

**Demography, Movement Patterns, and Habitat Selection of Blanding's Turtles at Canadian
Nuclear Laboratories in Chalk River, Ontario**

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ABSTRACT

The development and implementation of effective species and population-specific management strategies requires population-specific information. To demonstrate the relative extirpation risk associated with various road mortality scenarios for a population of Blanding's turtles at Canadian Nuclear Laboratories in Chalk River, Ontario, a Population Viability Analysis was conducted. Road mortality of two adult females every ten years resulted in population extirpation within 200 years relative to a stable population not experiencing road mortality. To accommodate informed decision-making for the management of this species at risk, the movement patterns and habitat selection of this Blanding's turtle population were described. There was no significant difference between males and females in distance moved between relocations in either the spring or the summer, but turtles moved greater distances in the spring than in the summer. Annual and seasonal home range size did not differ between the sexes or between spring and summer periods. A compositional analysis indicated Blanding's turtles preferred marsh habitats over bog, swamp, lake, and upland. Matched-paired logistic regression was used to determine selection of microhabitat features, such as type of vegetation, in the spring and summer. Turtles preferred sites with warmer air temperatures, shallower water, a higher availability of open water, and greater coverage of emergent and floating vegetation types in the spring period. In the summer period, turtles preferred sites characterized by cooler, deeper water, a higher availability of open water, and greater coverage of emergent and floating vegetation types. This population of Blanding's turtles appears to be relatively small and the continued threat of road mortality indicates a delicate situation for its persistence. Considering seasonally preferred habitats will best inform management decisions for seasonal work restrictions and future development plans.

RÉSUMÉ

Le développement, l'implantation et l'administration de stratégies efficaces de gestion d'espèces et de populations nécessitent de l'information spécifique à ces populations. Une analyse de viabilité de population a été effectuée afin de démontrer le risque de disparition associé à différents scénarios de mortalité routière d'une population de tortue mouchetée aux Laboratoires Nucléaires Canadiens de Chalk River en Ontario. La mortalité routière de deux femelles adultes à chaque dix années résulte en la disparition de cette population en moins de 200 ans comparé à une population où il n'y aurait pas de mortalité routière. Pour permettre une prise de décision éclairée quant à la gestion de cette espèce en péril, les mouvements ainsi que la sélection de l'habitat de cette population de tortues mouchetées sont décrits. Il n'y avait pas de différences significatives entre les mâles et les femelles quant à la distance parcourue au printemps ou à l'été, par contre les tortues parcouraient de plus grandes distances au printemps qu'à l'été. L'aire du domaine vital annuel ou saisonnier ne variait pas entre les sexes ni entre le printemps et l'été. Une analyse de composition a indiqué que les tortues mouchetées avaient une préférence pour les marais plutôt que les tourbières, les marécages, les lacs ou la terre ferme. Une régression logistique appariée fut utilisée afin de déterminer la sélection des caractéristiques du micro-habitat, tel que le type de végétation, au printemps et à l'été. Les tortues préféraient les sites avec des températures de l'air plus élevées, de l'eau moins profonde, une plus grande surface d'eau libre ainsi qu'une plus grande couverture de végétation émergente et flottante au printemps. À l'été, les tortues préféraient les sites avec de l'eau plus froide et plus profonde, une plus grande surface d'eau libre ainsi qu'une plus grande couverture de végétation émergente et flottante. Cette population de tortues mouchetées semble être relativement petite et la menace continue de mortalité routière indique une situation délicate pour sa continuité. C'est en

considérant les habitats saisonniers préférés que la gestion sera la mieux informée pour prendre des décisions quant aux restrictions du travail saisonnier et à la planification de développements futurs.

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TABLE OF CONTENTS

Abstract	II
Résumé	III
Acknowledgements	V
Table of Contents	VII
List of Tables	IX
List of Figures	XI
List of Appendices	XIV
General Introduction	1
Biodiversity Loss and Conservation Laws.....	1
Spatial Ecology.....	3
Blanding’s Turtle.....	4
Study Area.....	5
Objectives.....	5
Chapter One	7
Introduction.....	8
Methods.....	9
Demography.....	9
Population Viability Analysis.....	10
Results.....	12
Demography.....	12
Population Viability Analysis.....	13
Discussion.....	13
Demography.....	13
Population Viability Analysis.....	15
Chapter Two	25
Introduction.....	26
Methods.....	27
Movement Patterns.....	27
Population Range and Home Range	28
Results.....	30
Movement Patterns.....	30
Population Range and Home Range	30
Discussion.....	31
Movement Patterns.....	31
Population Range and Home Range	33
Chapter Three	40
Introduction.....	41
Methods.....	42
Macrohabitat Use.....	42
Microhabitat Use.....	43
Results.....	46
Macrohabitat Use.....	46
Microhabitat Use.....	46

Discussion.....	48
Macrohabitat Use.....	48
Microhabitat Use.....	49
Implications for Blanding’s Turtle Conservation in Chalk River, Ontario.....	68
Demography.....	69
Movements and Home Ranges.....	70
Multiple Scale Habitat Selection.....	72
Literature Cited.....	74
Appendix 1.....	85
Appendix 2.....	86

LIST OF TABLES

Table 1-1	Carapace and plastron measurements for adult male (n = 8) and adult female (n = 13) Blanding’s turtles (<i>Emydoidea blandingii</i>) in Chalk River, Ontario.....	17
Table 1-2	Linear and logistic regression results for the Vortex sensitivity analysis on parameters used in the Chalk River Blanding’s turtle (<i>Emydoidea blandingii</i>) Population Viability Analysis.....	18
Table 2-1	Review of published Blanding’s turtle (<i>Emydoidea blandingii</i>) home range areas (ha) and lengths (m) ± Std. Err. (N) for males (M), females (F) and gravid females (GF) for comparison with those reported in this study. Whether a significant difference in values was detected between males, females and/or gravid females is also indicated.....	35
Table 3-1	Descriptions of habitat types modified from Edge et al. (2010) and the Northern Manual of the Ontario Wetland Evaluation System (2013), used for the compositional analyses of preferred habitat type in a population of Blanding’s turtle (<i>Emydoidea blandingii</i>) in Chalk River, Ontario	54
Table 3-2	Habitat variables used in the matched-paired logistic regression for a population of Blanding’s turtle (<i>Emydoidea blandingii</i>) in Chalk River, Ontario.....	55

Table 3-3	Matched-paired logistic regression model that best explained microhabitat selection for the active season of 2014 and 2015 across all individual Blanding’s turtles (<i>Emydoidea blandingii</i>) (n = 19) captured in Chalk River, Ontario.....	56
Table 3-4	Habitat preference determined by compositional analysis of habitat types, for a population of Blanding’s turtle (<i>Emydoidea blandingii</i>) in Chalk River, Ontario.....	57
Table 3-5	Mean percent of habitat types available and used by for a population of Blanding’s turtle (<i>Emydoidea blandingii</i>) (n = 19) in Chalk River, Ontario.....	58
Table 3-6	Models tested for suitability in matched-paired logistic regressions used in CRL Blanding’s (<i>Emydoidea blandingii</i>) turtle microhabitat selection analyses in Chalk River, Ontario. Models with the lowest AIC value were used for the active season, spring period and summer period analyses.....	59
Table 3-7	Matched-paired logistic regression model that best explained microhabitat selection in the spring period of 2014 and 2015 across all individual Blanding’s turtles (<i>Emydoidea blandingii</i>) (n = 19) in Chalk River, Ontario.....	60
Table 3-8	Matched-paired logistic regression model that best explained microhabitat selection in the summer period of 2014 and 2015 across all individual Blanding’s turtles (<i>Emydoidea blandingii</i>) (n = 19) in Chalk River, Ontario	61

LIST OF FIGURES

- Figure 1-1** Large hoop net with lead line and wings for diverting aquatic traffic towards the mouth of the trap. The buoy is in place to maintain an air gap within the net. Here a field team member is checking the net for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario.....19
- Figure 1-2** Marking of Blanding’s turtles (*Emydoidea blandingii*) is performed by making a v-shaped notch in marginal scutes of an individual following the numbering sequence provided by the Ontario Ministry of Natural Resources (OMNR). The depth of the notch equals to 1/3 to 1/2 the depth of the scute.....20
- Figure 1-3** Frequency histogram of size classes for adult male, adult female and sub-adult female Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario between 2014 and 2015.....21
- Figure 1-4** Number of locations and re-locations by radio-tracking, hoop netting, and the opportune capturing by month summed between 2014 and 2015 of Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Road sightings and sightings while tracking another individual were considered “opportune captures”22
- Figure 1-5** Stage classes of Blanding's turtles (*Emydoidea blandingii*) captured in Chalk River, Ontario between 2014 and 2015.....23

Figure 1-6	Impact of road mortality on mean Blanding’s turtle (<i>Emydoidea blandingii</i>) population sizes in Chalk River, Ontario, based on a population viability analysis over 500 years. The Baseline scenario did not include a road mortality input where all other scenarios included road mortalities of either one or two females every ten, 20 and 50 years.....	24
Figure 2-1	Mean distance moved by Blanding’s turtles (<i>Emydoidea blandingii</i>) in Chalk River, Ontario between relocations for the 2015 season, and the spring and summer periods of 2015. The asterisk indicates significance.....	36
Figure 2-2	Blanding's turtle (<i>Emydoidea blandingii</i>) population range in Chalk River, Ontario, 2014-2015.....	37
Figure 2-3	Blanding's turtle (<i>Emydoidea blandingii</i>) ranges for the spring and summer periods from 2014 to 2015 in Chalk River, Ontario.....	38
Figure 2-4	Mean home range size of Blanding’s turtles (<i>Emydoidea blandingii</i>) for the spring and summer periods in Chalk River, Ontario.....	39
Figure 3-1	Frequency of observation of Blanding’s turtle (<i>Emydoidea blandingii</i>) position within aquatic (A) and terrestrial (B) habitats at location/re-location points between 2014 and 2015 during the active season in Chalk River, Ontario. Locations/re-locations where turtles were caught within hoop nets were excluded.....	62
Figure 3-2	Habitat rankings for selection within the population range at 0.05 significance for Blanding’s turtles (<i>Emydoidea blandingii</i>) in Chalk River, Ontario. Bars indicate	

where comparisons between habitat types yielded no significance at the 0.05 level.....63

Figure 3-3 Habitat rankings for selection within individual home at the 0.05 level of significance ranges for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.....64

Figure 3-3 Selection and availability of habitat variables between 2014 and 2015 in the active season for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. A) Air temperature, B) water depth, C) emergent vegetation, D) floating vegetation and E) water temperature.....65

Figure 3-4 Selection and availability of habitat variables between 2014 and 2015 in the spring period for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. A) Air temperature, B) water depth, C) emergent vegetation, D) floating vegetation and E) open water.....66

Figure 3-5 Selection and availability of habitat variables between 2014 and 2015 in the spring period for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. A) Water temperature, B) water depth, C) emergent vegetation, D) floating vegetation and E) open water.....67

LIST OF APPENDICES

Appendix 1:	Population viability analysis input parameters for the Blanding’s turtle (<i>Emydoidea blandingii</i>) population in Chalk River, Ontario.....	85
Appendix 2:	Individual home range sizes and associated kernel smoothing factors (h) for Blanding’s turtles (<i>Emydoidea blandingii</i>) captured and tracked between 2014 and 2015 in Chalk River, Ontario.....	86

GENERAL INTRODUCTION

Biodiversity Loss and Conservation Laws

Current species declines are an ecological concern of a global scale (Barnosky et al. 2011, Galetti and Dirzo 2013, Kurten 2013, McCauley et al. 2015). Evidence in the literature continues to grow, indicating rates of species decline and extinction have accelerated since pre-human history (Barnosky et al. 2011, Ceballos et al. 2015, Mace et al. 2016). Defaunation has largely been attributed to anthropogenic factors such as habitat loss and degradation, exploitation, climate change, environmental pollution, and introduced invasive species, though parasites and disease also play a role (Hulme et al. 1999, Gibbons et al. 2000, Brooks et al. 2002, Walther et al. 2002, Araújo et al. 2006, Chaves et al. 2007, Galetti and Dirzo 2013, McCauley et al. 2015). Data compilations from around the world indicate 22% of mammal species and 15% of bird species are considered threatened or extinct (Galetti and Dirzo 2013).

This global species loss has been described as the sixth mass extinction event on Earth, to which reptiles are not immune (Gibbons et al. 2000, Wake and Vredenburg 2008, Ceballos et al. 2015). As of 2000, there were over 6500 reptile species globally documented and by 2014 approximately 44% had been evaluated by the IUCN (Ceballos et al. 2015, CESCC, 2001). Of the 6500 species, 42 were native terrestrial (non-marine) reptiles in Canada and only 18 of these were considered Secure by the Canadian Endangered Species Conservation Council (CESCC). The majority of reptile species assessed by the CESCC under the Accord for Risk in Canada were ranked as: At Risk, May Be At Risk, Sensitive, and Undetermined (CESCC, 2001). Turtle

populations are of particular conservation concern due to species' peculiar life histories: extreme longevity, late sexual maturation, and naturally low rates of hatchling recruitment which contribute to low population growth rates and high sensitivities to the loss of reproductive adults from populations (Congdon et al. 1983, 1987, Congdon 1993, Araújo et al. 2006, Beaudry et al. 2008). Life-history traits such as these may lead to a higher vulnerability of populations to both climate change and, more localized, environmental change (Congdon and Dunham 1997, Gibbons et al. 2000, Root et al. 2003).

In Canada, legislative action at both the provincial and federal levels has been undertaken in the pursuit of species preservation and conservation. At the provincial level, the Endangered Species Act (ESA) in Ontario is purposed to identify species at risk, to protect these species and their habitats, and to promote stewardship for species protection and recovery. At the federal level, the purposes of the Species at Risk Act (SARA) are to prevent wildlife from becoming extirpated or extinct, to provide for Extirpated, Endangered or Threatened species recovery after human-induced loss has occurred, and to manage species of Special Concern.

There are two steps in the recovery planning process for species at risk in Canada. The first step is to develop a recovery strategy where species requirements, population threats, and recovery objectives are outlined. In the second step, a recovery action plan is developed, stating measures to be taken and likely impacts of these measures. The identification of critical habitat is required in both phases of this recovery planning process and, once defined, all critical habitat on federal land must be protected by the federal government (SARA, SC 2002 c29, sec 37-64; Mooers et al. 2010).

Intuitively, the habitats of species at risk are stated in SARA as being “key to their conservation”. Developing and implementing well informed, effective species management and recovery strategies requires understanding the habitat requirements and patterns of movement across a landscape. Habitat selection and movement studies provide a means of achieving this conservation goal through information gathering and knowledge development for informed decision-making.

