RESEARCH ARTICLE

Effective Placement of Road Mitigation Using Lessons Learned from Turtle Crossing Signs in Ontario

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ABSTRACT

In landscapes inundated with roads, wildlife is likely to negatively interact with vehicles during its lifetime. Wildlife crossing signs are easily deployed, cost-effective, and meant to encourage wildlife-friendly driving practices in hopes of reducing wildlife-vehicle collisions (WVCs) along roads. Here we use the placement of turtle crossing signs as a case study to provide recommendations for informed placement of mitigation structures across regional landscapes in Ontario and elsewhere. We collected relevant information (design, theft, and location) from 369 turtle crossing signs placed along roads. We then compiled turtle-vehicle collision data from various sources to statistically analyze where they occur in relation to habitat and road type. We also compared the locations of turtle crossing signs to validated hotspots, which was equivalent to 19,000 km of road in Southern Ontario. We found that at least 27% of signs were stolen and at least 10 different design types exist for crossing signs in Ontario. Thirteen percent of signs were not located at validated hotspots, and turtle-vehicle collisions occurred most often on paved highways and county roads. We conclude that a road mitigation strategy should accurately inventory where structures are located and monitor their effectiveness. Structures should be selectively placed using the best available information, such as metapopulation science and WVC data, especially in regions heavily fragmented by roads. In multi-jurisdictional regions, an effective strategy should also consider regional coordination that focuses on standardized sign design and information sharing in an adaptive approach.

Keywords: crossing signs, mitigation placement, turtle, road, wildlife-vehicle collisions

Over the past century, roads have become the most significant anthropogenic modification of terrestrial habitat (Forman and Alexander 1998). As a result, wildlife road mortality has been increasingly identified as a prominent threat for many species of wildlife. In Canada, reported wildlife-vehicle collisions (WVCs) with large animals increased at an average of 7.55% per year from 1994–2004 (Transport Canada, unpublished data). Roads also fragment the landscape, altering animal distribution and movement patterns during annual migrations when animals are in search of breeding sites and critical food sources (Trombulak and Frissel 2000).

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In Southern Ontario, small animal carcasses of birds, small mammals, amphibians, and reptiles are prevalent and well documented on roads (Ashley and Robinson 1996; Ontario Road Ecology Group 2011). This road mortality poses a particularly significant conservation issue for many reptiles, turtles, and snakes that are listed as Species At Risk (SAR) under the Ontario Endangered Species Act (2007) (Ashley et al. 2007, Seburn 2007). Snakes are especially prone to road mortality from intentional collisions with motorists (Ashley et al. 2007), and turtles frequently encounter roads on their annual egg-laying migrations while searching for suitable nesting sites (Haxton 2000, Steen et al. 2006).

To mitigate road mortality and improve landscape connectivity, it is necessary to identify and prioritize specific locations on roads where WVCs are concentrated in a regional context (Gunson et al. 2012). Mitigation planning that strives to maintain regional species persistence is crucial for conservation planning in fragmented and disturbed landscapes (Marsh and Trenham 2001). In Southern Ontario, the total length of major roads has increased 5-fold between 1935 and 1995 (Fenech et al. 2005), and there is no point further than 1.5 km from a road (Ontario Road Ecology Group, unpublished data).

Once locations are selected, several mitigation designs exist, which vary in cost and permanence in the road network. These could include structures, such as underpasses and fencing (Aresco 2005), or less structural measures, such as wildlife crossing signs (Al-Ghamdi and AlGadhi 2004, Krisp and Durot 2007). Wildlife crossing

