DEVELOPMENT OF A PROVINCE-WIDE WILDLIFE MITIGATION STRATEGY FOR BOTH LARGE AND SMALL ANIMALS ON ONTARIO'S HIGHWAYS

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ABSTRACT

In response to increasingly fragmented landscapes, Europeans have responded with comprehensive processes that identify where conflicts between linear infrastructure and ecological networks will likely occur at the national and Pan-European level. In the last ten years, the United States has followed suit with an explosion of statewide maps that integrate ecological and transportation networks. In Canada, no similar approach has been initiated until the development of a Wildlife Mitigation Strategy (WMS) for the Ontario Ministry of Transportation (MTO).

The main objective of the WMS is to integrate available data, expertise and tools into a first generation framework that will define where road mitigation should be prioritized along Ontario's 19,000 km of highways for both large and small animals. Animals targeted include Species at Risk (SAR) turtles, snakes, small mammals, and birds that are protected under the Endangered Species Act (2007) as well as large animals, e.g. moose, deer, and black bears that pose a public safety risk. Other components of the WMS include evaluation of Wildlife Habitat Awareness (WHA) signs for turtles and snakes, a review of tools used for data collection and management, and public awareness strategies.

The large animal decision tool uses crash data to define where high risk wildlife-vehicle collision (WVC) hotspots occur. Supplementary to the spatial analysis, metrics such as the proportion of WVCs, crash severity, and vehicle risk were evaluated at defined hotspots. The small animal tool focuses on using habitat models that predict where road mortality will occur for habitat specialists such as the Blanding's Turtle, Foxsnakes, and Massasauga Rattlesnakes.

Hotspots are validated with historic and recent presence data for each species. Other pieces of information include fragmentation indices such as effective mesh size. These tools (spatial and compiled attribute data) are currently being applied to mitigation planning efforts on several highways as well as being integrated into a user-friendly mapping interface for easy access by transportation decision-makers.

Currently the small animal tool has been used to place several WHA signs along provincial highways. These signs are also being evaluated with motorist surveys, road wildlife encounter surveys, and traffic speed counters at six locations throughout the province. Preliminary findings have shown that motorists notice signs and slow down after signs are initially placed. This information will be used to assess the effectiveness and use of both temporary, e.g. WHA signs as well as more permanent measures such as crossing structures and fencing.

The first generation of the strategy has identified several knowledge gaps, data limitations, and collaborative opportunities that will provide building blocks for future iterations of the strategy.

INTRODUCTION

The impetus for development of the Ontario Ministry of Transportation (MTO) Wildlife Mitigation Strategy (*MTO WMS unpublished report*) was the Wildlife Habitat Awareness (WHA) sign policy (*Ministry of Transportation 2012*) developed by the MTO Traffic Office in partnership with the MTO Environmental Policy Office and in consultation with the Ontario Ministry of Natural Resources and Forestry (MNRF) and the Ontario Road Ecology Group. The WHA sign policy facilitates the placement of generic designs for small animal taxa (snakes, turtles, small mammals, birds, and amphibians) to raise public awareness of where species at risk habitat occurs along Ontario's provincial highways.

The policy was initiated in response to an increase in public requests for signs on highways as well as the need to provide mitigation tools for Ontario's Endangered (END) and Threatened (THR) small animals where roads have been identified as a threat. For example seven of Ontario's eight turtle species are identified as Species at Risk (SAR) and roads are a threat for five of these species.

The development of the policy was a progressive step towards strategic mitigation planning because previously wildlife warning signs for turtles and snakes were placed informally on municipal roads via partnerships between municipalities and non-government agencies (*Gunson & Schueler 2012*). A well-designed sign strategy requires selective placement of signs where they will be most effective, followed up with inventory and maintenance to ensure signs are not stolen. Too many signs impede effectiveness because motorists become desensitized to their meaning. Furthermore, sign placement should be based on where wildlife is most likely to be impacted by vehicles (hotspots), and where motorists are most likely to see the signs and relate wildlife crossings to them (*Gunson & Schueler 2012*). This is especially the case for MTO WHA signs because it is proposed that these signs could be used as markers for more substantial, permanent mitigation measures in the future.

The policy qualifies the placement of a sign with the following criteria:

1) The road must bisect habitat for an Endangered (END) or Threatened (THR) SAR where road mortality is a threat;

2) The target species habitually cross the road, or have been documented as living next to the right-of-way, based on monitoring surveys and field investigations.

The WHA sign policy is still currently in a test phase and preliminary results are provided in this paper.

The criteria above set the stage for the development of a planning tool that can be used to define where wildlife mitigation should be prioritized for END and THR SAR along 19,000 km of the provincial highway network.

Similar to prioritizing hotspots for small animals, efforts are needed to prioritize where road mitigation is needed for Ontario's large wildlife species (e.g. deer, moose, bear and wolf). Wildlife-vehicle collisions (WVCs) with large animals pose a significant public safety issue to both motorists and wildlife and from 2000 to 2010 there was on average of 4,497 WVCs per year (MTO Road User Safety, unpublished crash data). With an estimated average vehicle-damage cost of about $2,800 per crash (*L-P Tardif & Associates 2003*), this equates to a total of $12.5 million annually just for property damage costs in Ontario alone.

