Are roads a barrier to movement in Blanding's turtles (*Emydoidae blandingii*)?

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BIO 4009
Honours Project

April 30th, 2012

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Abstract

Studies in road ecology are becoming increasingly important to determine the effects of roads on ecological processes and on wildlife populations. The fragmentation of natural landscapes by linear anthropogenic features has several negative consequences, such as decreasing connectivity between habitats, inhibiting animal movement, and isolating populations. The barrier effect limits animal movement through behavioural avoidance and mortality during crossing attempts. I investigated the impact of road networks on the movement patterns of Blanding's turtles (*Emydoidae blandingii*) from 6 wetland sites in Ontario and Québec, Canada. A total of 63 Blanding's turtles (30 females, 27 males, and 6 juveniles) were monitored via radio-telemetry during their active season from April-September 2010 and 2011. Road avoidance was quantified, for each individual, by comparing the number of observed crossings with the number of expected road crossings predicted by 1000 movement path randomizations. The results of this study demonstrated that the Blanding's turtle population in Québec significantly avoids crossing roads, but the Ontario population does not. Roads were a significant barrier to movement of 7 of the 63 turtles and the barrier effect was not influenced by neither sex nor road surface. Preserving demographic and genetic connectivity of animal populations separated by roads is a major conservation challenge for species at risk such as the Blanding`s turtle.

Introduction

The rapid expansion of road networks, followed by housing and industrialization, has been radically changing landscapes worldwide. Studies in road ecology, regarding the interaction between road networks and the natural environment (Forman *et al.*, 1998), are becoming increasingly important to determine the effects of roads on ecological processes and on wildlife populations. Natural landscapes in Canada are becoming progressively more fragmented by linear anthropogenic features, the Canadian road network extending over 1042.3 x 10^3 km as of 2010 (Transport Canada, 2010). About 32% of these roads can be found within the provinces of Ontario and Québec. In addition to this extensive road system, Canada has an abundant and rapidly growing vehicular fleet, 19.7 million vehicles being reported in 2009 (Transport Canada, 2010).

Construction of roads causes habitat loss, habitat degradation, habitat fragmentation, as well as direct animal mortality due to collisions with vehicles (Fenech *et al.*, 2000, Forman *et al.*, 1998, Jaeger *et al.*, 2005, Lode, 2000, Rico *et al.*, 2007, Trombulak *et al.,* 2000). As forested lands are cleared and wetlands drained, animal populations must deal with limited habitat availability and smaller individual home ranges which in turn may cause stress, reduce individual fitness, and compromise population viability (Benitez-Lopez *et al.*, 2010, Fenech *et al.*, 2000, Forman *et al*, 1998, Gill *et al.*, 1996). Roads provide an open canopy, a lack of ground cover, and have different thermal characteristics than the surrounding habitats (Rico *et al*., 2007, Shepard *et al*., 2008). All these factors contribute in disturbing wildlife behaviours such as mating, nesting, migration, and foraging success, as well as can increase predation risk (Jaeger *et al.*, 2005). As the ecological impact of roads has been estimated to extend outwards for more than 100 meters and to affect up to 15-20% of the total land area of most nations (Forman, 2000), research in road ecology is important, especially as the cumulative effects of roads are increasing yearly.

Fragmentation is the degree to which a natural habitat, once continuous, is divided into remnant isolated patches (Fahrig, 2003). Animal populations may require more than one habitat type to complete their life cycle, forcing them to move between these patches. Roads are one of the most prominent human features that create barriers to wildlife movement and thereby decrease connectivity (Dixo *et al.*, 2009, Epps *et al*, 2005), which is the ability of an individual to move through the landscape unimpeded by natural or human landscape features (Bowne *et al*., 2006). Excessive fragmentation of habitat by roads can inhibit animal movement, reducing gene flow and restricting access to important resources (Mader, 1984, Reh *et al.*, 1990, Vos *et al.*, 1998, Wilkings, 1982). This phenomenon is known as the barrier effect, consequently subdividing animal populations into smaller, more vulnerable and partially isolated local populations (Arnold *et al*., 1993, Holderegger *et al.*, 2010, Lode, 2000, Rico *et al.*, 2007). The barrier effect can affect a population by either changing its behaviour, as road avoidance is common (Bruns, 1977, Dyer *et al.*, 2001, Merriam *et al.*, 1989, Reh *et al*., 1990, Van Dyke *et al.*, 1986), by causing additionally mortality, as individuals who attempt to cross roads collide with vehicles (Ashley *et al*., 1996, Fahrig *et al.*, 1995, Rosen *et al*., 1994), or both (Trombulak *et al.*, 2000).

Studies in the emerging field of road ecology have shown that many species avoid crossing roads (Clarke *et al.*, 1998, Dyer *et al.*, 2002, Mader, 1984, Oxley *et al.*, 1974). The barrier effect can have both demographic and genetic consequences on animal populations (Forman *et al.*, 1998, Holderegger *et al.*, 2010, Row *et al*., 2007, Shepard *et al*., 2008). Denied access to resources such as suitable habitat, food, mates, and breeding sites can lower reproductive and survival rates which in turn may reduce population persistence (Jaeger *et al.*, 2005). Furthermore, small isolated populations may be subjected to reduced genetic diversity, due to a lack of gene flow, and increased population fluctuation over time (Epps *et al.*, 2005, Forman *et al.*, 1998, Shepard *et al*., 2008). Restricted gene flow can lead to inbreeding and lower heterozygosity levels in populations (Saccheri *et al*., 1998), which can then increase the probability of extinction (Dixo *et al*., 2009, Dyer *et al.*, 2002, Fahrig *et al.*, 1995, Lande, 1988, Liao *et al.*, 2009, Saunders *et al.,* 1991). In this context, the degree of population isolation generally depends on the relative success of different species in crossing roads (Fenech *et al*., 2000, Jaeger *et al.*, 2005). In addition, the degree to which an animal population's persistence will be affected by roads depends not only on road avoidance behaviour and road mortality, but also on the population's sensitivity to habitat loss, degradation and fragmentation, as well as road size and traffic volume (Jaeger *et al.*, 2005, Rico *et al.*, 2007).

