Why Did the Reptile Cross the Road? Landscape Factors Associated with Road Mortality of Snakes and Turtles in the South Eastern Georgian Bay area

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Abstract

Road mortality is believed to contribute to population declines in snakes and turtles, but there have been few attempts to quantify landscape features associated with road mortality in these taxa. We surveyed a secondary road near Georgian Bay, Ontario (45 52'N, 80 50'W) daily by automobile between April and October, 2003 and 2004. We measured landscape factors associated with roadkill of reptiles using multivariate statistics and a geographic information system (GIS). A total of 340 road crossings were analyzed (269 snakes, 71 turtles; 91% dead on the road), 44 of which involved species at risk in Canada. Snake crossings peaked during August, whereas turtle crossings peaked during June. We performed multiple regressions to assess the relative importance of the measured landscape factors using total reptile, snake, and turtle crossing counts for buffered, equal-length road segments as output variables. The following landscape variables explained much (R2 = 0.354) of the distribution of reptiles killed along this road: distance from Georgian Bay, driveways, buildings, road intersections, adjacent wetlands, and water crossings. Overall, roadkill tended to be closer to Georgian Bay and further from driveways. Factors contributing to roadkill for species at risk should be considered prior to planning roadway expansion.

Keywords: *road mortality, snake, turtle, reptile, landscape features, Georgian Bay, roadkill*

Introduction

The negative effects roadways have on wildlife are well documented and widespread (Forman and Alexander, 1998; Spellerberg, 1998; Trombulak and Frissell, 2000; Forman *et al.*, 2003). Roads fragment habitat (Findlay and Houlahan, 1997; Bohemen, 1998; Aresco, 2003) and are directly responsible for significant wildlife mortality (Ashley and Robinson, 1996; Bohemen, 1998; Bonnet *et al.*, 1999; Lodé, 2000; Enge and Wood, 2002; Aresco, 2003). Snakes and turtles are susceptible to road mortality because most are slow moving, are attracted to road shoulders for nesting or the heat of road surfaces for thermoregulating (Bernardino and Dalrymple, 1992; Ashley and Robinson, 1996; Enge and Wood, 2002; Arseco, 2003), are too small to be spotted on the road, or may be killed deliberately (Bonnet *et al.*, 1999). Furthermore, the effects of roadkill episodes are detrimental as many snakes and turtles are long-lived, mature slowly, and have low juvenile survival; therefore a small amount of adult mortality could result in altered population structures (Findlay and Houlahan, 1997; Gibbs and Shriver, 2002; Marchand and Litvaitis, 2004; Steen and Gibbs, 2004; Aresco, 2005; Gibbs and Steen, 2005).

Known as “Cottage Country”, the Georgian Bay area is increasingly popular as a weekend destination for city-dwellers in southern Ontario (District of Muskoka, 2004). Rising summer traffic volume creates the demand for highway improvements, road expansions, and road creation for access to lakeside properties. Road ecology research and application of relevant results could have the greatest impact where ecologically important habitats, species, and processes are being threatened by rapid landscape change and degradation (Forman *et al.*, 2003). We argue that “Cottage Country” in Georgian Bay qualifies as such a region.

The Georgian Bay area is scattered with lakes, rivers and wetlands, resulting in the construction of many roads adjacent to, or bisecting wetlands. Findlay and Houlahan (1997) suggest that roads negatively affect species richness in wetlands. Research also shows that roadkill levels are high in areas with wetlands (Forman *et al.*, 2003), but the fine-scale landscape features associated with reptile roadkill remain uncertain. If landscape features such as water crossings and wetlands determine where reptiles attempt to cross roads, then roadkill locations should correspond with such features.

We predicted that road sections closer to Georgian Bay and other wetlands would be associated with higher roadkill numbers (Findlay and Houlahan, 1997) and less roadkill would occur in developed areas where wetland habitat was scarce. In order to identify any taxon-specific patterns, we also compared the factors associated with total reptile roadkill, with snake and turtle roadkill separately. If reptile crossings are more likely to occur in areas with specific landscape factors, this information could be used to inform the planning process and direct efforts of mitigation.