Defining temporal activity periods for a species is important in teasing out the factors driving movement and selection. For example, patterns of movement and selection may change to reflect both temporal variation in resource availability and changes in the biological needs of the species (Meeks and Ultsch 1990, Edge et al. 2010). Traditionally, activity periods are discriminated either by the division of months or weeks in the active season or by the biology of the target species (Brown & Brooks 1993; Beaudry et al. 2009; Edge et al. 2010; Millar 2010). The division of the active season by month or by weeks provides the convenience of equivalent temporal periods for analysis as this division can be applied to any population. However, using the changing biological requirements of the focal species to determine activity periods holds the advantage, or disadvantage, of specificity to a local population.

Spatial Ecology

Johnson (1980) first described the order of habitat selection processes. The First order refers to the selection of a geographical range of a species while the Second order defines the homerange an individual selects from within the geographical range of the population or species (Johnson 1980). The Third order of selection is the use of particular habitat factors from those available within the homerange (Johnson 1980). Further, a Fourth order in which things such as food items

may be selected from those available at selected sites is described by Johnson and Prairie (1980), however, the present study focuses on the second and third orders which I will henceforth refer to as selection of a habitat type within the population range and the home range, respectively.

Blanding's Turtle

Blanding's turtles "*Emydoidea blandingii*" (Holbrook, 1838) are a federally protected species under SARA in Canada. A disjunct population of Blanding's turtles in Nova Scotia was listed as Endangered in 2000, while the more widely dispersed Great Lakes/St Lawrence population was listed as Threatened in 2005.

Known to live in excess of 75 years, the Blanding's turtle is among the longest-lived species within the Emydidae family (Brecke & Moriarty 1989). The oldest known Blanding's turtle was recaptured in 2016 at the age of 83 (Erickson, 2016). Physically, they are most easily distinguished by their yellow throat and chin (Baker and Gillingham 1983). Blanding's turtles have a hinged plastron and a spotted or streaked carapace (Congdon et al. 2008). Adults typically weigh between 800 and 1600 g and females reach sexual maturity between 14 and 21 years of age (Congdon et al. 1983; Congdon & Van Loben Sels 1991; Congdon & van Loben Sels 1993). A reliable estimate by Congdon et al. (1983) for minimum plastron length of sexually reproducing females is 162 mm. Females produce one clutch of 3-19 eggs a year, but not necessarily every year (Congdon and Van Loben Sels 1991).

Many semiaquatic turtle species rely on the availability of different aquatic and terrestrial habitats throughout their active season (Roe and Georges 2007). Specifically, seasonal changes

in habitat use have been observed for Blanding's turtle. Upland sites are commonly used for nesting and during inter-wetland movements for this species (Beaudry et al. 2009). Blanding's turtles will undertake inter-wetland as well as extensive intra-wetland movements throughout their active seasons as habitat preference shifts temporally (Edge et al. 2010). These upland and inter-wetland movements mean individuals often encounter a high risk of mortality during these periods largely due to necessary road crossings (Aresco 2005, Beaudry et al. 2008, 2010).

Study Area

This study was conducted on Canadian Nuclear Laboratories (CNL) lands at Chalk River Laboratories (CRL) in Chalk River, Ontario. The site is delineated by a 3.7 m tall chain-link fence. The lands cover 3870 ha and are situated along the Ottawa River. Infrastructure at CRL occupies approximately 50 ha while the remaining 3820 ha are covered in wetlands, mixed-wood forests, air and groundwater monitoring stations, and a gravel road network with a single paved road for employee access to CRL. For the purposes of this study, the term "population" will be used to refer to all Blanding's turtles with home ranges overlapping the extent of the CRL site.

Objectives

The development and implementation of effective species and/or population-specific management strategies requires individual/population specific information, particularly on industrial lands where the primary mandate is not the preservation of species. Blanding's turtles are present on CNL lands where the company mandates focus on decommissioning, waste management, and science and technology development. This project supports CNL in its effort to be compliant with SARA and implement proper management strategies for a mobile species at risk while maintaining operations on site.

This project aims to describe the movement patterns and habitat selection of Blanding's turtles on CNL lands to accommodate informed decision-making for species at risk population management. To achieve this, the demography and viability of the population were described, the movement patterns and ranges were described, and habitat selection at multiple scales was examined across spring and summer.

CHAPTER ONE

DEMOGRAPHY OF BLANDING'S TURTLES IN CHALK RIVER, ONTARIO: IMPLICATIONS FOR POPULATION VIABILITY

Introduction

The use of demographic models in population viability analyses (PVA) has been commonplace for management decision-making for wildlife populations since the early 1980's (Beissinger and Westphal 1998, Midwood et al. 2014). PVAs use demographic estimates (e.g., population size and carrying capacity) and estimates of age-specific vital rates (e.g., survival, mortality, and age of sexual maturity) and their associated variances to predict the probability of extinction for a population within a projected period of time. Thus, the precision and accuracy of PVAs are largely dependent on the quality of demographic data for the focal species (Beissinger and Westphal 1998).

Reliable estimates of survival and mortality are particularly difficult to accrue for cryptic, rare species found at low densities because these estimates rely on the probability of re-locating known individuals (Beissinger and Westphal 1998). Additionally, reliable estimates of the variance in demographic traits and vital rates are difficult to obtain for long-lived species because they require long-term data sets for individuals of all ages or life-stages (Beissinger and Westphal 1998, Midwood et al. 2014, Matthiopoulos et al. 2015). Often, data from other, similar populations or species are used in place of missing data for a focal species.

For some turtle species, the longevity of juvenile and adult stages coupled with differences in age of sexual maturity can lead to wide-ranging variation in reproductive traits (e.g., size-specific fecundity; Congdon et al. 1993). This reinforces the necessity of long-term datasets when estimating demographic characteristics to capture most of the variation within a population. Long-term studies on Blanding's turtles have provided many of the most reliable estimates on

population demographics and vital rates for the species, some with over 43 years of collected data (1953-2007) (Congdon et al. 1994, 2008).

Conserving Blanding's turtle populations can be a particular challenge due to the species' longevity, late sexual maturation and low rate of hatchling recruitment which contribute to low population growth rates and high sensitivities to the loss of reproductive individuals from populations (Congdon et al. 1983, 1987, 1993, Araújo et al. 2006, Beaudry et al. 2008). Life-history traits such as these may lead to a higher vulnerability of populations to human-induced loss, most commonly, road mortality (Congdon and Dunham, 1997).

The demography of the Blanding's turtle population at CNL in Chalk River, Ontario, was described based on the individuals captured in 2014 and 2015. The capture-mark-recapture data were used to calculate a population size estimate which was used with other demographic data as parameters within a PVA. Together, these elements provide not only a snapshot of the 2014-2015 population, but a projection of its potential future states by making relative situational comparisons between varying rates of road mortality.

Methods

Demography

Multiple capture methods were employed in 2014 to determine the most effective methods of capture for this population and how best to allocate project resources. The large hoop nets and visual surveys were the most successful methods of capture for this population and so these methods were exclusively employed in 2015 (Figure 1-1).

After capture, the turtle was transferred to the laboratory. Several body measurements were collected to the nearest millimeter for use in determining the sex of captured turtles: carapace length (CL), carapace width (CW), carapace height (CH), plastron length (PL), plastron width (PW), and mass. Individuals were marked according to a system developed by the Ontario Ministry of Natural Resources (OMNR) (Figure 1-2).

Blanding's turtles were sexed and stage-classed following the methods of Congdon and van Loben Sels (1993) (Figure 1-3; Table 1-1). Surveyors determined gravidity in the field by digital examination of the inguinal region to ascertain the presence of oviductal eggs (Ross and Anderson 1990). Stage classes for individuals used in this study included sub-adults and adults, as hatchlings were not captured. All animals were handled according to the guidelines of the Canadian Council on Animal Care and the University of Ottawa Animal Care Committee (permit # SARA-2014-0275 and SARA-OR-2015-0301; protocol # BL-284).

The mark-re-capture method implemented in 2014 was continued in the 2015 season. A Petersen-Lincoln model, corrected for bias towards low estimates, was used to estimate the number of Blanding's turtles in the study area.

Population Viability Analysis

A PVA was performed for the CRL Blanding's turtle population using the software VORTEX 10 (Lacy 1993, 2000) over 500 years with 1000 iterations, similar to the methods of Midwood et al. (2014). Population-specific values were used as parameters where applicable (Appendix 1).

Where population-specific parameters were unavailable due to the lack of long-term monitoring data, species-specific parameters from populations as similar in life-history as reasonably possible were obtained from the literature (Appendix 1). Carrying capacity was set high, relative

to the estimated population size, at 500 individuals as density dependence has not been shown to play a substantial role in the regulation of turtle populations (Galbraith et al. 1988, Brook and Bradshaw 2006). Good data on juvenile survival rates are scarce, therefore I made informed adjustments to this parameter to achieve a stable population over 500 years. This allowed for meaningful relative comparisons of extinction risk between simulation scenarios (Beissinger and Westphal 1998, Ellner et al. 2002). Realistic road mortality scenarios were elaborated based on CRL data from 2009-2015 where two females were reportedly hit on CRL roads within the past seven years.

A single-factor sensitivity analysis was conducted in Vortex to determine which parameters influenced the PVA model with the least amount of change in value. When conducting sensitivity tests incorporating multiple iterations, sampling points, and test parameters within models, there are trade-offs regarding the quantity of samples collected and the time required for running a test. Therefore, I elected to run a single test incorporating all non-integer parameters.

The probability of extinction (PE) was sampled 200 times for each of the nine parameters from a uniform distribution bound between zero and 100 (Table 1-2). Because 45% of output values for PE were equal to 1, I first transformed the PE data into a binary dependent variable and conducted linear regressions for each parameter. This allowed me to determine which parameters had the highest contribution to the probability of $PE = 1$. Then, I used logistic regressions to determine the parameters that most influenced changes in PE. Due to the presence of zeros and ones in the PE data, these values were replaced by 0.0001 and 0.9999 for use in the logistic regression.

Results

Demography

The number of captured individuals increased from nine in 2014 to 23 in 2015. New captures occurred between May and July, decreasing in frequency with time. This is likely because most individuals in the population had been captured and marked by July 2014 and because turtles are most active in the spring. Most locations and re-locations of individuals were achieved by radio-tracking and hoop netting, while opportune sightings were responsible for the least number of locations/re-locations (Figure 1-4). Using the mark-re-capture data, a corrected Petersen-Lincoln model determined an adult-sub-adult population estimate of 25 ± 4 individuals (Bailey 1951, 1952).

Of the 23 individuals captured and marked in this study, eight were adult males, 12 were adult females, and three were sub-adult females (Figure 1-5). The male to female sex ratio for the adults was 0.67; a binomial test indicated this ratio not to be different from 1:1 ($p = 0.21$, $CI = 0.164 - 0.573$). Gravid females were found in 2014 (three) and 2015 (five), where two individuals were found gravid in both 2014 and 2015.

No Blanding's turtle nests were identified and no hatchlings were captured. In 2015, field team members observed mating events involving a total of six individuals (three males, three females) on June 19th, July 22nd, and August 20th. Of the three females found mating, two had been gravid and one was determined not gravid in the spring of 2015; all three were confirmed to be gravid in 2014.

Population Viability Analysis

In the absence of road mortality, the Blanding's turtle population size remained stable over the 500 years simulated, experiencing an extinction risk of 77% (SE = 0.01) (Figure 1-6). Mean time to extirpation was 171 years (SE = 3.9) for those simulations going extinct. When road mortality of one adult female every 50 years was introduced, extinction risk increased to 90% (SE < 0.01) where mean time of extirpation was 139 years (SE = 3.0) for simulations where the population went extinct. Similarly, when a road mortality of one female every 20 years was introduced, extinction risk increased to 99% (SE < 0.01) where mean time to extirpation was 103 years (SE = 2.1) for simulations where the population went extinct. When road mortality of two females every ten years was introduced, extinction risk was 100% (SE = 0) where mean time of extirpation was 57 years (SE = 0.6) for simulations where the population went extinct. Of the nine parameters tested in the sensitivity analysis, all but two had significant effects on the probability of extinction (Table 1-2).

Discussion

Demography

Despite extensive search efforts, a total of only 20 adult and three sub-adult Blanding's turtles were captured and marked between 2014 and 2015 at CRL. This population appears to be both small and female-biased as only eight males, all adults, were captured and marked. The absence of observed or captured hatchlings and the low number of immature individuals is normal for a population of this size indicates a delicate situation for its persistence.

Factors such as habitat loss and fragmentation, and road mortality can lead to population declines for many freshwater turtle species. Particularly, a high risk of road mortality for nesting females often leads to male-biased sex ratios (Browne and Hecnar 2007). A sex ratio of 1:1 is expected in natural populations because selection will favour an even sex ratio (Fisher 1930, Egbert 1970). Thus, if the sex ratio of the CNL Blanding's turtle population had deviated significantly from the expected 1:1 some explanation would have been warranted.

Sampling biases due to survey techniques or trap design can also influence observed sex ratios (Browne and Hecnar 2007). Road surveys will likely indicate a female-biased sex ratio, as it is primarily females travelling to roadsides for the loose, sandy substrate in which to dig nests. At CRL, though road surveys were conducted, the most successful, and therefore more used, method of capture was hoop netting. Using hoop nets for capture has been reported as a method without sexual bias for Blanding's turtles, but with male bias in another freshwater turtle (Ream and Ream 1966, Browne and Hecnar 2007). Thus, sampling bias was unlikely the leading factor for an observed female-biased sex ratio at CRL.

Alternatively, sexual bias due to warmer nest temperatures may explain the female-bias observed in the CRL population. Neonate sex ratios are influenced by nest temperature which tends to be higher at roadside nesting sites (Ewert and Nelson 1991, Asaeda and Ca 1993). Warmer nest temperatures yield female-biased Blanding's turtle clutches and produce no males when incubated at 30°C (Ewert and Nelson 1991). Warmer nest temperatures are associated with exposed roadside nesting sites, which are available to Blanding's turtles at CRL due to high road density and waste management infrastructure around and adjacent to core wetlands (Asaeda and Ca 1993). Although efforts were undertaken to survey for nesting females and identify nest locations, no nests or nesting females were observed in either of the study years. Therefore, nest

temperatures could not be recorded in the field and the effect of incubation temperature on population sex-ratio remains speculative.