Although all roads generally are a barrier to movement for most species, some are impacted more than others. Wetland species, such as turtles, commonly show a reduced tendency to cross roads (Forman *et al.*, 1998). A study on two box turtles, *Terrapene carolina* and *Terrapene ornata,* demonstrated that both species crossed roads significantly less often than predicted by chance, indicating strong road avoidance (Shepard *et al*., 2008). Whether roads act as barriers to Blanding's turtles, *Emydoidea blandingii*, is unknown. The species is currently listed as "Threatened" in Ontario and Québec (COSEWIC 2005), and the increased fragmentation of the subpopulations by road networks is thought to be in part responsible. Blanding's turtles have delayed age at maturity, low reproductive output, and extreme longevity (Congdon *et al.*, 1993, Gibbs *et al*., 2002). These life history traits render them highly vulnerable to increased rates of adult mortality and the negative effects of roads (Brooks *et al.*, 1991, Shepard *et al*., 2008). There exists a time lag between when roads are implemented and when their full effects are evident, but the negative genetic effects on animal populations such as turtles might be even harder to observe over short time-scales, thus placing the populations at high risk of extinction because of a failure to detect an incrementally worsening problem (Congdon *et al.*, 1994). Long-term demographic studies of various turtles indicate that as little as 2-3% additive annual mortality is likely more than most turtle species can absorb and still maintain stable populations (Condgon *et al.*, 1993, Gibbs *et al*, 2002).

In addition, populations that require different habitat types to complete their life history will be sensitive to resource inaccessibility by roads (Jaeger *et al.*, 2005). Turtles roam during at least part of their annual life cycle, including daily wandering to exploit ephemeral food supplies and seasonal migrations to escape drought or freezing (Gibbs *et al*., 2002). Female Blanding's turtles need to find suitable nesting habitats while gravid, which could affect their tendencies to cross roads and even render them more susceptible to roadkill (Haxton, 2000). Their vulnerability to roadkill is further affected by their attempts to nest on gravel roads or on the shoulders of paved roads (COSEWIC 2005). Differences in behaviour between reproductive classes, such as mate searching and nest prospecting, can be reflected in movement patterns which could alter an individual`s tendencies to cross roads (Aresco, 2005, Morreale *et al.*, 1984, Row *et al.*, 2007).

The goal of this study is to test the hypothesis that roads pose a barrier to the movement of Blanding's turtles. If roads are avoided, I predicted the number of observed road crossing by each individual to be smaller than the number of road crossings if turtles moved randomly with respect to roads. I obtained the number of observed road crossings from movement data obtained via radio-telemetry on 63 individuals in two populations. I generated the number of expected road crossings in the absence of avoidance by 1000 randomizations of the movement path for each individual. A random walk analysis has been shown to be fitting when analyzing animal movement (Bartumeus *et al.*, 2005) and to be a powerful method to test for road avoidance (Shepard *et al.*, 2008). I also predicted that the degree of road avoidance may differ with sex and road type. As female Blanding`s turtles have been reported to travel long distances in search of suitable nesting habitats, I predicted road avoidance to be greater in males. As different road types are associated with different characteristics, I predicted road avoidance to be greater for paved vehicular roads as these are generally wider and have greater traffic volumes.

Materials and methods

Study area and species

The Blanding's turtle, *Emydoidea blandingii*, is a semi-aquatic medium-sized turtle characterized by a bright yellow throat and chin (COSEWIC 2005). It inhabits wetlands and upland habitats (Joyal *et al.* 2000, Ross *et al.*, 1990), typically found in areas such as marshes, creeks, wet prairies, fens, and the edge of lakes and ponds (Hartwig *et al.*, 2007, Rowe *et al.*, 1991). During the active season, between April and September (Millar *et al.*, 2011), 63 turtles were tracked with the use of radio-telemetry for a total of 2412 locations. Individual turtles were captured opportunistically, by hand or using net traps and crab pots, then each was given a unique ID and a radio transmitter was attached to its carapace.

Data on 52 of the turtles (22 females, 24 males and 6 juveniles) was gathered in 2010 from 5 natural area sites in Québec, Canada. With few exceptions, all individuals were tracked every 2 to 4 days from April to August, and then once weekly in September, for a total of 1783 locations (mean number of locations per individual being 34.3). The five main sectors range from Gatineau Park, in the Collines-de-l'Outaouais Regional County, to Clarendon in Pontiac County. These were comprised of wetlands, intermixed or surrounded primarily by both forest and agricultural land, as well as some perturbed land. Clarendon, located in the Ottawa Valley, is partially located on NCC protected land and characterized by mixed forest cover. Bristol, also in the Ottawa Valley, has more perturbed land (crops, active mine, wood mill), and some mixed forest cover. Shawville, also in the Ottawa Valley, is located on private land and characterized by agriculture and urbanized and industrial areas. Eardley-Masham, located in the Canadian Shield, a conservation area of Gatineau Park, is characterized by mixed forest cover and low wetland density (bogs and fends). Finally, Gatineau Park West located at the limit of the conservation area, is characterized by one large marsh surrounded by forest and fields. The sectors are bisected by roads open to vehicular traffic, both paved and unpaved, as well as other transportation infrastructure not open to vehicular traffic such as bike paths and railroads (Figure 1). All five sectors, ranging about 60-130 km^2, are located along the North shore of the Ottawa River.

The data on the 11 remaining turtles (8 females and 3 males) was gathered in 2011 from a site in the west-end of Ottawa, the South March Highlands, Ontario, Canada. Although this site is also comprised of a wetland forest, it is surrounded by the town of Kanata, fields, and a golf course (Figure 2). Individuals were tracked three times a week, from April to September, for a total of 629 locations (mean being 57.2).

