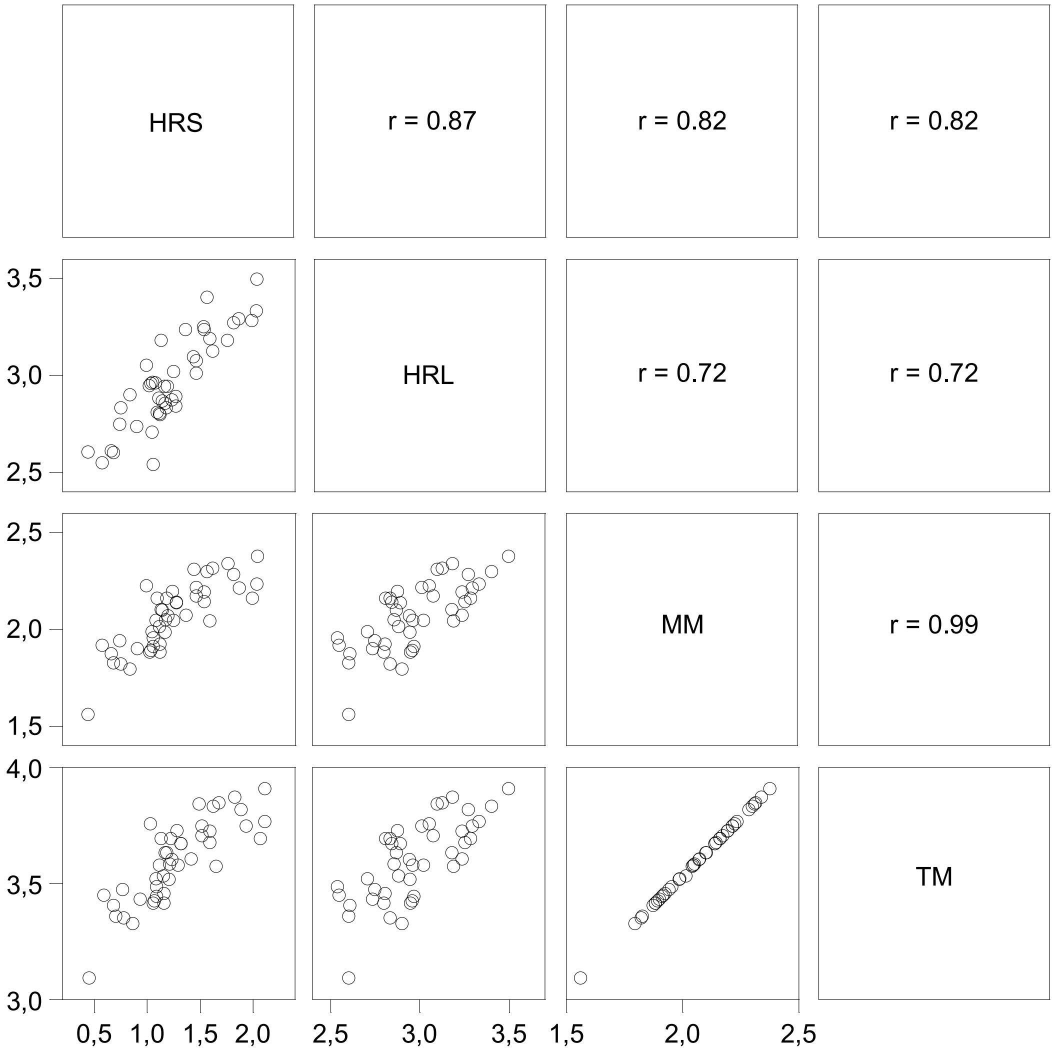

Figure A1- 1. Correlation matrix of log transformed movement variables measured in Blanding's turtles (n = 44): Home range size (HRS), home range length (HRL), mean move (MM), and total move (TM). Pearson's correlation coefficients are shown above the diagonal.