Environmental contaminants can also affect neonate sex ratio within incubating turtle nests. Polychlorinated biphenols (PCBs), industrialized chemicals, will act as environmental estrogens when introduced to developing reptilian eggs (Bergeron et al. 1994). Reptiles have been common biomonitoring models for several classes of environmental contaminants however, contaminants were not evaluated in this CRL study and thus no inferences can be made (Crain and Guillette 1998, Matsumoto et al. 2014).

Population Viability Analysis

In this study, the only additional source of mortality to naturally expected rates was road mortality. There are other external sources of mortality or loss for freshwater turtle populations, such as environmental contaminants, illegal collection and boat collisions (Compton et al. 2002, Bell et al. 2006, Bulté et al. 2010). The additive effect of these influences would further endanger the persistence of the CNL Blanding's turtle population, though illegal collection and boat collisions are unlikely to be common threats to the CNL Blanding' turtle population as access to the site is restricted.

A sensitivity analysis of several parameters used in the PVA indicated the PE for the Chalk River Blanding's turtle population was not affected by the percent of females producing at least one clutch or by the percent of males breeding within a year. The parameter which explained the most variation in PE was the percent of adult females producing no clutches and the percent of adult females breeding within a year, followed by the percent of hatchling mortality, sex ratio at hatching, and the percent annual hatchling mortality. Interestingly, this is the first sensitivity test

conducted in Vortex to include the parameter for sex ratio at hatching (Robert Lacy, pers. comm.). It is an important inclusion to make considering one theory of adaptive benefit for some reptiles is temperature dependent sex determination, where females could manipulate the sex ratio of a population by making selective choices about nesting sites (Warner and Shine 2005).

Blanding's turtle populations are particularly vulnerable to losses incurred through road mortality due to their life history traits (Aresco 2005, Beaudry et al. 2008, 2010, Congdon et al. 2008). Population decreases and local extirpation of a long-lived freshwater turtle could occur with less than 10% increase in annual mortality of adult females (Brooks et al. 1991, Congdon et al. 1993, 1994). Congruently, a sensitivity test of the parameters used in the CNL Blanding's turtle PVA indicated the probability of extinction for the Chalk River population to be significantly influenced by changes in adult mortality rates. Road mortality is a particular concern for Blanding's turtles at CRL if annual adult female road mortality continues to exceed 2% in the next few years.

Table 1-1 Carapace and plastron measurements for adult male (n = 8) and adult female (n = 12) Blanding's turtles (*Emydoidea blandingii*) in Chalk River, Ontario.

Body Attribute	Adult Male (n = 8)		Adult Female (n = 13)	
	Mean ± SE	Range (min-max)	Mean ± SE	Range (min-max)
CL (mm)	230.25±5.15	200-251	205.21±6.08	163-239
CW (mm)	155.13±3.42	109-173	137.67±4.42	94-170
CH (mm)	89.69±3.05	79-104.5	85.97±2.73	70-98
PL (mm)	206.84±11.82	125-236	202.83±5.64	166-238
PW (mm)	119.63±2.45	109-134	114.17±3.76	94-137
Mass (g)	1689.25±106.18	1110-2128	1298.33±111.99	706-2046

Table 1-2 Linear and logistic regression results for the Vortex sensitivity analysis on parameters used in the Chalk River Blanding's turtle (*Emydoidea blandingii*) Population Viability Analysis.

Parameter	Linear Regression for Binary Dependent Variable			Logistic Regression		
	t	p	R ²	t	p	R ²
Sex ratio at hatching	13.25	< 0.001	0.47	13.45	< 0.001	0.48
Percent adult females breeding	-23.17	< 0.001	0.73	-37.28	< 0.001	0.88
Percent adult females with 0 clutch	23.93	< 0.001	0.74	36.49	< 0.001	0.87
Percent adult females with 1 clutch	–	–	–	-0.33	0.74	0.001
Percent adult males breeding	–	–	–	-0.39	0.70	0.001
Percent hatchling mortality	16.01	< 0.001	0.56	27.40	< 0.001	0.79
Percent juvenile mortality	13.72	< 0.001	0.49	13.39	< 0.001	0.48
Percent adult female mortality	6.15	< 0.001	0.16	5.88	< 0.001	0.15
Percent adult male mortality	12.87	< 0.001	0.46	12.91	< 0.001	0.46

– Indicates where a linear regression could not be performed because all values for the dependent variable equaled zero.



Figure 1-1 Large hoop net with lead line and wings for diverting aquatic traffic towards the mouth of the trap. The buoy is in place to maintain an air gap within the net. Here a field team member is checking the net for Blanding's turtles (*Emydoidea blandingii*) in Chalk River, Ontario.

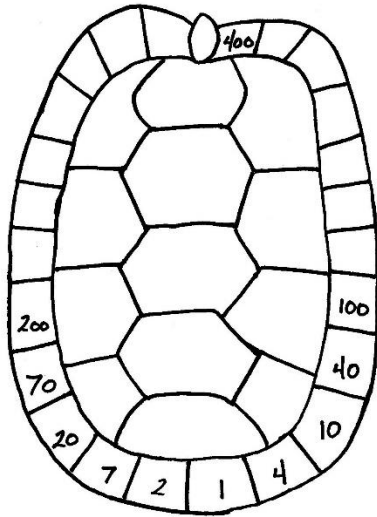


Figure 1-2 Marking of Blanding's turtles (*Emydoidea blandingii*) is performed by making a v-shaped notch in marginal scutes of an individual following the numbering sequence provided by the Ontario Ministry of Natural Resources (OMNR). The depth of the notch equals to $1/3$ to $1/2$ the depth of the scute.

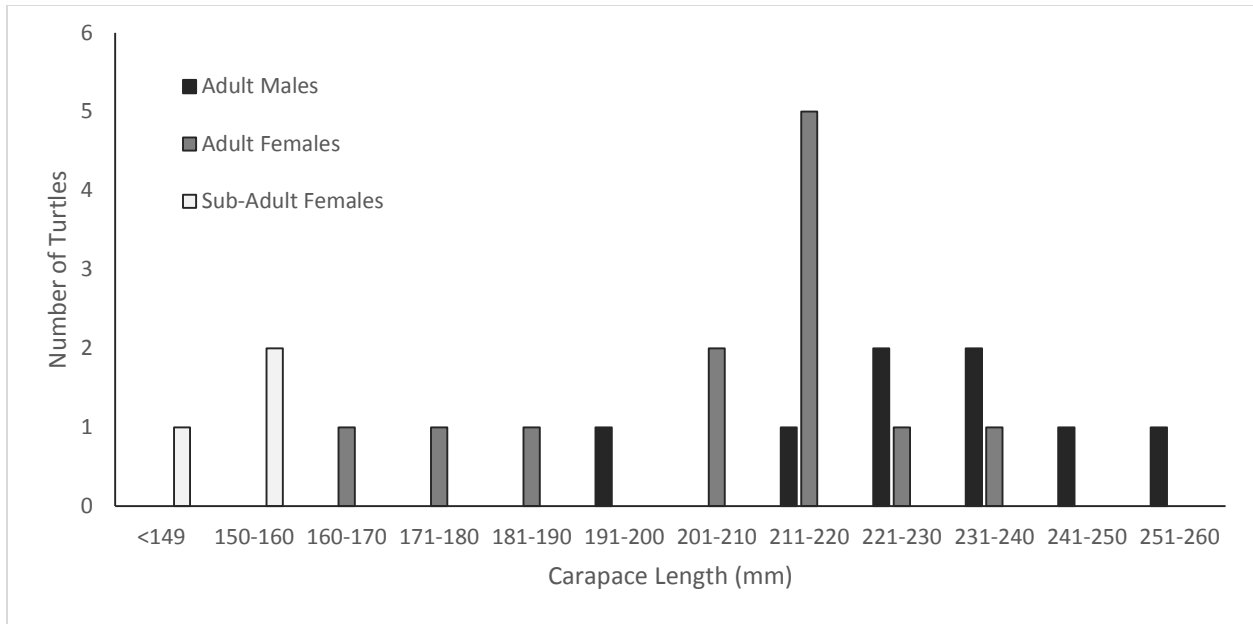


Figure 1-3 Frequency histogram of size classes for adult male, adult female and sub-adult female Blanding's turtles (*Emydoidea blandingii*) in Chalk River, Ontario between 2014 and 2015.

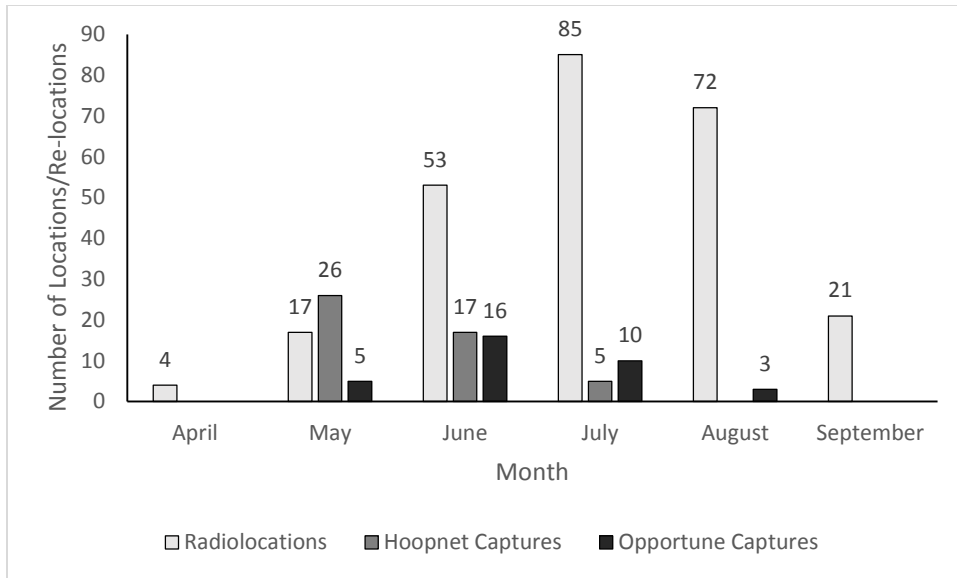


Figure 1-4 Number of locations and re-locations by radio-tracking, hoop netting, and opportune capturing by month summed between 2014 and 2015 of Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Road sightings and sightings while tracking another individual were considered “opportune captures”.

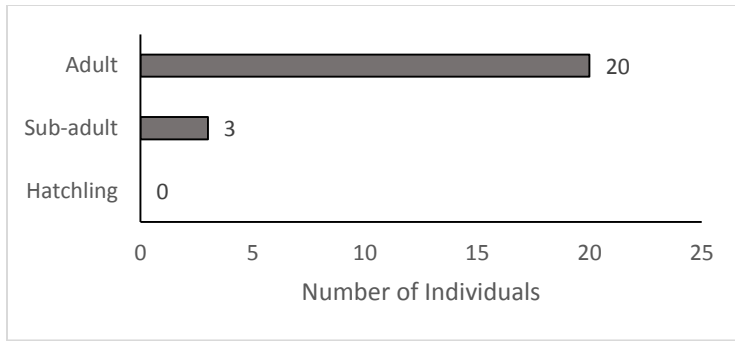


Figure 1-5 Stage classes of Blanding's turtles (*Emydoidea blandingii*) captured in Chalk River, Ontario between 2014 and 2015.

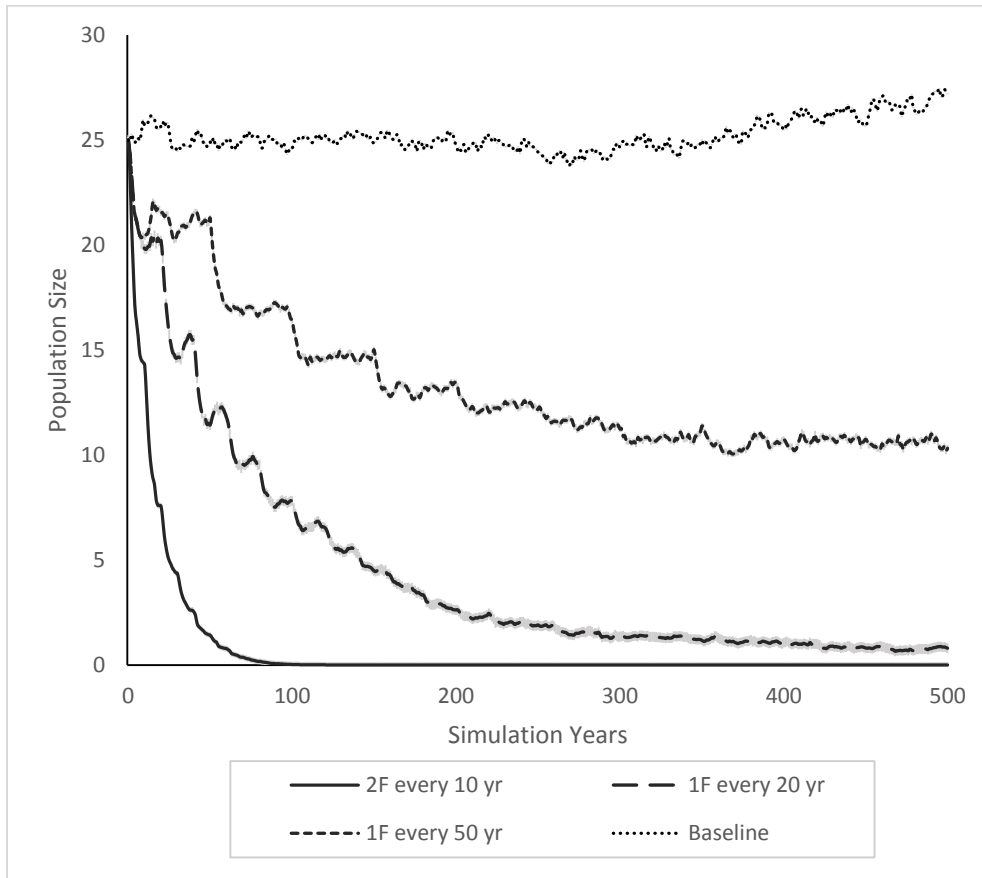


Figure 1-6 Impact of road mortality on mean Blanding’s turtle (*Emydoidea blandingii*) population sizes in Chalk River, Ontario, based on a population viability analysis over 500 years. The Baseline scenario did not include a road mortality input where all other scenarios included road mortalities of either one or two females every ten, 20 and 50 years. Grey bars indicate standard error.