Because implementation of wildlife mitigation is an added cost to road projects, and uncertainty exists about effectiveness and implementation, it is critical that mitigation decisions be made based on sound strategy and data. Currently, highway improvements are planned for and implemented based on engineering, safety and /or capacity issues and planning for wildlife is done on a project-by-project basis through the environmental assessment process. Project-by-project based mitigation is very costly and inefficient and can lead to mitigation that does not address the most critical needs for wildlife conservation and public safety. It also adds a new layer of complexity to the road building and rehabilitation process. The objective of the MTO WMS therefore was to integrate available data, expertise and tools into a first generation framework that could be used to define where wildlife mitigation should be prioritized for both large and small animals on provincial highways. These tools are detailed in this presentation as:

1) Small Animal Mitigation Planning Tool (SAMPT)

2) Large Animal Mitigation Planning Tool (LAMPT)

SAMPT and LAMPT have been integrated into the ministry's Provincial Highways Management Division's new MTO Maps user-friendly mapping interface. This allows internal staff to be proactive in applying hotspot prioritization mapping to internal mitigation planning efforts. For example the SAMPT tool was applied to mitigation planning on several MTO highways in 2015 (*Merriam and Gunson in press*).

Data limitations during development of these tools point to the need for more data sharing and collaboration with partners namely at a provincial level, e.g. Ontario Provincial Police (OPP) and MNRF to facilitate routine updates of SAMPT and LAMPT with new data.

SMALL ANIMAL MITIGATION PLANNING TOOL (SAMPT)

Objective: Define location of hotspots for END and THR SAR along the provincial highway network that can be evaluated in a Geographic Information System (GIS) using the best available data.

Target Species: Blanding's Turtle (*Emydoidea blandingii*, THR), Massasauga Rattlesnake (*Sistrurus catenatus*, THR) (Georgian Bay population), and Eastern Foxsnake (*Pantherophis gloydi*, Carolinian population, END).

Tool Development: Predictive occurrence models were used to evaluate species occurrence patterns on roads and this was extrapolated to other roads. These methods work well for species or species groups that show patterns in their occupancy of habitat, commonly termed habitat specialists (*Patrick et al. 2012*). These models are well suited for this study because only presence opportunistic data was available and not every road had been sampled. Furthermore, because the target species are rare, the likelihood of observing them on roads or roadsides is low. In some cases, a local population extirpation may have occurred and no individuals exist in the current habitat bisected by the road. In this case, mitigation may still be warranted to assist in restoring the population if road impacts were the cause of its extirpation.

Steps 1 through 5 define the process for development of the SAMPT which is also outlined in Figure 1.

Step 1: Assemble observations of target species on roads:

Data were gathered from the Natural Heritage Information Centre (NHIC) and mapped in a GIS for the target species. Data from a concurrent MTO project that systematically collected Blanding's Turtle observations along Highway 7 and 41 in 2012 and 2013 were used to develop the model in N. Ontario (*Gunson et al. 2014*). NHIC data were used to develop the model in S. Ontario (*NHIC unpublished data*).

Step 2: Correlate habitat predictors from FRI and SOLRIS layers:

Logistic Regression models were generated by comparing observations with randomly generated locations on roads, using the respective land-use layer where the species occurred. Random locations were generated points (equal to or greater than the observed locations) along the same roads where the species were found. A 500 m radius circle was used to extract the proportional area of land-use around each observed and random location. This 500 m circle was also used to create 1 km linear spatial units along the entire provincial road network.

Step 3: Extrapolate to entire road network:

The model produced from Step 2 was used to measure a probability score (0-1) associated with each 1 km linear spatial unit along provincial roads where the species occurred. Figure 2 shows the process described in Steps 1, 2 and 3. The inset shows the buffer proportions around observed and random locations used to develop the model, and the red hotspots along highways in N. Ontario where the model was extrapolated to predict likelihood of Blanding's Turtle occurrence on roads.

Step 4: Validation of model performance:

The ability of the model to predict where a SAR observation is likely to occur along each linear unit was evaluated using Area Under the Curve (AUC) methods. There were only enough data to perform validation with an independent data set for Blanding's Turtles north and south of the Canadian Shield. Both models performed fairly well (between 0.70 and 0.80), a score that is expected for broad-level landscape analyses.

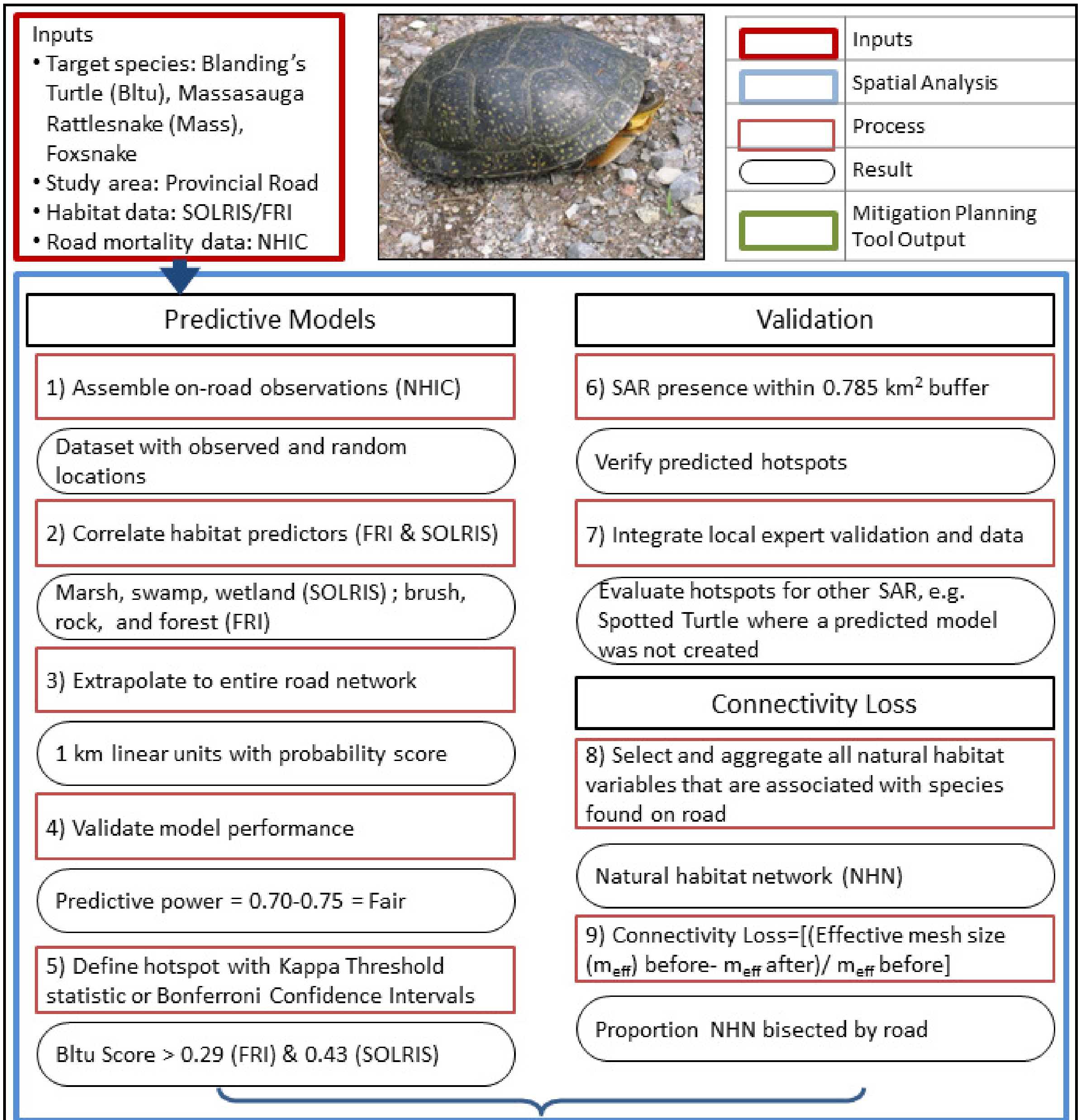
Step 5: Defining a hotspot:

Two methods were used to prioritize where mitigation was most needed using the probability scores obtained from the predictive models. Bonferroni Confidence Intervals (BCI) were calculated for five equally sized categories between 0 and 1 (*Cherry 1996*) for both Foxsnakes and Massasauga Rattlesnakes. This method evaluates whether more dead animals are likely than expected by chance for each score class (*Gunson et al. 2012*). In addition to BCI, a Maximum Kappa Threshold (MKT) statistic was used as a binary threshold to classify each 1 km linear unit into hotspots and coldspots for Blanding's Turtles (*Freeman & Moisen 2008*). These measures may be used as a guide for defining hotspots, however as a general rule, as the probability score increases the habitat is more suitable for the target species.

Marsh, swamp and forest were the best predictors for the Blanding's Turtles in Southern Ontario and brush/alder, rock and open wetland in Northern Ontario. In total, there were 1,727 km of road identified as hotspots for Blanding's Turtles and 39% of these hotspots were validated with presence of Blanding's Turtles.

Eastern Foxsnake hotspots were associated with marsh, swamp, forest and undifferentiated habitat. Of the 60 km of hotspots, only 7 km could be validated with the presence of Foxsnakes from the NHIC data.

Massasauga Rattlesnakes were most frequently associated with rock outcrops and to a lesser extent agriculture. Forest was not included in the model because it was negatively correlated with rock. Of the 836 km of highway that the model was extrapolated to, 135 km were hotspots, and 43 km (32%) were validated with presence of Massasauga Rattlesnakes (*NHIC unpublished data*). The predictive applicability of the Eastern Foxsnake and Massasauga Rattlesnake models are limited due to low sample size for model development and validation.



Hotspot ID (3)	MTO Region/Hwy	Juris	Hotspot (5)	SAR present (6)	Connectivity Loss (9)	Mitigation plan	Next Steps
1) 15303	ER/62	Cty Hastings	BltuScore=0.45	None	0.49	CS & Fencing	Needs to be validated, consult MNR or survey
2) 19616	CR/9	Reg. York	BltuScore=0.46	None	0	Fencing only	Needs to be validated, consult MNR or survey
3) 11669	NER/529	Dist. Parry Sound	BltuScore=0.72, MassScore=0.40	Mass	0.50	CS & Fencing	Multi-species hotspot, validate for bltu
4) 14033	CR/6	Guelph	BltuScore=0.54	Bltu	0.49	CS & Fencing	Assess culverts, and transportation planning documents

FIGURE 1 Overview of development of Small Animal Mitigation Planning Tool (*MTO WMS Unpublished Report*)