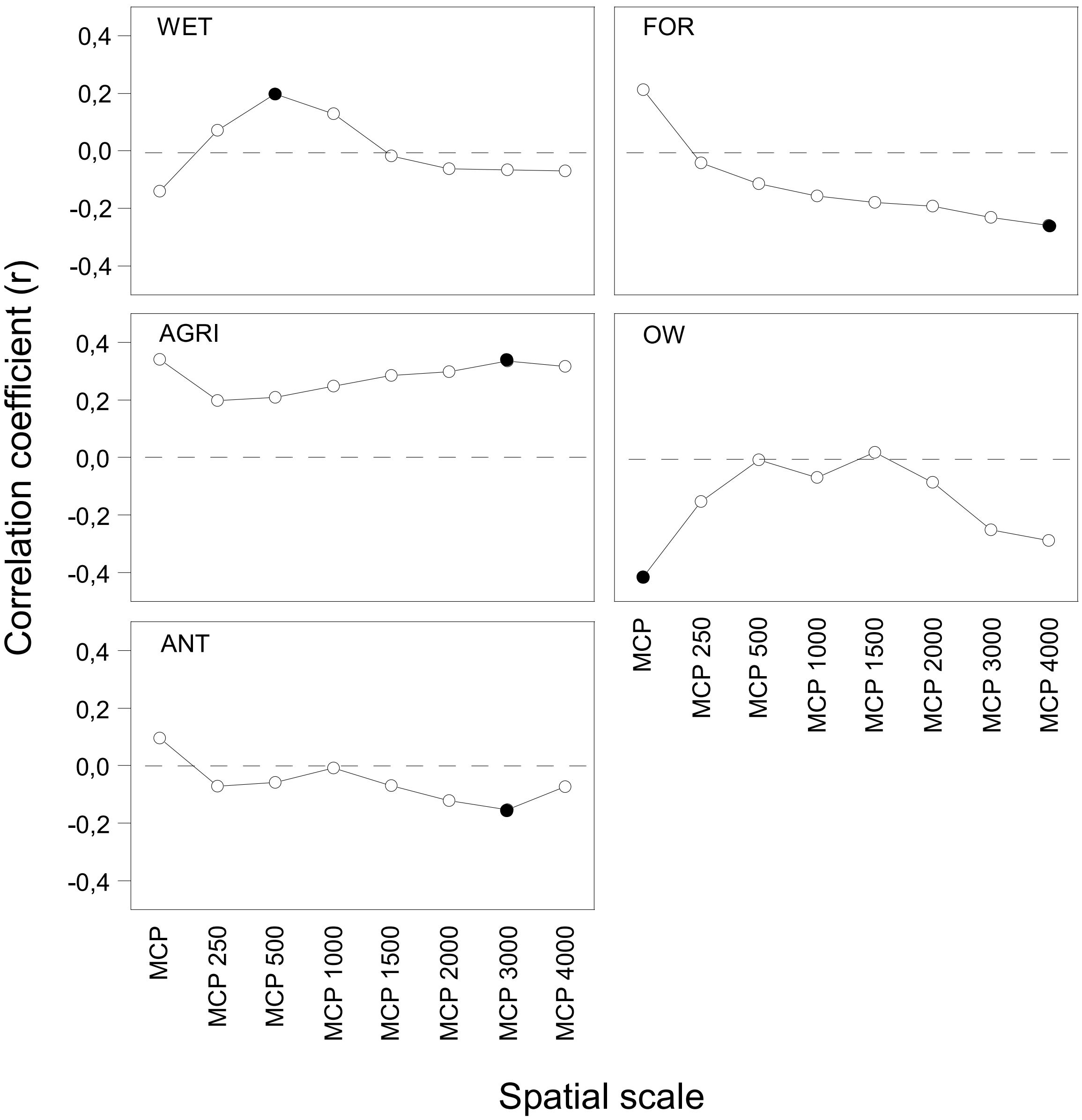

Figure A1- 2. Correlation coefficients (Pearson’s r) of the square root transformed landscape composition variables at eight spatial scales with home range size (n = 44). The number following MCP is the radius length added to the MCP to build the buffer. Dark symbols show the spatial scale used in home range size modelling, and the dashed line corresponds to null correlation.

