HIGHWAY 401 (GANANOQUE TO BROCKVILLE) SPECIES-AT-RISK ROAD ECOLOGY PROJECT 2014-2016

Ontario Ministry of Natural Resources Species at Risk Stewardship Fund

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A2A | Algonquin to Adirondacks Collaborative

Ontario Road Ecology Group

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Cameron Smith
Chair, Algonquin to Adirondacks Collaborative (A2A) Road Ecology Committee
info@a2acollaborative.org

Mandy Karch
Coordinator, Ontario Road Ecology Group
ontarioroadecologygroup@gmail.com

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1.0 INTRODUCTION

Highway 401 is a ribbon of death for animals trying to cross where it spans the Frontenac Arch between Gananoque and Brockville. It is especially lethal for Snapping Turtles, but also deadly for Blanding's Turtles, Gray Ratsnakes, Milksnakes, and Eastern Ribbonsnakes, all of which are species at risk (SAR). In the course of surveys for this study conducted during 2014 and 2015 we documented 97 dead SAR. It is equally deadly for animals that are not species at risk, and we counted 828 dead non-SAR vertebrates. Consequently, for all the species dying on the highway, this report recommends remedial work on culverts and widening of bridge spans over watercourses to provide safe ways for them to get across, as well as monitoring of these actions. The need for an overpass to facilitate wildlife crossing and improve landscape connectivity is also demonstrated, and we recommend a thorough and systematic analysis of ecological factors and land conservation status to identify the most appropriate location for its construction.

It is impossible to overstate the need for safe passage across the highway, because as it stands now, the highway is an insurmountable barrier to connectivity between Ontario and New York State. Connectivity is important, because the Frontenac Arch is a critical link for biodiversity in eastern North America. It is the only area east of Thunder Bay capable of accommodating the movement of species north and south on the scale that will be required under climate change. Both sides of the St. Lawrence River have abundant habitat, and the Thousand Islands (actually 1,864 islands) provide stepping stones **(Figure 1)** for species crossing the river. However, Highway 401 is like a door that has been slammed in their faces. This door needs to be opened.

Figure 1. *An early morning view of the Thousand Islands in the St. Lawrence River.*

Highway 401 between Gananoque and Brockville is a divided highway with two lanes in each direction handling about 31,487 vehicles a day in summer on average. That works out to – on average – a vehicle going each way every 5.49 seconds. No wonder animals have trouble crossing, even in areas without concrete barriers in the median.

Crossing roads and highways is especially challenging for reptiles and amphibians (i.e. herpetofauna). There is legislation in place that requires protection and establishes measures for the recovery of SAR, for example Government Response Statements, Recovery Strategies, COSEWIC Status Reports, the Multi-species Action Plan of the Thousand Islands National Park of Canada. But so far little has been done to limit the carnage on the highway. Yet it is well established, not only in this report, that wildlife/vehicle collisions are a significant source of direct mortality for various SAR herpetofauna (Ashley and Robinson 1996; Row *et al*. 2007). It goes without saying that collisions and near collisions also pose a safety risk for drivers on the highway.

This Project was designed to identify SAR herpetofauna hotspots (i.e. places on the highway where there were concentrations of SAR snakes and turtles that had been killed, or were found alive), and to recommend mitigation measures. Although not required under the terms of the Project, data on other animals found on the highway was also collected. Project deliverables included an opportunistic wildlife/highway interaction dataset, a local and current opportunistic SAR presence dataset, a computer model (based on local landscape features) that predicts and prioritizes hotspots, and a set of mitigation recommendations aimed at SAR protection and recovery.

Highway 401 crosses the Frontenac Arch at its narrowest point, similar to the pinchpoint in an hourglass **(Figure 2)**. Designated a World Biosphere Reserve since 2002, the Arch is a 50-kilometre ridge of exposed granite that connects the boreal forests of the Canadian Shield in the Algonquin Highlands to the Adirondacks in New York State. From the Adirondacks, there are connections through the Appalachian Mountains to Georgia, and through the Green Mountains to Maine and New Brunswick. The Arch is exceedingly rich in biodiversity. For instance, the Thousand Islands National Park lists 31 SAR in areas adjacent to Highway 401. The movement of animals throughout the Frontenac Arch and beyond is critical for large-scale ecological integrity, especially since larger animals disperse over great distances.

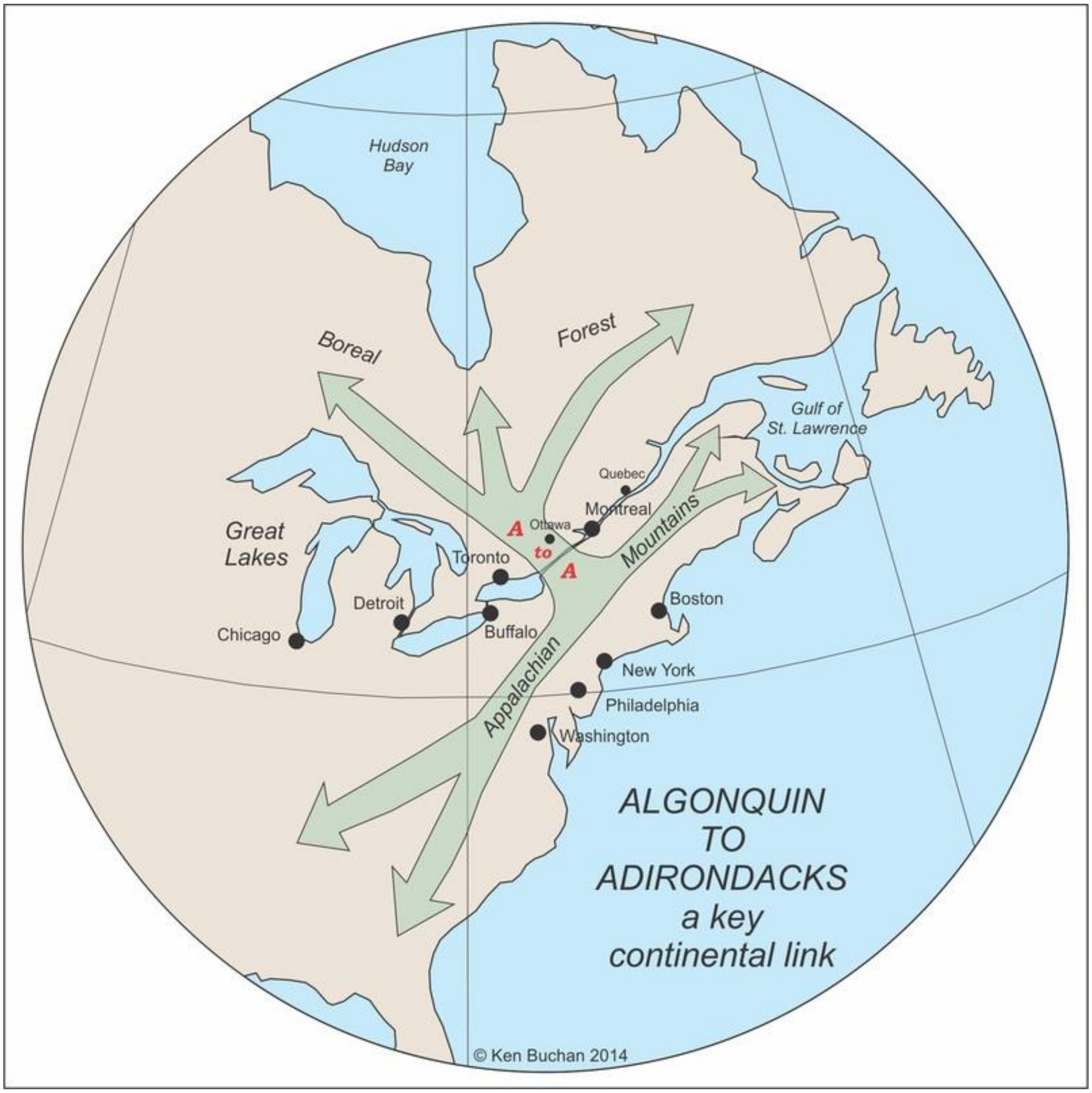

Figure 2. *The Algonquin to Adirondacks linkage in a continental context. The arrows indicate continental-scale linkages, with the pinch-point link of A2A crossing the St. Lawrence River at the Frontenac Arch.*

Within the study area, the target SAR species were: Blanding's Turtle (*Emydoidea Blandingii*), Common Five-lined Skink (*Plestiodon fasciatus*), Eastern Musk Turtle (*Sternotherus odoratus*), Eastern Ribbonsnake (*Thamnophis sauritus*), Gray Ratsnake (*Pantherophis spiloides*), Milksnake (*Lampropeltis triangulum*), Northern Map Turtle (*Graptemys geographica*), Snapping Turtle, (*Chelydra serpentina*), and Spotted Turtle (*Clemmys guttata*). For these SAR, road mortality is identified as a significant threat and is an urgent priority to mitigate (e.g. Kraus *et al*. 2010, Seburn 2010, OMNRF 2015).

Landscape permeability (i.e. porosity) across Highway 401 was previously investigated on behalf of A2A by Ross 2004, and information from his report was incorporated into field work protocols. The Project built on his research, which assisted greatly in generating an opportunistic SAR and wildlife/road interaction dataset.

Also of immense help was the Masters of Environmental Studies thesis by Evelyn Garrah on wildlife road mortality on the Thousand Islands Parkway, completed in 2012 under the supervision of Prof. Ryan Danby of Queen's University. Her thesis formed the basis for predictive modeling of road mortality hot spots which was instrumental, when combined with field research on Highway 401, in mapping SAR hotspots.

The Project was guided throughout by the goals of:

1. Improving landscape connectivity across Highway 401, and within the Frontenac Arch;
2. Protecting local herpetofauna SAR through road ecology mitigation efforts;
3. Promoting biodiversity within the Frontenac Arch;
4. Improving driver safety on the highway.

The Project's findings will contribute to OMNRF's province-wide conservation efforts, and assist MTO in providing a practical and pragmatic approach to environmental management (EPR 2014), as well as informing MTO's Wildlife Mitigation Strategy.

And let it not be overlooked that achieving connectivity and improving biodiversity for the Frontenac Arch will also benefit people, not only by securing ecological services, but by offering the peace and inspiration that individuals require — or as Robert Browning put it — by providing opportunities for people to smooth the cramping in their souls.

2.0 BACKGROUND

The impacts of roads on wildlife are frequently categorized as indirect or direct (Coffin 2007). Indirect effects are those related to a reduction in population connectivity as a result of habitat fragmentation and behavioural responses such as road avoidance (Andrews *et al*. 2008). Direct effects involve mortality caused by collisions with vehicles, and have been identified as a major threat to some wildlife populations (Fahrig *et al*. 1995; Gibbs & Shriver 2002; Beaudry *et al*. 2008). Wildlife species at greatest risk of direct effects are those attracted to roads to forage or for thermoregulation, slow-moving animals, and those with large movement ranges, (Jochimsen *et al*. 2004). Herpetofauna (amphibians and reptiles) fall into this high-risk group and experience elevated levels of road mortality compared with other taxa (Ashley & Robinson 1996). These taxa are also the focus of increasing conservation attention worldwide due to rapidly declining populations and vulnerability to extinction (Stuart *et al*. 2004; Böhm *et al*. 2013).

Reducing direct mortality by implementing mitigation measures is a significant component of many regional and species-specific conservation strategies and management efforts including signage, traffic calming measures, wildlife overpasses, culverts, and fencing have been implemented in many areas (see Beckmann *et al*. 2010). However, their success depends on knowledge of the spatial patterns of mortality on a road or the variables that influence where mortality occurs (Yanes *et al*. 1995; Forman & Alexander 1998; Trombulak & Frissell 2000).