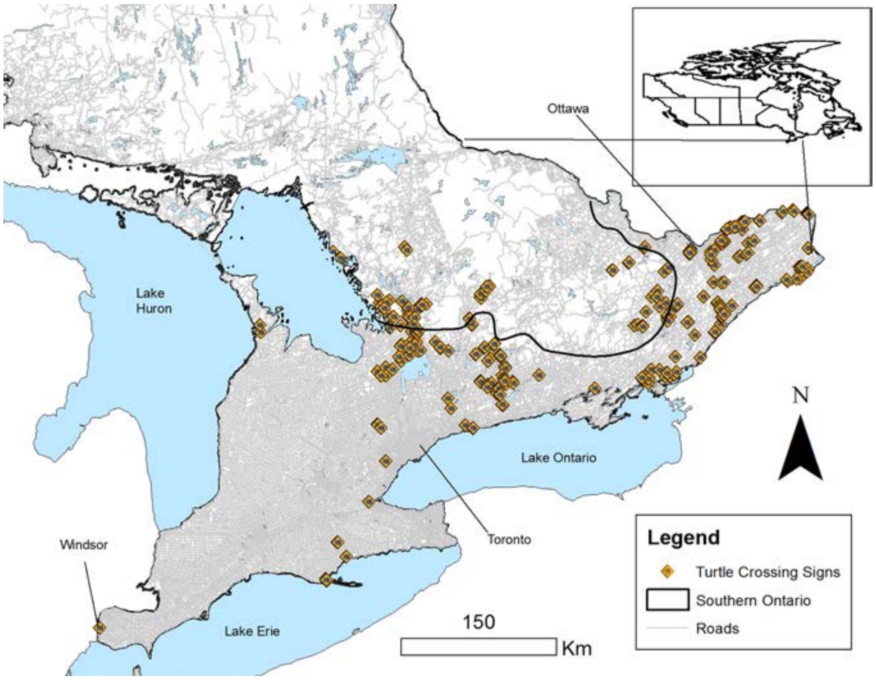

Figure 1. Study area showing the spatial extent of Southern Ontario, roads, and turtle crossing signs.

signs are advantageous because they are relatively inexpensive and easily deployed; however, these advantages have previously led to less optimal placement of signs (Langton et al. 1986), and little is known about how effective they are at reducing road mortality for wildlife (Huijser et al. 2007).

We used lessons learned from the placement of over 700 turtle crossing signs on municipal roads in Southern Ontario to inform selective and rigorous placement of mitigation measures in a regional context. We compared habitat and road-related features between locations of observed turtle-vehicle collisions and where turtle crossing signs were placed along roads. We then discuss and provide recommendations for selective mitigation placement that uses the best information available.

Methods

We compiled an on-road presence (alive and dead-on-road) database for all freshwater turtle species in southern Ontario from 1970 to 2011 from the Ontario Herpetofaunal Atlas, Natural Heritage Information Centre (Ontario Ministry of Natural Resources), Ontario Reptile and Amphibian Atlas (Ontario Nature), Bishops Mills Natural History Centre and other recent data sets (2010–2011) available from Conservation Authorities, special research studies, and the Ontario Road Ecology Group. Species included painted turtles (*Chrysemys picta*), snapping turtles (*Chelydra serpentina*), Blanding's turtles (*Emydoidea blandingii*), wood turtles (*Glyptemys insculpta*), spotted turtles (*Clemmys guttata*), and northern map turtles (*Graptemys geographica*).

We then obtained information (design, number of times stolen, and location) of turtle crossing signs in 2011 using 3 methods. We first contacted 2 main distributors of turtle crossing signs in the province, the Toronto Zoo's Adopt-A-Pond and Turtle S.H.E.L.L. Tortue, located in Rockland, Ontario, to determine where crossing signs had been delivered. We then followed up with respective agencies (Conservation Authorities, environmental non-profit groups, and municipal transportation departments) that received and placed signs to compile relevant information. Next we recorded the geographic position of turtle crossing signs that we encountered during opportunistic travel on municipal roads during the study period. Third, we asked concerned citizens and biologists to provide turtle sign locations and other information using on an online data form available at www.eco-kare.com/turtle_sign_inventory.html. We then imported all signs into a Geographic Information System (GIS; ArcMap 10.0) for spatial analysis.