Methods

Study Site

Muskoka Road Five is a winding road that cuts through two hamlets, fields, forest, rock barrens and wetlands, and has 0.6 m narrow gravel shoulders and a speed limit of 60 km/hr. It is a paved two-lane side road that connects Highway 400 to the town of Honey Harbour, Ontario (45 52'N, 80 50'W), located in the township of Georgian Bay. Honey Harbour is a popular summer cottage destination that contains several large marinas and is the mainland headquarters for Georgian Bay Islands National Park. In the summer of 2004, the human population swelled to 2 144 seasonal households, and traffic volume peaked at 3 000 cars per day (District Municipality of Muskoka, 2004).

Data Collection

We surveyed a 12.2 km section of Muskoka Road Five daily by vehicle at speeds of 40-60 km/hr from April to October in 2003 and 2004. With very few exceptions, one round-trip was surveyed during daylight hours. We recorded all snake and turtle species observed on the road (both alive and dead), and recorded the distance to nearest property or landmark for each observation. We removed all carcasses from the road to avoid duplication, and moved live reptiles across the road in the direction they appeared to be traveling. Unidentifiable reptile carcasses were considered in analysis as unidentifiable snake or turtle.

We recorded all property numbers and landmark locations using a handheld GPS unit (Map 76, Garmin, USA). Each roadkill was mapped in ArcView 3.2 (Environmental Systems Research Institute, 1999) after data collection was complete. A total of 366 reptiles were observed on the road; however, 25 records were removed from analysis because of poor spatial accuracy. The data under-represent the total number of reptiles killed on the road because we did not survey at night and could not quantify the number of reptiles removed by scavengers or concerned citizens, and those too small to see from a vehicle.

Creation of Landscape Variables using GIS

We used ArcView GIS 3.2 (Environmental Systems Research Institute, 1999) to map and analyze the data. Muskoka Road Five data were isolated from the Ontario Base Map road data (Ministry of Natural Resources, unpublished data, Parry Sound, 2002). The road was clipped to 12.2 km to represent the daily survey area. We then split the road into 122 segments, each 100 m in length, and recorded the number of reptile observations that occurred along each road segment. A digital 1998 infrared air photo mosaic (Parks Canada, unpublished data, Honey Harbour, 2004) was used to digitize where driveways and water crossings intersected the road and all buildings within 300 m of the road. We buffered each 100 m road segment by 50 m (Figure 1), and counted the number of driveways, buildings and water crossings within each buffer. The area of each road buffer was 1.77 hectares (17 650 m^2).

Forest Resource Inventory data (Westwind Forestry Stewardship Inc., unpublished data, Parry Sound, 2002) were used to describe the local habitat. Fifteen habitat classes were amalgamated into five classes, which included water, road, field, forest, and rock (Figure 1). We cross-referenced these habitat types with the 1998 colour infrared aerial photographs, and recorded the percentage of habitat within each of the 122 road segment buffers.

We created distance surfaces using the Spatial Analyst Extension (Environmental Systems Research Institute, 1999) for water, water crossings, Georgian Bay, buildings, and driveways. Avenue programming language (Environmental Systems Research Institute, 1999) was used to add 100 points at 1 m intervals along each 100 m road segment and to connect the distance surface grid value to each point along the road. We averaged the distance for the 100 points that fell along a 100 m road segment to determine the average distance of each road segment to driveways, water crossings, buildings, water, and Georgian Bay.

Statistical Analysis

We used a chi-squared goodness-of-fit test to determine whether the number of reptile crossings was randomly distributed within each segment. The eighteen variables created using GIS were entered into a multivariate regression model using SPSS 11•01 (SPSS, 2001) to determine which variables explained the distribution of reptile road crossings along each 100 m segment. The number of variables was reduced to eight after systematically removing those with high multicollinearity, and with a standardized coefficient (Beta) of <0.10, thus producing the most parsimonious model (Table 1). Multiple regression analysis using the same eight variables was repeated for snake crossings and turtle crossings separately.