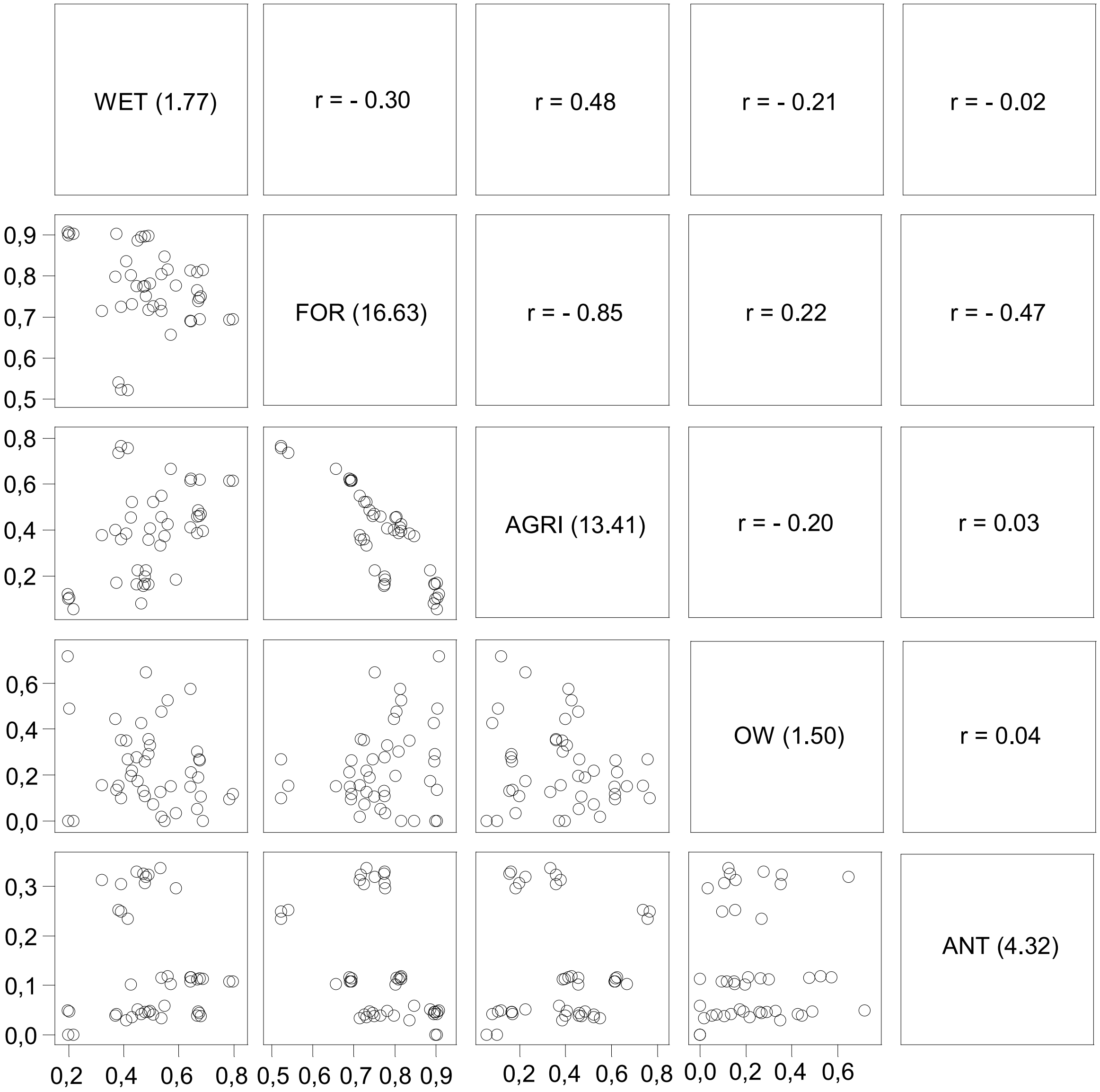

Figure A1- 3. Correlation matrix of the square root transformed landscape composition variables used to model home range size in Blanding's turtles. VIFs are shown in parentheses on the diagonal, and correlation coefficients (Pearson's r) are above the diagonal. Correlation was examined on the whole dataset.