CHAPTER TWO

MOVEMENTS AND HOME RANGES OF BLANDING'S TURTLES IN CHALK RIVER, ONTARIO

Introduction

Migration between suitable habitat patches or within patches large enough to sustain a number of interacting populations supports the regional and local persistence of species (Gonzalez et al. 1998). Landscapes that facilitate habitat and population connectivity are especially important for the persistence of small populations, or populations below the Minimum Viable Population (MVP) size as they facilitate sociality, augment mating opportunities, and increase genetic diversity (Gibbs, 1993). A literature review by Semlitsch and Bodie (2003) suggests the protected terrestrial buffer zone around a wetland should extend 127-289 m for turtles to include a mean minimum core terrestrial habitat determined from 28 species. This is a stark comparison to the generalized standard of a 30-60 m buffer zone for the protection of water resources (see Semlitsch & Bodie 2003 for examples).

Several studies have described movement patterns across the distributions of freshwater turtle species. Specifically, periods of activity for Blanding's turtle populations can be characterized by the biological needs of the species driving activity patterns, for example nesting, or by temporal shifts in resource availability, such as the cover provided by vegetation. Blanding's turtles have three biologically distinct periods during the active season; pre-nesting (ice-break to mid-May), nesting (late May to mid-June), and a summer period of decreased activity (late June into September) before migration to hibernacula which occurs between September and October (Kiviat 1997; Edge 2008; Beaudry et al. 2009). The beginning of the pre-nesting period can be determined as the date of first emergence from hibernacula and the beginning of the nesting period can be defined as the date at which the first gravid female is observed and ends when the last gravid female is confirmed to have laid her eggs (Edge 2008).

In Chalk River, the first emergence from hibernacula in 2015 was 23 April, and the first gravid females were detected on 11 and 2 June in 2014 and 2015, respectively. The summer period was determined to begin once all known gravid females had nested (20 June 2015) and concluded on the last day of field work (28 September 2015). Despite rigorous field effort in the spring of 2015, a high transmitter failure rate and a priority for increasing the sample size of animals with radio-transmitters led to insufficient data in the pre-nesting and nesting periods to analyze these periods separately. Thus, data from these periods were combined and considered the spring period for analyses (23 April – 19 June).

To best inform management decisions, in particular those pertaining to seasonal work restrictions and future infrastructure development in Chalk River, patterns of movement were considered. Specifically, seasonal movement patterns of male and female Blanding's turtles were described to indicate when turtles were travelling and therefore would be more likely to be intercepted by vehicles on roads or by surveyors in the field. Whole-population and individual (home) range distributions were also described to best show the areas of site occupied annually and seasonally by the population and its individuals.

Methods

Movement Patterns

A transmitter was fitted onto the posterior marginal scutes of a turtle when it met the required minimum mass of 250 g, taking care to avoid using scutes previously notched or drilled for identification. Transmitters were Holohil SI-2FT, weighing 16 g with 24 months of battery life. When attaching a transmitter to a female, the supracaudal scutes were avoided so as not to impede future mating attempts. A high-speed rotary tool was used to drill two holes on the

posterior marginal scutes to affix the transmitter to the carapace. Two small stainless steel bolts fixed the transmitter to the carapace and the device was then coated in marine silicone to prevent it catching on debris as the turtle moved. Once the silicone dried, the turtle was released at the location of capture.

Radio-tagged individuals were located on foot or by boat using a hand-held receiver (Wildlife Materials International, Murphysboro, Illinois, USA) and three-element Yagi antenna (Advanced Telemetry Systems, Minnesota, USA) approximately once to twice a week. Individuals were located no more than once in a two-day period to prevent autocorrelation of the data (Innes et al. 2008). Tracking began in April when the ice broke on wetlands with known hibernacula and concluded 28 September when most turtles reached known or suspected overwintering locations. Hibernacula were confirmed between January and March 2015 for four individuals with working transmitters. All locations were recorded using a hand-held GPS (Garmin GPSMap 76, Olathe, Kansas, USA) with an accuracy of 2-5 meters.

Data from the 2014 season were insufficient ($n \leq 9$), thus all movement analyses were performed using data from the 2015 season where $n = 14$ to 19 individuals. Distance moved between relocations was measured as a straight-line distance in ArcMap 10.2 (ESRI 2013) and all movement comparisons were conducted in R 3.2.2 (R Core Team 2015). A Kruskal-Wallis test, paired with a Nemenyi post-hoc test was used to test for significant differences in movement between the spring and summer periods because variances were insignificantly unequal.

Population Range and Home Range

All home range comparisons were conducted in R 3.2.2 and Welch's test was used instead of a student's t-test when assumptions of homogeneity were not met. All population range

calculations were conducted in ArcMap 10.2 and were defined as 100% minimum convex polygons (MCPs) buffered to encompass all kernel home ranges. Home range calculations were conducted in R 3.2.2 and were defined as 95% kernels adjusted to equal the area of a corresponding MCP home range (Row and Blouin-Demers 2006). This area adjustment consists of changing the smoothing factor (h) when calculating kernel home range. Home range area increases significantly as the smoothing factor is increased, however, this increase is not consistent across individuals. Therefore, MCPs were used to calculate home range size, while kernels with an individual-specific adjusted smoothing factor were used to indicate habitat use (Row and Blouin-Demers 2006) (Appendix 2).

A limitation of MCPs is that the location points used to create the vertices of the polygons indicate a turtle would not use the habitat directly adjacent to it yet outside the polygon. Applying a buffer adjusts for this by including habitat immediately adjacent to individuals' home ranges. Semlitsch and Bodie (2003) recommend a buffer of up to 289 m for reptiles from the edge of an aquatic site. Specifically, Congdon et al. (1983) and Ross et al. (1990) reported mean distances moved from an aquatic site as 135 m and 168 m for Blanding's turtles, with a maximum observed distance of 1115 m. Thus, to ensure all kernel home ranges were encompassed within population range calculations, population range MCPs were buffered. The CRL Blanding's population range MCP was extended by applying a 200 m buffer while population range MCPs for the spring and summer periods were buffered by 50 m and 80 m, respectively (Edge et al. 2010).

Results

Movement Patterns

Mean distance moved between relocations (MDR) was compared between sexes in the spring period ($t = 1.71$, $df = 12$, $p = 0.11$) and summer periods ($t = 1.08$, $df = 16$, $p = 0.43$). However, a comparison of MDR across the active season (23 April to 28 September) indicated males had a higher MDR than females ($t = 2.16$, $df = 16$, $p = 0.05$). Because MDR did not significantly differ between the sexes in the spring and summer periods, sex-specific data were pooled to compare MDR between the periods. MDR was calculated for the active season, the spring period, and the summer period as 153.5 ± 16.20 m, 241.8 ± 35.01 m, and 113.8 ± 8.5 m respectively. The MDR in the spring season was significantly higher than the MDR for the summer period ($\chi^2 = 16.49$, $df = 2$, $p < 0.001$) (Figure 2-1).

Population Range and Home Range

The Blanding's turtle population range over the two-year study was 519 ha (Figure 2-2). The population range, within the spring and summer periods, were 441 ha and 387 ha, respectively (Figure 2-3). It should be noted that limited sampling was undertaken in the more remote northern wetlands at CRL. Thus, the actual population range could be larger than the one described herein.

There was no correlation between number of radio locations and annual individual home range size ($n = 19$, $R^2 = 0.005$, $p = 0.46$). Home range size was uncorrelated to the number of location points per individual in the spring ($n = 14$, $R^2 < 0.01$, $p = 0.47$). In the summer, home range size was correlated with the number of location points per individual, however, this explained little of

the variance in observed home range size ($n = 18$, $R^2 = 0.07$, $p = 0.04$). No significant differences were found between male and female mean annual home range size ($t = 0.04$, $df = 17$, $p = 0.97$), spring home range size ($t = -0.79$, $df = 10$, $p = 0.45$) and summer home range size ($t = 1.09$, $df = 16$, $p = 0.29$). Data were thus pooled between the sexes and mean home range size between the spring and summer periods was tested. Individual annual home ranges spanned from 3.4 ha to 56.7 ha with a mean of 13.1 ± 12.3 ha. Within the spring period, home range size spanned from 2.6 ha to 61.6 ha with a mean of 11.1 ± 14.8 ha. During the summer period, home range size spanned from 2.7 ha to 26.9 ha with a mean of 8.0 ± 5.8 ha. No significant difference was found in home range size between the spring and summer periods ($t = 0.72$, $df = 16$, $p = 0.50$) (Figure 2-4).

Discussion

Movement Patterns

Blanding's turtle movements appeared to be their most extensive in the spring at CRL. Greater movements were expected in the spring period because males will conduct mate-searching excursions when mating opportunities are not abundant at hibernacula in the late fall and early spring (Buhlmann and Gibbons 2001, Pearse and Avise 2001, Semlitsch and Bodie 2003, Congdon et al. 2008). Additionally, gravid females will conduct extensive nesting migrations in the spring period while in search of adequate nesting sites (Congdon et al. 2008, Markle and Chow-Fraser 2014). Thus, females were expected to conduct more extensive movements in the spring than males, however, this was not evident in the CRL population.

Females would be expected to travel greater distances if there were limited availability of nesting sites and males would be expected to travel greater distances if mating opportunities were not

abundant at hibernacula (Congdon et al. 1983, Gibbs 1993, Innes et al. 2008). The fact that males at CRL did not move significantly greater distances than females may be attributed to several factors. Far-reaching nesting migrations may not have been required for gravid females to find adequate nesting locations, as soft, sandy substrates and exposed bedrock around the core wetlands used by the population offered access to potential nesting sites. Similarly, extensive migrations would not be required if road-side nesting sites were used, as gravel roads currently border core wetlands on multiple sides. Additionally, due to the small sample size of individuals, non-gravid females were pooled with gravid females in these comparisons. Thus, female MDR could have been low because of this inclusion of non-gravid females who do not need to find nesting sites. However, Hasler et al. (2015) reasonably suggested nesting migrations may be restricted in a more developed landscape due to an increase of anthropogenic barriers.

It is important to consider movement patterns in a site-specific context and to avoid interpreting results as absolute and transferring these from one location to another (Markle and Chow-Fraser 2014). For example, females from populations in Central Wisconsin, New Hampshire, Southeastern Michigan, and Southeastern Ontario travel a greater mean daily distance than males in the spring and/or throughout the active season (Ross and Anderson 1990, Innes et al. 2008, Congdon et al. 2011, Millar and Blouin-Demers 2011). Other studies, conducted in Maine, in Algonquin Park (Ontario), in Ottawa (Ontario), and in New Hampshire, closer to the northern range limit of the species, reported no significant differences between male and female movements in any activity period, but that distances moved were higher in the spring relative to the summer (Beaudry et al. 2009, Edge et al. 2010, Hasler et al. 2015, Walston et al. 2015). It is also important to note that the number of individuals tracked, the survey methods, the length of the tracking season, and the landscape composition can vary considerably between studies. These

reports highlight the relevance of site-specific studies for the purposes of management decision-making and understanding the species' ecology.

Population Range and Home Range

Though Hamernick (2000) reported no significant difference in Blanding's turtle home range size estimation using MCPs and 95% kernels, different methods will often produce different results for home range size and shape (Row and Blouin-Demers 2006). For the CRL population, MCPs were used to estimate home range size and 95% kernels equal in size to these MCPs were used to more appropriately estimate actual home range on the landscape (Row and Blouin-Demers 2006). Home range sizes of Blanding's turtles at CRL were not significantly different between the sexes and fell well within reported ranges for the species. Similarly, home range length of Blanding's turtles at CRL also fell within the range of values reported in the literature (Table 2-1).

The findings of no difference in home range size between sexes or among activity periods at CRL is also consistent with past studies conducted in pristine, agriculturally developed and suburban sites, due to high individual variation within the population (Hamernick 2000, Grgurovic and Sievert 2005, Edge et al. 2010, Fortin et al. 2012) (Table 2-1). Mean home range size of male and female Blanding's turtles have been estimated to range 0.8-57.11 ha and 0.6-61.18 ha, respectively, using various methods (Ross and Anderson 1990, Hamernick 2000, Congdon et al. 2008, Edge 2008). In the pristine landscape of Algonquin Park, annual home range size averaged 57.1 ha and 61.2 ha for males and females respectively (Edge et al. 2010). Home range size also did not differ significantly for the Algonquin population between the sexes or among activity periods (Edge et al. 2010). Blanding's turtles in a suburban landscape of

Massachusetts had a mean annual home range area of 22 ha estimated using 95% kernels (Grgurovic and Sievert 2005). However, Grgurovic and Sievert (2005) also reported little overlap of an individual's home range between study years which could indicate an underestimation of lifetime home ranges.

Home range size may vary based on the quality and availability of resources. Blanding's turtles occupying small wetland areas, particularly those in close proximity to lakes, have been reported to maintain smaller home ranges than turtles occupying wetlands in suburban areas (Congdon et al. 2008). Comparatively, in a relatively pristine landscape Blanding's turtles also have been reported to occupy large home ranges, perhaps due to the limited availability of adequate nesting sites (Edge 2008). Selection for habitat types which satisfy the species' biological needs plays an important role in determining the home range size of individuals and the distances they are likely to travel.

Table 2-1 Review of published Blanding’s turtle (*Emydoidea blandingii*) home range areas (ha) and lengths (m) ± Std. Err. (N) for males (M), females (F) and gravid females (GF) for comparison with those reported in this study. Whether a significant difference in values was detected between males, females and/or gravid females is also indicated.