Road Avoidance

The recorded GPS coordinates were entered into ArcMap10 (Environmental Systems Research Institute, Redlands, California) using Universal Transverse Mercator units (UTM NAD83) to map the observed movements paths of all radio-tracked individuals. The minimum number of times each individual crossed a road during the study was determined by the number of times the straight lines linking successive locations intersected a road. Even though it is possible that an individual crossed roads between successive tracking days, it is assumed due to the relatively low mobility of the study taxa that the failure to detect such crossings is very small and would not be at a high enough frequency to impact the results. Using the Random Movement Generator function of the Movement Analysis software (see Appendix 2), 1000 random walk paths were generated for each individual. The Random Movement Generator starts with an individual's initial location and then generates a random walk path using the observed sequential distances moved between each tracking location while randomizing the direction (angle) of movement from each path. Restrictions were set for each study site, ensuring that the randomized paths did not exceed the study area or the turtle population's range. I then determined how many times these randomized movements paths crossed roads.

Statistical Analysis

To quantify road avoidance for each individual, I compared the number of observed and expected road crossings. For each individual, a distribution of the number of expected road crossings was built, and the individual was deemed to significantly avoid roads if its number of observed road crossings fell below the 5% percentile (i.e. one-tailed $p \leq 0.05$). Quantifying the degree of road avoidance at the population level was done by using a paired t-test comparing the median expected number of road crossings and the observed number of road crossings. The median was used as it is less sensitive to extreme observations than the mean (Hogg and Tanis, 2005), and many individual's expected road crossings were not normally distributed.

As the movement patterns could be affected by sex and the difference in behaviour between reproductive classes (Aresco, 2005, Congdon *et al*., 1993, Morreale *et al.*, 1984, Row *et al.*, 2007), road avoidance was compared between females and males. The number of observed crossings was subtracted from the mean expected value for each individual and analyzed using a Kruskal-Wallis test. A Kruskal-Wallis test is equivalent to a non-parametric ANOVA except the data have been ranked (Hogg and Tanis, 2005). Furthermore, as the barrier effect of a roads is thought to be dependent on the type of road surface (Fenech *et al*., 2000), roads open to vehicular traffic and those that are not were analysed separately. In addition, paved and unpaved vehicular road networks were also analysed separately. These were also compared using a Kruskal-Wallis test, for the Québec site only.

All statistical analyses were performed using R (R Development Core Team, Vienna, Austria). Tests were accepted as significant at alpha=0.05 and means were reported ± one standard error.

Results

Québec Population

Out of the 52 individuals, 24 of the radio-tracked Blanding's turtles crossed roads. Although 36 individuals crossed roads fewer times than expected if they were moving in a random manner in relation to roads (observed < 50% percentile expected), only 6 individuals crossed statistically significantly fewer times than expected by chance (observed > 5% percentile). Blanding's turtles crossed roads an average of 2.00 $\pm$ 0.42 times (maximum number of crossings = 12), but if moving randomly the Blanding's turtles would have crossed an average of 6.06 $\pm$ 0.03 times (maximum number of crossings = 55).

Roads not open to vehicular traffic were crossed on average 0.90 $\pm$ 0.25, while if moving randomly they would have been crossed on average 3.16 $\pm$ 0.02 times. Roads open to vehicular traffic on the other hand, were crossed on average 1.096 $\pm$ 0.32; paved roads being crossed 0.077 $\pm$ 0.054 and unpaved 1.02 $\pm$ 0.30. If Blanding's turtles would have been moving randomly, roads open to vehicular traffic would have been crossed on average 2.899 $\pm$ 0.019 times; paved roads 0.296 $\pm$ 0.005 times, and unpaved roads 2.599 $\pm$ 0.018 times.

Overall, the results of the paired t-test demonstrated that the Blanding's turtle population in Québec crossed roads significantly less often than predicted (t-value=5.736, DF=51, p<0.001). The results of the Kruskal-Wallis test demonstrated that, contrary to our predictions, there was no significant difference in the degree of road avoidance between roads not open to vehicular traffic and those open to vehicular traffic (chi-squared=7.8322, DF=11, p-value=0.7283); no significant difference between paved and unpaved roads (chi-squared=7.3847, DF =4, p-value=0.1169). Similarly, the results of the Kruskal-Wallis test demonstrated that there was no significant difference in the degree of road avoidance between the sexes (chi-squared=21, DF=21, p=0.4589), although females travelled a mean distance of 129.82 m between successive locations and males a mean distance of 118.42 m.

Ontario Population

Out of the 11 individuals, 3 of the radio-tracked Blanding's turtles crossed roads. Although 4 individuals crossed roads fewer times than expected if they were moving in a random manner in relation to roads (observed < 50% percentile expected), only 1 individual crossed statistically significantly fewer times than expected by chance (observed > 5% percentile). Blanding's turtles crossed roads an average of 2.63 ± 1.63 times (maximum number of crossings = 14), but if moving randomly the Blanding's turtles would of crossed an average of 6.38 ± 0.10 times (maximum number of crossings=122).

Overall, the results of the paired t-test demonstrated that the Blanding's turtle population did not cross roads significantly less often than predicted (t-value=0.5366, DF=10, p-value=0.6033). The results of the Kruskal-Wallis test once again demonstrated that there was no significant difference in the degree of road avoidance between the sexes (chi-squared=2, DF=2, p-value=0.3679), although females travelled a mean distance of 102.45 m between successive locations and males a mean distance of 50.68 m.

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Discussion

Several studies have documented road avoidance behaviour in animals such as reptiles, indicating that these linear structures are a barrier to their movement (Bowne *et al.*, 2006, Forman *et al*., 1998, Row *et al*., 2007, Shepard *et al*., 2008). The results of this study demonstrated that the Blanding's turtle population in Québec significantly avoids crossing roads, but the South March Highlands population does not. Although it was predicted that sex and road surface might affect an individual's tendency to cross roads and the extent of the barrier effect, no significant difference was found for either.

This barrier effect through road avoidance could have several negative consequences for the Québec population. Demographic connectivity across landscapes has been shown to be critical for long-term persistence of populations (Forman, 2000). As the individuals become continually genetically partitioned into subpopulations, gene flow will be low increasing the chance of extinction (Dyer *et al.,* 2002, Holderegger *et al.*, 2010, Shepard *et al*., 2008). As this species is long-lived and late maturing, the negative genetic effects might only be observable over long time scales, putting this already threatened population at an even higher risk (Brooks *et al*. 1991, Congdon *et al.*, 1994). Further studies on this population should include a population viability analysis, to determine the best management options. Population viability analysis integrates data on the species life history, demography and genetics with information on environmental variability, using computer models ranging from simples measures of population growth rate to complex spatial simulations, to predict whether the population will remain viable under various management options (Waples, 2002). According to previous studies, successful management and conservation programs for long-lived organisms like the Blanding's turtle are those that recognize the necessity of protecting all life stages; nestlings, juveniles and adults (Congdon *et al*., 1994).