Figure 1. Example of a 100 m road segment along Muskoka Road 5 (shown as a white line) and the associated variables. The 50 m buffer of the road segment is circled in black. Reptile roadkill is represented by stars, driveways by circles, water crossings by white squares, buildings by black squares, and habitat is symbolized with different fill patterns. The variables associated with this road segment are: 11 snakes, 1 turtle, 5 driveways, 1 water crossing, 8 buildings, 6% water area, and a 49% road area. On average the road segment has a 32 m distance to Georgian Bay, 37 m distance to water crossing, and 9 m distance to driveway.

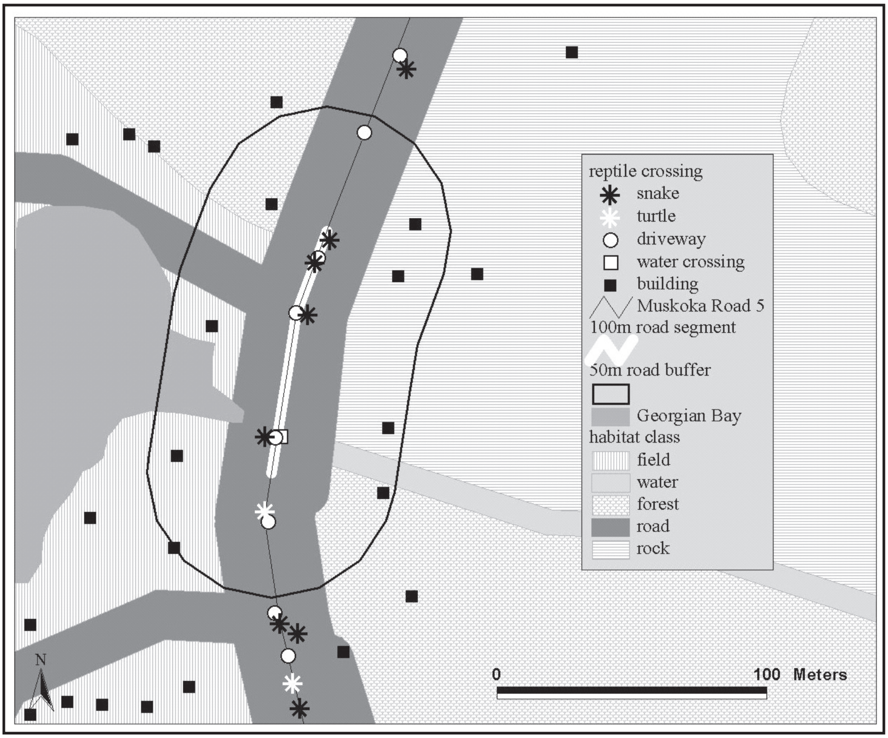


Table 1. Definition and description of variables used in the analysis of factors explaining high reptile-crossing sections of Muskoka Road Five, where each road segment (N=122) is 100 m in length and buffered by 50 m; averages were calculated over 1 m lengths within each entire segment length, and the numbers of structures and habitats were calculated for the entire buffered area.

Variable Name	Definition
Distance to driveway	Average distance (m) of road segment to the nearest driveway
Distance to Georgian Bay	Average distance (m) of road segment to Georgian Bay
Distance to water crossing	Average distance (m) of road segment to a water crossing (stream or culvert)
Number of driveways	Number of driveways within each buffered road segment
Number of water crossings	Number of water crossings (streams or culverts) within each buffered road segment
Number of buildings	Number of buildings within each buffered road segment
Road area	Number of 1x1 m squares consisting of roadway within each buffered road segment
Water area	Number of 1x1 m squares consisting of open water within each buffered road segment