Location	Method	Mean Home Range Area (ha) ± Std. Err. (N)				Mean Home Range Length (m) ± Std. Err. (N)				Sign. Diff.?	Reference
		M	F	GF	All	M	F	GF	All		
Ontario	MCP	13.20 ± 3.12 (7)	12.98 ± 4.06 (12)		13.06 ± 2.81 (19)	848.86 ± 64.79 (7)	852.30 ± 77.96 (12)		851.03 ± (19)	N	Hawkins and Blouin-Demers, unpub.
Ontario	MCP	8.5 ± 1.7 (20)	7.3 ± 3.2 (5)	20.3 ± 3.5 (12)	12.2 ± 1.8 (37)	630.8 ± 79.7 (20)	586.0 ± 130.5 (5)	1210.9 ± (12)	812.9 ± 78.1 (37)	Y	Millar and Blouin-Demers, 2011
Ontario	MCP	57.1 ± 15.3 (5)	61.2 ± 30.4 (16)								Edge et al. 2010
Wisconsin	MCP	26.1 (9)	20.7 (9)		25.5** (18)					N	Schuler and Theil, 2008
New Hampshire	MCP		6.8** (3)		3.3** (10)						Innes et al., 2008**
New Hampshire	MCP	3.7** (4)	1.5** (3)							N	Innes et al., 2008**
Massachusetts	Fixed Kernel (95%)	27.5 ± 0.10 (14)	19.9 ± 0.07 (27)		22 ± 0.06 (41)	866 ± 0.05 (19)		852 ± 0.04 (31)	856 ± 0.03 (50)	N	Grgurovic and Seivert, 2005
New York	MCP	7.5	12.3							N	Crockett, 2004, unpub.
Minnesota	MCP	94.9 ± 58.4 (8)	60.7 ± 12.6 (16)		72.1 ± 20.6 (24)	1794.0 ± 547.7 (8)		1472.0 ± 191.3 (16)	1579 (24)	N	Hamernick, 2001
Minnesota	MCP	38.4	35.4						906	N	Peipgras and Lang, 2000
Illinois	MPM*	1.4** (4)	1.2** (3)		1.3 ± 0.64 (7)	630 ± 304.9 (4)		800 ± 545.8 (3)		N	Rowe and Moll, 1991
Wisconsin	MPM*	0.76 ± 0.19** (2)	0.56 ± 0.15** (4)							N	Ross and Anderson, 1990
Illinois	MCP				9.5						Rowe, 1987

*Minimum Polygon Method (MPM) is equivalent to MCP

**area of activity center size, excluding areas used encompassed by long distance excursions such as hibernation and nesting forays

***median value was used when mean value was not report

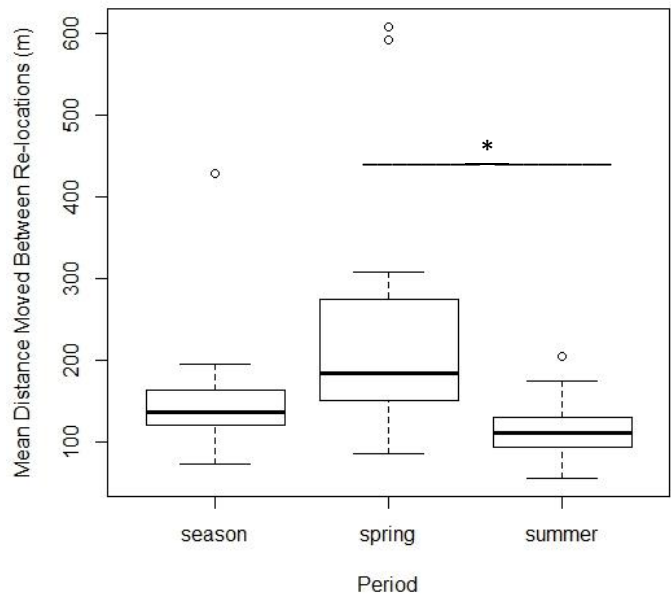


Figure 2-1 Means of daily-distance moved by individual Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario between relocations for the 2015 season, and the spring and summer periods of 2015. The asterisk indicates significance.

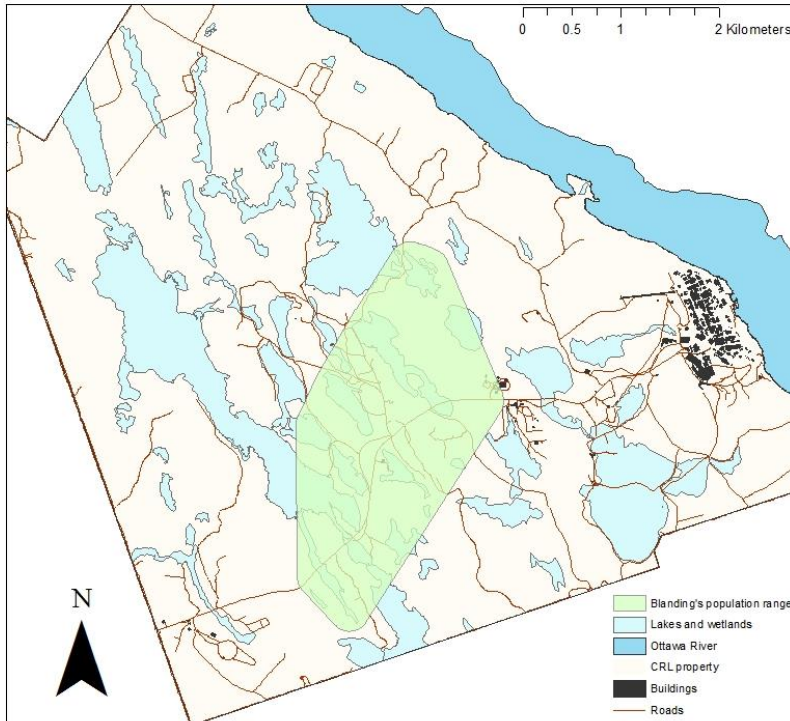


Figure 2-2 Blanding's turtle (*Emydoidea blandingii*) population range in Chalk River, Ontario, 2014-2015.

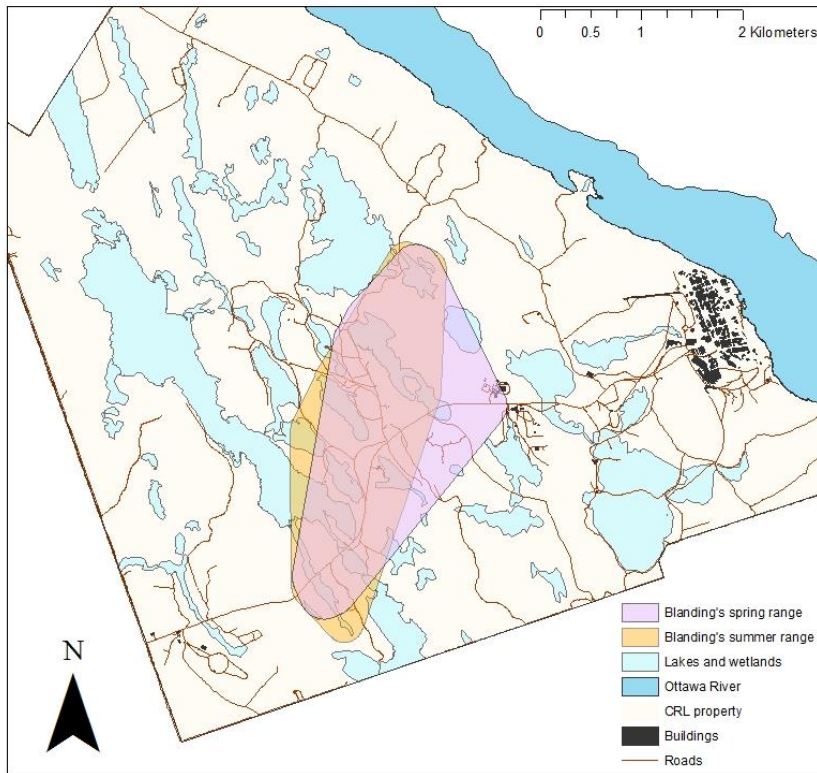


Figure 2-3 Blanding's turtle (*Emydoidea blandingii*) ranges for the spring and summer periods from 2014 to 2015 in Chalk River, Ontario.

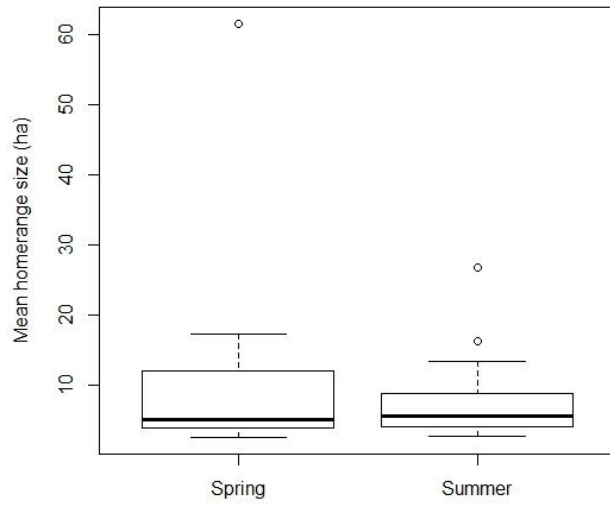


Figure 2-4 Means of home range size of individual Blanding's turtles (*Emydoidea blandingii*) for the spring and summer periods in Chalk River, Ontario.

CHAPTER THREE

MULTIPLE SCALE HABITAT SELECTION BY BLANDING'S TURTLES IN CHALK RIVER, ONTARIO

Introduction

Habitat selection studies are a common ecological tool for informing Species at Risk management and mitigating land-use practices within the ranges of Species at Risk. These studies aim to describe where and why animals are located in specific habitats when there are multiple available for use (Alldredge and Griswold 2006). This knowledge can then be used to elucidate the critical habitats of a species, a population, or even an individual animal. Towards the northern range limit of many turtle species, most field studies have been restricted to the span of the active season. Considering the active season may only consist of four to six months, analyses often pool data for the entire season and seldom consider biologically relevant periods or include data from the winter season.

The preferential use, or selection, of resources by a species indicates the resources used and required to fulfill the species biological needs. Biological needs can change depending on the time of year and the sex or age of an individual. Changing biological needs can then alter the selection of resources by a species, a population, or an individual.

Johnson (1980) described how selection for certain habitat types can occur at multiple scales. If habitat types are being used disproportionately to their availability (are being used non-randomly) then selection is said to be occurring for these habitat types (Aebischer et al. 1993). If selection is not detected, however, it cannot be concluded that selection is not occurring. For example, where selection occurs strongly at a coarse spatial scale (such as population range), selection may not be detectable at a finer scale (such as individual locations) because resources may be uniformly distributed within the strongly selected population range. Considering only the pattern of selection at a single scale can lead to misrepresentative results and recommendations

for management. Thus, evaluating selection at multiple scales provides a much clearer representation of habitat required by the species in question (Morin et al. 2005).

To yield the most reliably informative results in this study, habitat selection was considered and evaluated at three scales. The selection of macrohabitat types, such as marsh or bog, was evaluated at two scales: within the Blanding's turtle population range and then within individual's home ranges. At the finest spatial scale, the selection of microhabitat features, such as water temperature and vegetation type, were evaluated at turtle location points, determined by radio-tracking.

Methods

Macrohabitat Use

Every wetland > 0.5 ha within the CRL site was assigned to a macrohabitat type (Table 3-1) using the methods from the Northern Ontario Wetland Evaluation System (NOWES) and the Ontario Ministry of Natural Resources and Forestry (OMNRF) Forest Management Planning document (2013). When a turtle was located, the macrohabitat type in which it was situated was recorded for use in a compositional analysis. To detect selection of a habitat type within the population range and individual home ranges the compositional analysis was conducted in R 3.2.2. This was used to determine Blanding's turtle habitat use versus habitat availability at CRL (Aebischer et al. 1993). A compositional analysis tests the null hypothesis that available habitats are used randomly by individuals of a population. If habitat types were used non-randomly, a ranking matrix was created to establish the order of preference for each type. Pairwise comparisons were then used to determine if differences between ranks were significant.

Individuals were considered the sampling units at both scales, which avoids pseudoreplication and inflation of the degrees of freedom.

The landscape of the study area was divided into five habitat types for the compositional analysis (Table 3-1). A parametric test validated with a randomization test, where there was no change in the resulting rankings, was used to test for selection of individual homeranges from within the geographical range of the population. The presence of zeros in the matrix of available habitat dictated the use of a non-parametric randomization test in testing for selection for particular habitat factors from those available within homeranges. This is not uncommon when selection for particular habitat types is under focus because some types may not be available to all individuals. Thus, Lake was eliminated from this analysis because it was not available within any home ranges (Aebischer et al. 1993). Similarly, Swamp was also eliminated from this analysis because it was not used by more than one individual, thus, it was not available within more than one home range (Aebischer et al. 1993).

Microhabitat Use

When a turtle was located, several habitat characteristics were recorded within a 1 m radius plot using the turtle's location as a center point. A digital thermometer (Fisher Scientific, Ontario, Canada) was used to obtain both air temperatures in the shade within 5 cm of the water surface and water temperature within 15 cm of the surface. The depth at which the turtle was found was measured using a meter stick and the percent canopy cover and surface vegetation cover were also recorded. The consistency of soil/substrate constituents was recorded in percentages adding up to 100 (peat, woody detritus, muck, clay, sand, gravel, rubble, boulder, bedrock). The animal's position, the general vegetation, and macrohabitat type (Table 3-1) were also recorded.

The frequency of turtles located in aquatic and terrestrial positions was calculated, however, locations where individuals were captured in hoop nets were not included in these figures as they do not reliably portray use (Figure 3-1). All habitat features were not available to turtles captured in hoop nets at the time of sampling.

Paired, random plots were used to characterize habitat availability using the same features recorded at the turtle plots. The random plots were located by generating a random compass bearing between zero and 360° and a random distance between 10 and 50 m (the mean daily movements of Blanding's turtles in 2007 were 40 m at Brooker's Pond and, in 2006, were 44 m in Northeastern Algonquin Park) immediately after the turtle plot had been characterized (Edge 2008, Millar 2010). These random plots were constrained to fall within the boundaries of the macrohabitat type the corresponding turtle plot was in.

Matched-paired logistic regression was used to test for selection of microhabitat features within individual's home ranges. Ideally, a regression would be conducted for each individual and an mean for all individuals would be taken. However, I did not have sufficient data points per individual to fit individual models. Thus, I pooled the data for all turtles and used matched-paired logistic regression with a total of 306 paired sites. This method tests habitat use versus availability at the same time and place and does not require multivariate normality of the data. It is therefore more robust than MANOVA, non-paired logistic regression, or discriminant function analyses (North and Reynolds 1986). Environmental changes over time are controlled for by a paired design in which each turtle plot is compared to its paired random plot, thus ensuring random locations were available to the turtle at the time of its location (Compton et al. 2002). This does result in some pseudoreplication and some inflation of the degrees of freedom.

Akaike's Information Criterion (AIC) was applied to determine which model accounted for the most variation with the fewest variables. The model with the lowest AIC was then chosen to represent Blanding's turtle microhabitat preference, first across the active season and then within the spring and summer periods (Table 3-2).

To tease out the explanatory variables from the 28 collected, individual univariate tests were run and non-significant variables were eliminated from the analysis ($p > 0.25$). Due to the small sample size, data from both sexes were pooled (7 males, 15 females) and a total of 306 paired sites, 95 (35 male, 60 female) in the spring and 210 (71 male, 139 female) in the summer were used. The eight significant variables included in the analysis were air and water temperature, water depth, organic substrate, emergent vegetation, floating vegetation, submergent vegetation, and percent open water (Table 3-3). Group mean values were substituted for the few terrestrial sites where water temperature values were unobtainable to include this variable without affecting the water temperature mean.