Only 7 of the 63 turtles crossed roads statistically significantly fewer times than expected by chance. Although the barrier effect is not significantly observed through avoidance behaviour for the remaining 56 turtles, crossing roads readily renders them at risk of mortality due to collisions with vehicles. Traffic related mortality is considered to be among the major causes of mortality for many animals in human dominated landscapes, including reptiles (Bernardino *et* al., 1992, Langevelde *et al.*, 2009). This second aspect of the barrier effect could potentially be a significant limiting factor for the Blanding's turtle populations (Bernardino *et al*. 1992, Gibbs *et al*., 2002, Rico *et al*., 2007). Turtles roam around in search of habitat, food supplies and for seasonal egg laying, exposing them to the hazards of roads. Gravid females are thought to be especially susceptible to roadkill, as they have been reported to move more than 1 km on land to find a nesting site to lay eggs (Congdon *et al.*, 1983, Joyal *et al.*, 2000). Moreover, females have also been known to attempt to nest on gravel roads or the shoulders of paved roads (COSEWIK 2005). As the number of animals killed by vehicles worldwide each year is large (Bennett, 1991, Forman *et al.*, 1998, Mumme *et al.*, 2000) and as road mortality can have substantial effects on population demography (Trombulak *et al*, 2000), studies of road mortality patterns are important to identify the influential factors that can generate effective management strategies to reduce the number of roadkills (Shepard *et al.*, 2008).

Being able to understand the spatial ecology and accurately estimate the persistence time of species at risk is central to their conservation and is important to make informed decisions about land use, management and recovery (Liao *et al*., 2009, Millar *et al.*, 2011). Although ideally habitat degradation and fragmentation would be minimized, other engineering solutions can be used to mitigate the effects of roads (Ree *et al*., 2009). Wildlife crossing structures such as overpasses, tunnels, culverts, as well as exclusion fencing, can help in the maintenance of habitat connectivity and with keeping animals off roads to reduce road related mortalities (Clevenger *et al*., 2010). The maintenance of semi-natural levels of habitat connectivity via these crossing structures has been proposed to reduce the negative effects of fragmentation, offsetting the negative consequences of population isolation, and reducing demographic stochasticity (Bennett, 1990, Dixo *et al.*, 2009, Saunders *et al*., 1991). Population viability modelling can not only be used to determine the negative effects of threats such as road mortality on animal populations (Row *et al*., 2007), but can also be used in assessing the effectiveness of wildlife crossing structures. Future studies in road ecology and responsible design must be implemented to minimize the ecological impacts of the current road base and its future expansion.

Acknowledgements

I would like to thank Gabrielle Fortin, for gathering the radio-telemetry data from Québec and her help with the use of the ArcGIS 10. Similarly, I would like to thank Caleb Hasler and Nick Stow for access to the radio-telemetry data from the South March Highlands. I would like to thank Lorraine Proulx for her help with programming the Movement Analysis software and Hawthorn L. Beyer for answering my queries about the GME software. Finally, we would like to thank the Nature Conservancy of Canada, the Natural Sciences and Engineering Research Council, and the University of Ottawa for funding.

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Appendix I – Figures and Tables