APPENDIX II

Complementary results for models of wetland occupancy by Blanding's turtles

Collinearity

Collinearity is a common problem encountered in model selection and it can bias estimated model parameters and mask certain predictor effects (Freckleton, 2011). I evaluated the magnitude of collinearity among the landscape variables used to model wetland occupancy by the Blanding's turtle. Landscape composition was measured at both 1 km and 3 km scales around Blanding's turtle observation locations, so I examined collinearity separately for the two datasets. As recommended by Smith et al. (2009), I ran pairwise regressions between all landscape variables and measured variance inflation factors (VIFs) while including all predictors used to model home range size (Burnham and Anderson, 2002). I used the "car" package in R to measure VIFs.

Variables measured at a 1 km scale showed correlation varying from l r l = 0.03 – 0.75, and had VIFs ranging from 1.30 to 8.07 (Figure A2-1, Table A2-1). Variables measured at a 3 km scale showed correlation varying from l r l = 0.12 – 0.92, and had VIFs ranging from 1.61 to 15.93 (Figure A2-2). At both spatial scales, collinearity was strong for agriculture and forest proportions. The proportion of agriculture was strongly and negatively correlated to the proportions of forest and open water. Moreover, the relationship between those variables was stronger at a 3 km scale, which reflects the concentration of agriculture in intensive farming areas within the landscape. Other variables generally showed weak collinearity, with VIFs < 5. I included all the landscape composition variables in the models predicting wetland occupancy. I thus recommend cautious interpretation of the effect of forest and agriculture proportions on wetland occupancy by the Blanding's turtle.

Table A2- 1. Variance inflation factors of predictors used to model wetland occupancy by Blanding’s turtles (1 km scale model, n = 70; 3 km scale model, n = 22).

Parameter	**1 km scale**	**3 km scale**
WET	2.31	1.64
FOR	6.53	14.88
AGRI	8.07	15.93
OW	1.944	3.59
ANT	1.77	2.31
ROAD	1.30	1.61