One approach used to help guide the siting of these management efforts is to identify where clusters, or "hot spots" of wildlife road mortality exist; the rationale being that the locations best suited for implementation of mitigation efforts are those that experience the highest levels of mortality. Spatial clustering of road kills has been identified for many vertebrate taxa and clusters have shown to be associated with proximity to suitable habitat or important habitat features (e.g. Clevenger *et al.* 2003; Ramp *et al*. 2005; Langen *et al*. 2009; Barthelmess 2014). A second approach is to compare the locations of individual road mortality events with a variety of road and roadside habitat characteristics in efforts to identify the variables most influential in determining the location of mortality and to model road kill probability (e.g., Langen *et al.* 2009). Mortality may or may not be spatially clustered in these instances, but results have frequently shown that the locations of collisions are not randomly distributed (reviewed in Gunson *et al*. 2011); the implication being that areas where this suite of road and habitat conditions occur should also be targets for mitigation strategies.

In this study we combined both approaches; we conducted multiple surveys by foot in 2014 and 2015 along the Highway 401 study area and documented the species and location of all vertebrates found dead or alive on the road or roadside. We also developed a suite of statistical models using data collected from a previous study conducted on the nearby 1000 Islands Parkway to predict where hot spots of mortality should occur along Highway 401. The results of both methods were compared for the purposes of identifying priority locations for implementing mitigation measures along the nearby Highway 401.

3.0 STUDY AREA

The section of Highway 401 between the town of Gananoque (pop. 5,200) and the City of Brockville (pop. 23,400) is 51.2 km long, with a posted speed limit of 100 km/hour. The road has two lanes in each direction (four total) with minimal curvature. Eastbound and westbound lanes are separated by a 20 metre grassed median for much of the length, although a 3.7 km segment is completely divided by a 200m wide forested area. Adjacent land cover is a mix of forest, agriculture and wetland. Roadsides range from areas with shallow embankments and ditches to steep embankments with guardrails. Rock outcrops along the roadside are not uncommon in either direction and are quite steep in some locations. The Summer Average Daily Traffic (SADT) volume for vehicles travelling both east and west is 31,487 (Source: MTO Traffic Volume Data, Appendix 1).

Highway 401 intersects the Frontenac Arch at its narrowest point. The Frontenac Arch is a southern extension of the Canadian Shield that supports a high proportion of intact forest and wetland habitats. The Canadian portion of the Arch was designated a World Biosphere Reserve in 2002, in part due to its relatively intact landscape and high species diversity (UNESCO 2010). In turn, the Arch is part of the Algonquin-to-Adirondack (A2A) conservation corridor, a broad region linking Algonquin Provincial Park in Canada to Adirondack State Park in the United States (Keddy 1995) **(Figure 3)**. Two other roads in close proximity run parallel to Highway 401; the 1000 Islands Parkway just 2km to the south, and Highway #2 just 3 km to the north. In combination, these three roads represent a substantial "triple threat" to wildlife connectivity on the Frontenac Arch.

There are six turtle species resident in the study area, five of which are federally and/or provincially designated species at risk; and nine snake species, three of which are designated at risk (COSEWIC 2011). The area is thought to serve as an important zone for facilitating movement of large mammals through the A2A corridor and supports provincially significant breeding populations of several at-risk migratory birds (Keddy 1995; Cadman *et al*. 2007). Mitigating wildlife road mortality on the region's roadways is therefore important for biodiversity conservation at a local scale, but also at regional scales.

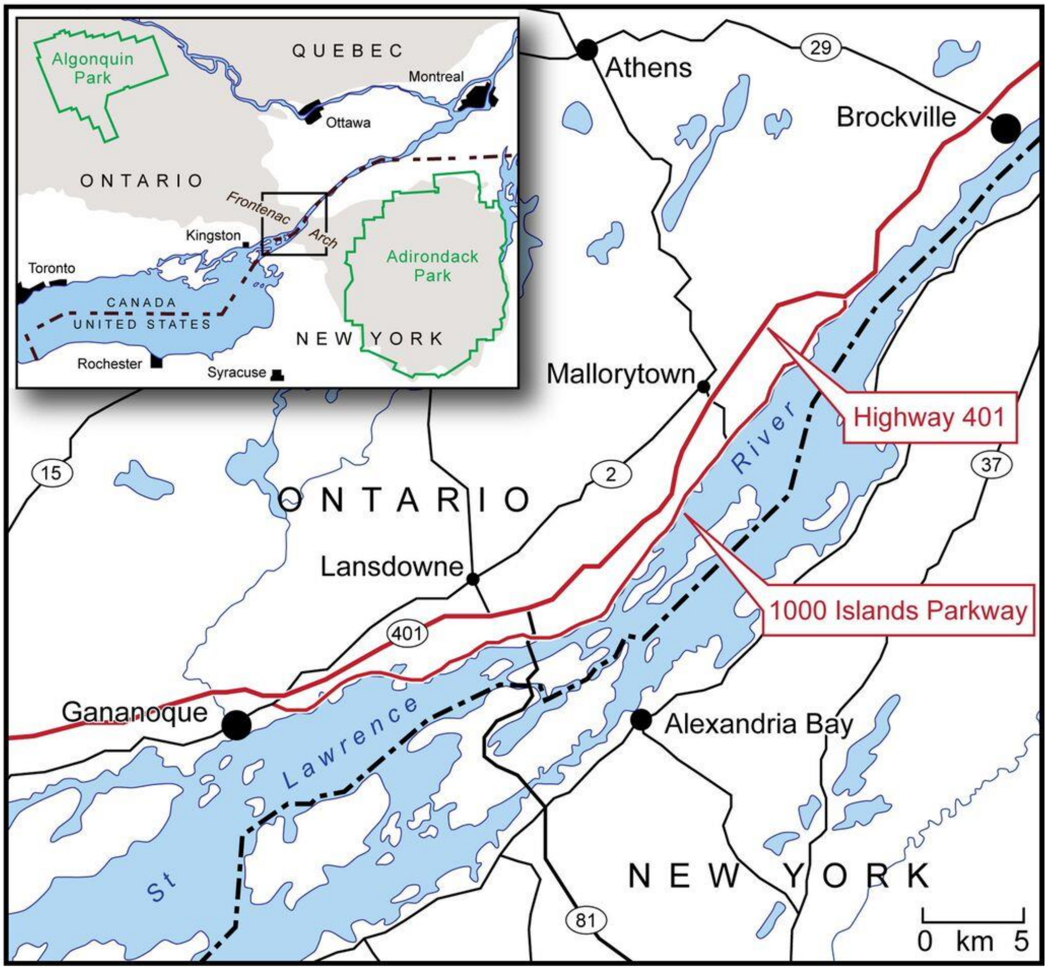

Figure 3. *Location of Highway 401 and the 1000 Islands Parkway in southeastern Ontario in relation to the Frontenac Arch and the Algonquin to Adirondack Conservation Corridor (inset). Precambrian bedrock of the Canadian Shield supporting a higher proportion of natural areas is shown in grey on the inset. Figure revised slightly from Garrah et al. (2015).*

4.0 PRIOR WORK

4.1 Highway 401

In 2004 a study was undertaken to examine the value of existing underpass structures along Highway 401 as passages for mammals and herptiles and to assess the porosity of different segments of the Highway as it relates to wildlife crossing (Ross 2004). The study focussed on a 46.9 km stretch extending from the west edge of Leeds County to the sound barrier wall at Long Beach. Each side of the road was walked and relevant structural features and qualities of the highway were documented and logged with a GPS receiver (Ross 2004). A scoring system based on variables including placement, size, shape, light, moisture, temperature, noise, substrate, approaches, and fencing was developed to assess the structures and evaluate their potential for use in facilitating safe passage of wildlife.

The study determined there were 11 structures appropriate for mammal passage. There were no structures specifically intended for wildlife passage, although evidence of wildlife use was observed at all of the structures. The structure that ranked highest was the bridge over the Gananoque River. The second highest ranked was a tall box culvert at the back of Landons Bay, which was originally built for livestock. A total of 37 underpasses were deemed appropriate for herptile passage, although five of those were ranked of low value; 15 were ranked as high value **(Figure 4)**.

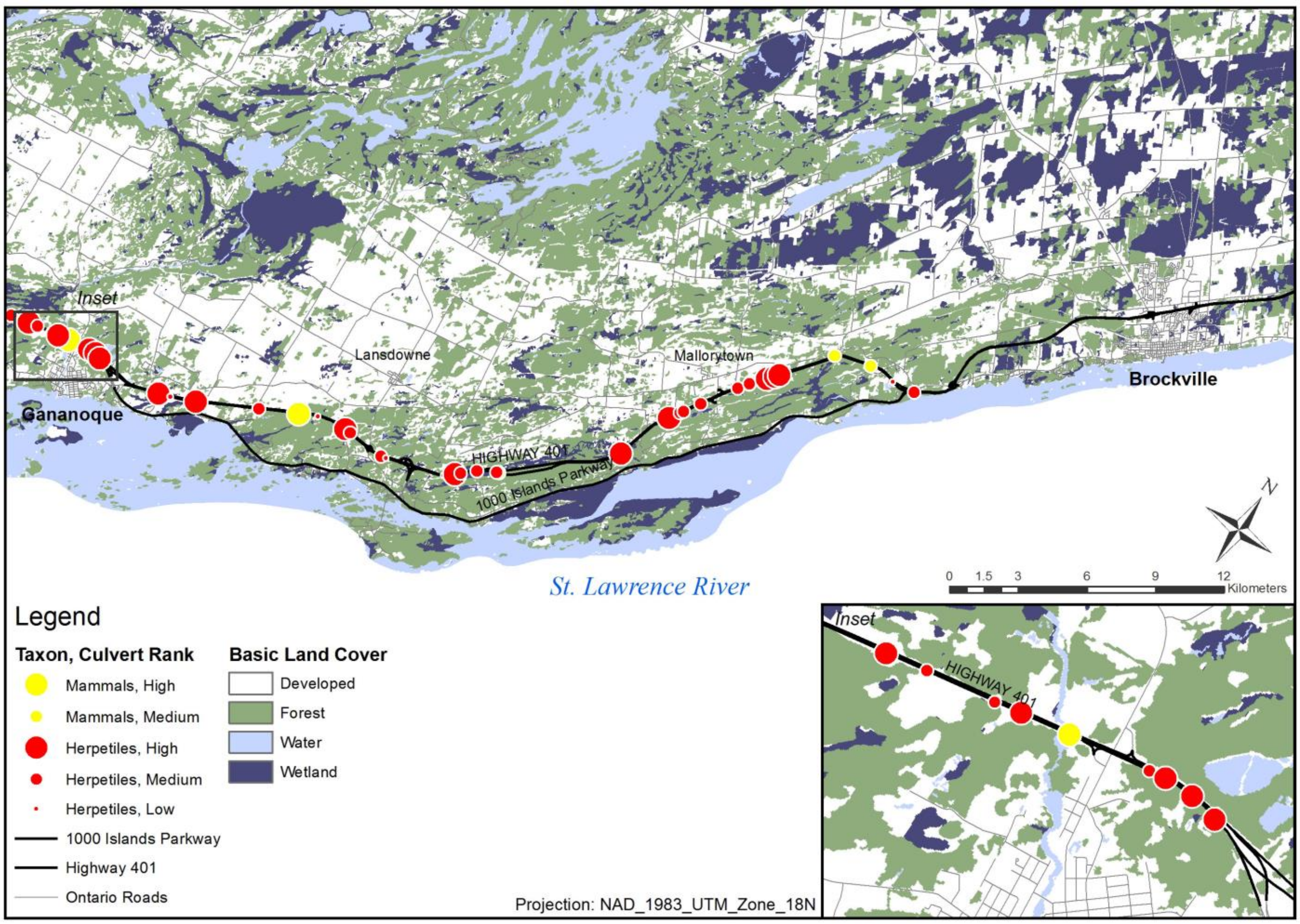

Figure 4. *Underpasses along the Highway 401 assessed to be appropriate for use by mammals and herptiles by Ross (2004). Symbol colour is indicative taxonomic group, size is indicative of potential value for each group.*

4.2 1000 Islands Parkway

A detailed study of wildlife mortality was conducted along the 1000 Islands Parkway from 2008 to 2011 (see Garrah 2012). Data for the study was collected during regular bicycle surveys in each year. The length of the Parkway was ridden 2-3 times per week from mid-April to mid-October and all vertebrate wildlife found dead on the road and road shoulders were identified to the most specific taxonomic level possible. A Global Positioning System (GPS) receiver with mobile GIS (Trimble Nomad, Sunnyvale, CA) was used to record the location of each animal. Surveys occurred in all weather conditions, on both weekdays and weekends. Details of survey protocols are provided in Garrah (2012).