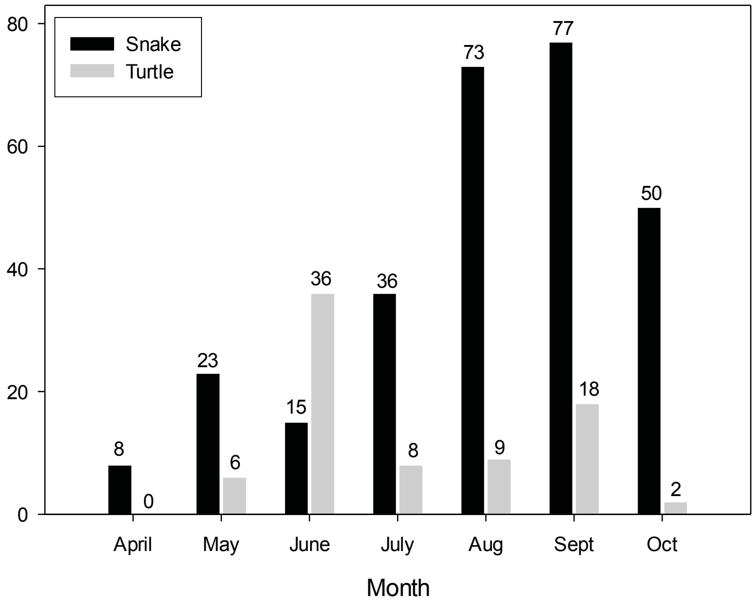
Results

A total of 340 snake and turtle crossings were analyzed representing 16 species (Table 2). Of all records, only 9% were alive on the road. Therefore, road crossings and roadkill were considered as synonymous. Significantly more snakes were recorded than turtles ($t = -7.371$, two-tailed, $p<0.0001$). Seventy-nine percent of all crossing attempts were made by snakes ($n = 269$), representing 10 species, three of which are listed as species at risk (COSEWIC, 2004). The remaining 21% of crossings were made by six different turtle species ($n = 71$), three of which are listed as species at risk (COSEWIC, 2004). The number of snake crossings peaked during August and September, whereas the number of turtle crossings peaked in June (Figure 2).

Table 2. Number of road crossings counted for snake and turtle species on Muskoka Road Five, Ontario, during daily vehicle surveys in 2003 and 2004.

Name	**COSEWIC Status**	**2003**	**2004**	**Total**
Snakes				
Northern Red-bellied Snake (*Storeria occipitomaculata*)	Not Listed	1	0	1
Eastern Ribbonsnake (*Thamnophis sauritus*)	Special Concern	4	1	5
Eastern Gartersnake (*Thamnophis sirtalis sirtalis*)	Not Listed	114	69	183
Eastern Foxsnake (*Elaphe gloydi*)	Threatened	8	9	17
Eastern Hog-nosed Snake (*Heterodon platirhinos*)	Threatened	1	1	2
Milksnake (*Lampropeltis triangulum*)	Special Concern	12	3	15
Smooth Greensnake (*Opheodrys vernalis*)	Not Listed	0	1	1
Northern Watersnake (*Nerodia sipedon sipedon*)	Not at Risk	14	16	30
Massasauga (*Sistrurus catenatus*)	Threatened	1	0	1
Dekay's Brownsnake (*Storeria dekayi*)	Not at Risk	7	0	7
Unidentifiable Snake		6	1	7
Total Snakes		***168***	***101***	***269***
Turtles				
Snapping Turtle (*Chelydra serpentina*)	Not Listed	1	3	4
Midland Painted Turtle (*Chrysemys picta marginata*)	Not Listed	11	43	54
Spotted Turtle (*Clemmys guttata*)	Endangered	0	2	2
Blanding's Turtle (*Emydoidea blandingii*)	Threatened	2	6	8
Northern Map Turtle (*Graptemys geographica*)	Special Concern	0	1	1
Stinkpot (*Sternotherus odoratus*)	Threatened	1	0	1
Unidentifiable Turtle		1	0	1
Total Turtles		***16***	***55***	***71***
Total Road Crossings		**184**	**156**	**340**

Figure 2. Monthly comparison of snake and turtle road crossings on Muskoka Road Five in 2003 and 2004 during daily vehicle surveys where grey represents the number of turtles and black represents the number of snakes. The total number of crossings is denoted above each bar. Turtles peaked in June, whereas snakes peaked during August and September.