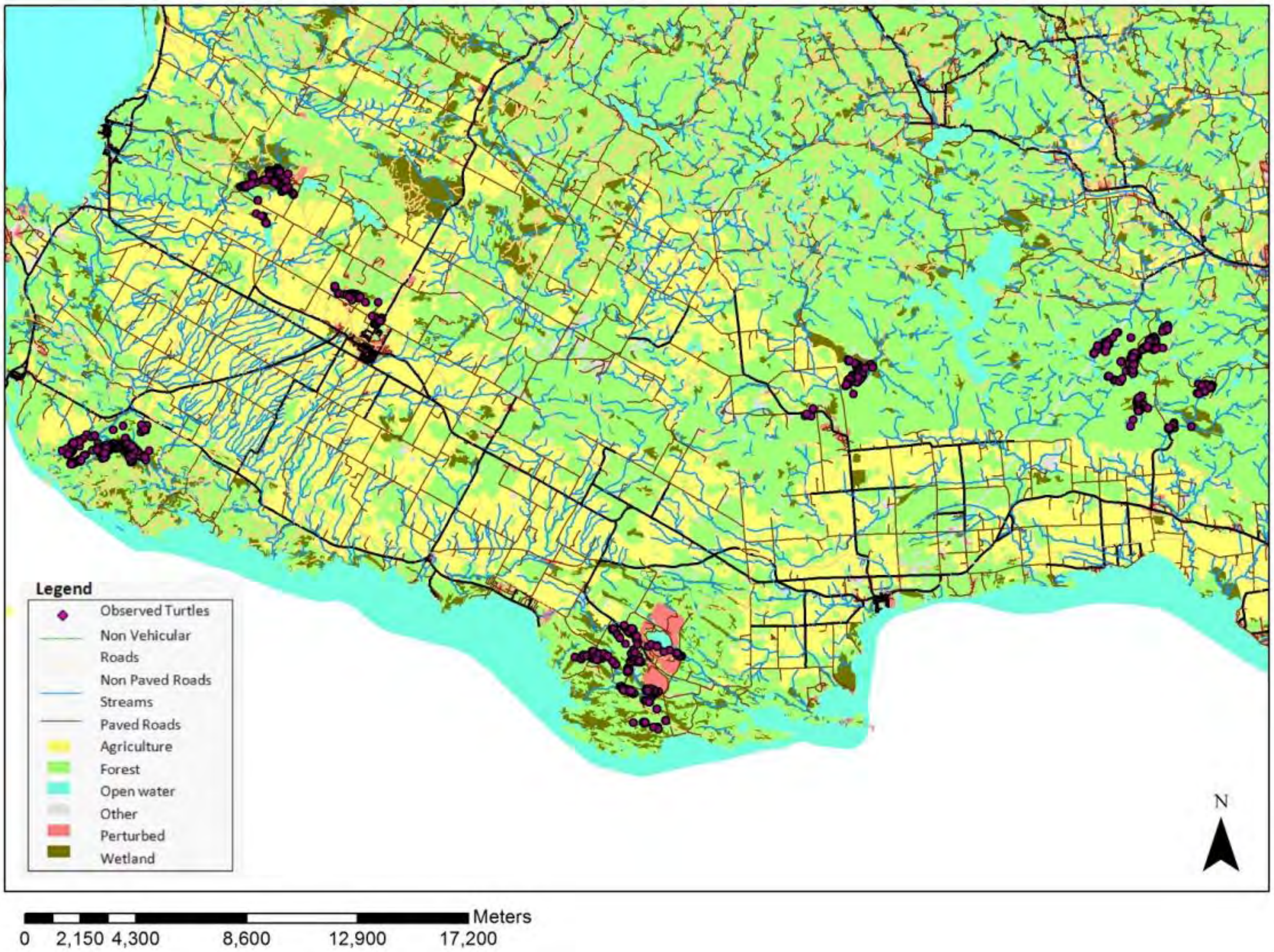
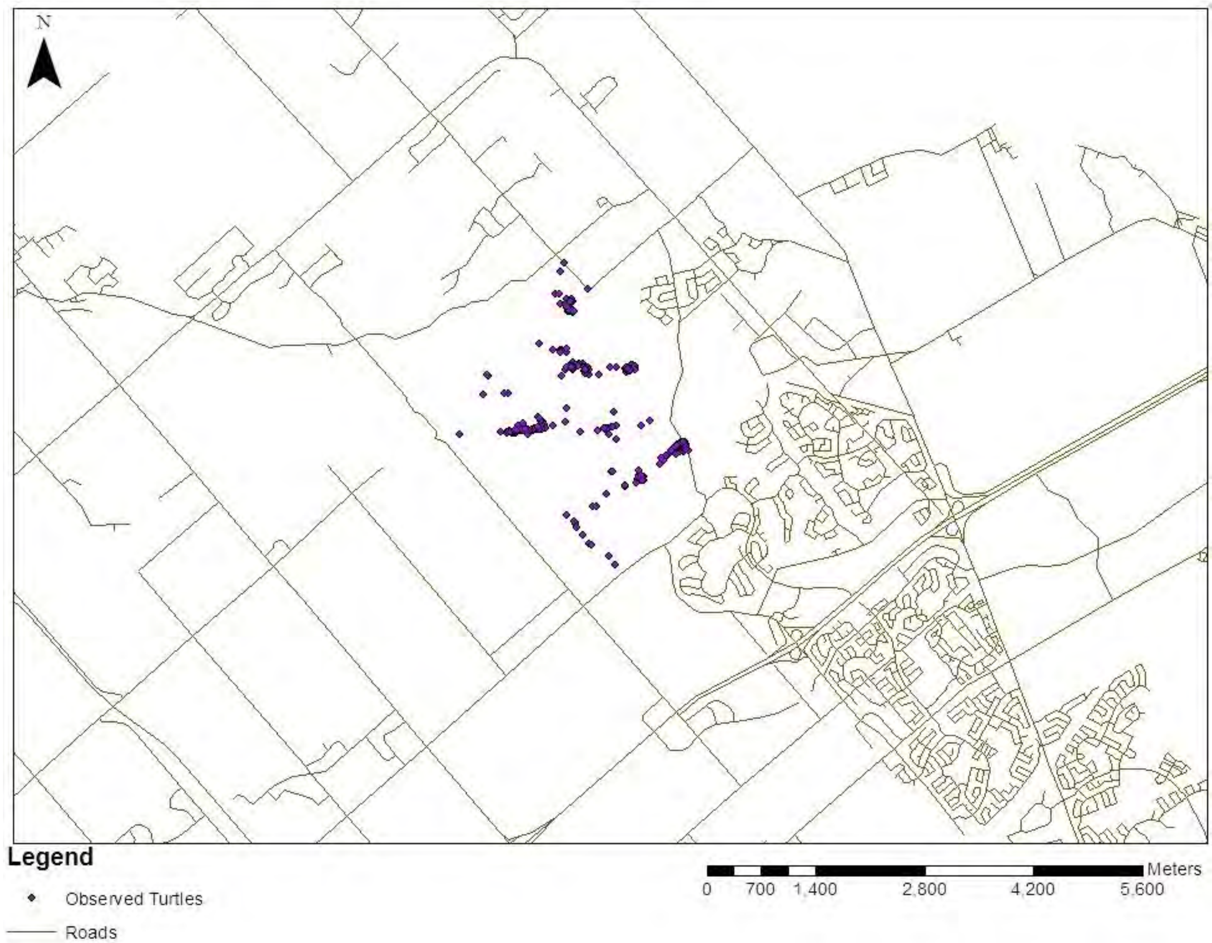
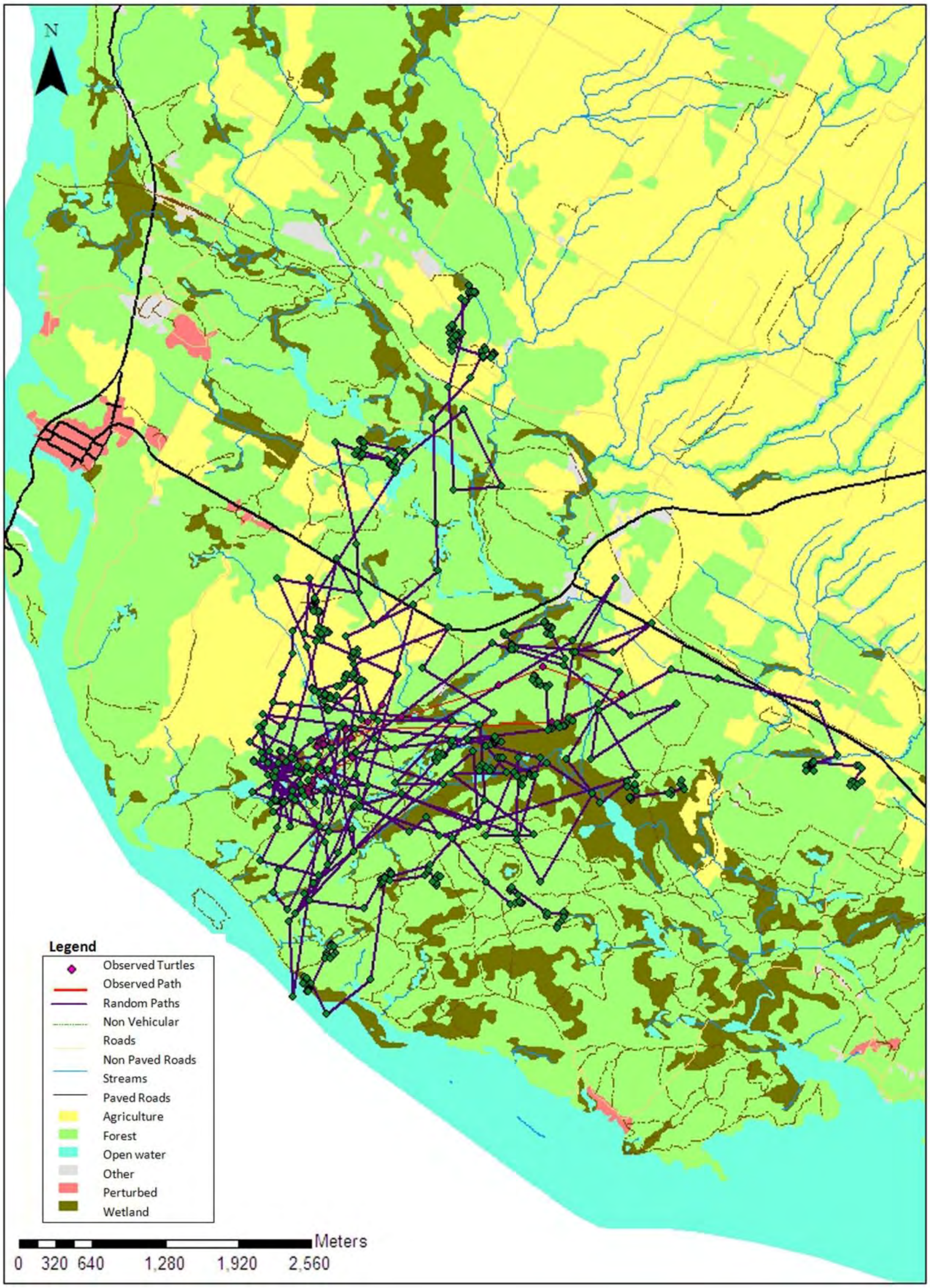