It was estimated that over 16,500 vertebrates are killed on the 1000 Islands Parkway between April and October each year, and that more than 70 vertebrates are killed on the road every day. Frogs comprised over 75% of this, but high numbers of birds, mammals and reptiles were also found. Data were analyzed with a view to identifying variation in the timing and location of wildlife mortality. Particular emphasis was placed on identifying "hot times" – or periods during the year when mortality is particularly high; and "hot spots" – locations along the road where mortality is high relative to other locations. All taxa except mammals exhibited distinct temporal peaks corresponding to phases in their annual life cycles. Statistical modeling using regression trees indicated that seasonality was the most important determinant acting on when an animal was killed. Daily variation in weather and traffic were only significant influences on mortality outside of these peak seasonal periods (Garrah *et al*. 2015).

The locations of individual wildlife mortalities were used to identify road mortality hot spots for each taxon in each year of study, as well as hot spots that were evident across multiple years. Analysis was conducted using the Getis-Ord Gi* statistic implemented in ArcGIS 10.0. Road segment lengths of 100, 200, 500 and 1000 m were used in the analysis. Similarity in results indicated minimal scale dependency in the data and a segment length of 200 m was carried forward for analysis and interpretation.

5.0 METHODS

5.1 Predictive Model

The objective of this component of the Highway 401 project was to utilize the detailed survey data available from the study of the 1000 Islands Parkway to help predict locations along Highway 401 that may be hot spots of vertebrate wildlife mortality. The 1000 Islands Parkway study collected data at a high spatial and temporal resolution and we aimed to exploit that level of detail. The study occurred in three basic phases:

1. Data assembly and mapping;
2. Model development;
3. Model application and analysis.

Methods and procedures associated with each phase are described below. In practice these three steps were not exclusive, but they are described as such for clarity.

5.1.1 Data Assembly and Mapping

Data assembly involved extracting and organizing all relevant spatial data to be used in this study. Both dependent and independent variables were recognized and are described below. Dependent variables refer to the values being explained (or predicted), and were available only for the 1000 Islands Parkway. Two basic categories of dependent variables were identified: (1) mortality location, and (2) hot spot importance. Independent variables refer to the variables used to explain (or predict) the dependent variable. These are available for both the 1000 Islands Parkway and Highway 401 and were obtained from geographically referenced data obtained from a variety of sources. Two basic categories were identified: (1) habitat and land cover variables, and (2) road-related variables.

i. Dependent variables – mortality location

Data on mortality location was derived directly from the mobile GIS files recorded in the field during the 1000 Islands Parkway study. Each record contained latitude and longitude of the observation, species or broad taxonomic group (bird, mammal, snake, turtle, anuran) when identifiable, date and time, position on the road (e.g. eastbound or westbound lane, roadway or shoulder, etc.), and other important notes recorded by the observer. The database included a total of 12,752 records across all 4 years of observation. A total of 638 individuals were not identifiable due to highly degraded condition and were not carried forward for further analysis in this project.

Summary of the database yielded 6 reptile species-at-risk recorded over the 4 years of study. However, none of the species were recorded in sufficient numbers to be considered separately in model development. As such, individual road mortality observations were initially lumped into the following groups: snakes, turtles, mammals, birds and frogs. Turtles were subsequently divided into painted turtles (the most common turtle species observed) and all turtles except painted turtles. Snakes were subsequently divided into watersnakes (the most common snake species observed) and all other snakes. An equivalent number of random points along the Parkway were generated where roadkill of each taxon was not observed. A minimum distance of 100m was maintained between kill locations and these random absences.

Frogs were extremely numerous and were found along the entire length of the Parkway (although hot spots were identified, see below). This prevented the selection of a sufficient number of absence points along the Parkway that could be considered spatially independent (i.e. it was impossible to achieve sufficient replication of absence points and still maintain a minimum separation of 100 m). As such, individual frog mortality locations were dropped from further consideration as a dependent variable.

ii. Dependent variables – hotspot importance

One of the major conclusions of the 1000 Islands Parkway study was that all but the most important hot spots of road mortality vary from year-to-year. As such, rather than using the locations of all hot spots and comparing them with absences (which would have included both the ephemeral and the enduring hot spots), we instead developed an index of hot spot importance for each 200 metre road segment, for each of snakes, turtles, frogs, mammals and birds. This was calculated as:

$$HSI = \frac{n}{N} \sum_{Y=2008}^{2011} \frac{d_Y}{D_Y}$$

where:

HSI = Hot spot importance

n = number of years the segment was identified as a hot spot for the taxon

N = total number of survey years (4 in this study)

Y = year of survey

dY = number of dead animals for the taxon found in the segment in the given year

DY = number of dead animals for the taxon found on the entire road in the given year

Values for each taxon were also summed to yield a total hot spot importance (∑*HSI*) (see Garah *et al*. 2015).

HSI values for each of the five taxa, as well as ∑*HSI*, were extracted at 50 m intervals along the Parkway (starting at 0.025 km), yielding 4 unique points for each 200m road segment. Because the data is continuous there was no need to extract absence points for comparison.

iii. Independent variables – habitat and land cover

The first type of independent variables – landscape and habitat variables – represent data that describes the characteristics of each dependent data location (i.e. the road kill presence/absence locations and the hot spot importance locations). These data were extracted from a variety of geographically referenced data sets obtained through the Government of Ontario. Determining the size of the area to be used in extracting these data was a critical step. Previous studies have used a wide variety of focal area size depending on focal species, study location, and local habitat considerations (reviewed in Gunson *et al*. 2011). We examined high resolution aerial photographs (DRAPE – Digital Raster Acquisition Project for Eastern Ontario) and considered multiple distances from the road in 50 m increments. Examination of the photographs with multiple distances superimposed indicated that a 50 m buffer around each point would be indicative of the local scale or "near road environment" and was selected. We were also interested in determining how broader-scale habitat variables influence mortality. After considering the typical home-range sizes of our focal species and the extent of movements typically recorded for them in the literature, we also selected 250m and 500 m as buffers, yielding areas of approximately 0.8 ha, 19.6 ha, and 78.5 ha around each point which were examined as zones of influence **(Figure 5)**. All analysis was conducted using ArcGIS v10.1.

Land cover data were extracted from the "Sustaining What We Value" database for Ecoregion 6E10 (SWWV 2011) (hereafter "6E10 database"). The second order classification within the BaseLandCover coverage (10m resolution) was used. This contains 12 land cover classes: (1) Swamp, (2) Aquatic, (3) Marsh (all grouped as 'Wetland' in third order classification); (4) Forest-undifferentiated, (5) Forest-coniferous, (6) Forest-mixed, (7) Forest-deciduous (all grouped as 'Forest' in the third order classification); (8) Agricultural; (9) Roads; (10) Aggregates; (11) Urban/Developed; (12) Water **(Figure 6)**. The area of each land cover type was determined for each of the three zones of influence, and a habitat diversity index was calculated based on the Shannon-Weiner Diversity index.

Landcover categories were also determined separately for areas north and south of the Parkway and Highway 401. Sorensen's dissimilarity metric was derived to compare relative habitat composition on either side of the road in order to determine if degree of landcover contrast influences road mortality.

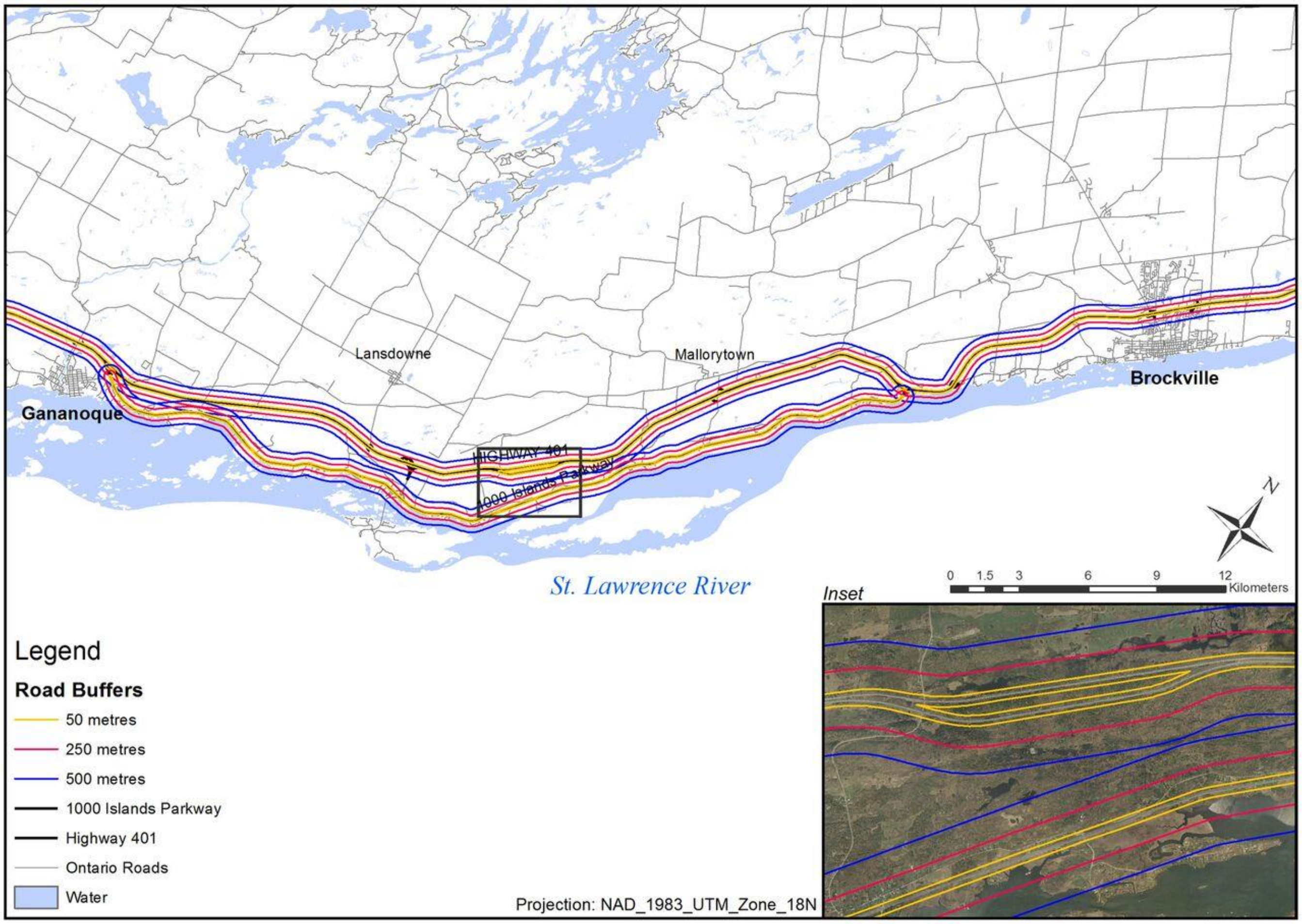

Figure 5. *Illustration of the three buffer sizes (50m, 259m, 500m) used to extract independent data along the 1000 Islands Parkway and Highway 401. The inset map illustrates the three distances superimposed over high resolution aerial photographs (DRAPE – Digital Raster Acquisition Project for Eastern Ontario). Data extracted using the 50 m buffer is considered reflective of the "near road environment". Data extracted using the 250m and 500m buffers reflect broader conditions. (© Ryan Danby)*

Terrain-related variables were extracted from the Ontario Provincial 10m resolution digital elevation (DEM) model. A slope steepness surface was generated from the DEM and the mean and standard deviation of elevation and slope were determined for each of the three zones of influence. The number of buildings in each zone of influence was also determined by conducting a focal area count based on the coverages contained within the 6E10 database.