There was a significant difference between the expected number of crossings per segment (if randomly distributed) and the observed number of crossings per segment (c2=419.971, p<0.01). There were 35 sections containing zero roadkill, and 21 sections containing six or more. Additionally, of the 21 high crossing segments, 11 (52.4%) were directly adjacent to another high (i.e., 6 or more) crossing segment.

The eight variables selected represent a significant portion of the variation in all three models (total reptile: F=7.734, p<0.0001, R2=0.354; snake: F= 4.935, p<0.0001, R2=0.259, and turtle: F=6.365, p<0.0001, R2=0.311) (Table 3). All eight variables significantly contributed to the variation in reptile roadkill (Table 3). For the snake roadkill model, five variables were significant at the 0.05 level for a one-tailed test (distance to driveway, distance to water crossing, number of driveways, distance to Georgian Bay, and road area) (Table 3). For the turtle roadkill model, only four of the eight variables were significant (water area, distance to Georgian Bay, number of water crossings, and distance to driveway) at the 0.05 level for a one-tailed test (Table 3).

As the average distance to driveways and number of driveways per segment decreased, the number of roadkills also decreased (Table 3). Similarly, as the average distance to the nearest water crossing per segment decreased, the number of roadkills also decreased. There were significantly more roadkill in segments closer to Georgian Bay (Table 3). Road segments containing more water crossings and buildings also contained more roadkills (Table 3). As the area of road per buffered road segment increased (representing

Table 3: The unstandardized (B) and standardized (ß) coefficients for the three multiple regression models with independent variables: snake, turtle and total reptile community, where (*) and (**) represent 0.05 and 0.01 levels of significance for one-tailed tests respectively. The variance (R2) and adjusted variance (R2adj) for each of the three models is provided along with the F values and significance levels.

Variable	**Snake**		**Turtle**		**Total Reptile**	
	B	**ß**	**B**	**ß**	**B**	**ß**
Distance to driveway	-2.43E-02	-0.276**	-9.10E-04	-0.218*	-3.34E-02	-0.309**
Distance to Georgian Bay	1.51E-03	0.206*	8.15E-04	0.234**	2.33E-03	0.258**
Number of water crossings	6.61E-01	0.118	6.10E-01	0.229*	1.271	0.184*
Road area	7.95E-04	0.148*	2.28E-04	0.089	1.02E-03	0.155*
Water area	7.89E-05	0.035	4.03E-04	0.374**	4.82E-04	0.172*
Number of driveways	-3.72E-01	-0.243*	-6.68E-02	-0.092	-4.39E-01	-0.233*
Number of buildings	2.50E-01	0.196	8.04E-02	0.133	-3.30E-01	0.211*
Distance to water crossing	-2.53E-03	-0.270**	3.25E-05	0.007	-2.50E-03	-0.217*
Model R2, (R2adj)	**0.259, (0.206)**	**0.311, (0.262)**	**0.354, (0.308)**			
Model F	**4.936, p<0.0001**	**6.365, p<0.0001**	**7.734, p<0.0001**			

the presence of intersections and curves), the number of roadkills also increased. Similarly, as the area of water within each road segment increased, the number of roadkills increased.

Discussion

It is possible that drivers are less likely to swerve to avoid or stop to move a snake than a turtle, possibly explaining why more snakes were killed than turtles. Alternatively, snakes (especially garter snakes) may simply be more common in the area than turtles. A high percentage of reptiles were found dead or mortally injured on the road (91%), similar to other studies (Bernardino and Dalrymple, 1992; Rosen and Lowe, 1994; Enge and Wood, 2002).

Snake roadkill peaked in late summer, which coincides with the time of year when live-bearing snakes give birth. Bonnet *et al.* (1999) found that higher mortality levels relate to higher levels of snake activity. Other studies noted hatching and birth (Enge and Wood, 2002) as reasons for snake roadkill peaks in late summer. A small increase in snake crossings occurred in May. A higher number of snake roadkill were expected during May, in correspondence with migration from hibernation sites and mating seasons for most species. Since cottage country traffic is generally low until late May (District of Muskoka, Unpublished Data, 2003), it may be that traffic volume is a more powerful roadkill-determining factor for snakes than their life history. Variations in traffic intensity have been found to increase mortality for some amphibian species (Mazerolle, 2004).