Figure 1 – Map demonstrating the road networks and habitat surrounding the 5 study sites in Québec, Canada. The 1783 recorded locations are shown for the 52 radio-tracked Blanding's turtles (*Emydoidae blandingii*).



<u>Figure 2</u> – Map demonstrating the road network surrounding the South March Highlands in Ottawa, Ontario, Canada. The 629 recorded locations are shown for the 11 radio-tracked Blanding's turtles (*Emydoidae blandingii*) in the area.



<u>Figure 3</u> – Map showing one individual's observed movement path, turtle ID 271 from Clarendon, Québec. It`s observed movement path, shown in bold red, demonstrated a total of 12 road crossings. Shown in dashed purple lines are 15 of its random movement paths, based on random walk simulation with the Movement Analysis software.

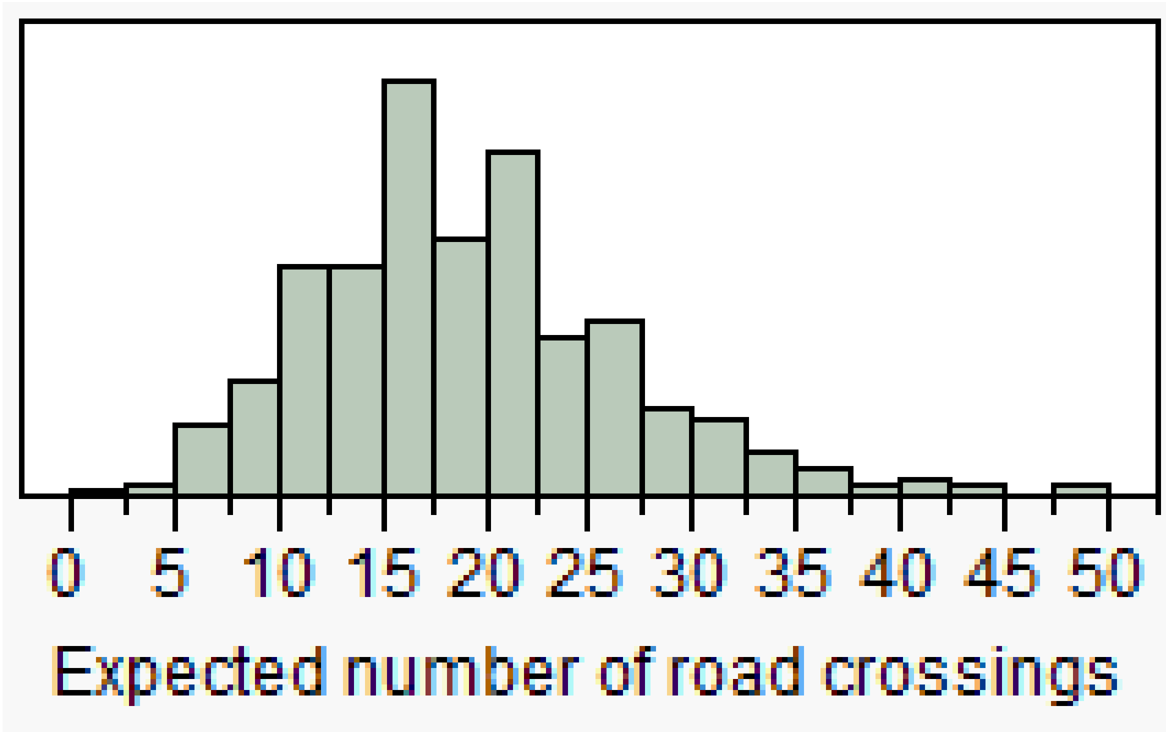


Figure 4 - Histogram demonstrating the distribution of the expected number of road crossings for an individual, turtle ID 271 from Clarendon, Québec. Expected numbers of road crossings are based on 1000 random walk movements. The observed number of road crossings for this individual was 12 (12>6, the 5% percentile), and the turtle was found to not significantly avoid crossing roads.