We used a previously developed landscape model that predicted where amphibians and turtles were most likely to be killed on roads (hotspots) in Southern Ontario (south of the Canadian Shield, Figure 1) for our habitat comparison (Gunson et al. 2012). The model mapped wetland-forest habitat known to be associated with turtle road mortality using the Southern Ontario Land Resource Information System (SOLRIS) in a GIS (Langen et al. 2012). The SOLRIS layer classifies land use from 2000–2003 data at a resolution of 15 × 15-m pixels and is derived from a combination of satellite imagery, topographic maps, and aerial photography (Ontario Ministry of Natural Resources 2007). All wetland pixels (swamps, fens, bogs, marshes, and open water) were given a score of 100, all forest pixels (forest, mixed forest, deciduous forest, and plantations) were given a score of 50, and all other land use pixels (open, agriculture, and built-up) were given a score of 0. We used the weighted land use layer to calculate a Habitat Suitability Index (HSI) defined as the sum of land use pixels within a 200-m radius (12.6 ha area) for each 15 × 15-m road pixel in the Ontario Road Network (ORN) (Ontario Ministry of Natural Resources, unpublished data).

Final HSI scores ranged from 0–55,000, and we grouped them into 11 classes at intervals of 5,000. We then used Chi-squared statistics to compare a count of 1,293 observed dead-on-road turtles with what was expected for each score class. We filtered the dataset for dead-on-road turtles because previous research has shown that factors influencing both alive and dead-on-road wildlife locations can differ (Neumann et al. 2011). The expected counts were based on the proportional road length assigned to each score class. We then used Bailey‘s confidence intervals to evaluate whether each score class was significant ($p < 0.05$), having more or less turtles than expected by chance (Cherry 1996).

To address spatial autocorrelation (see Dormann et al. 2007), we reduced multiple mortality events for the same species reported on the same day and that were within 500 m of each other to 1 event (Gunson et al. 2012). We considered locations 500 m apart to be independent events because other research has demonstrated that turtle road mortality hotspots occurred on segments ≤500 m for turtles in upstate New York (Langen et al. 2012).

Turtle sign locations were imported into a GIS, and we selected only signs that were within the spatial extent of the SOLRIS layer. For unpaired signs, we used a combination of turtle habitat (wetland-forest) as depicted by the SOLRIS layer and the described location to delineate the length of the likely hotspot. We then obtained a maximum, mean, and standard deviation HSI from the road pixels spanned by the signs. The standard deviation was a measure of the variability of habitat between paired signs.

We summarized other road-related features important for improving placement of turtle crossing signs. We used Bailey’s confidence intervals as described above to analyze the road class (highway, county or township road) and road surface (gravel or paved) where dead-on-road turtles were most likely found.

Figure 2. Turtle crossing design adopted by a) Turtle S.H.E.L.L. Tortue in 1998 and b) Toronto Zoo, Adopt-A-Pond Programme in 2009.

Results

We obtained information for 469 turtle crossing signs placed along roads throughout Ontario, and we secured accurate geographic locations (decimal degrees, datum WGS 84) for 336 signs, 121 paired and 94 unpaired (Figure 1). The majority (75%) of the geographic locations were obtained as part of this study because many of the agencies had not accurately referenced sign locations when signs were placed on roads. Unpaired signs were either deliberately placed alone, or its pair was not found and reported. On average, paired signs were spaced 1,010 m apart (range: 67–6,400 m; SD 955).

Field work and telephone surveys indicated that at least 132 (27%) of the documented signs had been stolen. This is a conservative estimate because we were not able to survey or check the roads to see if all signs reported were still present. Ninety-six percent of the signs were of 2 types: the aerial-flattened turtle, the original design

Table 1. Summary of observed and expected dead-on-road turtles for each score class with the percent length of roads classified as Coldspots and Hotspots in Southern Ontario.