Turtle roadkill peaked in June, coinciding with nesting season. Turtles often attempt to dig nests in the loose gravel at roadsides (Aresco, 2003) and are therefore vulnerable to road traffic at this time. This is in contrast to the results of Ashley and Robinson (1996) who found that painted turtle roadkill peaked in May as a result of overwintering hatchlings dispersing from roadside nests. Few juvenile turtles were recorded in this study, possibly because hatchlings are difficult to spot from a distance.

As hypothesized, roadkill was not distributed randomly throughout the 122 road segments. Other studies have also reported that roadkill is spatially clustered (Bernardino and Dalrymple, 1992; Clevenger *et al.*, 2003; Malo *et al.*, 2004). Segments containing a high number of roadkill were likely to be adjacent to other segments containing a high number of roadkill indicating that appropriate roadside habitats spanned distances greater than that of our segments (100 m).

Eight variables significantly contributed to the distribution of reptile crossings (Table 1). Fewer roadkills occurred in segments containing many driveways. In areas where driveways are dense, human development is high and reptile habitat is often poor, thus, reptile densities are likely to be low. Clevenger *et al.* (2003) also found fewer roadkills close to urban areas. There was significantly more reptile roadkill in segments with a higher number of buildings, resulting from the fact that buildings are often located close to water. Of all buildings analysed in this study (those within 300 m from the road), 86.6% were within 150 m of the Georgian Bay shoreline.

Most reptile species in the area use wetlands for foraging, nesting, or overwintering; therefore, segments closer to Georgian Bay had significantly more roadkill for all three models. Segments that are close to the Georgian Bay shoreline have lower topography, tend to be wetter, and would have higher quality habitats nearby. All turtle species recorded are aquatic or semi-aquatic, and subsequently, all turtle roadkill was clustered in areas close to water. Findlay and Houlahan (1997) found that species richness was negatively affected if roads are within two kilometres of a wetland. In our study, roads were never further than 413 m from a lake or wetland.

Segments containing more road surface area have roadway intersections or sharp bends and were associated with higher numbers of roadkill. Intersections require a reptile to cross a larger section of road, thus increasing their risk of getting hit by a car. Sharp bends in the road make it difficult for drivers to see and avoid hitting an animal. Winding segments of road have also been found to contain more roadkill of larger mammals (Nielsen *et al.*, 2003; Malo *et al.*, 2004).

Segments of road with a greater number of water crossings, where streams, drainage ditches, or culverts bisect the road, had more roadkill than areas without. Water crossings contained wetland habitats on both sides of the road and were therefore likely connecting suitable habitats on either side of the road. However, segments with a closer *distance* to water crossings had fewer roadkills. It is suspected that reptiles used culverts instead of crossing over the road surface in these cases. Similarly, Clevenger *et al.* (2003) and Lodé (2000) found fewer mammal and amphibian roadkills in areas close to safe passageways. Other reptiles have been reported to use culverts where available for passage underneath roadways (Yanes *et al.*, 1995; Aresco, 2003; Dodd *et al.*, 2004). Alternatively, areas with suitable habitat on both sides of the road could have lower reptile densities due to prolonged yearly mortality (Findlay and Bourdages, 2000). Further study could investigate whether reptile populations are low in areas where roads bisect suitable habitats.

The model proposed by this study was created using only two years of data for one secondary road. It would be informative to test the model by surveying other roadways in the Muskoka District to determine whether it is possible to accurately predict high reptile roadkill areas. If so, mitigation efforts could be more effective if focused on high roadkill areas. Additionally, if the proposed model can be applied effectively to the greater Georgian Bay area it can be used to aid in reptile conservation and planning for new roadways, especially where predictions could be used to minimize animal-vehicle collisions at the road design stage (Malo *et al.*, 2004). This study suggests that straight roads with culverts far from wetland habitats are likely to have less of an impact on amphibian populations than windy roads that are located close to water.

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