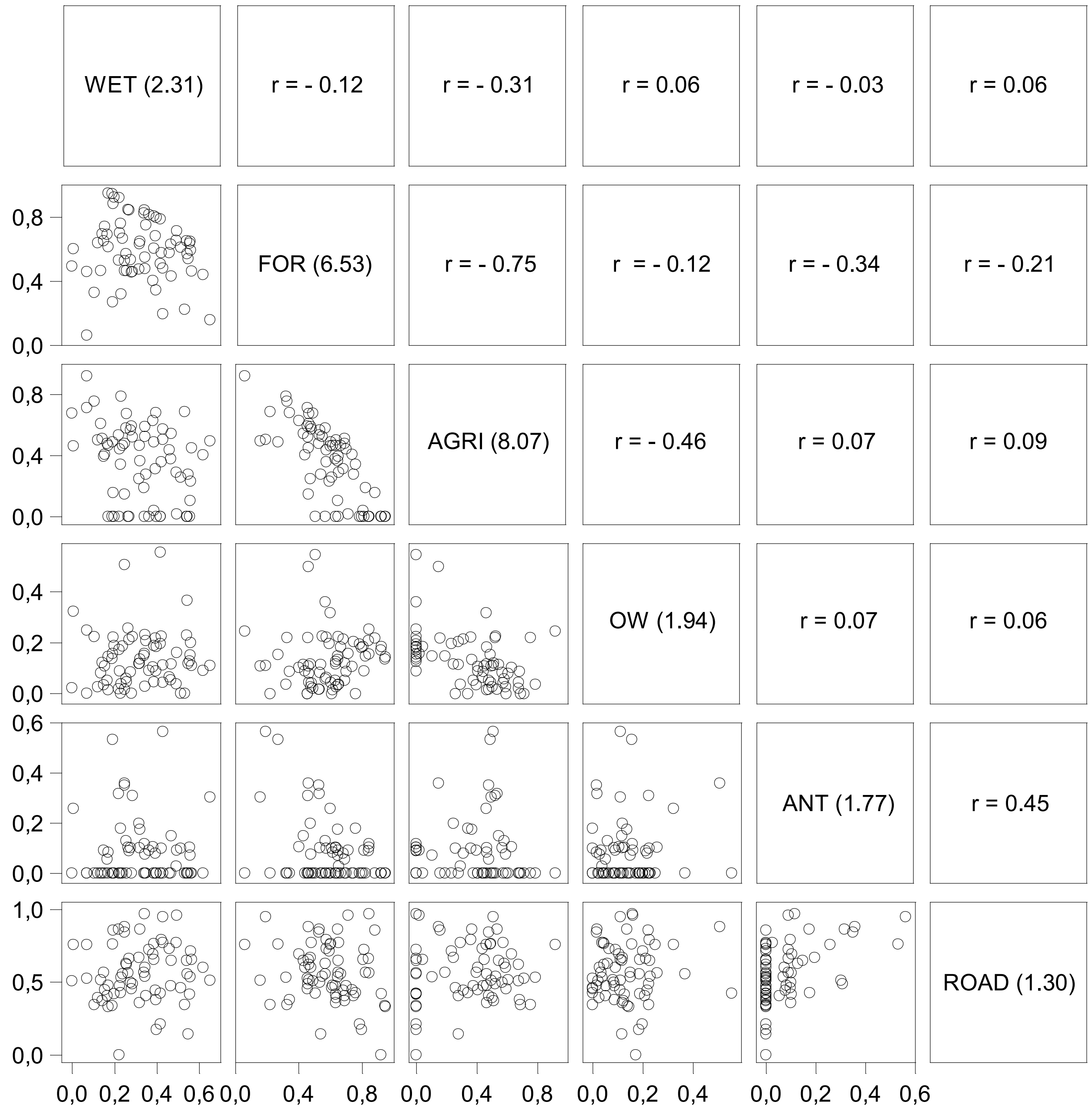

Figure A2- 1. Correlation matrix of landscape composition variable measured at a 1 km scale, and used to model wetland occupancy by Blanding's turtles. VIFs are shown in parentheses on the diagonal, and correlation coefficients (Pearson's r) are above the diagonal.