Landscape connectivity was recently modeled for the Frontenac Arch and surrounding areas by Koen *et al*. (2014). The process used Circuitscape, a software package based on algorithms borrowed from electronic circuit theory. The final map is a current density map with each cell representing the probability of use by moving animals, and tested against fishers (*Martes pennanti*) and reptiles (**Figure 7**). As with the terrain variables, we determined the mean and standard deviation of landscape connectivity in each zone of influence around each point. However, because of the 100 m resolution of the dataset, standard deviation is not particularly meaningful for the 50 m radius analysis extent.

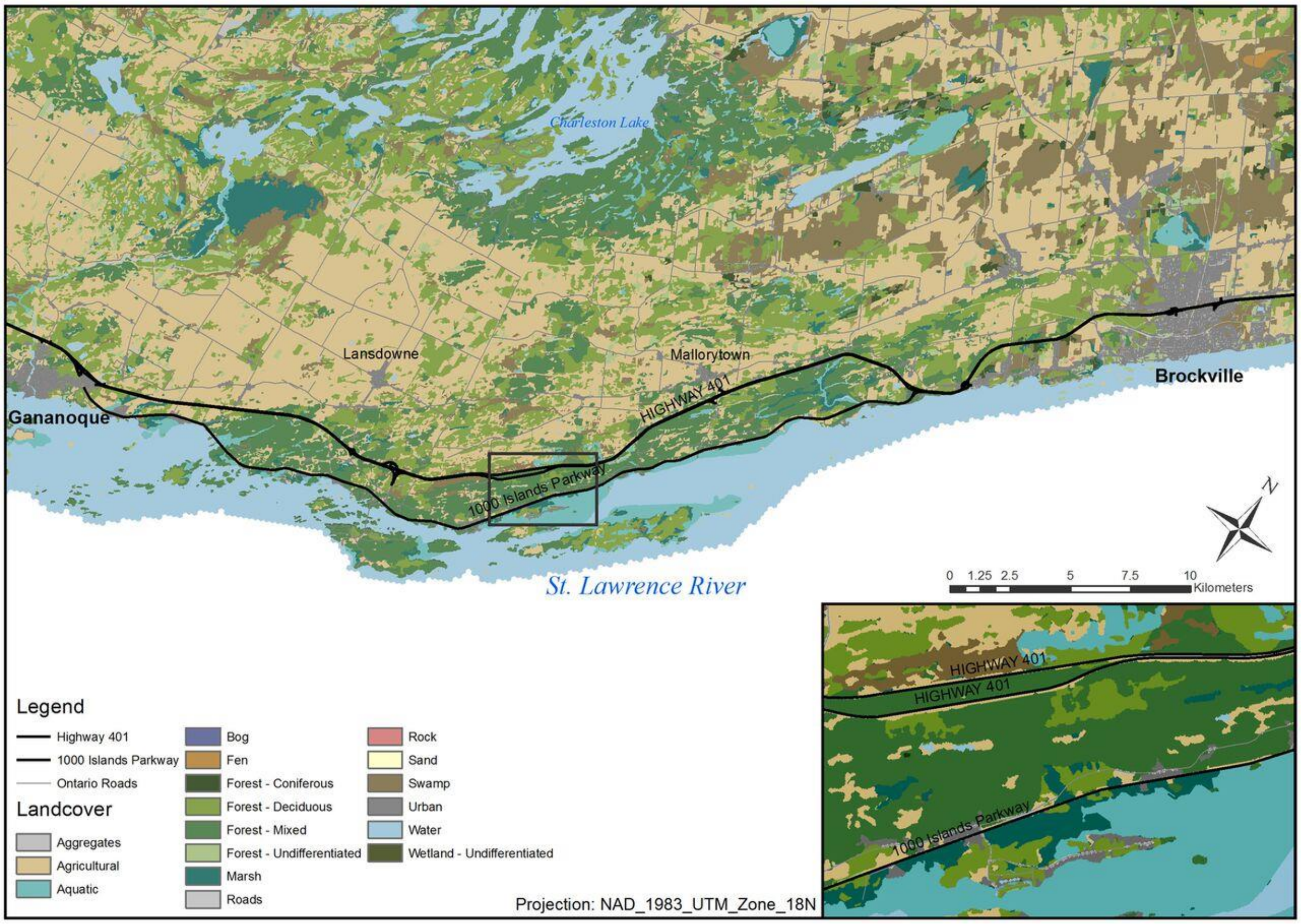

Figure 6. *Distribution of land cover types in the study area. Data were extracted from the "Sustaining What We Value" database for Ecoregion 6E10 (SWWV 2011) and extracted at the focal scales of 50 m, 250m, and 500 m resolution. (© Ryan Danby)*

Three "distance-to" measures were also derived. Distance to forest interior was generated by measuring the Euclidian distance from each point to the forest interior areas identified in the "Val10_ForestInterior100" layer of the 6E10 database. A wetland interior layer is not contained in the database so we generated one ourselves using the "Val7_WetlandCover" coverage and then obtained the measures of Euclidian distance. Finally, Euclidian distance to open water was also calculated and was based on measures from the OHN_Waterbodies coverage accessed through Land Information Ontario (**Figure 8**).

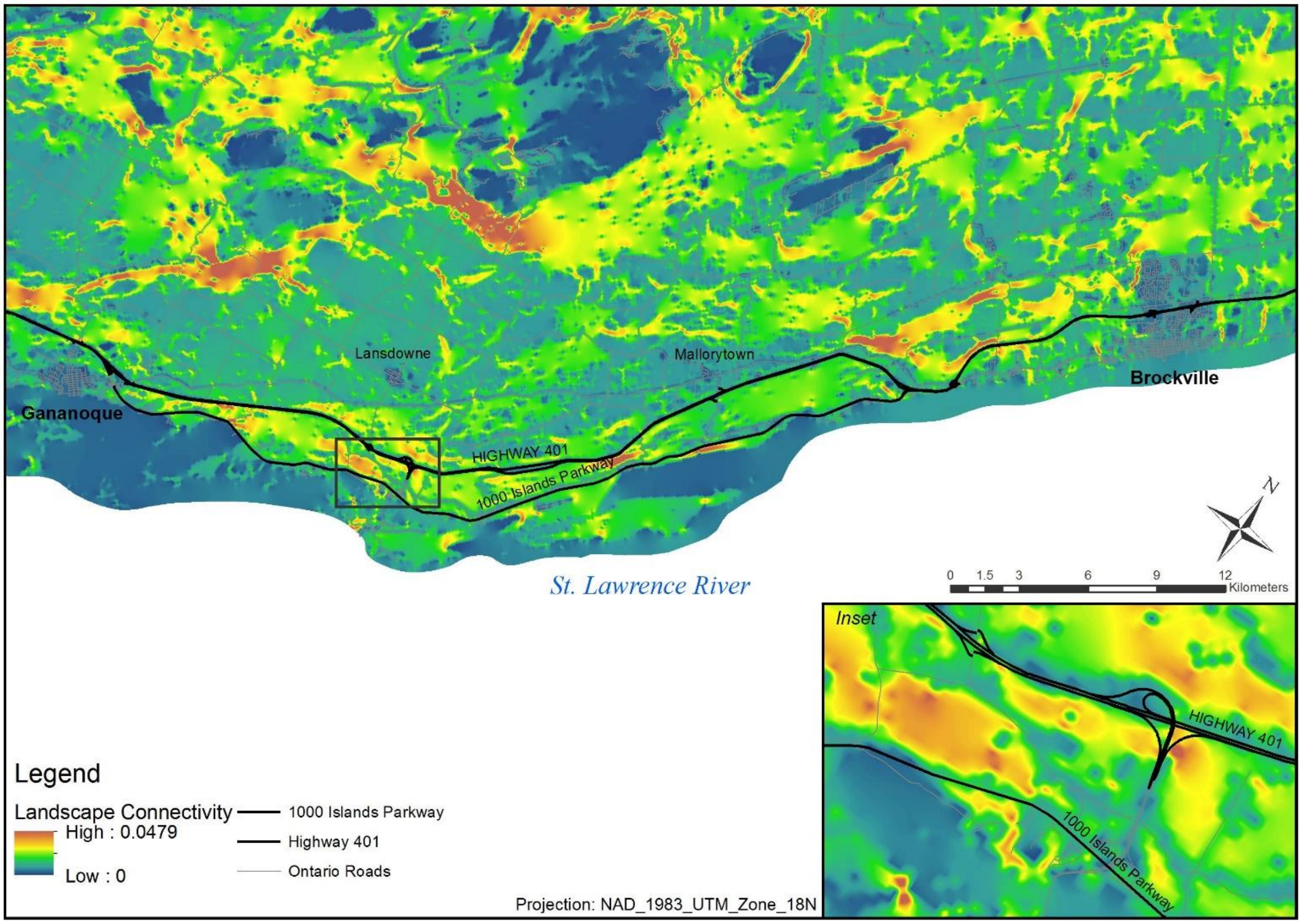

Figure 7. *Landscape connectivity in the study area as mapped by Koen et al. (2014). Mean values and standard deviations were extracted at the focal scales of 50 m, 250m, and 500 m resolution. (© Ryan Danby)*

iv. Independent variables – road features

The second class of independent variables used were road-related variables, representing data about the road itself. These data were obtained from geographically referenced databases available through the Government of Ontario. Culvert locations along the 1000 Islands Parkway and Highway 401 were obtained from the Ministry of Transportation in polyline format; a point field was generated to indicate locations where the roads intersected with the culverts. A 1 metre resolution raster file was then generated to map Euclidian distance to road-culvert intersections (**Figure 9**). An equivalent process was used to generate “distance to” maps for road intersections, as identified from the Ontario Road Network database), and road-waterway locations, as identified from the OHN_Waterbodies data base. In addition to the distance maps, the number of culverts, road intersections, and road-waterway intersections were tallied within the 50m, 250m and 500m radii.

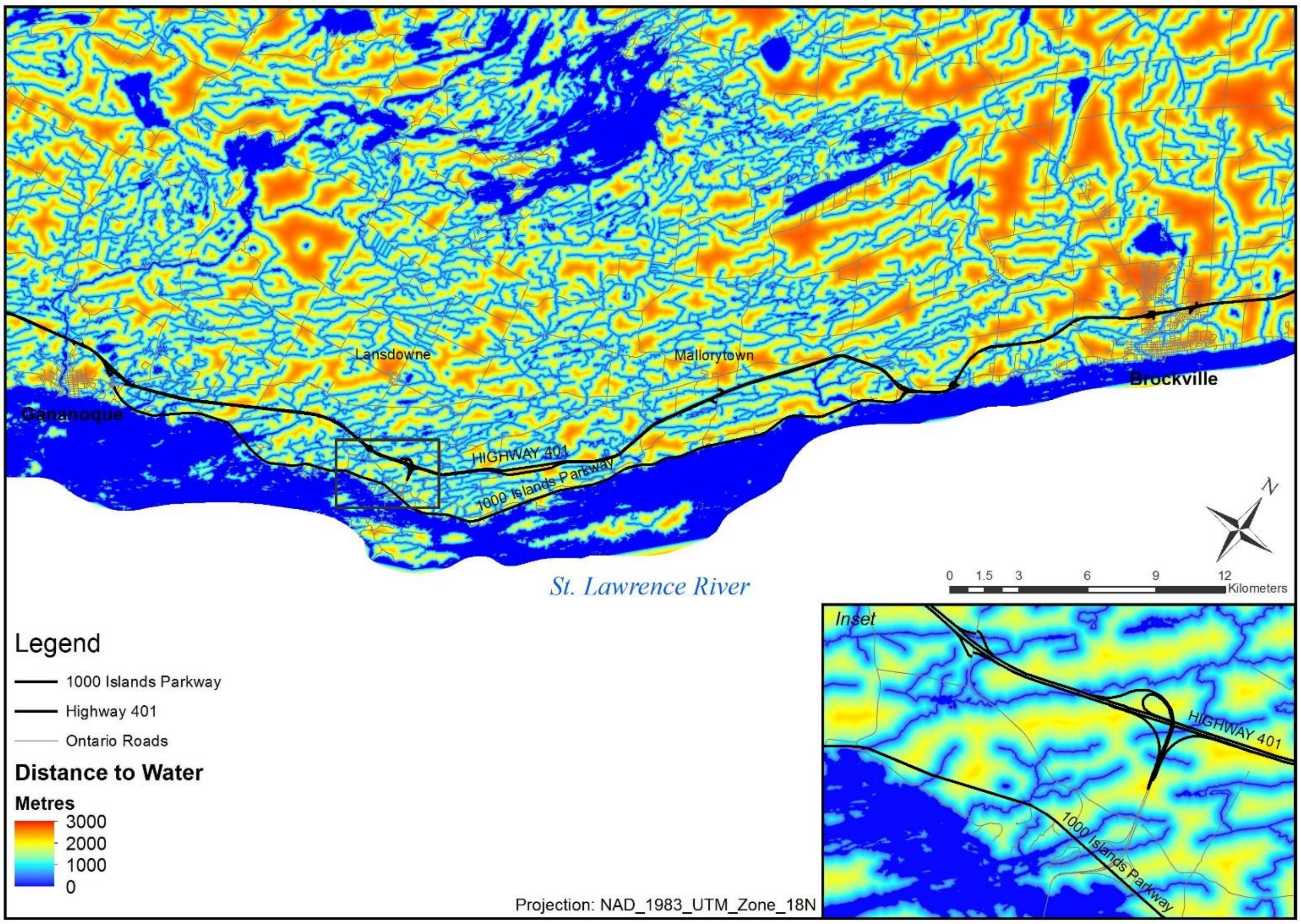

Figure 8. *Euclidian distance to open water in the study area. Similar maps were also derived for distance to interior forest and interior wetland. (© Ryan Danby)*

There has been some suggestion in other studies that curvature of roads may influence road mortality. To test this, we calculated road sinuosity – a measure of how much the road deviates from a straight line – using segment lengths of 50, 250 and 500 metres. Values were extracted at each of the dependent variable locations.