Score Class	Observed	Expected	Percent Length
Coldspot			
0–5,000	215	902	69.7
Total	**326**	**1432**	**69.7**
Non significant			
5,001–10,000	155	130	10.0
10,001–15,000	122	88	6.8
Total	**433**	**345**	**16.8**
Hotspot			
15,001–20,000	160	62	4.8
20,001–25,000	161	47	3.6
25,001–30,000	100	28	2.2
30,001–35,000	106	17	1.3
35,001–40,000	85	10	0.7
40,001–45,000	74	6	0.5
45,001–50,000	115	4	0.3
Total	**1294**	**275**	**13.4**

adopted by Turtle S.H.E.L.L. Tortue in 1998 (Figure 2a), and the side-view tortoise, more recently adopted by the Toronto Zoo in 2009 (Figure 2b). We also found 8 other turtle design types during the study period.

More turtles than expected were found on roads in Southern Ontario with an HSI score >15,000, herein referred to as hotspots ($p < 0.05$), and this was equivalent to almost 19,000 km or 13.4% of road (Table 1). Chi-squared analyses with Bailey's confidence intervals showed less turtles than expected were found on roads with an HSI score ≤ 5,000, herein referred to as Coldspots, equivalent to 69.7% of the total road length (Table 1).

Thirteen percent of the signed roads had a maximum HSI lower than the Hotspot threshold (15,000), and 26% of the signed locations had a mean HSI below the Hotspot threshold. The maximum and mean HSI score between signed locations was 31,781 and 23,987, respectively. Variability in habitat (standard deviation) along road segments spanned by signs ranged from 0 to 14,994 (mean 5,412).

Dead-on-road turtles were found more than expected on county roads and provincial highways and less than expected on township roads ($p < 0.05$). In addition, dead-on-road turtles were found more often on paved roads than on unpaved roads. The majority (82%) of signs were placed along paved roads, and 18% were placed along gravel roads. Fifty-three percent were located along arterial roads, 14% along a collector or highway, and 32% were on local streets.

Discussion and Recommendations

Sign locations were mainly determined by regional environmental groups in each township or county. In some cases, regional Conservation Authorities and district Ministry of Natural Resource offices informed transportation agencies about where to place signs. These organizations used a combination of citizen science data (i.e. where there were visual reports of turtles on the road) or habitat information (i.e. where the road bisected favorable turtle habitat). We are not aware of any agency using the provincially available turtle on road data (Natural Heritage Information Centre, Ontario Ministry of Natural Resources, Peterborough, Ontario) to inform placement of turtle crossing signs.

It is not known how many turtle crossing locations exist on municipal roads in Ontario. Many signs are installed by individuals rather than conservation or transportation agencies, and signs are only sometimes inventoried by the responsible organizations. In addition, many signs are stolen. An inventory of crossing sign locations and other relevant information is essential baseline data required for monitoring and maintaining turtle crossing signs. This is especially crucial for a strategy where little information exists on whether signs do indeed reduce turtle road mortality (Huijser et al. 2007). Segments of roads with high turtle mortality may warrant more effective and proven mitigation measures, such as placement of fencing at drainage culverts or the use of an integrated culvert-fencing system along the road (Dodd et al. 2004, Aresco 2005, Caverhill et al. 2011).

At least 27% of turtle crossing signs were reported to us as stolen. High theft rates may be promoted by a combination of flashy and varied sign designs or placement of signs on local roads with little to no traffic. Sign designs that are more standardized may eventually decrease theft rate; however, they may also decrease motorist receptiveness. Some jurisdictions have increased sign awareness by placing signs seasonally when turtles are most heavily impacted by traffic (i.e. in June during turtle egg-laying seasons; Steen et al. 2006). Seasonal sign placement combined with a timely public awareness campaign can also increase mitigation effectiveness (Joyce and Mahoney 2001).