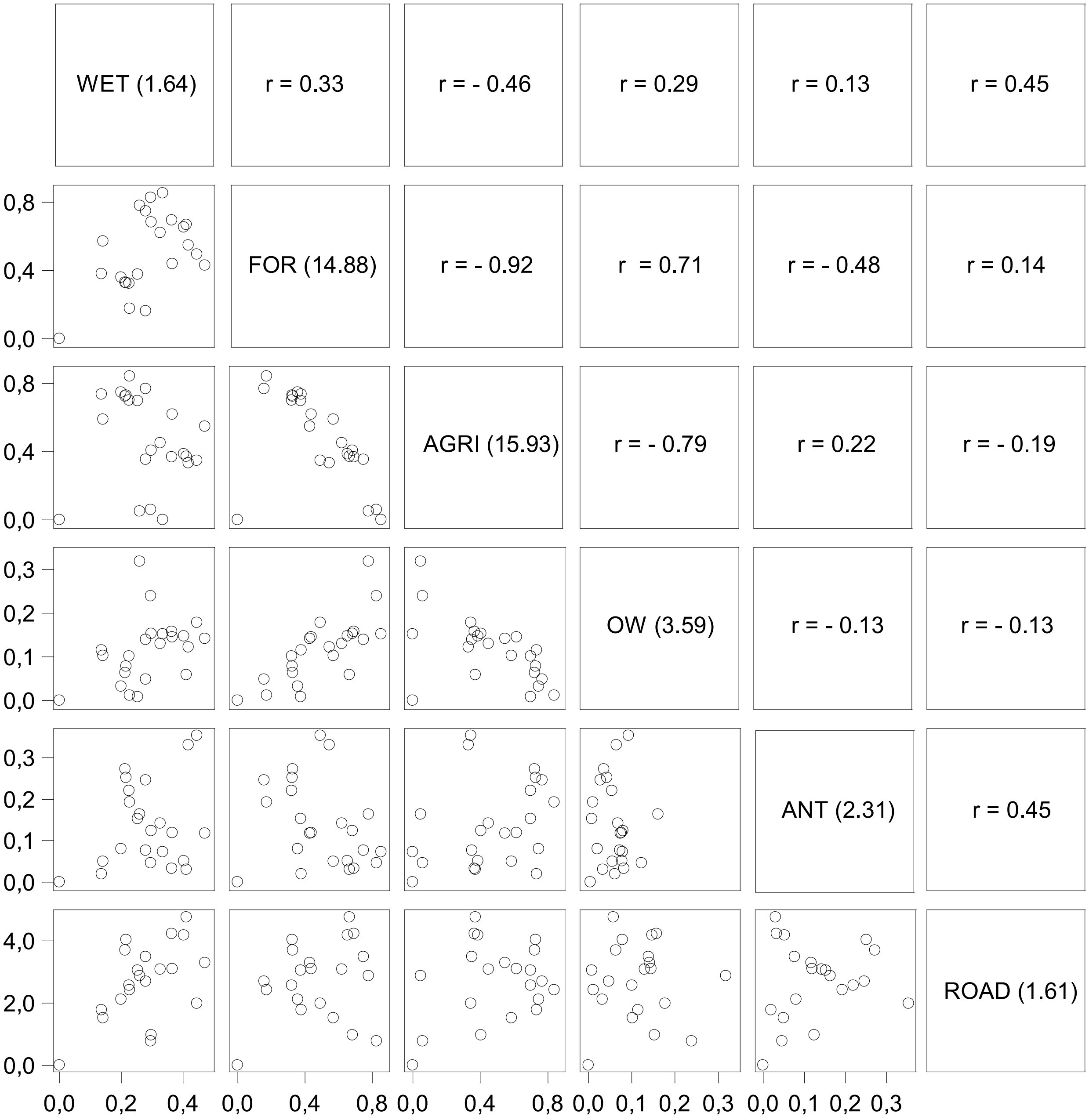

Figure A2- 2. Correlation matrix of landscape composition variables measured at a 3 km scale, and used to model wetland occupancy by Blanding's turtles. VIFs are shown in parentheses on the diagonal, and correlation coefficients (Pearson's r) are above the diagonal.

LITERATURE CITED

Ahlers, A. A., E. J. Heske, R. L. Schooley, and M. A. Mitchell. 2010. Home ranges and space use of muskrats O*ndatra zibethicus* in restricted linear habitats. Wildlife Biology 16:400-408.

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

Andrews, K. M., and J. W. Gibbons. 2005. How do highways influence snake movement? Behavioral responses to roads and vehicles. Copeia 2005:772-782.

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.

Austin, D., W. D. Bowen, and J. I. McMillan. 2004. Intraspecific variation in movement patterns: Modeling individual behaviour in a large marine predator. Oikos 105:15-30.

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

Beaudry, F., P. G. deMaynadier, and M. L. Hunter Jr. 2009. Seasonally dynamic habitat use by spotted (C*lemmys guttata*) and Blanding's turtles (E*mydoidea blandingii*) in maine. Journal of Herpetology 43:636-645.

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

Berg, Å. 2002. Composition and diversity of bird communities in swedish farmland–forest mosaic landscapes: The amount of forest (at local and landscape scales) and occurrence of residual habitats at the local scale are shown to be the major factors influencing bird community composition in farmland–forest landscapes in central sweden. Bird Study 49:153-165.

Blanding’s Turtle Recovery Team. 2005. National Recovery Plan for the Blanding’s turtle(*Emydoidea blandingii*) Nova Scotia Population. 63 pp.

Blevins, E., and K. A. With. 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.

Blouin-Demers, G., L. P. G. Bjorgan, and P. J. Weatherhead. 2007. Changes in habitat use and movement patterns with body size in black ratsnakes (*Elaphe obsoleta*). Herpetologica 63:421-429.

Blouin-Demers, G., and P. J. Weatherhead. 2002. Implications of movement patterns for gene flow in black rat snakes (E*laphe obsoleta*). Canadian Journal of Zoology 80:1162-1172.