The organic substrate variable included substrates consisting of humus, woody detritus, peat, and muck (Marchand and Litvaitis 2004). The emergent plant variable included narrow-leaved, robust, broad-leaved and woody emergent types as described by the Northern Ontario Wetland Evaluation System (Edge et al. 2010, Millar and Blouin-Demers 2011, NOWES 2013). Sites characterized by woody vegetation were few and cover was minimal, thus this type was included in the emergent variable and was not considered as distinct. The floating and submergent vegetation types were also characterized based on methods outlined by the NOWES (2013).

Results

Macrohabitat Use

When evaluating selection of individual homeranges within the geographical range of this population, habitats were ranked as Marsh>Upland>Bog>Swamp>Lake where Lake was not selected by any individuals (Table 3-4). Pairwise comparisons revealed Marsh was significantly preferred to all other habitat types, Upland and Bog were considered interchangeable, and Bog and Swamp were considered interchangeable (Figure 3-2). Swamp and, most notably, Lake and Upland were used less than their respective availabilities (Table 3-5). When the selection of habitat types within home ranges was evaluated, habitats were ranked as Marsh>Bog>Upland where Upland was used much less than its availability (Table 3-4, Table 3-5). Pairwise comparisons revealed Marsh to be significantly preferred over Upland, Marsh and Bog to be considered interchangeable and Bog and Upland to be considered interchangeable (Figure 3-3).

Microhabitat Use

At 92.9% of locations during the active season, Blanding's turtles were using aquatic habitat. In aquatic habitats, adult males and females were primarily observed to be submerged mid-water column at 80.5% and 72.1% of observations, respectively (Figure 3-1). Sub-adult females were primarily observed at the surface of the water at 50.0% and submerged mid-water column at 42.9%, and were never observed using terrestrial habitat (Figure 3-1).

The best model for the active season was significant, but explained a relatively small portion of the variation ($R^2 = 0.10$, LL = 64.31, $p < 0.001$). Across the active season, Blanding's turtles selected for higher air temperatures and percent cover of emergent vegetation, floating vegetation, and open water (Table 3-6). The confidence intervals for the water temperature and water depth probabilities of selection include both positive and negative values, thus it is unclear if turtles were selecting for higher or lower temperatures and depths when considering the entire

active season. The probability of site selection by Blanding's turtles increased by 5.8% with a one degree increase in air temperature (Figure 3-4). Similarly, the probability of selection increased by 64.6%, 72.5% and 60.3% with an increase of 25% in percent cover of emergent vegetation, floating vegetation, and open water, respectively (Figure 3-4).

The best fitting model for the spring period was significant and included air temperature, water depth, emergent vegetation, floating vegetation, and open water ($R^2 = 0.19$, $LL = 39.74$, $p < 0.001$) (Table 3-7). In the spring period, Blanding's turtles selected sites with higher air temperatures and shallow water with a high percent coverage of emergent vegetation, floating vegetation, and open water (Figure 3-5). A one degree increase in air temperature increased the probability of selection by a Blanding's turtle by 12.7% while an increase of 25 cm in water depth decreased the probability of selection by 35.7%. A 25% increase of emergent and floating vegetation cover resulted in an increased probability of selection of 86.2% and 90.4%, respectively. Similarly, an increase of 25% open water cover resulted in an increase of 88.3% in selection probability.

Within the summer period, the best fitting model was significant and included water depth, emergent vegetation, floating vegetation, and open water ($R^2 = 0.12$, $LL = 51.91$, $p < 0.001$) (Table 3-8). Blanding's turtles selected sites with deeper, cooler water and higher percent coverage of emergent vegetation, floating vegetation, and open water (Figure 3-6). An increase of 25 cm in water depth increased the probability of selection by 37.7% and an increase of water temperature by one degree decreased the probability of selection by 6.6%. The probability of selection by a turtle increased by 57.4%, 68.5% and 54.0% with a 25% increase in emergent vegetation, floating vegetation, and open water, respectively.

Discussion

Macrohabitat Use

Blanding's turtles will occupy habitats such as lakes, marshes, swamps, beaver ponds, man-made ponds and slow-flowing streams, and will use terrestrial habitats during extensive nesting migrations (Ross and Anderson 1990, Rowe and Moll 1991, Bury and Germano 2003, Congdon et al. 2008, Markle and Chow-Fraser 2014). Reportedly, wetlands such as marshes, swamps, and ponds are preferred by Blanding's turtles (Ross and Anderson 1990, Kiviat 1997, Edge et al. 2010, Millar and Blouin-Demers 2011). This is relatively consistent with the ranked preferences of Blanding's turtles in Chalk River.

A compositional analysis of the selection of home ranges within the geographic range of the Blanding's turtles in Chalk River indicated a strong preference for Marsh over Upland, Bog and Swamp, and a strong avoidance of Lake (Figure 3-2). Blanding's turtles strongly preferred Marsh and weakly avoided Upland types when selection of habitat types within home ranges was evaluated (Figure 3-3). Similarly, Edge et al. (2010) were able to detect an avoidance of upland habitats selected within the geographical range of Blanding's turtles in a relatively pristine landscape within Algonquin Park, though they were unable to detect selection of habitat types within individual's home ranges. Blanding's turtles on a protected island in Georgian Bay preferred shallow wetlands (similar to the Marsh type within Chalk River) and bogs, when selection from the geographical range was evaluated, and bogs, when selection within home ranges was evaluated, while all other types were used in proportion to their availability (Markle and Chow-Fraser 2014).

If strong selection occurs at the coarser, geographic scale, then selection at finer scales, such as the home range scale, can be difficult to detect because required resources are accessibly distributed due to selection at the coarser scale. If habitat selection is detected, it is important to consider the quality of these habitats and whether the habitat types are used disproportionately to their availability (Mysterud and Ims 1998). Depending on the availability and quality of habitats, multiple types may be required to fill the biological needs of the species. For example, shallow, vegetated wetlands may provide adequate cover and food items for juveniles, vernal pools and ditches could be used as staging areas antecedent to nesting and upland sites would provide ideal nesting locations for adult females (Bury and Germano 2003, Millar and Blouin-Demers 2011, Markle and Chow-Fraser 2014).

Microhabitat Use

The data and associated variances were best described when models were fitted to spring and summer periods individually compared to pooling data for the active season. In spring, Blanding's turtles elected higher air temperatures, shallower water, and higher coverage by vegetation than were randomly available. In summer, Blanding's turtles selected for sites with deeper, cooler water, and higher coverage by vegetation than were randomly available. Turtles selected sites of similar air temperatures in spring ($19.0 \pm 0.57^{\circ}\text{C}$) and summer ($22.2 \pm 0.24^{\circ}\text{C}$). Water temperature at selected sites were also similar between the spring ($20.3 \pm 0.43^{\circ}\text{C}$) and summer ($23.3 \pm 0.25^{\circ}\text{C}$).

Blanding's turtles at CRL were expected to select for warmer temperatures than were available in the spring period because the coldest environmental temperatures were observed in this period. Behaviourally maintaining higher body temperatures in the spring would likely provide

physiological benefits for this ectothermic species (Huey and Kingsolver 1989). Blanding's turtles at CRL selected sites with higher air temperatures than random sites, which was consistent with observations of position within microhabitats, where turtles were most commonly observed mid-water column and at the surface of the water (Figure 3-1A). Turtles may have utilized these positions and preferred shallower water to behaviourally thermoregulate (Hartwig and Kiviat 2005, Edge et al. 2010).

In the heat of the summer, turtles may select cooler, deeper sites to maintain body temperatures within the species optimal range (Huey and Kingsolver 1989). Millar and Blouin-Demers (2011) found Blanding's turtles on Grenadier Island selected cooler water temperatures, similar to the CRL Blanding's turtles during the summer period. Comparatively, Edge et al. (2010) found no evidence of selection for temperature variables in the pre-nesting, nesting, or summer periods by Blanding's turtles in Algonquin Park. However, Edge et al. (2010) did find Blanding's turtles selected deeper water in the summer period, consistent with Blanding's turtles at CRL.

Marshes and ponds characterized by open water and emergent vegetation are commonly preferred by Blanding's turtles (Ross and Anderson 1990, Kiviat 1997, Millar and Blouin-Demers 2011). This is consistent with the selection of sites with greater coverage of emergent and floating vegetation as well as a greater availability of open water by CRL turtles in both the spring and summer periods. Additionally, Blanding's turtles at CRL were primarily observed occupying positions at the water's surface or mid water column, particularly the sub-adults, where floating and emergent vegetation types are the dominant sources of cover. As sub-adults are not yet sexually mature, they have no motivation for mate-searching and nesting forays. Thus, they typically remain within the core of their established home ranges, rarely venturing

into upland habitat and residing within shallow wetlands primarily characterized by emergent vegetation (Congdon et al. 2008).

No evidence of selection for submerged vegetation or organic substrates was found. Similar to the findings of Hartwig and Kiviat (2005), Millar and Blouin-Demers (2011) found Blanding's turtles on Grenadier Island selected for floating and submergent vegetation types and muck substrates. In Minnesota, Blanding's turtles selected for emergent, floating, and submergent vegetation (Hamernick 2000). Edge et al. (2010) reported no evidence of selection by Blanding's turtles in Algonquin Park for vegetation types within any period, except for emergent vegetation in the summer. The lack of evidence for selection of submerged vegetation at CRL, despite evidence for its preference in the literature, could be explained if submergent types were abundantly distributed within selected wetlands. Alternatively, it could be attributed to field sampling error where the presence of submerged vegetation was difficult to distinguish and resultantly was recorded as open surface water.

Site-selection by Blanding's turtles at CRL was characterized primarily by vegetative variables. This is inconsistent with Millar and Blouin-Demers (2011) who reported structural habitat components played a greater role than vegetation type in habitat selection by Blanding's turtles. However, vegetation types do contribute structurally to a habitat and perhaps emergent and floating vegetation types at CRL provided adequate structure to the water-column so that submergent types were not particularly sought out by turtles (Carter et al. 1999). The lack of detection of preference for submergent vegetation and organic substrates by Blanding's turtles could also be attributed to the ubiquitous distribution of these characters throughout the population's range at CRL.

Submerged and emergent vegetation types harbour higher densities of macroinvertebrate preys, offer warmer microclimates, and provide shelter from environmental conditions and predators (De Szalay and Resh 2000, Hartwig and Kiviat 2005). Blanding's turtles are primarily carnivorous omnivores, with diets generally consisting of small crustaceans, molluscs, insects, earthworms, fish, frogs, and some vegetation (Congdon et al. 2008). Where crayfish were absent, aquatic insects, snails and fish have been reported as principal components of Blanding's turtle diets (Congdon et al. 2008). In Algonquin Park, however, habitat selection based on macroinvertebrate abundance was not detected, as no difference was found in macroinvertebrate abundance between turtle and random plots (Edge 2008). One explanation could be that macroinvertebrates considered in the study of Edge (2008) were not prey species. However, considering the largely generalist dietary tendency of Blanding's turtles across the species range, it may be more reasonable to attribute this to ample abundance of prey items throughout individual ranges.

At CRL, selection for emergent and floating vegetation could be explained by association with higher densities of prey species, warm microclimates, and refuge. Density of food items and prey species were not considered in this study at CRL, therefore their role cannot be evaluated directly. Selection for emergent and floating vegetation was consistent with warmer air temperatures in the spring period, suggesting selected sites had thermoregulatory potential while providing some refuge from predators. In the summer period, selection for these vegetation types as well as cooler deeper water may indicate Blanding's turtles sought out sites offering refuge not only from predators, but from hot environmental conditions and wetland drying.

Table 3-1 Descriptions of habitat types modified from Edge et al. (2010) and the Northern Manual of the Ontario Wetland Evaluation System (2013), used for the compositional analyses of preferred habitat type in a population of Blanding’s turtle (*Emydoidea blandingii*) in Chalk River, Ontario.

Type	Description
Bog	Live tree cover does not exceed 25 % and peat hummocks are observed. No fen indicator species are observed. The water table is high and/or near the surface. Usually, less than 14 species of vascular plants.
Marsh	Is permanently or periodically flooded. Dominant vegetation is emergent with subdominant floating and submergent types.
Swamp	A wooded wetland with slowly moving or stagnant water and more than 25% live tree cover.
Lake	Bodies of water >50 ha in surface area and a maximum depth exceeding 5 m.
Upland	Terrestrial areas with no standing water.

Table 3-2 Habitat variables used in the matched-pairs logistic regression for a population of Blanding’s turtle (*Emydoidea blandingii*) in Chalk River, Ontario.

Variables	Coefficient	SE	Increase	Odds Ratio	95% CI*
Air Temp	0.061	±0.029	1°C	1.062	(1.003, 1.125)
Water Temp	-0.054	±0.029	1°C	0.947	(0.894, 1.003)
Water Depth	0.289	±0.154	25 cm	1.335	(0.987, 1.806)
%Emergent	1.037	±0.229	25%	2.821	(1.801, 4.418)
%Floating	1.290	±0.291	25%	3.634	(2.053, 6.433)
%Open Water	0.925	±0.229	25%	2.522	(1.609, 3.954)

Table 3-3 Matched-paired logistic regression model that best explained microhabitat selection for the active season of 2014 and 2015 across all individual Blanding’s turtles (*Emydoidea blandingii*) (n = 19) captured in Chalk River, Ontario.

Variable	Description
<i>Structural</i>	
TempA	Air temperature (°C)
TempW	Water temperature (°C)
Depth	Water depth from substrate to surface (cm)
%Org	Percentage of substrate made up of organics
<i>Vegetative</i>	
%Open	Percentage of open water at the surface
%Emerg	Percentage of emergent vegetation
%Float	Percentage of floating vegetation
%Sub	Percentage of submerged vegetation

Table 3-4 Habitat preference determined by compositional analysis of habitat types, for a population of Blanding's turtle (*Emydoidea blandingii*) in Chalk River, Ontario.

Order of Selection	Preferred ↔ Avoided	Statistics	
		λ	p
2 nd	Marsh>Upland>Bog>Swamp>Lake	0.006 ^{a,c}	<0.001 0.002 ^c
3 rd	Marsh>Bog>Upland	0.846 ^b	0.046 ^c

^a: Wilk's lambda.

^b: Weighted mean lambda; used when zero values occur in the matrix of available habitats.

^c: Randomized p value.

Table 3-5 Mean percent of habitat types available and used by for a population of Blanding’s turtle (*Emydoidea blandingii*) (n = 19) in Chalk River, Ontario.

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

*No variances are associated with these values as the available habitat is constant across all individuals.

– No location points were located within the habitat type.

Table 3-6 Models tested for suitability in matched-pairs logistic regressions used in CRL Blanding’s (*Emydoidea blandingii*) turtle microhabitat selection analyses in Chalk River, Ontario. Models with the lowest AIC value were used for the active season, spring period and summer period analyses.