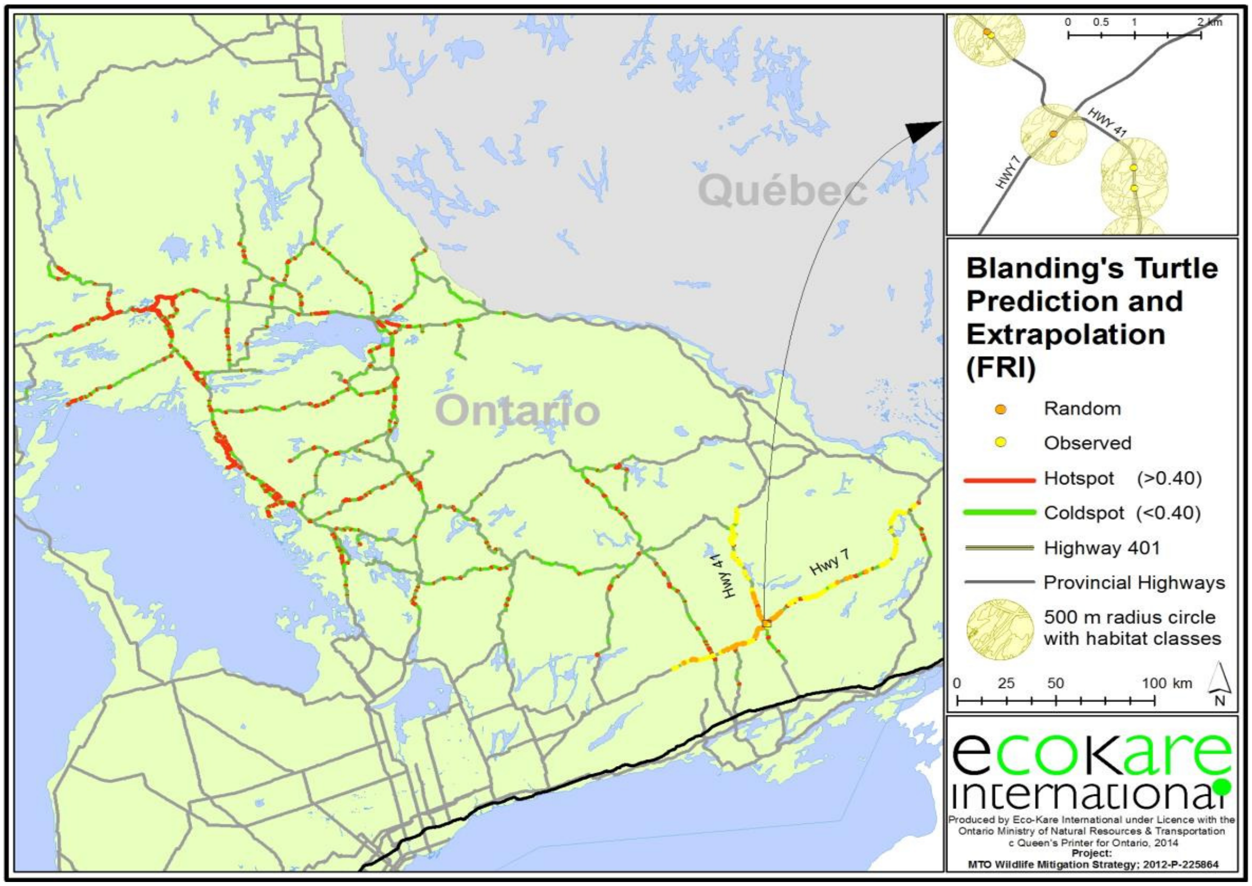


FIGURE 2 Overivew of predictive occurrence model development and extrapolation for Blanding's Turtles (*MTO WMS, Unpublished Report*)).

LARGE ANIMAL MITIGATION PLANNING TOOL (LAMPT)

Objective: Define location of hotspots for large animals along the provincial highway network that can be evaluated in a Geographic Information System (GIS) using the best available data.

Target Species: Large animals, most specifically White-tailed Deer (*Odocoileus virginianus*), Moose (*Alces alces*), Black Bear (*Ursus americanus*), and Wolves (*Canis lycaon*).

Data: The crash data (both wildlife and other type) from 2006 to 2009 were used as the baseline data source for development of the LAMPT (*MTO Traffic Office*). Data that spans over four years captures variability in the frequency of Wildlife Vehicle Collisions (WVCs) at hotspots.

Limitations of the data are there is a five year time lag, it lacks species-specific information, and spatial error may be as high as 2,154 meters ± 1,620 meters, according to a study that compared 26 paired WVC locations that were georeferenced into an Alberta Transportation geodetic system and also measured with a GPS (*Clevenger et al. 2002*). There is also under-reporting because crash locations need to be reported to the OPP, and result in over $1,000 of damage; therefore crashes involving heavy commercial trucks would largely go unreported.

Development of LAMPT is summarized in Steps 1 through 8 and in Figure 3 (see *MTO WMS unpublished report* for more detail).

Step 1. Identify unique ID for each LHRS key station:

The first step was to obtain an understanding of the MTO Linear Highway Referencing System (LHRS) that is used to geo-reference features on the provincial highway network. The LHRS uses a key reference listing or unique ID to reference stations at specific offset distances from landmarks along the highway network. Examples of landmarks are a highway intersection or bridge crossing.

Step 2. Assemble and map the crash data:

In the field, the Ontario Provincial Police (OPP) measures the distance (km) from a crash location to a referenced landmark. This distance is then transcribed by MTO to an offset value or distance measurement to the nearest hundredth decimal place from the reference landmark. The MTO then uses a special mapping tool to translate the key reference plus the offset value to latitude and longitude co-ordinates (decimal degrees) for mapping in a GIS.

Step 3. Delineate hotspots on provincial road network:

A cluster analysis was used to aggregate WVCs that were within 500 m of each other. Each of these clusters were then defined as WVC hotspots along the road and varied in length from 1 km to 24 km (Figure 4).

Step 4. Join road segment where no WVCs occurred:

Line segments without WVCs, i.e. not defined as hotspots were joined to the hotspots to have a complete provincial road network.

Other measures were also evaluation for each hotspot in order to further prioritize the need for mitigation at each hotspot, these included:

Step 5. Relative Incidence of WVCs per km/year

Step 6. Severity:

From 2006-2009 there were 11 (2.75 per year) reported fatalities, 1,079 injuries, and 17,678 reported incidents of property damage associated with WVCs. For severity, a categorical metric, crashes were classified into property damage, injury and fatality.

Step 7. Risk of WVC; WVC/AADTV (2010):

This metric is equivalent to the risk of a vehicle being involved in a WVC per hotspot. The Annual Average Daily Traffic Volume Data (AADTV) was obtained from the MTO Traffic Office for 2010 for highway segments defined by the LHRS. Jenks optimization method was used to classify the continuous values into Very Low, Low, Moderate, High and Very High. High values represent a high count of WVCs and low traffic volumes.

Step 8. Percentage of all crash types that involve wildlife:

This is important information because there may be a large number of WVCs on a highway segment relative to other crash types. In such cases the respective jurisdiction may focus safety budgets on highway maintenance and mitigation efforts that reduce these types of crashes. Equal intervals was used to classify these road segments into Very Low, Low, Moderate, High and Very High. The percentage of WVCs per hotspot ranged from 0.48 to 1 and the average percentage of WVCs was 63%.