Table 1 – Summary table demonstrating the results of the analysis on two Blanding's turtle (*Emydoidae blandingii*) populations (N=63).

a) Comparison of the mean observed road crossing and average expected road crossing computed using 1000 random walk movements, for both Blanding's turtle populations found in Québec and Ontario, Canada (N=52 and 11 respectively).

	Treatment		t-test	
	Observed	**Predicted**	**p-value**	**t-value (DF)**
Québec	2.00 ± 0.42	6.06 ± 0.03	p<0.001	5.736 (51)
Ontario	2.63 ± 1.63	6.38 ± 0.10	0.6033	0.5366 (10)

b) Summary statistics of results from the Kruskal-Wallis, non-parametric tests, testing whether sex influenced an individual`s tendency to cross roads for both the Québec and Ontario populations (N= 52 and 11 respectively).

	Kruskal-Wallis		
	Chi-squared	**DF**	**p-value**
Québec	21	21	0.4589
Ontario	2	2	0.3679

c) Comparison of the mean observed road crossing and mean expected road crossings computed using 1000 random walk movement, for different roads types in Québec, Canada (N=52).

		Treatment			
		Observed		**Expected**	
		Mean	**SD**	**Mean**	**SD**
Roads not open to vehicular traffic		0.90	0.25	3.16	0.02
Vehicular Roads	Unpaved	1.02	0.30	2.599	0.018
	Paved	0.077	0.054	0.296	0.005
	Total	1.096	0.32	2.899	0.019

d) Summary statistics of results from the Kruskal-Wallis non-parametric test, testing whether road surfaces influenced an individual's tendency to cross roads for the Québec population (N=52).

	Kruskal-Wallis		
	Chi-squared	**DF**	**p-value**
Non vehicular & Vehicular	7.8322	11	0.7283
Unpaved & Paved	7.3847	4	0.1169

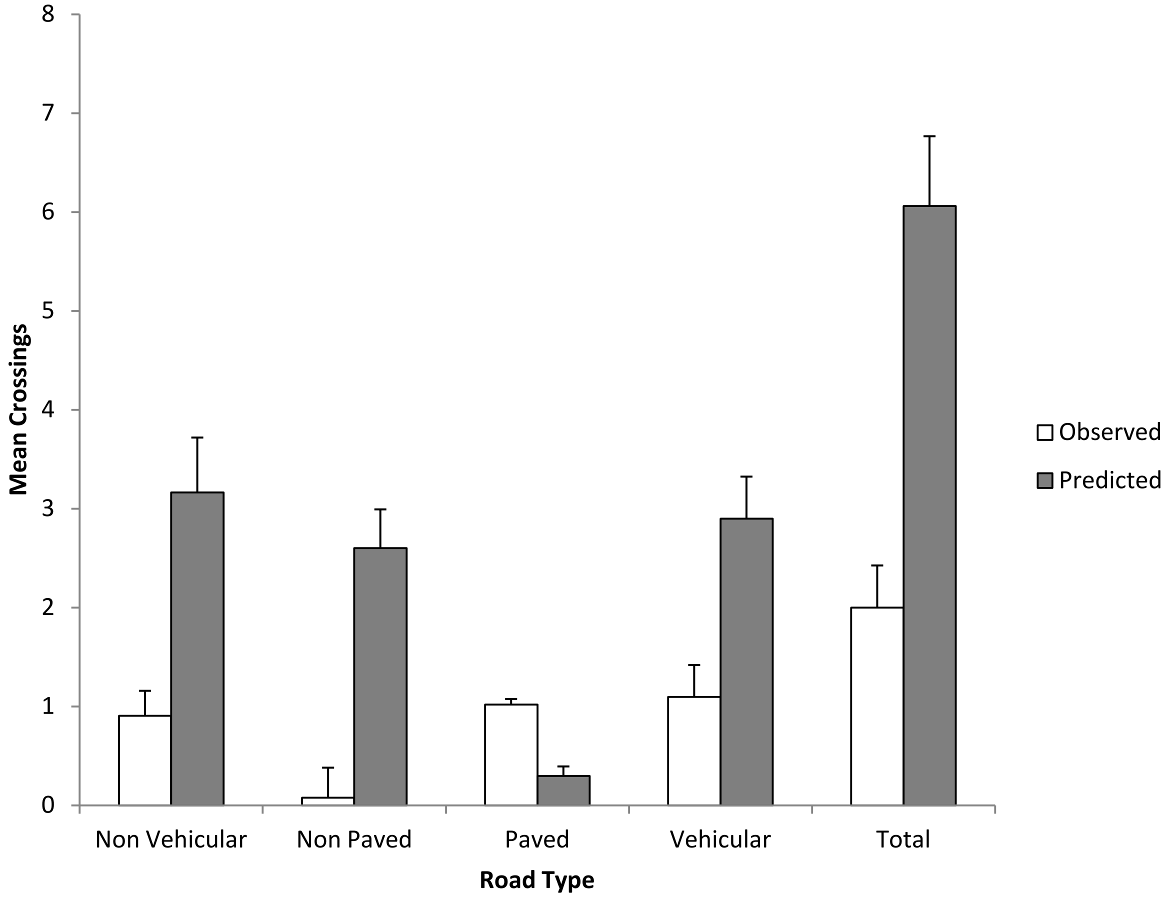


Figure 5 – Mean (±SE) observed and expected number of road crossings over different road types by Blanding's Turtle (*Emydoidea blandingii*) in Québec, Canada (N=52). Vehicular roads represent the sum of both non paved and paved roads.