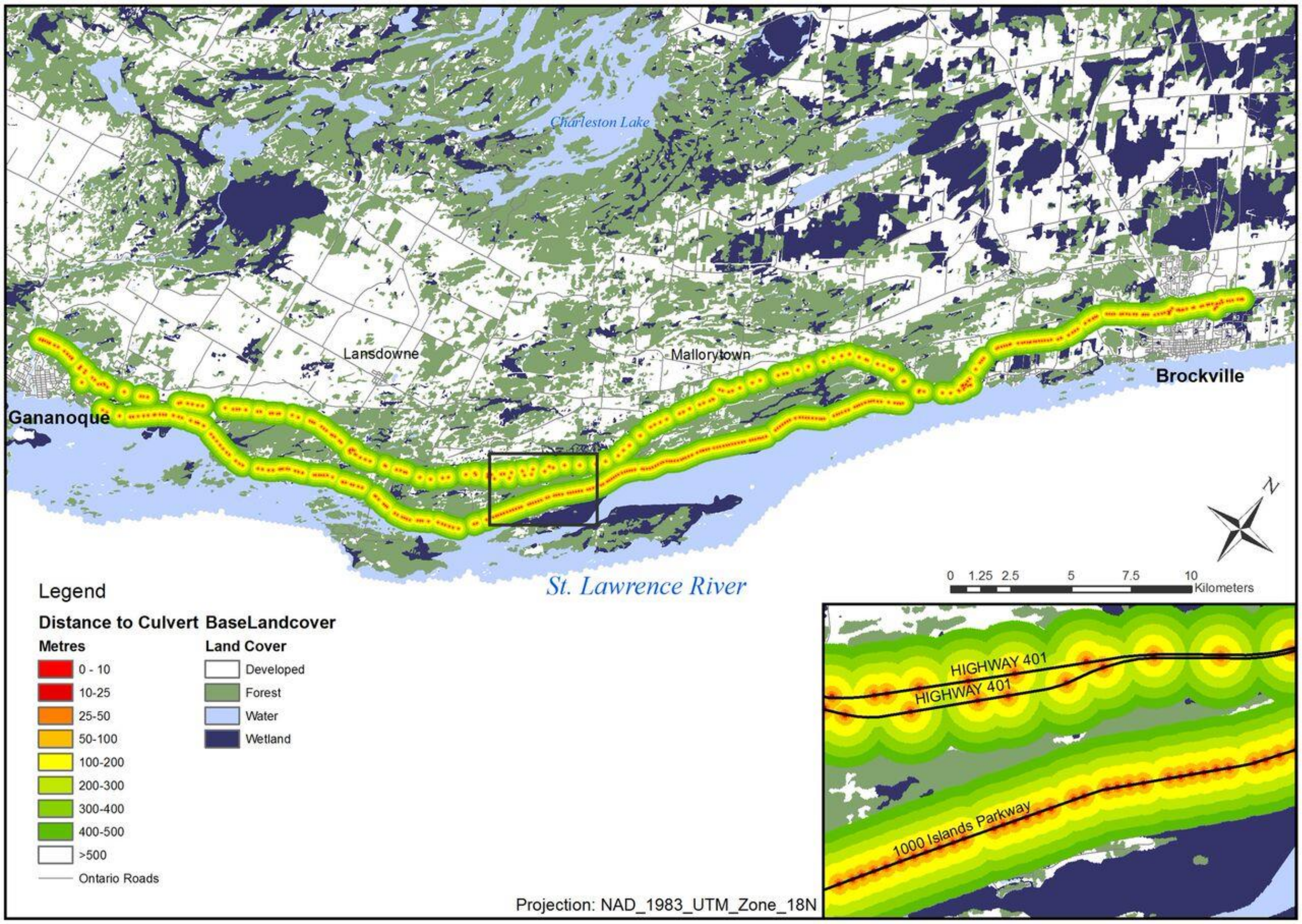

Figure 9. *Euclidian distance to culverts located along the 1000 Islands Parkway and Highway 401. Similar maps were derived for distance to road intersections and distance to points where the roads passed over watercourses and waterbodies. (© Ryan Danby)*

Consultation with the Ministry of Transportation indicated that there is no high resolution mapping of roadsides available for the study area outside of sporadic site plans. We therefore used the 10m DEM to derive a measure of roadside steepness. The road elevation at a given location was identified from the DEM and then divided by the average location within a 50 m radius. In this sense, values less than 1 are indicative of road locations that are lower than their immediate surroundings. Values greater than 1 are higher than their surroundings. The greater the values deviate from 1, the steeper the roadside. This index was also calculated separately for opposite sides of the road (in the same fashion as the land cover metric).

5.1.2 Model Development

Classification and regression tree analysis (De'ath & Fabricius 2000) were used for model development and were constructed using JMP v.11 (SAS Institute, Cary, NC). The possibility of hierarchical interactions (e.g. that wetlands are important, but only when near large bodies of water) and the potential for identifying thresholds in these variables that could be used to help inform management, were the two main reasons this method was chosen.

Classification trees were developed to identify the variables most related to presence or absence (i.e. categorical response) of turtle roadkill and snake roadkill. A minimum node of 5% of all cases was used. Twenty percent of data was withheld for validation purposes and trees were pruned at the point where additional splits failed to yield an increase in the r^2 of the validation data model.

Regression trees were used to identify the variables that are most related to hotspot magnitude (i.e. continuous response) for snakes, turtles, and all vertebrate taxa combined. Regression trees were grown to the point where additional splits yielded no significant model improvement, assessed by examining rate of change in the second order Akaike Information Criterion (AICc). A minimum node size of 10 cases was used to limit tree growth.

There were 90 independent variables for potential use in model development (Appendix II). Steps were taken to reduce this number to a manageable number of biologically meaningful variables. To remove redundancy and reduce collinearity in the data we ran a comprehensive correlation matrix on all remaining predictor variables using Pearson's product-moment correlation. When $r \geq 0.7$ or ≤ -0.7 then variables were inspected and the following rules were used to guide parameter removal:

- Absolute elevation was highly correlated with the amount of wetland at all scales of analysis. We removed absolute elevation since the priority was to focus on habitat variables that influence roadkill.
- Landcover classes were grouped together into three broader classes (water, wetland, forest) at the 50m scale because of a lack of diversity in landcover types at that scale.
- There was high colinearity among most of the water-related and wetland-related variables. We addressed this by focusing on differences between the two sides of the road at the 50m scale rather than on the total amount. At the 250m scale we opted to favour total amount over the relative differences between sides of the road.
- Many variables were highly correlated between scales. For instance, the amount of deciduous forest at 250m was highly correlated with the amount of deciduous forest at 500m. Models

were first developed using only a single scale of analysis, such that there was a separate model developed for local, 50m, 250m, and 500m. However, the 250m and 500m models yielded similar results and we opted to use the 250m scale habitat variables.

For the presence-absence dataset we also compared median values of all predictor variables using Mann-Whitney / Wilcoxon rank test. When values for present and absent locations were significantly different ($p \leq 0.05$) then the variable was retained. When there was no significant difference then the variable was removed from further consideration. This was also completed for turtles positively identified in the field as painted turtles vs. all other species, and for snakes positively identified as watersnakes vs. all other snake species. These species-based analyses were conducted to determine what differences existed between species.

5.1.3 Model Application and Analysis

Regression trees of hotspot importance consistently outperformed the classification trees for presence/absence prediction (as evaluated by regression coefficients, see Results). As such, it was decided that hotspot importance would be the metric predicted for Highway 401. The best performing model for turtles, snakes, and all taxa was applied to a set of regularly spaced locations along Highway 401 to yield maps of predicted hotspot importance. Points were generated at 50 m intervals along the entire length of the Highway 401 study area and the complete suite of independent variables was generated for each point using each of the 4 scales of interest (i.e. 0m, 50m, 250m, 500m). The eastbound and westbound lanes of the 401 were considered as one single road except where the two directions are separated by more than 50m. In those locations the two directions were considered separate roads and discrete sets of points were generated for each.

The regression tree rules developed from the 1000 Islands Parkway were then applied to the set of independent data extracted at each point along Highway 401. The resulting point field was then transformed to a continuous grid using inverse distance weighting (IDW) within ArcGIS. A cell size of 25m was used with a search distance set to the nearest 12 points (typically equivalent to 300m). The analysis extent was set to a 50m buffer applied to the Highway 401line network. The resulting maps of predicted hotspot importance were compared to observed locations of roadkill along Highway 401 during 2014 and 2015 with a view to identifying similarities and differences between the two datasets. All observations from the field surveys were used to generate kernel density maps (250m search radius) of observation density. Map colouration, resolution, and output extent were set identical to the Hotspot Importance maps for the purpose of comparison.

5.2 Field Data Collection

Field researchers surveyed Highway 401 on foot from Gananoque (44.334151N 76.23535W) to Butternut Bay (44.52075N 75.78252W) from May to December 2014 and June to November 2015. Researchers adhered to the Safety and Survey Protocol (Appendix III) and recorded evidence of wildlife/road interactions (e.g. remains/carcasses (i.e. feathers, fur, teeth, bones), prints, scat, nests, and live specimens). Once remains were collected and catalogued, they were discarded in habitat away from roadside shoulders to avoid redundant entries, unless a carcass was on the roadway where researchers were not allowed to enter for safety reasons. In 2014, the survey focused on existing drainage culverts and areas 200 m east and west on both the north and south terminuses. Fieldworkers parked on side roads, bridges and crown land, and walked on highway shoulders on the outside of the guard rail to culverts in accordance with the MTO Encroachment Permit (EC-2014-420-17) that prohibited parking on Highway 401. In 2015, a different approach was taken to achieve a more complete survey of the entire study area. Researchers parked and walked distances between Highway 401 overpasses surveying the entire stretch for signs of wildlife/road interactions on the roadway, shoulder and roadside habitat/ditches. The length of the study area was surveyed on foot a total of three times over the course of the 2015 season.