Figure 4 shows the output from the LAMPT tool when displaying the relative incidence of WVCs per km/year. The incidence of WVC for each hotspot ranged from 0.09 to 4.01 WVCs per km/year and averaged 0.46 WVC per km/year. Jenks optimization method was used to classify the continuous values into five classes: Very Low, Low, Moderate, High and Very High (see Figure 6).

The primary objective of LAMPT was to evaluate where road mitigation be prioritized along the provincial road network. The tool does not include any ecological measures such as connectivity or habitat models, therefore its applicability to prioritizing where connectivity mitigation measures such as underpasses and overpasses are required to re-connect habitat is limited. The tool is a first-generation framework that can inform where mitigation is required to reduce the rate of WVCs at hotspots.

Next steps include integration of habitat-based predictive models similar to what was done for small animals above. Furthermore, tools such as circuitscape show promise for developing connectivity maps and movement pathways for animals across roads (*Koen et al. 2014*).

Inputs

- Target species: large animals (moose, deer, wolf, black bear, elk) involved in wildlife-vehicle collision
- Study area: Ontario provincial road network
- All Crash data

Inputs

Spatial Analysis

Process

Result

Mitigation Planning Tool Output

Defining Hotspots with Crash Data

1) Identify unique ID for each LHRS station

Linear Highway Referencing System (LHRS) + distance offset = 9 digit number

2) Summarize and map crash data (2005-2009) per unique ID

Import summarized crash data in ArcMap 10.0 (WVC 2006 - 2009)

3) Delineate hotspots on provincial highway network

Perform cluster analysis that grouped WVCs together that were within 500 m

Hotspots (4,136 total) defined as clusters with at least one WVC that varied in length from 1 km to 24 km

4) Attach non-WVC road segments with hotspots (WVC road segment)

Provincial road network with WVC hotspots and associated attribute data (see Step 5)

Prioritization Metrics per Hotspot

5) Rate WVCs per km/year

Very Low >0 & ≤ 0.37; Low >0.37 & ≤ 0.64; Med > 0.64 & ≤ 1.07; High >1.07 & ≤ 2.20; Very High >2.20 & ≤ 4.01

6) Severity

Low = Property Damage (PD); Moderate = Injury (INJ); or High = Fatality (FAT)

7) Risk per vehicle = WVC/AADTV (2000-2010) * 1000

Very Low >0 & ≤5.45; Low > 5.45 & ≤ 12.00; Med > 12.00 & ≤ 22.58; High >22.58 & ≤ 42.86; Very High >42.86 & ≤ 112.50

8) Percentage WVC

Very Low >0 & ≤20; Low > 20 & ≤ 40; Med > 40 & ≤ 60; High >40 & ≤ 60; Very High >60 & ≤ 80

Hotspot ID; Location;Length	5) Rate /km/yr	6) Severity	7) WVC Risk (WVC/AADTV)	8) Percent	Mitigation Plan Next Steps
1) Obj. ID 5229; Hwy 417; ER, 4.9 km	2.28 (Very High)	INJ	1.03 (Very Low)	20% (Low)	Fencing moderate priority however major freeway, borders other hotspots, need field assessment
2) Obj. ID 7829; Hwy 69, NER, 2.5 km	0.49 (Low)	INJ	0.72 (Low)	42% (Med)	Fencing not a priority from 2006-2009 data but reintroduction of elk may increase rate; extend animal fence from Trout Lake Rd
3) Obj. ID 4046; Hwy 35, NER, 14.5 km	1.71(High)	INJ	28.3 (High)	60 (High)	Fencing a priority, Mountain Lake Bridge present

FIGURE 3 Overview of development of Large Animal Mitigation Planning Tool (*MTO WMS Unpublished Report*).