This study found that on some occasions (13%), turtle crossing signs did not span preferable turtle habitat adjacent to roads. To maximize resources and increase sign effectiveness, selective placement that uses the best available data is required. For example, accurate WVC data has previously been used for large animals, such as moose (*Alces alces*) and deer (*Odocoileus* spp.) (Krisp and Durot 2007, Found and Boyce 2012). Wildlife collision data can be used in combination with kernel density optimization (Krisp and Durot 2007), baseline habitat mapping (Gunson et al. 2012), and predictive modeling (Gunson et al. 2011, Langen et al. 2012) to inform placement of mitigation measures, such as signs on roads.

If proven effective, crossing signs would be a cost-effective option to mitigate widespread turtle road mortality in regions heavily fragmented by roads. Baseline mapping showed that 19,000 km of road are probable hotspots in Southern Ontario. Additional criteria for prioritization should focus on both reducing road mortality and reconnecting habitat across roads. Previous work by Van der Grift and Pouwels (2006) used the size and spatial configuration of habitat and metapopulation and population viability theory to determine rules of prioritization for regional placement of mitigation measures.

On average, signs were spaced approximately 1 km apart, and distance tabs of up to 4 km were used with signs to inform drivers of the length of road travelling through presumed hotspots. In addition, the quality of turtle habitat varied greatly between paired signs. Some of the variability can be explained by sign placement before the presumed hotspot to warn motorists of the upcoming risk. However, careful attention should be given to placing paired signs that span a continuous wildlife crossing hotspot because this may increase motorist awareness and ultimately sign effectiveness. A study in New York showed that, on average, turtle road mortality hotspots were 500 m long (Langen et al. 2012), which is also a logical distance to retain a motorist's attention.

The majority of turtle crossing signs were located where turtle road mortality was highest on paved highways and county roads; however, a number of signs were placed along gravel (18%) and township or local roads (32%). Sign placement on roads should be prioritized where traffic volumes reach thresholds that either pose a high road mortality risk and/or pose a risk to turtle population persistence. For example, Gibbs and Shriver (2002) recommend that roads with more than 100 to 200 vehicles/lane/day in regions with dense road networks (>1 km of road/km²) can have substantial limitations on land turtles (e.g., Blanding's turtle and large-bodied pond turtles, such as the snapping turtle). Sign placement on roads with more traffic (county roads and provincial highways) may also decrease the risk of sign theft because it would be more difficult to steal a sign unnoticed.

Conclusions

Turtle crossing signs are commonly used to mitigate turtle road mortality because at the very least it is believed that signs are an effective education and awareness tool and can help change driver response to turtles on roads. Some evidence exists to support this. For example, Schueler and Karstad (2007) compared the era of turtle sign placement (2000–2007) to the decade before (1990–1999) and found that there was a significant increase in the proportion of living turtles seen on roads in Eastern Ontario. This result, combined with the increased concern expressed about turtle road mortality by concerned individuals, led them to suspect that motorists on provincial highways and county and township roads are actively avoiding collisions with turtles.

Opportunistic turtle on road data used in this study has its limitations. It does not determine crossing sign effectiveness because it is not known if a particular road location was sampled with equal effort before and after a sign was placed, or in some cases when the sign was put up. However, at the very least the data should be used to determine the relationship between observed and random turtle on road locations. Concurrent to opportunistic data collection, more rigorous study designs are required that look at the ratio of alive and dead-on-road turtles before and after sign placement.

Vehicle collisions with turtles are a well-documented threat to turtle populations in Ontario and elsewhere in North America (Ashley and Robinson 1996, Gibbs and Shriver 2002, Seburn 2007, Beaudry et al. 2008, Caverhill 2012). Mitigating this threat for regions with dense road networks requires extensive planning, coordination, and optimization of limited resources. A well-thought out approach that considers rigorous placement of a combination of mitigation strategies, such as retrofitted culverts and turtle crossing signs, in combination with public awareness campaigns, can achieve a much-needed coordinated response to Ontario's declining turtle populations.

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