6.0 PROJECT FINDINGS

6.1 Predictive Model

6.1.1 All Species Hotspot Importance (∑HSI) Model

Six variables were used to build the $\sum HSI$ model (**Figure 10**). The data were initially split on the amount of marsh within a 250m radius (20ha). Locations with more than 45.4% marsh were likely to have an $\sum HSI$ more than twice that of any other location along the 1000 Islands Parkway. The node of the tree with the second highest mean $\sum HSI$ value was based on a two-level split; if the difference in wetland area from one roadside to the other was greater than 11.6% and Shannon landscape diversity

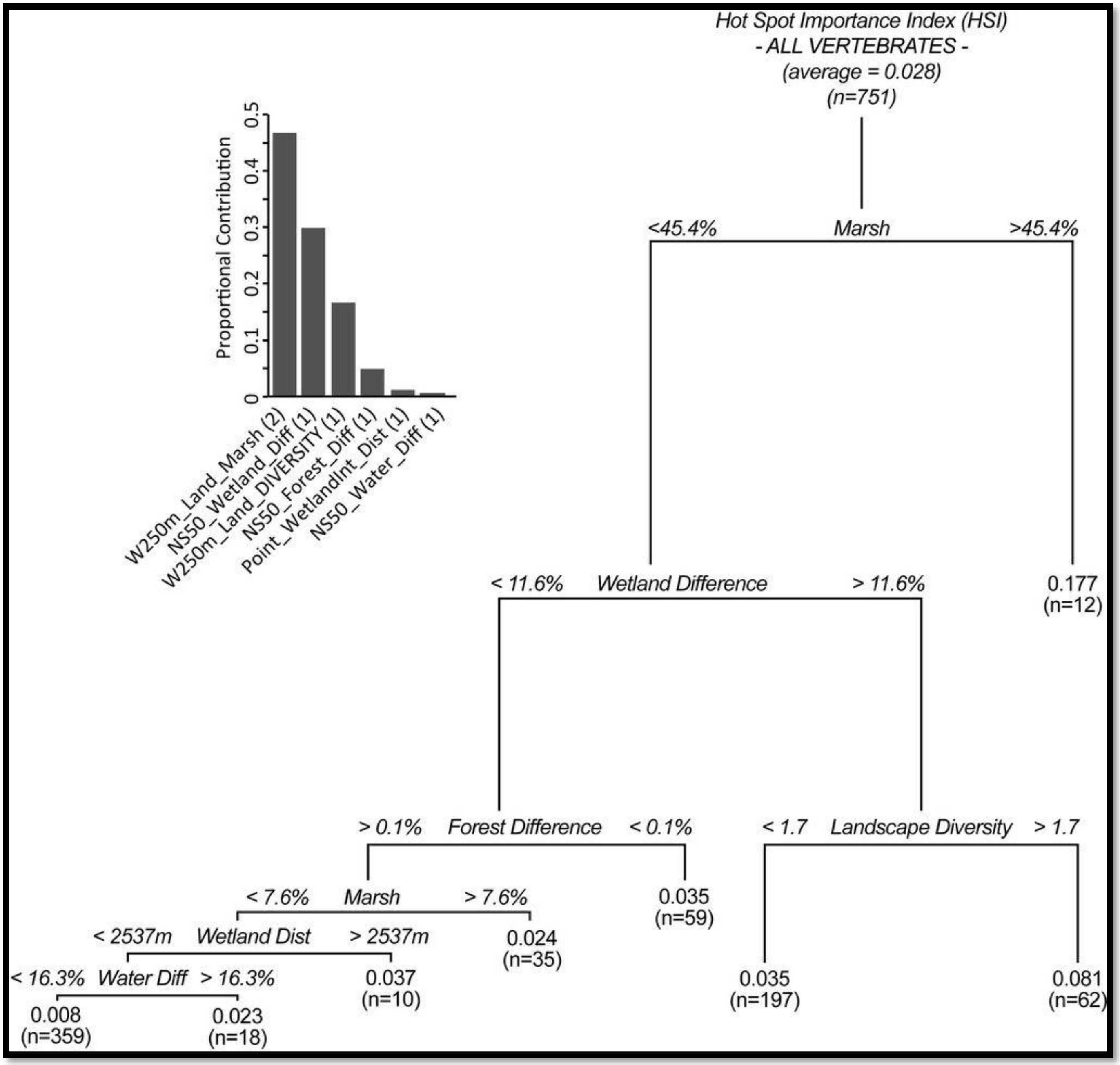

Figure 10. *Hierarchical regression tree describing the variables most related to the hot spot importance (HSI) for all vertebrates on the 1000 Islands Parkway. Starting at the top of a tree, each split is represented as a dichotomy and successive splits partition the data into increasingly homogenous subsets. The length of each tree branch is proportionate to the relative deviance explained by each split in the model. The value at each node (∑HSI) is the mean of all data used to develop the node and, thus, the predicted response based on all criteria above that node. Bar chart at upper left illustrates the proportional contribution of each variable used to the total amount of variance described by the model.*

was greater than 1.7, then $\sum HSI$ averaged 0.81. However, if Shannon landscape diversity was less than 1.7, or if roadside wetland habitats did not differ, then average $\sum HSI$ values averaged 0.37 or less (**Figure 10**). The overall pseudo-r^2 of the model was 0.422.

6.1.2 Turtle Hotspot Importance (HSI_{TURT}) Model

Five variables were used to build the HSI_{TURT} model (**Figure 11**). As with $\sum HSI$, the data were initially split on the amount of marsh within a 250m radius (20ha). Locations with more than 45.6% marsh were likely to have the highest HSI_{TURT}, averaging 0.086. Marsh area was used twice in the model, resulting in a high proportional contribution for this variable (0.68). Shannon landscape diversity was the second variable used to partition the data. In landscapes comprised of less than 45.6% marsh, those with a diversity index greater than 1.8 tended to have a higher HSI_{TURT} than other areas comprised of less than 45.6% marsh (mean 0.053 vs. 0.032). The overall pseudo-r^2 of the model was 0.366.

6.1.3 Snake Hotspot Importance (HSI_{SNAK}) Model

Four variables were used to build the HSI_{SNAK} model (**Figure 12**). Again, proportion of the 20ha landscape comprised of marsh was the most important variable influencing HSI_{SNAK} and the threshold value was similar to the previous two models, with areas comprised of more than 43.9% marsh having the highest HSI_{SNAK} (mean = 0.085). This initial split contributed to over 75% of the explained variance in the model. Areas with less than 43.9% marsh, and with very few roads (<4.2% of the landscape) had the next highest HSI_{SNAK}, averaging 0.041. All other areas averaged just above 0.002.

6.1.4 Species Variability

Results of the Mann-Whitney / Wilcoxon rank test showed that painted turtles had significantly different ($p \leq 0.05$) means for 5 of the 90 initial predictor variables compared to all other species of turtles. In contrast, watersnakes had significantly different means for 43 of the 90 initial predictor variables compared to the other snake species. The final model selected for snakes should be interpreted with significant caution given this high level of difference among snake species. Although there was no significant difference related to total marsh within a 250m radius (the variable with the highest proportional contribution to the model) this is not necessarily surprising since the process of partitioning proceeds with the goal of homogenizing subsets as much as possible. In light of these results, the turtle

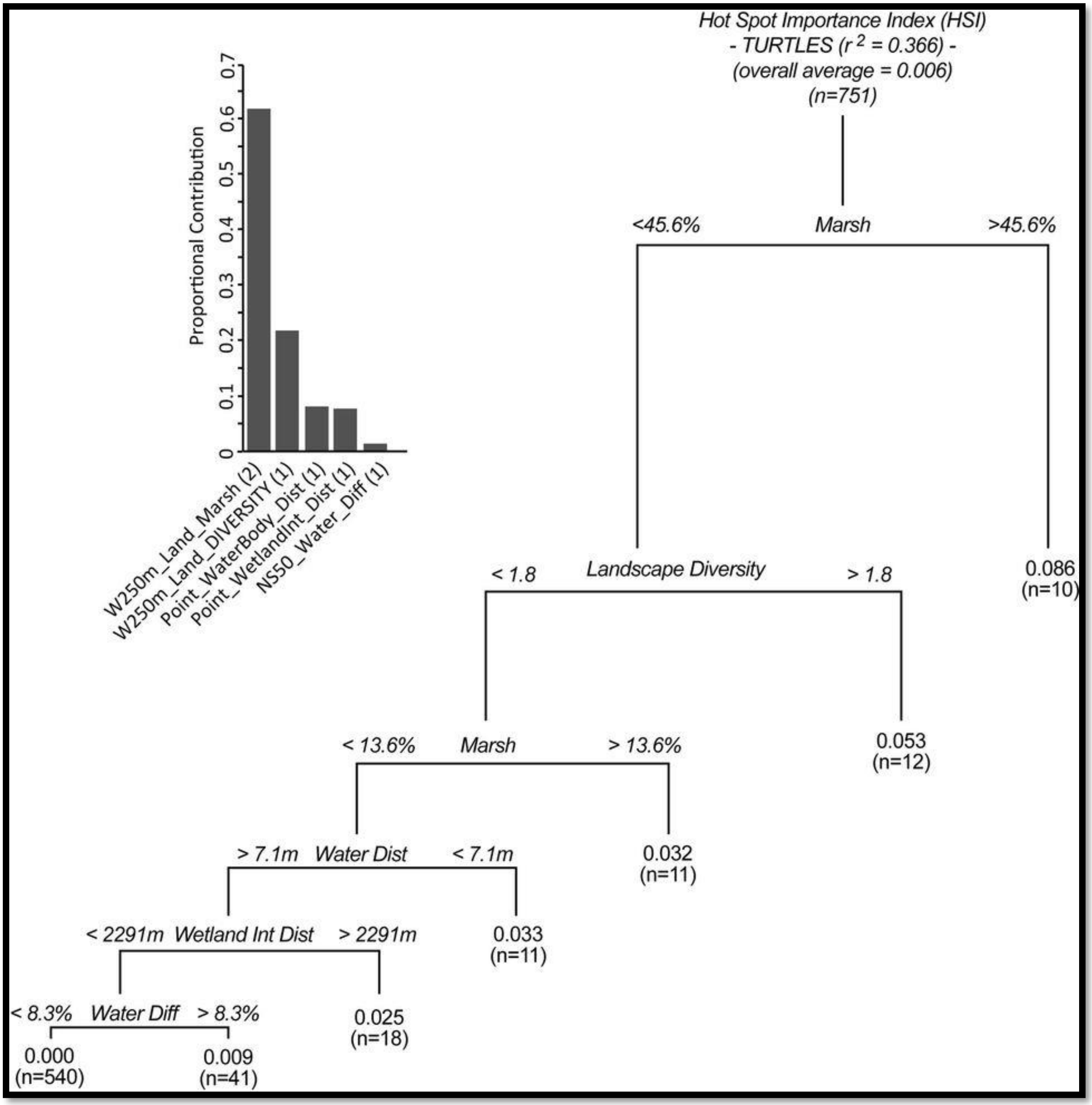

Figure 11. *Hierarchical regression tree describing the variables most related to the hot spot importance (HSI) for turtles on the 1000 Islands Parkway. Starting at the top of a tree, each split is represented as a dichotomy and successive splits partition the data into increasingly homogenous subsets. The length of each tree branch is proportionate to the relative deviance explained by each split in the model. The value at each node (HSI_{TURT}) is the mean of all data used to develop the node and, thus, the predicted response based on all criteria above that node. Bar chart at upper left illustrates the proportional contribution of each variable used to the total amount of variance described by the model.*