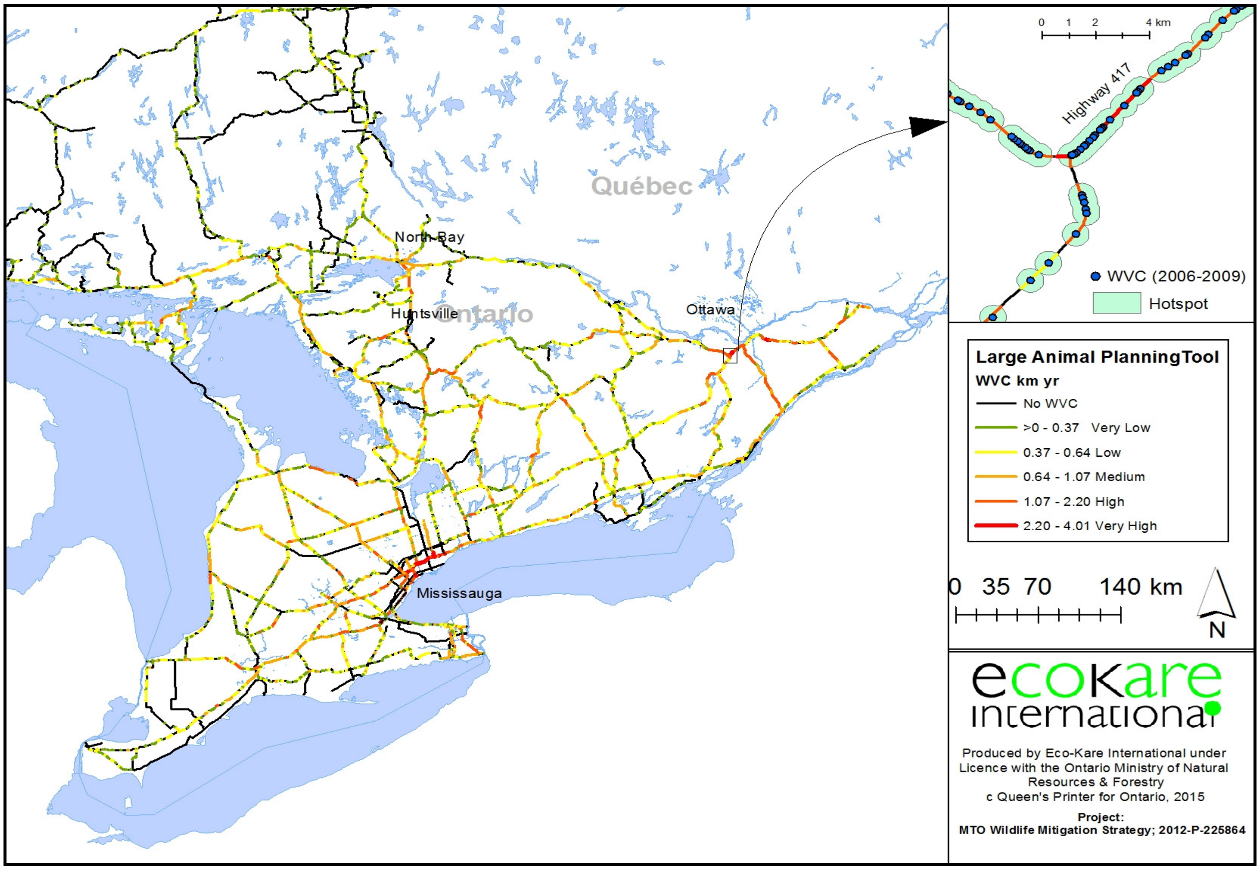


FIGURE 4 Output from large animal mitigation planning tool that displays the WVC hotspots from Low to High using the WVC Rate=Count WVC/km/year (*MTO WMS Unpublished Report*)).

WHA SIGN EVALUATION

Due to a lack of knowledge of sign effectiveness at eliciting the desired response from motorists (to reduce speed and watch out for wildlife), as well at reducing wildlife road mortality a study design was developed to evaluate three key aspects of WHA sign effectiveness:

1) Measure whether WHA signs reduce taxa-specific road mortality (compare mortality before and after the signs are erected) by conducting road surveys;

Six Blanding's Turtle and one Massasauga Rattlesnake hotspots were selected on MTO highways (Figure 5). The hotspots were selected based on whether they were verified with historical and current road-kill for the target species. In addition, three of the five hotspots also had previous systematic data collected along its length and along control sections of highway that could be compared with a before, after, control, Impact (BACI) study design. The analysis for this study is currently underway.

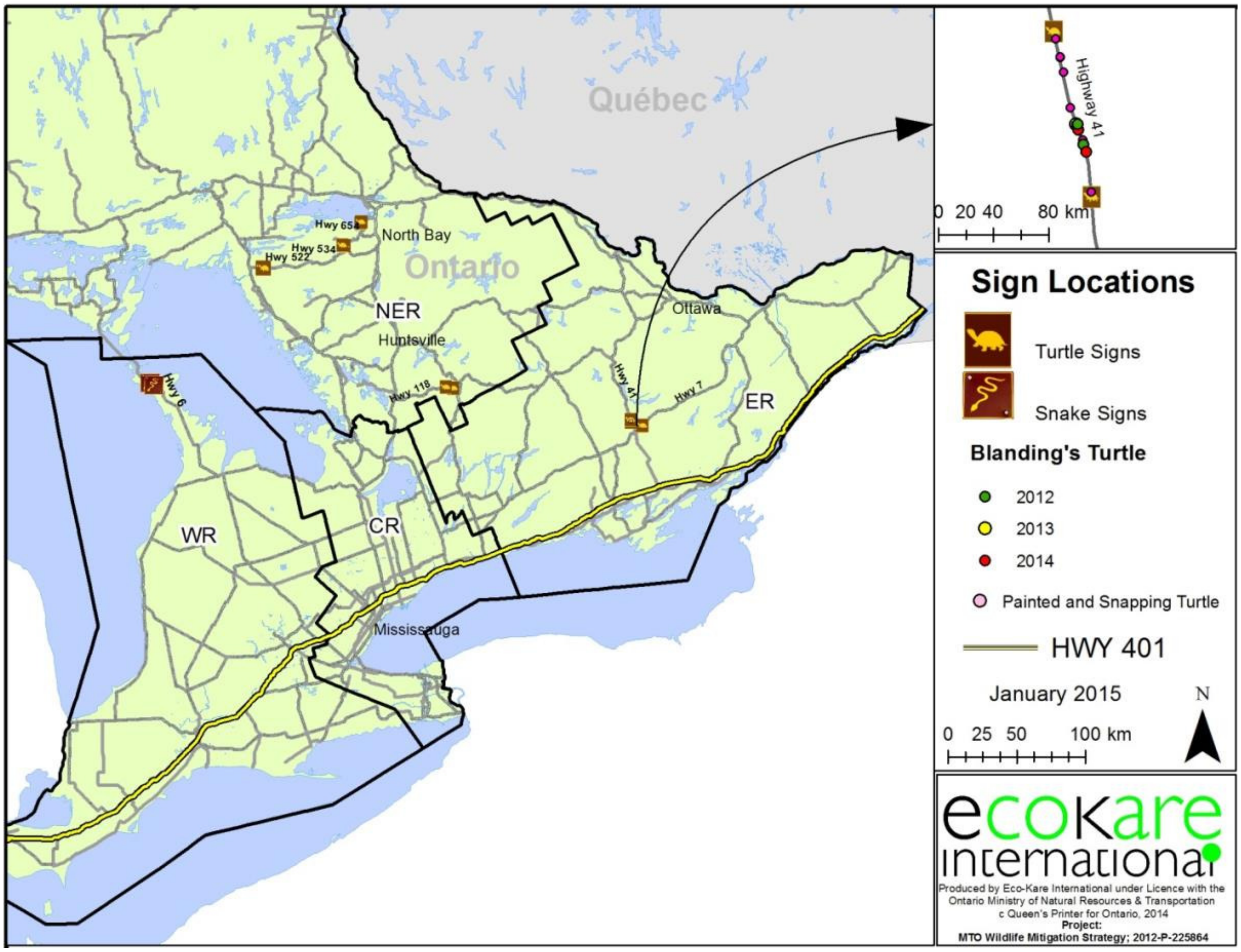


FIGURE 5 Location of WHA signs that were surveyed for turtles on road, and were selected for motorist surveys and traffic speed counts (*MTO WMS Unpublished Report*).