Model	AIC
<i>Active Season</i>	
TempA + Depth + %Emerg + %Float + %Org + %Open + %Sub + TempW	375.81
TempA + Depth + %Emerg + %Float + %Org + %Open + TempW	373.82
TempA + Depth + %Emerg + %Float + %Open + TempW	371.90
<i>Spring Period</i>	
TempA + Depth + %Emerg + %Float + %Org + %Open + %Sub + TempW	105.03
TempA + Depth + %Emerg + %Float + %Org + %Open + TempW	103.54
TempA + Depth + %Emerg + %Float + %Org + %Open	102.22
TempA + Depth + %Emerg + %Float + %Open	101.96
<i>Summer Period</i>	
TempA + Depth + %Emerg + %Float + %Org + %Open + %Sub + TempW	253.67
TempA + Depth + %Emerg + %Float + %Org + %Open + TempW	251.74
TempA + Depth + %Emerg + %Float + %Org + %Open	249.88
Depth + %Emerg + %Float + %Open + TempW	249.21

Table 3-7 Matched-paired logistic regression model that best explained microhabitat selection in the spring period of 2014 and 2015 across all individual Blanding’s turtles (*Emydoidea blandingii*) (n = 19) in Chalk River, Ontario.

Variables	Coefficient	SE	Increase	Odds Ratio	95% CI*
Air Temp	0.136	±0.040	1°C	1.145	(1.058, 1.239)
Water Depth	-0.812	±0.389	25 cm	0.444	(0.207, 0.952)
%Emergent	1.981	±0.621	25%	7.250	(2.147, 24.487)
%Floating	2.340	±1.178	25%	10.384	(1.033, 104.392)
%Open Water	2.144	±0.657	25%	8.536	(2.357, 30.907)

*from odds ratio

Table 3-8 Matched-paired logistic regression model that best explained microhabitat selection in the summer period of 2014 and 2015 across all individual Blanding’s turtles (*Emydoidea blandingii*) (n = 19) in Chalk River, Ontario.

Variables	Coefficient	SE	Increase	Odds Ratio	95% CI*
Water Temp	-0.073	±0.027	1°C	0.929	(0.881, 0.980)
Water Depth	0.473	±0.188	25 cm	1.604	(1.111, 2.318)
%Emergent	0.853	±0.267	25%	2.345	(1.392, 3.951)
%Floating	1.157	±0.321	25%	3.179	(1.693, 5.969)
%Open Water	0.777	±0.267	25%	2.175	(1.289, 3.668)

*from odds ratio

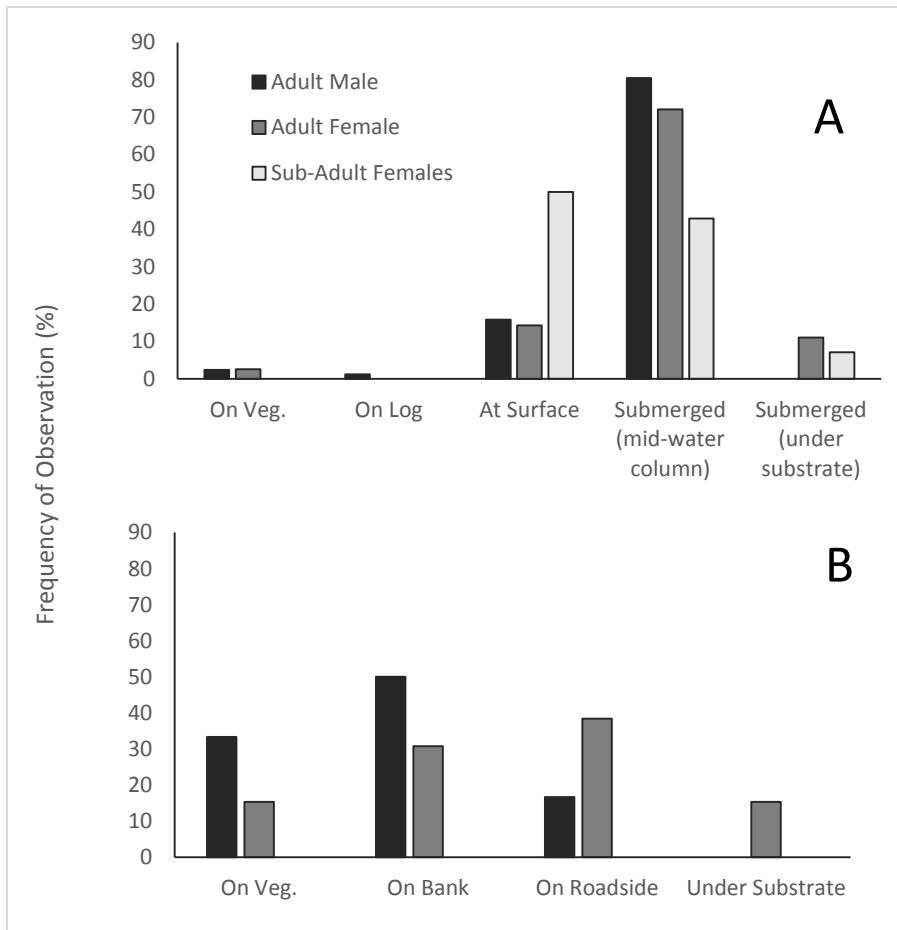


Figure 3-1 Frequency of observation of Blanding’s turtle (*Emydoidea blandingii*) position within aquatic (A) and terrestrial (B) habitats at location/re-location points between 2014 and 2015 during the active season in Chalk River, Ontario. Locations/re-locations where turtles were caught within hoop nets were excluded.

Marsh Upland Bog Swamp Lake

Figure 3-2 Habitat rankings for selection within the population range at 0.05 significance for Blanding's turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

Marsh Bog Upland

Figure 3-3 Habitat rankings for selection within individual home at the 0.05 level of significance ranges for Blanding's turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Bars indicate where comparisons between habitat types yielded no significance at the 0.05 level.

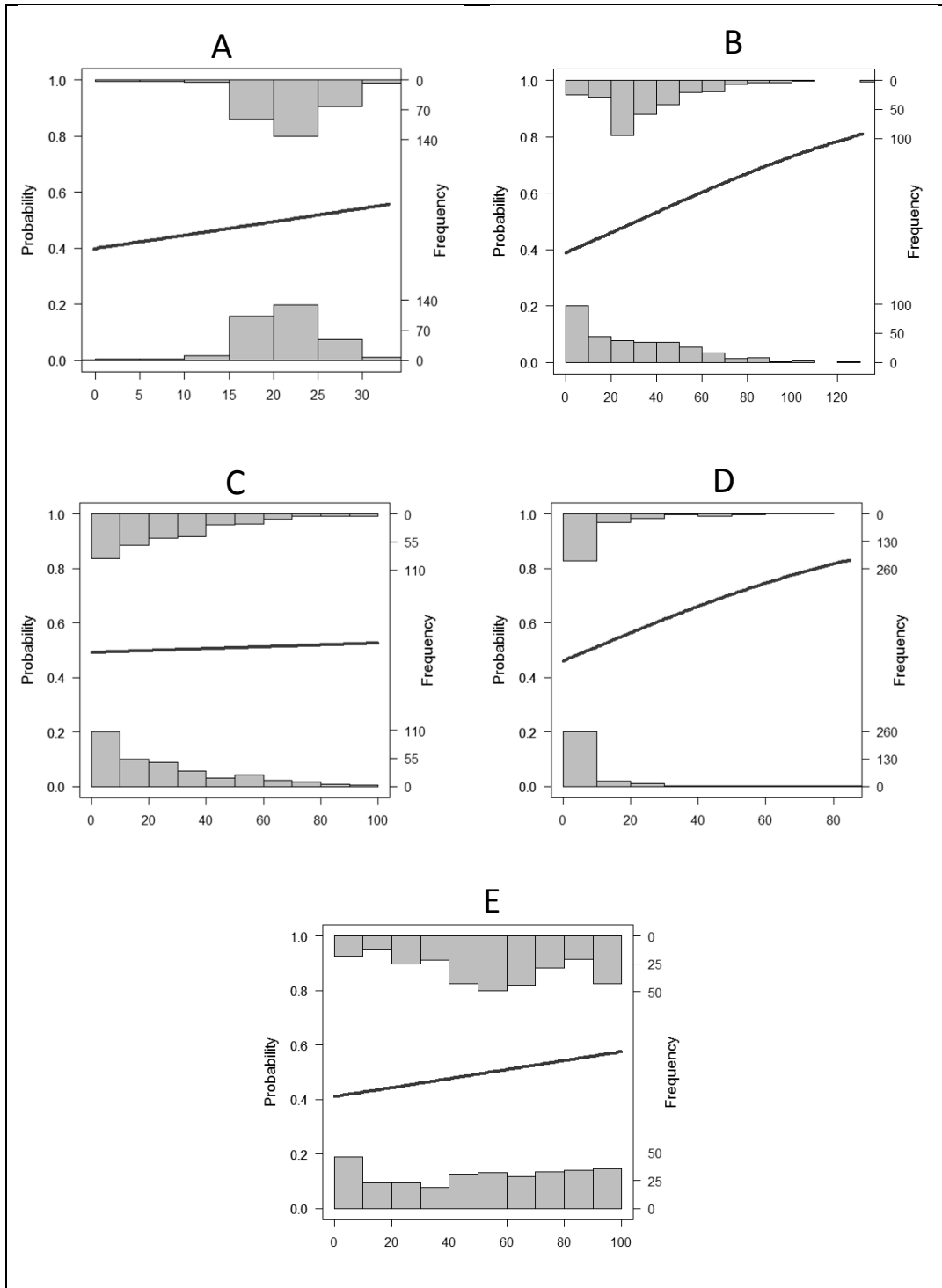


Figure 3-4 Selection and availability of habitat variables between 2014 and 2015 in the active season for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Shows frequency of observation and probability of selection by a Blanding’s turtle. A) Air temperature, B) water depth, C) emergent vegetation, D) floating vegetation and E) water temperature.

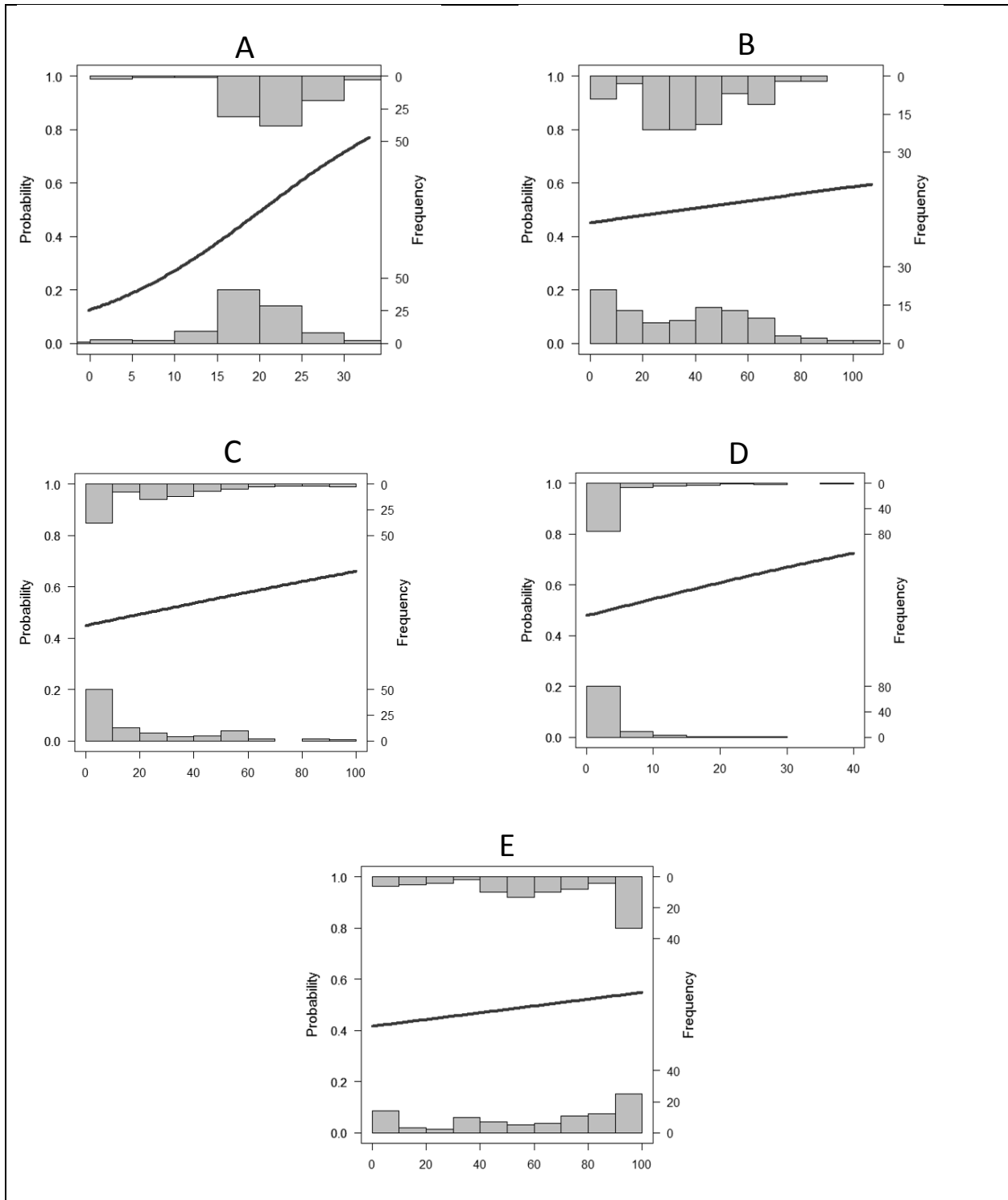


Figure 3-5 Selection and availability of habitat variables between 2014 and 2015 in the spring period for Blanding’s turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Shows frequency of observation and probability of selection by a Blanding’s turtle. A) Air temperature, B) water depth, C) emergent vegetation, D) floating vegetation and E) open water.