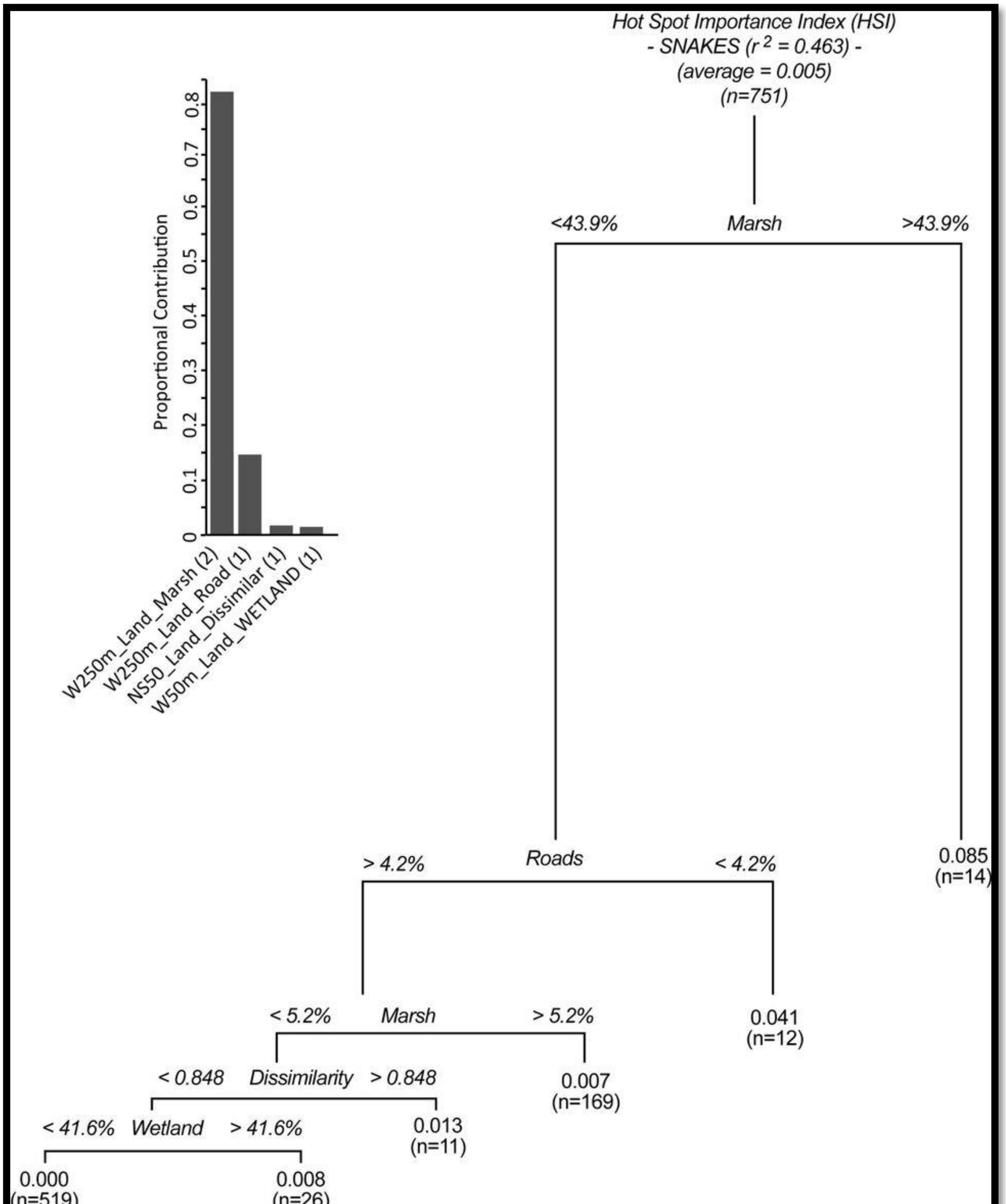

Figure 12. *Hierarchical regression tree describing the variables most related to the hot spot importance (HSI) for snakes on the 1000 Islands Parkway. Starting at the top of a tree, each split is represented as a dichotomy and successive splits partition the data into increasingly homogenous subsets. The length of each tree branch is proportionate to the relative deviance explained by each split in the model. The value at each node (HSI_{SNAK}) is the mean of all data used to develop the node and, thus, the predicted response based on all criteria above that node. Bar chart at upper left illustrates the proportional contribution of each variable used to the total amount of variance described by the model.*

model is a more valid depiction of conditions associated with turtle hotspots than the snake model is for snake hotspots – despite the higher r^2 associated with the snake model. The model developed for snakes may be suitable for an "average" snake, but our analysis indicates that separate models for watersnakes and all other species would be very different from each other. In summary, conditions associated with turtle hotspots vary less between different species than do conditions associated with snake hotspots. Therefore, we proceeded with caution when interpreting predictions of snake hotspots along Highway 401. Future work should focus on generating two separate presence-absence models for watersnakes and all other snakes in order to confirm this.

6.1.5 Model Application to Highway 401 and Comparison with Observations

Regression tree rules for all vertebrate species, as well as for turtles and snakes, were applied to the set of independent points extracted for Highway 401, yielding predictions of $\sum HSI$, HSI_{TURT}, and HSI_{SNAK} for the length of the roadway (**Figure 13**, **Figure 14**, **Figure 15**). Comparison of the predictions with actual observations yielded mixed results for all of the models, with areas of agreement and disagreement apparent.

For snakes, the model underrepresented road kill locations, but had good agreement along the eastbound portion of the divided section of the 401 just east of Escott Road, as well as the section of the highway at Legges Creek, east of Gananoque. For turtles, the model had agreement with the observed areas of high roadkill density at the Gananoque River, Legges Creek, and LaRue Creek. A long stretch of the Highway between Landons Creek and Knights Creek (west of Reynolds Road) was identified as a potential hotspot due to its complex intermixing of wetland and water features. Many non-SAR vertebrates, including Painted Turtles, were found along this stretch during the two years of survey.

For all vertebrates, the model predicted the highest $\sum HIS$ along a short stretch of highway just west of Escott Road. This location is associated with large areas of marsh on either side of the highway and a large concrete bridge-culvert structure connects the two habitats. Several vertebrates were observed on the road in this location, including species at risk snakes and turtles. The entire stretch of road from this location west to Hwy 137 was identified as a significant hotspot from the field observations but $\sum HIS$ values predicted by the model along that stretch were varied. Two other locations of notably high agreement between the model and observations were Legges Creek and the north end of

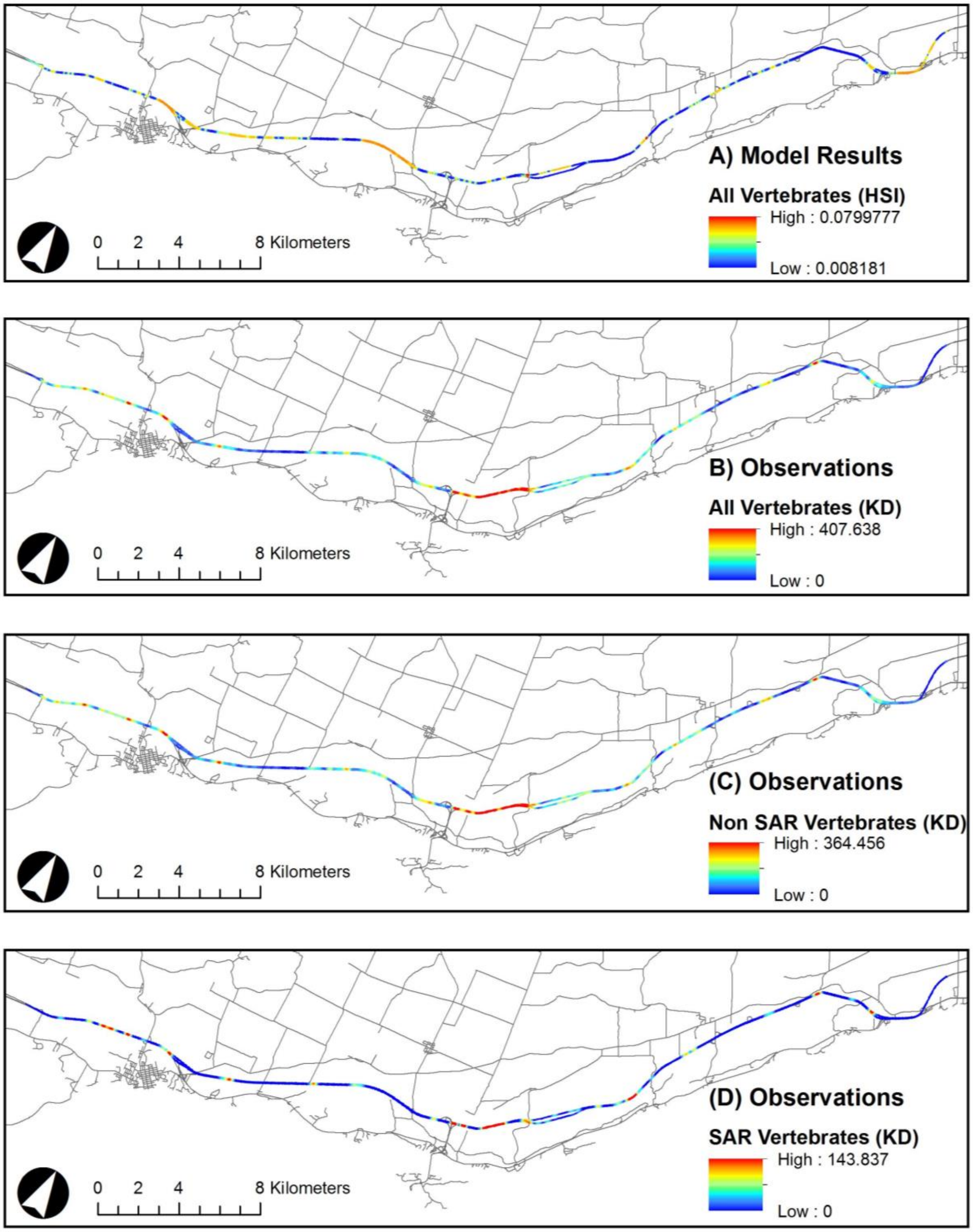

Figure 13. *Comparison of predicted hot spot importance for all vertebrate taxa (turtles, reptiles, mammals, birds, anurans) based on a model calibrated for the 1000 Islands Parkway (A), with kernel density estimates of all vertebrate observations (B), and all vertebrate non species-at-risk observations (C) and all vertebrate species-at-risk observations (D), in 2014 and 2015. (© Ryan Danby)*

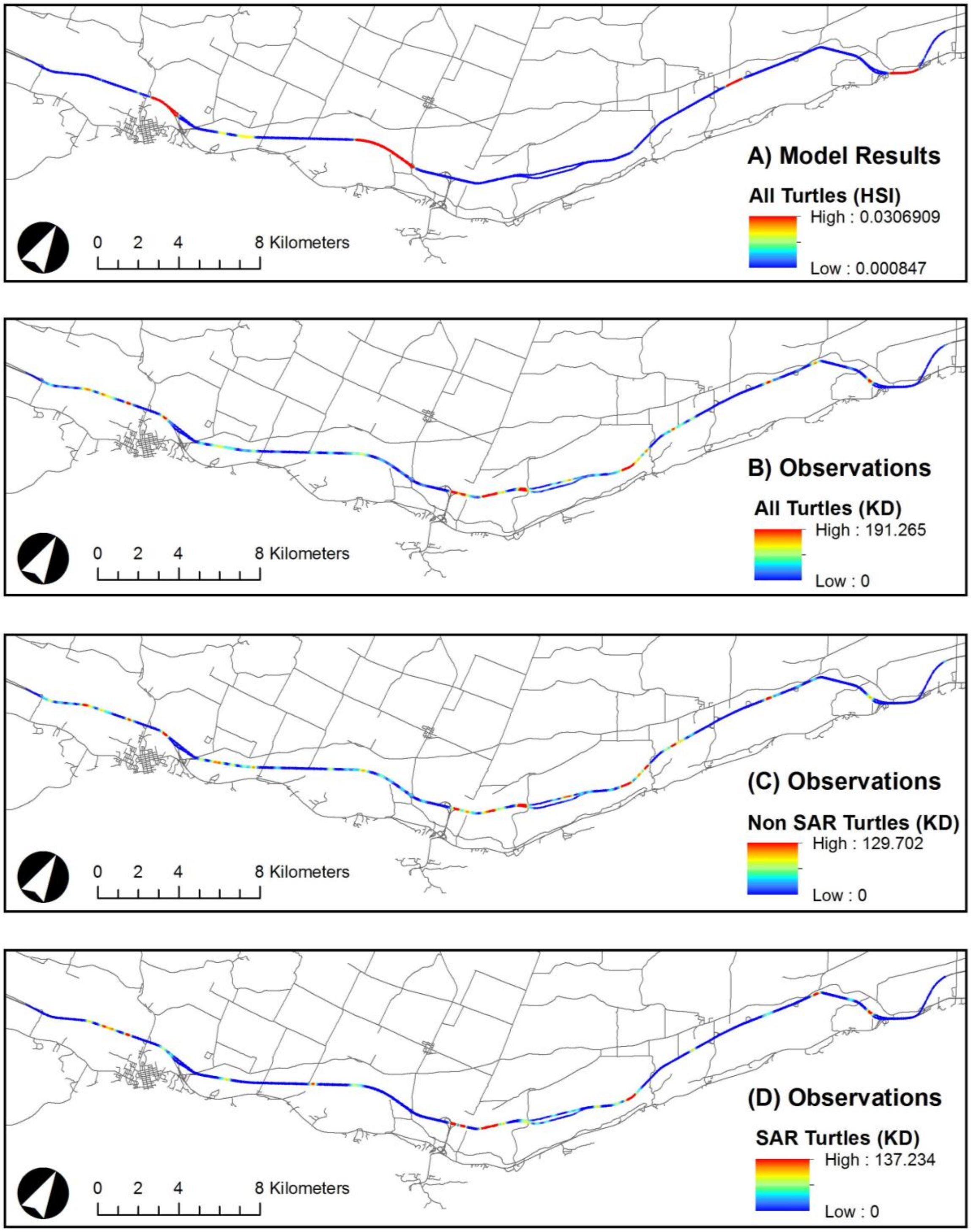

Figure 14. *Comparison of predicted hot spot importance for turtles based on a model calibrated for the 1000 Islands Parkway (A), with kernel density estimates of all turtle observations (B), all turtle non species-at-risk observations (C), and all turtle species-at-risk observations (D), in 2014 and 2015. (© Ryan Danby)*