2) Measure whether motorists notice signs by conducing motorist surveys;

A total of 172 surveys were conducted between 9 June and 9 September 2014. Motorist surveys were conducted at gas stations, convenience stores, or roadside chip truck stops soon after WHA turtle signs were installed on Highways 7, 41, 118, 6 and 654 in Eastern, Northeastern and Western Ontario in June 2014. Drivers of vehicles were targeted, to maintain consistency of responses, and because drivers have control of the vehicle to avoid collisions with turtles. Only motorists that appeared not to be engaged in other activities were approached, i.e. had the 'time' while waiting for food or filling a car with gas. To ensure independent responses, surveys were conducted only with individuals who had not overheard previous surveys.

After it was established whether the driver had indeed passed by the sign, the survey was conducted in three parts to establish whether:

a) Motorists noticed the sign (Part 1);

Sixty-seven percent of drivers that drove past the signs noticed them, and this was higher for turtles (71%) than snakes (61%);

b) There was a behavioural reaction of motorists to signs (Part 2) and;

Reactions were considered positive if the sign changed their behaviour in the desired manner (i.e. slowed down, watched for turtles or snakes, more alert, happy to see sign, or showed sign to passenger). Sixty-three percent of motorists had a positive reaction to the signs and of these 29% reported that they looked for turtles or snakes after seeing the sign, 4.7% were more alert or careful and 7.5% reported that they slowed down.

c) Motorists were aware of road mortality threats to SAR turtles and snakes (Part 3).

About half of respondents were aware that turtles or snakes were SAR, and about half were aware of turtles or snakes being killed on roads.

In conclusion a well-thought out education and awareness campaign used in conjunction with signs would be warranted to improve WHA sign effectiveness and will also have the following additional benefits:

- Encourage behavioural change in motorists that is not possible with only signs;
- Provide rationale for this change by educating on the conservation consequences of losing one or two animals;
- Please the driving public that expressed that something more should be done to reduce turtle and snake road mortality; and
- Influence the motoring public at a larger scale for a widespread issue.

Components of an education and awareness campaign include:

- Speed reduction signs and / or enforcement;
- Use of signs or public information boards where motorists frequently stop along the highway;
- Seasonal media alerts;
- Government websites and pamphlets;
- Public awareness videos at highway service centre locations.

3) Measure whether motorists respond to signs by reducing speed by conducting traffic speed study.

The study design selected was a before (B) – after (A) and a control (C) – impact (I) design also known as a BACI illustrated in Figure 6. The before time period is defined from April 17th, to April 24th, 2014 when no WHA turtle signs were on the highway. The after time period is defined as May 27th to June 3rd when there were WHA turtle signs on the highway. The control is defined as 500 m before the sign was noticed by the driver and the impact was 200 m after the sign was noticed by the driver.

Speed was used as the primary measure to determine if motorists responded to the WHA signs at four locations on two highways. The four locations were one each in the northbound and southbound lanes of Highway 41, and one each in the eastbound and westbound lanes of Highway 7 in Eastern Ontario. At each speed monitoring station, speed was measured at a counter that was attached to 2 hoses set at a fixed distance apart (Figure 6).

The speed differential was measured by subtracting the speed recorded at the impact location from the speed recorded at the control location for both the before and after time periods. These were then compared to determine whether motorists travelled slower after driving by the WHA sign.

This type of study design is ideal because it controls for any biases in the data due to changing road conditions, e.g. changing road alignment, because the counters are at the same locations during the before and after time period. In addition, any biases due to vehicles travelling faster or slower between the two time periods are controlled for with the use of a differential measure. In other words, a motorist may travel faster at stations C and D than at stations A and B simply because weather conditions are better.

This is controlled for because it is assumed that due to better road conditions the motorist is travelling faster at both stations C and D. So when the speed differential between C and D is measured and compared with the speed differential at A and B, it captures only the difference in speed that occurred due to the presence of the sign (Figure 6).