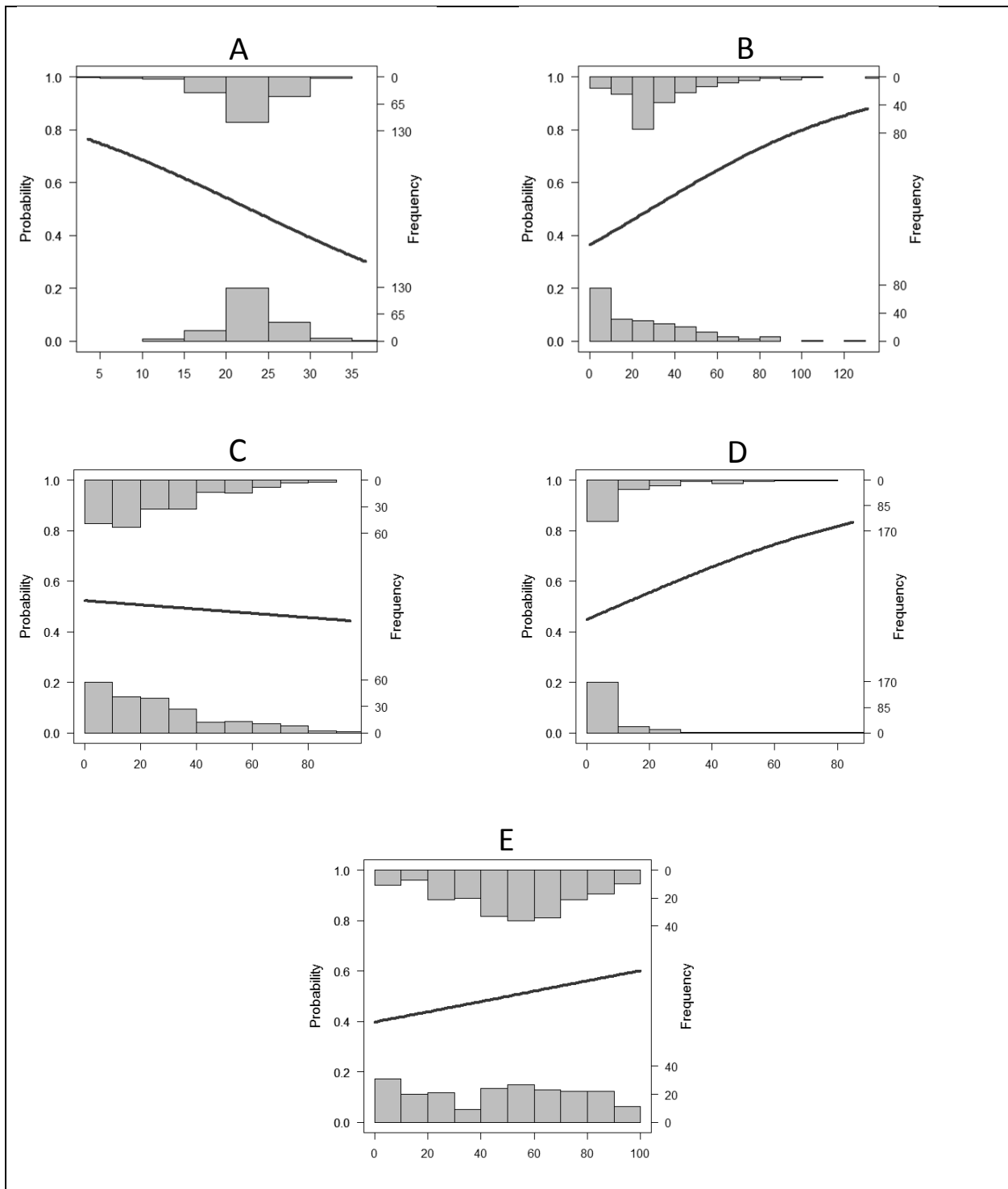


Figure 3-6 Selection and availability of habitat variables between 2014 and 2015 in the summer period for Blanding's turtles (*Emydoidea blandingii*) in Chalk River, Ontario. Shows frequency of observation and probability of selection by a Blanding's turtle. A) Water temperature, B) water depth, C) emergent vegetation, D) floating vegetation and E) open water.

**IMPLICATIONS FOR BLANDING'S TURTLE CONSERVATION
IN CHALK RIVER, ONTARIO**

Demography

Road mortality is a function of road (and industrial work site) proximity to wetlands, travel corridors, and nesting locations used by turtles (Congdon et al. 2008). The installation of culverts and drift fences has been and remains an effective method for keeping Blanding's turtles off roads (Congdon et al. 2008, Woltz et al. 2008). Woltz et al. (2008) recommended beneath-road crossing structures to consist of tunnels > 0.5 m in width, lined with natural substrates, and paired with a 0.6-0.9 m high fence to best enable crossings of frog and turtle species. Once sites have been selected, the effectiveness of drift fences is largely dependent on installation and maintenance. Turtles can become trapped on roads when drift fences contain openings, are not long enough to contain turtle movements, or do not guide animals towards road crossing structures (Glista et al. 2009; EEH pers. obs.).

Mitigating the effects of road mortality in adults by attempting to increase hatchling recruitment may also be a viable management option for Blanding's turtles. Nest predators such as skunks, raccoons and mink scavenge turtle nests, often destroying whole clutches. Controlling nest predator populations, particularly along abrupt edges between habitat types, could be effective when these populations are relatively high (Kolbe and Janzen 2002, Congdon et al. 2008). The caging of new turtle nests can potentially be very effective if considerable effort is expended locating new nests in the spring (Congdon et al. 2008). In Nova Scotia, between 1994 and 1996, the productivity of nests (nests producing at least one live hatchling) which were caged for protection ranged between 18.1% and 93.3% (Standing et al. 1999). Eggs that remained unhatched in these nests, due to nest flooding and inadequate nest temperatures, ranged between 26.5% and 94% annually. Thus, the use of nest caging in attempts to effectively increase Blanding's turtle recruitment remains unreliable. Congdon et al. (2008) described short-term

attempts to create or enhance nesting sites with no notable success. Blanding's turtles are known to demonstrate nest site fidelity, though this is not an absolute attribute (Beaudry et al. 2010). Longer term attempts to create artificial nesting sites in areas with a high likelihood of interception by gravid females or enhance known nesting sites may yield more successful results. Currently, the CRL population is small and the loss of reproducing adults will have a significant impact on its persistence. Continuing to implement seasonal restrictions on industrial work in locations near core wetlands will contribute to minimizing damage or loss of laying females and their nests. Although mitigating losses due to road mortality and nest predation would play an important role in the recovery and persistence of this population, education will also be an essential approach. Educating employees, contractors, and visitors to the CRL site on the identification, life-history, and impacts of site infrastructure on species at risk will provide those with a sense of engagement in Blanding's turtle conservation efforts and promote future involvement.

Movements and Home Ranges

Documenting the movement and home range patterns of this Species at Risk is fundamental to effective land management and conservation efforts for local populations. The SARA states the distinct importance of identifying critical habitats for the recovery of threatened species (SARA, SC 2002 c29, sec 37-64). Delineating home ranges from patterns of movement annually and seasonally, especially over several years, indicates areas of use and areas of critical habitat in respective activity periods. Radio-tracked Blanding's turtles at CRL used an annual average of 13.1 ha, a spring average of 11.1 ha and a summer average of 8.0 ha to fulfill their annual activity cycles, though there was a high degree of variation between individuals.

Movements and home range boundaries may be constrained by urban and industrial development. Habitat suitability for Blanding's turtles in Ontario increased with increasing forest, alvar, wetland, and exposed bedrock area and decreased with increasing land development for agricultural and urban uses (Millar 2010). For Blanding's turtles across 70 sites in Southern Ontario, the amount of forested area on a landscape influenced the species occurrence more than other landscape features, such as the number of wetlands (Quesnelle et al. 2013). Fortin et al. (2012), however, were unable to predict Blanding's turtle home range size accurately based on landscape composition across five study locations, suggesting there were other factors driving patterns of movement in these populations. No relationship between morphometric features and home range size was reported by Walston et al. (2015), who suggested resource distribution across a landscape, climate, and population density as primary drivers of movement.

Habitat fragmentation due to anthropogenic development across a landscape will reduce habitat and population connectivity for this species at risk. The dissection of populations by roads into more vulnerable and more isolated subpopulations is known as the barrier effect (Andrews 1990, Gerlach and Musolf 2000, Coffin 2007). This effect was specifically observed in a population of Blanding's turtles in Québec which avoided road crossings, regardless of road type (paved, unpaved) (Proulx et al. 2014). Although avoidance behaviours do contribute to the barrier effect of roads, so too does the increased risk of mortality by directly impacting demography (Proulx et al. 2014).

Future studies and impact assessments should consider the quality and composition of landscapes as well as road densities within population and home ranges. This would provide more detailed insight on the future impacts industrial operations and land development may have on the local population. Understanding the seasonal patterns in movement, range distribution, and core

wetland use remains critical to effective management of the Blanding's turtle. Maintaining contiguous habitat patches composed of relatively undisturbed forest and wetland areas is an important management consideration for conserving genetic and demographic connectivity. Additionally, ten of the 28 Blanding's turtles captured at CRL between 2009 and 2015 have been found on roads or have crossed roads on site. Therefore, road and operation density around core wetlands and seasonal migration routes should also be considered in devising management plans for this species.

Multiple Scale Habitat Selection

Conservation efforts for Blanding's turtle at CRL should focus on maintaining habitats used by the population throughout the annual cycle. Accordingly, observed hibernation sites were included in determining Blanding's turtle population and home ranges at CRL to best represent annual habitat use. Blanding's turtles at CRL were observed using Marsh, Swamp, Bog, and Upland habitats with a strong overall preference for Marsh. Upland was observably used by males and females as corridors between individual wetlands and by gravid females during the nesting season. Multiple habitat types were utilized between 2014 and 2015 at CNL, which indicates the importance maintaining a diversity of habitats and available resources to satisfy the biological needs of the species.

As resource requirements fluctuate with age, sex, and time of year, considering the heterogeneity of habitat complexes is fundamental. In addition to wetlands known to be used by Blanding's turtles, wetland management should include wetlands characterized by floating and emergent vegetation (including shrubs) with contiguous areas of shallow open water, as the maximum depth a turtle was observed to use was 131 cm. Though preference for submerged vegetation

types was not observed in this study, in wetlands dominated by emergent and floating types, disturbance of submerged vegetation should be limited to retain water column structure and available refuges for both turtles and potential prey species.

Upland areas surrounding wetlands designated as critical habitat help mitigate the effects of environmental and anthropogenic disturbances, accommodate stages in the life cycles of most prey species, and are used by Blanding's turtles to facilitate fundamental behaviours (e.g., traveling and basking). Thus, it may not be enough to consider these areas as "buffer zones" and instead these should be considered "critical associated upland habitat" (Buhlmann and Gibbons 2001). Quesnelle et al. (2013) concluded that conserving forested areas surrounding core wetlands would provide more benefit for freshwater turtle conservation than the creation of new wetlands alone. Therefore, it will be imperative for CNL to consider and manage upland areas surrounding core wetlands, and the core wetlands themselves, as critical Blanding's turtle habitat. As a general recommendation for future habitat selection studies on freshwater turtles, a standardized method of classifying habitats and habitat features would allow for more meaningful comparisons between studies. The Canadian Wetland Classification System and the Ontario Wetland Evaluation System are excellent resources and facilitate comparison within Ontario and across Canada.

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Appendix 1: Population viability analysis input parameters for the Blanding's turtle (*Emydoidea blandingii*) population in Chalk River, Ontario

Parameter	Input	Explanation
Female Reproductive Age	14 ^{1,2,7}	Actual minimum age of first reproduction. (Mean= 17.5, Max = 20)
Male Reproductive Age	13 ²	Minimum age of maturity taken from figure ² .
Maximum Reproductive Age	66 ³	Oldest recorded reproductive female. Oldest reproductive male recorded was 67 ⁹ .
Maximum lifespan	77 ⁸	Oldest recorded.
Max # Broods/Year	1 ¹	Some may not reproduce every year. See 1 for justification.
Max # Progeny/Clutch	19 ^{1,2,7}	(Mean = 10, Min = 3) ^{1, 2, 7}
Sex Ratio at Birth	50 ^{4,5}	1:1 assume unbiased
% Adult Females Breeding	55%	2014-2015 CRL: 6 adult females breeding of 11 adult females surveyed
Approximate Mean/SD for Offspring per Brood	11.7±2.7 ⁴	
Hatchling Mortality (stage 0-1)	62.5% ⁹	
Female Mortality		
<i>Juvenile Baseline</i>	18.6%	13% higher than adult mortality for reptiles in general ¹⁰ (17% for Blanding's based on an adult mortality rate of 4% ^{1,4}).
<i>Adult</i>	4% ^{1,4}	
Male Mortality		
<i>Juvenile baseline</i>	18.6%	13% higher than adult mortality for reptiles in general ¹⁰ (17% for Blanding's based on an adult mortality rate of 4% ^{1,4}).
<i>Adult</i>	4% ⁴	
Carrying Capacity	500 ¹¹	To simulate unlimited carrying capacity.
Initial Population Size	25	CNL Blanding's population size estimate.
Extinction definition	1 ⁵	One individual remains ⁵

¹Congdon et al. 1993, ²Congdon and Van Loben Sels 1991, ³Congdon et al. 2001, ⁴Beaudry et al. 2008, ⁵Midwood et al. 2015, ⁷Congdon et al. 1983, ⁸Breke and Moriarty 1989, ⁹Paterson et al. 2014, ¹⁰Pike et al. 2008, ¹¹Row, Blouin-Demers & Weatherhead 2007

Appendix 2: Individual home range sizes and associated kernel smoothing factors (h) for Blanding’s turtles (*Emydoidea blandingii*) captured and tracked between 2014 and 2015 in Chalk River, Ontario.

Individual	h	Active Season		Spring Period		Summer Period	
		Number of Locations	95% Kernel area (ha)	Number of Locations	95% Kernel area (ha)	Number of Locations	95% Kernel area (ha)
702	49	14	18.76	6	16.54	8	13.43
703	16	19	4.13	7	2.83	12	2.74
706	16	12	3.35	0	–	12	3.35
707	24	19	7.76	5	3.94	14	5.40
709	36	5	8.27	4	–	1	–
710	26	20	11.61	10	8.18	10	5.47
711	82	19	56.65	6	61.55	13	16.23
712	32	16	8.26	7	8.15	9	3.52
715	25	23	11.47	6	4.66	16	8.63
716	25	23	8.84	7	4.88	16	7.01
717	25	15	9.49	5	4.52	15	6.45
719	25	16	8.00	0	–	12	4.87
721	55	20	19.77	7	12.05	13	11.94
722	22	16	6.21	6	2.59	10	3.59
723	60	14	32.70	5	17.27	9	26.86
724	23	19	8.33	7	5.45	12	5.67
725	23	20	6.57	5	2.73	15	5.43
727	20	17	4.59	0	–	17	4.04
732	51	16	13.45	0	–	16	8.79

– Kernel home ranges were not calculated for individuals with less than five location points.