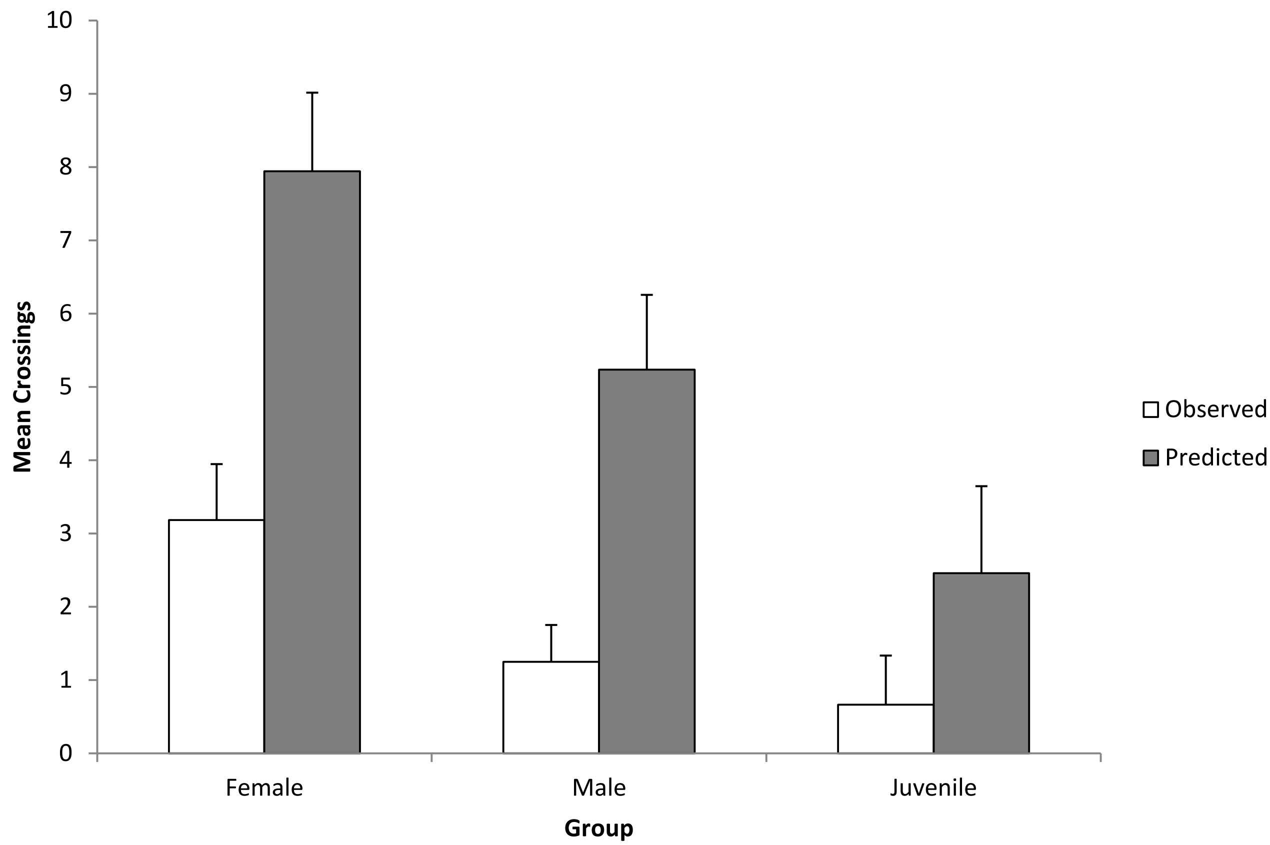


Figure 6 – Mean (±SE) expected and observed number of road crossings for different sexes and reproductive classes by Blanding's Turtle (*Emydoidea blandingii*) in Québec, Canada (N=52).

Appendix II - Creation of the Movement Analysis Program

- Name: Movement Analysis
- Three functions:
    - XY to Path Creator
    - Random Movement Generator
    - Intersection Point Finder

XY to Path Creator

<inWalks> <outPaths> [animalId] [x] [y]	
inWalks	Input file containing the recorded walks (csv)
outPaths	Output file created to contain the recorded random paths (csv)
animalId	Name of the column containing the animal ID (default is ID)
x	Name of the column containing the x coordinate (default is x)
y	Name of the column containing the y coordinate (default is y)

*<required>, [optional]

Random Movement Generator Requirements

1. Starts with an individual's initial location
2. Generates a random walk path using the observed distance moved between each tracking location
3. Randomized the direction (angle) of movement from each point

Random Movement Generator

[inRestrictions]	<inWalks> <outWalks> <outPaths> [animalId] [x] [y] [n]
inRestrictions	Input file containing east, west, north and south restrictions (csv)
inWalks	Input file containing the recorded walks (csv)
outWalks	Output file created to contain the generated random walks (csv)
outPaths	Output file created to contain the generated random paths (csv)
animalId	Name of the column containing the animal ID (default is ID)
x	Name of the column containing the x coordinate (default is x)
y	Name of the column containing the y coordinate (default is y)
n	Number of movements to generate (default is 1000)

*<required>, [optional]

Intersection Point Finder

<inPaths> <inIntersects> <outCount> <outStats> [animalId] [movementId] [fromX] [fromY] [toX] [toY] [pointX] [pointY]	
inPaths	Input file containing the random paths (csv)
inIntersects	Input file containing the intersects between the paths and roads (csv)
outCount	Output file created to contain the intersect count (csv)
outStats	Output file created to contain the statistics (csv)
animalId	Name of column containing the animal ID (default is AnimalID)
movementId	Name of column containing the movement ID (default is MovementID)
fromX	Name of column containing the path's FROM X coordinate (default is FromX)
fromY	Name of column containing the path's FROM Y coordinate (default is FromY)
toX	Name of column containing the path's TO X coordinate (default is ToX)
toY	Name of column containing the path's TO Y coordinate (default is ToY)
pointX	Name of column containing the intersecting point's X coordinate (default is POINT_X)
pointY	Name of column containing the intersecting point's Y coordinate (default is POINT_Y)

*<required>, [optional]