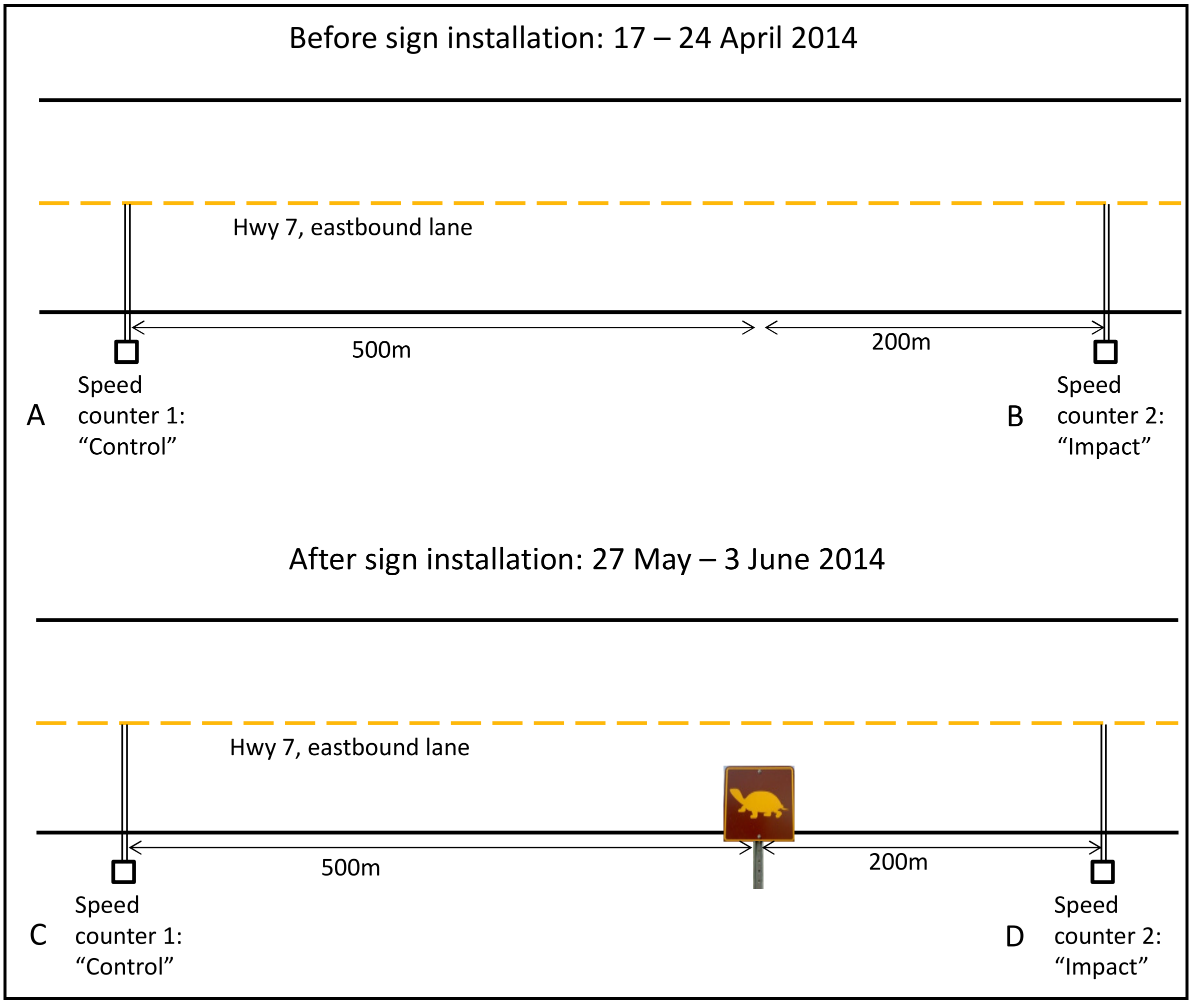


FIGURE 6 Illustration of a BACI design to measure whether there was a change in speed before and after the WHA signs were installed (*MTO WMS Unpublished Report*).

At the three stations included in the analysis, there was a significant reduction in speed after the WHA signs were installed. At the Highway 41 SB station and the Highway 7 EB station the motorists went slower 500 m before the sign and 200 m after the sign both before and after sign installation. However, the motorists travelled significantly 'more slowly' after the signs went up and this speed reduction varied from 4 km/hr. to 3.3 km/hr. At the Highway 7 WB station motorists travelled faster 500 m before the sign and 200 m after the sign, before and after the signs went up; however the difference in speed was significantly less fast (1.2 km /hr. speed reduction) after the signs went up (Table 1).

Other studies have also shown a temporary speed reduction with installation of signs, for example, Al-Ghamdi and AlGadhi (*2004*) showed a significant reduction from 3 to 7 km per hour with the use of signs where camels cross the road. Future work needs to look at whether speed reductions occur at signed locations one to two years later due to a desensitisation to signs.

TABLE 1. Results from traffic speed study at two highways (*MTO WMS, Unpublished Report*); NB=Northbound, SB=Southbound, EB=Eastbound, WB=Westbound

Site	Mean speeds BEFORE signs were installed (km/h)			Mean speeds AFTER signs were installed (km/h)			p-value
	500 m before sign (control)	200 m after sign (impact)	Difference (trend)	500 m before sign (control)	200 m after sign (impact)	Difference (trend)	
Hwy 41 SB	102.6	98.7	**-3.9 (slower)**	99.7	91.7	**-7.9 (slower)**	p<0.0001
Hwy 7 EB	94.2	86.9	**-7.3 (slower)**	98.7	88.2	**-10.6 (slower)**	p=0.058
Hwy 7 WB	91.3	95.5	**4.2 (faster)**	106.7	109.6	**3.0 (faster)**	p<0.0001

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Richard Sadowski with Geomatics, MTO, managed, provided data and mapping expertise throughout the project. The Ministry of Natural Resources and Forestry provided Natural Heritage Information Centre reptile data for validation and development of the small animal mitigation planning tool as well as expertise from key Species at Risk personnel including Joe Crowley and Jake Rouse.

Last, the MTO, eastern region funded by the Highway Infrastructure Innovation Funding Program (2012 and 2013) provided Blanding's Turtle data on Highway 7 that was the foundation of the scientific models developed in the process.

BIOGRAPHICAL SKETCHES

Brenda Carruthers has worked for the Ontario Ministry of Transportation for 30 years, mostly within the ministry's environmental function. She has developed policy for a variety of environmental factor areas to ensure compliance with environmental legislation during the highway development process and is currently working on a wildlife mitigation strategy for provincial highways including design policies and planning tools, as well as construction specifications.

Kari Gunson is a self-employed road ecologist with 16 years of expertise with planning for and monitoring road-wildlife mitigation measures for both large and small animals in Ontario and elsewhere. Her work has led to over 16 peer-reviewed papers and five book chapters in the field of road ecology and Geographic Information Science.

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