Bowne, D. R., M. A. Bowers, and J. E. Hines. 2006. Connectivity in an agricultural landscape as reflected by interpond movements of a freshwater turtle. Conservation Biology 20:780-791.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multi-model inference : A practical information-theoretic approach. Second edition. Springer, NJ, USA.

Collins, R. J., and G. W. Barrett. 1997. Effects of habitat fragmentation on meadow vole (M*icrotus pennsylvanicus*) population dynamics in experiment landscape patches. Landscape Ecology 12:63-76.

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

Congdon, J. D., O. M. Kinney, and R. D. Nagle. 2011. Spatial ecology and core-area protection of Blanding’s turtle (E*mydoidea blandingii*). Canadian Journal of Zoology 89:1098-1106.

Congdon, J. D., D. W. Tinkle, G. L. Breitenbach, and R. C. van Loben Sels. 1983. Nesting ecology and hatching success in the turtle E*mydoidea blandingi*. Herpetologica 39:417-429.

COSEWIC, 2005. COSEWIC assessment and update status report on the Blanding's Turtle *Emydoidea blandingii* in Canada. 40 pp.

Dubois, Y. 2009. Distribution de la tortue mouchetée (*Emys blandingii)* et cartographie des aires prioritaires de conservation et des corridors écologiques à l’intérieur et en périphérie du parc de la Gatineau. Conservation de la nature Canada pour la Commission de la capitale nationale. 56 pp.

Edge, C. B., B. D. Steinberg, R. J. Brooks, and J. D. Litzgus. 2009. Temperature and site selection by Blandings turtles (E*mydoidea blandingii*) during hibernation near the species northern range limit. Canadian Journal of Zoology 87:825-834.

Edge, C. B., B. D. Steinberg, R. J. Brooks, and J. D. Litzgus. 2010. Habitat selection by Blanding's turtles (E*mydoidea blandingii*) in a relatively pristine landscape. Ecoscience 17:90-99.

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

Fahrig, L., and T. Rytwinski. 2009. Effects of roads on animal abundance: An empirical review and synthesis. Ecology and Society 14:21.

Freckleton, R. P. 2011. Dealing with collinearity in behavioural and ecological data: Model averaging and the problems of measurement error. Behavioral Ecology and Sociobiology 65:91-101.

Fretwell, S. D. 1972. Populations in a seasonal environment. Princeton University Press, NJ, USA.

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

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

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

Hamernick, M. G. 2000. Home ranges and habitat selection of Blanding’s turtles (E*mydoidea blandingii*) at the Weaver Dunes, Minnesota. Final report submitted to the Nongame Wildlife Program, Minnesota Department of Natural Resources. 18 pp.

Helm, A., I. Hanski, and M. Pärtel. 2006. Slow response of plant species richness to habitat loss and fragmentation. Ecology Letters 9:72-77.

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

Joyal, L. A., M. McCollough, and M. L. Hunter Jr. 2000. Population structure and reproductive ecology of Blanding's turtle (E*mydoidea blandingii*) in maine, near the northeastern edge of its range. Chelonian Conservation and Biology 3:580-588.

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

Kapfer, J. M., J. R. Coggins, and R. Hay. 2008. Spatial ecology and habitat selection of bullsnakes (P*ituophis catenifer sayi*) at the northern periphery of their geographic range. Copeia 2008:815-826.

Kapfer, J. M., C. W. Pekar, D. M. Reineke, J. R. Coggins, and R. Hay. 2010. Modeling the relationship between habitat preferences and home-range size: A case study on a large mobile colubrid snake from North America. Journal of Zoology 282:13-20.

Kerr, J. T., and D. J. Currie. 1995. Effects of human activity on global extinction risk. Conservation Biology 9:1528-1538.

Kindlmann, P., and F. Burel. 2008. Connectivity measures: A review. Landscape Ecology 23:879-890.

Loi sur les espèces menacées et vulnérables L.R.Q, c. E-12.01

Long, E. S., D. R. Diefenbach, B. D. Wallingford, and C. S. Rosenberry. 2010. Influence of roads, rivers, and mountains on natal dispersal of white-tailed deer. Journal of Wildlife Management 74:1242-1249.

Marchand, M. N., and J. A. Litvaitis. 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.

Mayor, S. J., D. C. Schneider, J. A. Schaefer, and S. P. Mahoney. 2009. Habitat selection at multiple scales. Ecoscience 16:238-247.

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

McCormick, S. D., L. P. Hansen, T. P. Quinn, and R. L. Saunders. 1998. Movement, migration, and smolting of Atlantic salmon (*Salmo salar*). Canadian Journal of Fisheries and Aquatic Sciences 55:77-92.

McKee, J. K., P. W. Sciulli, C. D. Fooce, and T. A. Waite. 2004. Forecasting global biodiversity threats associated with human population growth. Biological Conservation 115:161-164.

Millar, C. S., and G. Blouin-Demers. 2011. Spatial ecology and seasonal activity of Blanding's turtles (E*mydoidea blandingii*) in ontario, canada. Journal of Herpetology 45:370-378.

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

Mitrovich, M. J., J. E. Diffendorfer, and R. N. Fisher. 2009. Behavioral response of the coachwhip (M*asticophis flagellum*) to habitat fragment size and isolation in an urban landscape. Journal of Herpetology 43:646-656.

Morellet, N., B. Van Moorter, B. Cargnelutti, J. M. Angibault, B. Lourtet, J. Merlet, S. Ladet, and A. J. M. Hewison. 2011. Landscape composition influences roe deer habitat selection at both home range and landscape scales. Landscape Ecology 26:999-1010.

Nams, V. O., and M. Bourgeois. 2004. Fractal analysis measures habitat use at different spatial scales: An example with american marten. Canadian Journal of Zoology 82:1738-1747.

Noyce, K. V., and D. L. Garshelis. 2011. Seasonal migrations of black bears (*Ursus americanus*): Causes and consequences. Behavioral Ecology and Sociobiology 65:823-835.

Piñeiro, G., S. Perelman, J. P. Guerschman, and J. M. Paruelo. 2008. How to evaluate models: Observed vs. predicted or predicted vs. observed? Ecological Modelling 216:316-322.

Reunanen, P., A. Nikula, M. Mönkkönen, E. Hurme, and V. Nivala. 2002. Predicting occupancy for the siberian flying squirrel in old-growth forest patches. Ecological Applications 12:1188-1198.

Ross, D. A., and R. K. Anderson. 1990. Habitat use, movements, and nesting of *Emydoidea blandingii* in central Wisconsin. Journal of Herpetology 24:6-12.

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

Row, J. R., G. Blouin-Demers, and S. C. Lougheed. 2012. Movements and habitat use of eastern foxsnakes (*Pantherophis gloydi*) in two areas varying in size and fragmentation. Journal of Herpetology 46:94-99.

Smith, A. C., N. Koper, C. M. Francis, and L. Fahrig. 2009. Confronting collinearity: Comparing methods for disentangling the effects of habitat loss and fragmentation. Landscape Ecology 24:1271-1285.

Species at Risk Act S.C. 2003, c. 29

Spetz, J. 2008. Diet, habitat use, and reproduction characteristics in an ohio population of Blanding's turtle (*Emydoidea blandingii*) in a Lake Erie coastal plains marsh. Unpublished M.Sc. Thesis. John Carroll University. University Heights, OH.

van Beest, F. M., I. M. Rivrud, L. E. Loe, J. M. Milner, and A. Mysterud. 2011. What determines variation in home range size across spatiotemporal scales in a large browsing herbivore? Journal of Animal Ecology 80:771-785.

Villard, M. A., M. K. Trzcinski, and G. Merriam. 1999. Fragmentation effects on forest birds: Relative influence of woodland cover and configuration on landscape occupancy. Conservation Biology 13:774-783.

Wiens, J. A. 2002. Central concepts and issues of landscape ecology. pp. 3-1 In: K. J. Gutzwiller (Ed). Applying Landscape Ecology in Biological Conservation, Springer-Verlag New York Inc., New York, USA.