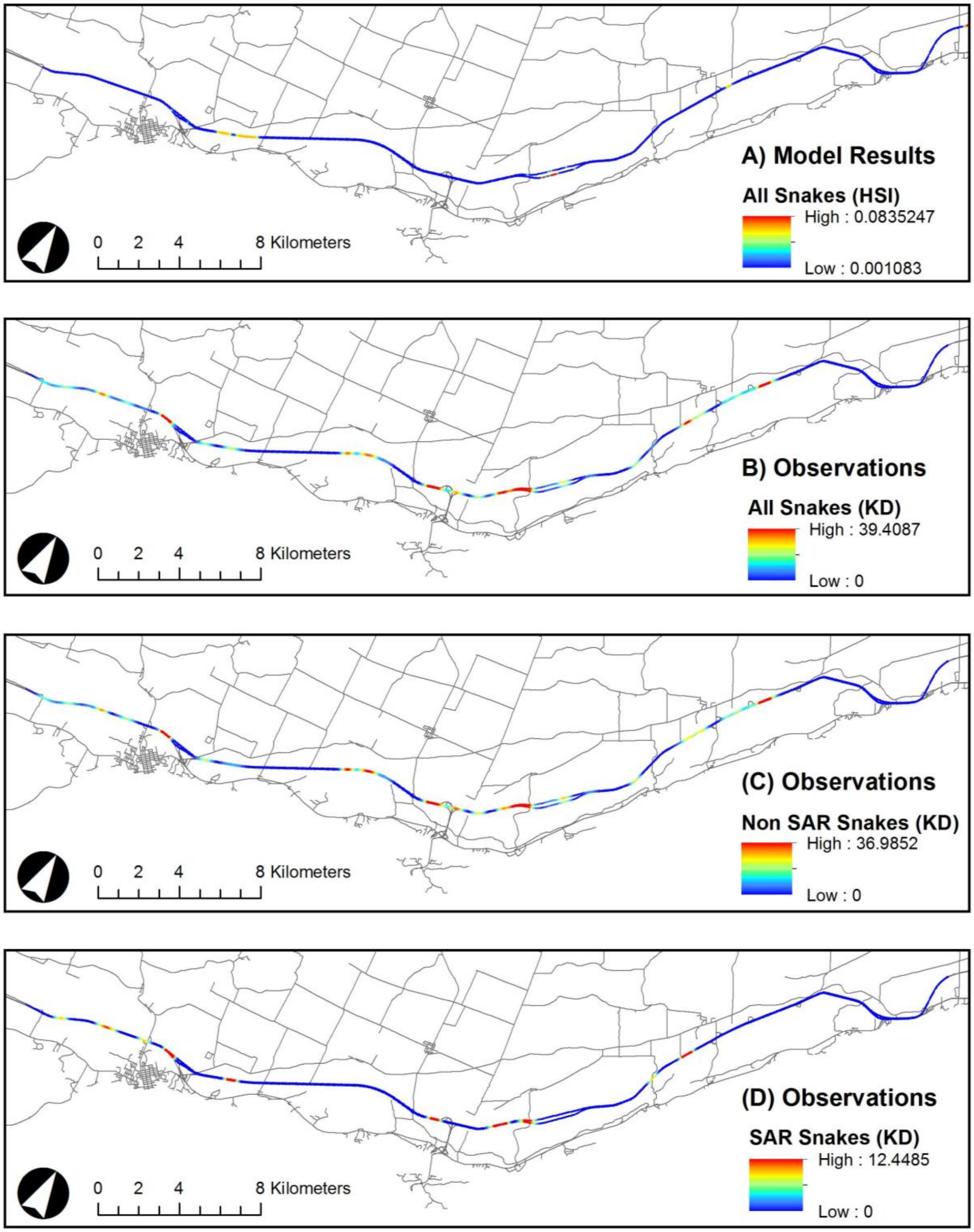

Figure 15. *Comparison of predicted hot spot importance for snakes based on a model calibrated for the 1000 Islands Parkway (A), with kernel density estimates of all snake observations (B), all snake non species-at-risk observations (C), and all snake species-at-risk observations (D), in 2014 and 2015. (© Ryan Danby)*

East Townline Road at Butternut Bay. As with the turtle model, the all vertebrates model predicted that high $\sum HSI$ values would be found between Landons Creek and Knights Creek west of Reynolds Road but this was not an area of particularly high vertebrate observations.

6.1.6 Model Assessment

Overall, there was only moderate agreement between the models and the field observations. There were some areas along Highway 401 where the two agreed, and we believe these areas should be targeted for mitigative measures (see below). However, there are areas where agreement was poor; either because high levels of road mortality were observed but the model did not predict them (underestimation), or areas where the models predicted higher potential for road mortality than what actually was observed (overestimation).

The development of generic models for taxa with multiple species could lead to both over and underestimation. As discussed above, 6 reptile species-at-risk were recorded dead on the 1000 Islands Parkway during the 4 years of study. However, none were recorded in sufficient numbers to be considered separately in model development here and we could not develop statistically robust multivariate models for individual species-at-risk. Instead, models were developed for snakes as a group and turtles as a group. The assumption inherent in this approach is that the general habitat requirements of the different species comprising these groups are similar. However, as we noted above with respect to snakes, analysis of our data indicates that this is a flawed assumption.

Specialization of the model to the 1000 Islands Parkway likely resulted in underestimation. A basic assumption of the modeling component of the study is that the relationships obtained from the 1000 Islands Parkway are applicable to Highway 401. However, the two roads are very different. The 1000 Islands Parkway is a two-lane road with peak seasonal traffic of 4000 vehicles day^{-1}. Highway 401 is a four-lane expressway with peak traffic volume an order of magnitude greater and speed limits that are 20 km/hr higher. Furthermore, because the 1000 Islands Parkway runs immediately adjacent to the St. Lawrence River, the two sides of the road have substantive differences in land cover, while the two sides of Highway 401 are more similar in adjacent land cover and habitat. Interestingly, some measure of landcover difference was used in each of the three models. Moreover, the first split in each model was based around large areas (>40% within a 250m radius) of marshland. The 1000 Islands Parkway has several stretches of road where these conditions are met, and these are where the most significant road mortality hotspots occurred along that roadway. However, Highway 401 has very few of these expansive marshland areas, meaning that only a handful of locations were ever predicted to have the highest possible HSI, which is why underestimation was prevalent. This is an extension of model overfitting, even though we pruned the models to avoid overfitting to the 1000 Islands Parkway data. This is clearly not ideal, but the close proximity of the 1000 Islands Parkway, combined with the availability of its pre-existing detailed data on wildlife road mortality, made it the best available comparison. These differences do not impact generation of the models (i.e. the models serve the 1000 Islands Parkway well), but they are critical to consider when interpreting their predictions on the 401.

Finally, overestimation could be a function of a phenomenon known as "the ghost of roadkill past" (Eberhardt *et al.* 2013). In this scenario, locations predicted to have a high *HSI* but for which there are fewer observations of road mortality actually could have been hot spots at some time in the past, but local species populations are now depressed due to persistent road mortality. The concept is difficult to demonstrate in the absence of historic data but it warrants significant attention. Efforts to connect both sides of a roadway with safe passage structures could help facilitate population restoration at these locations. For this reason, we feel it is important to consider roadkill mitigation measures in areas where the field data may not suggest it, but where the models do.

6.2 Field Data Collection

A total of 550 SAR and non-SAR vertebrates were recorded during 2014 surveys and 576 were recorded during 2015 surveys. Of these, 1066 were recorded as dead on road (DOR) or alive on the road or roadside (AOR) and carried forward for mapping and hotspot analysis (**Figure 16**).

6.2.1 Non-SAR Wildlife/Road Interactions

Non-SAR mammals, reptiles, birds, amphibians and insects were found dead on road (DOR) during the study (**Table I**). In total, 1006 non-SAR vertebrates were recorded, of which 828 were dead (Appendix IV). Counted among confirmed and suspected DOR were six Beaver (*Castor canadensis),* two Eastern Red Bat (*Lasiurus borealis),* two Southern Flying Squirrel (*Glaucomys Volans*), nine Fisher (*Martes pennanti*), 172 Muskrat (*Ondatra zibethicus*), 11 White-tailed Deer (*Odocoileus virginianus*), 29 Coyotes (*Canis latrans*), and one suspected Black Bear (*Ursus americanus*). Among the DOR bird species were two Barred Owl (*Strix varia*), and one Great Blue Heron (*Ardea hrodias*). Among the 165 confirmed and suspected DOR reptiles were 105 Painted Turtle (*Chrysemys picta*), and eight Northern Water Snake (*Nerodia sipedon*). Among the 32 confirmed DOR amphibians were two Spotted Salamander (*Ambystoma *maculatum*), and frogs representing at least three different species. Invertebrates documented on the road included bumblebee, dragonfly, and butterfly species.

Table I. *Non-SAR vertebrate /road interactions (including tracks, burrows, nests, scat) documented on Highway 401 between Gananoque and Brockville in 2014 and 2015. Individuals not recorded as dead on road (DOR) were found alive on the road or roadside.*

Taxa	DOR	Total
Mammal	566	596
Birds	65	93
Reptiles	165	275
Amphibians	32	42
Total	**828**	**1006**

Table Ia. *Non-SAR mammal species. Individuals not recorded as dead on road (DOR) were found alive on the road or roadside.*

Common Name	Confirmed ID	DOR	Suspected ID	DOR	Total	Total DOR
Unknown	165	163	0	0	**165**	**163**
Muskrat	142	141	31	31	**173**	**172**
Raccoon	60	58	8	8	**68**	**66**
Porcupine	45	44	2	2	**47**	**46**
Coyote	24	22	8	7	**32**	**29**
White-tailed Deer	19	9	3	2	**22**	**11**
Lagomorph (Rabbit & Hare)	12	11	0	0	**12**	**11**
Squirrel	9	7	2	2	**11**	**9**
Weasel	9	9	0	0	**9**	**9**
Mouse/Rat/Rodent	7	4	0	0	**7**	**4**
Beaver	6	4	2	2	**8**	**6**
Skunk	5	5	0	0	**5**	**5**
Fisher	4	4	5	5	**9**	**9**
Southern Flying Squirrel	2	2	0	0	**2**	**2**
Eastern Red Bat	2	2	0	0	**2**	**2**
Vole	2	1	0	0	**2**	**1**
Stoat	2	2	13	12	**15**	**14**
American Mink	2	2	0	0	**2**	**2**
Groundhog	1	1	1	1	**2**	**2**
Gopher	1	1	0	0	**1**	**1**
Marten	0	0	1	1	**1**	**1**
Black Bear	0	0	1	1	**1**	**1**
Total	**519**	**492**	**77**	**74**	**596**	**566**

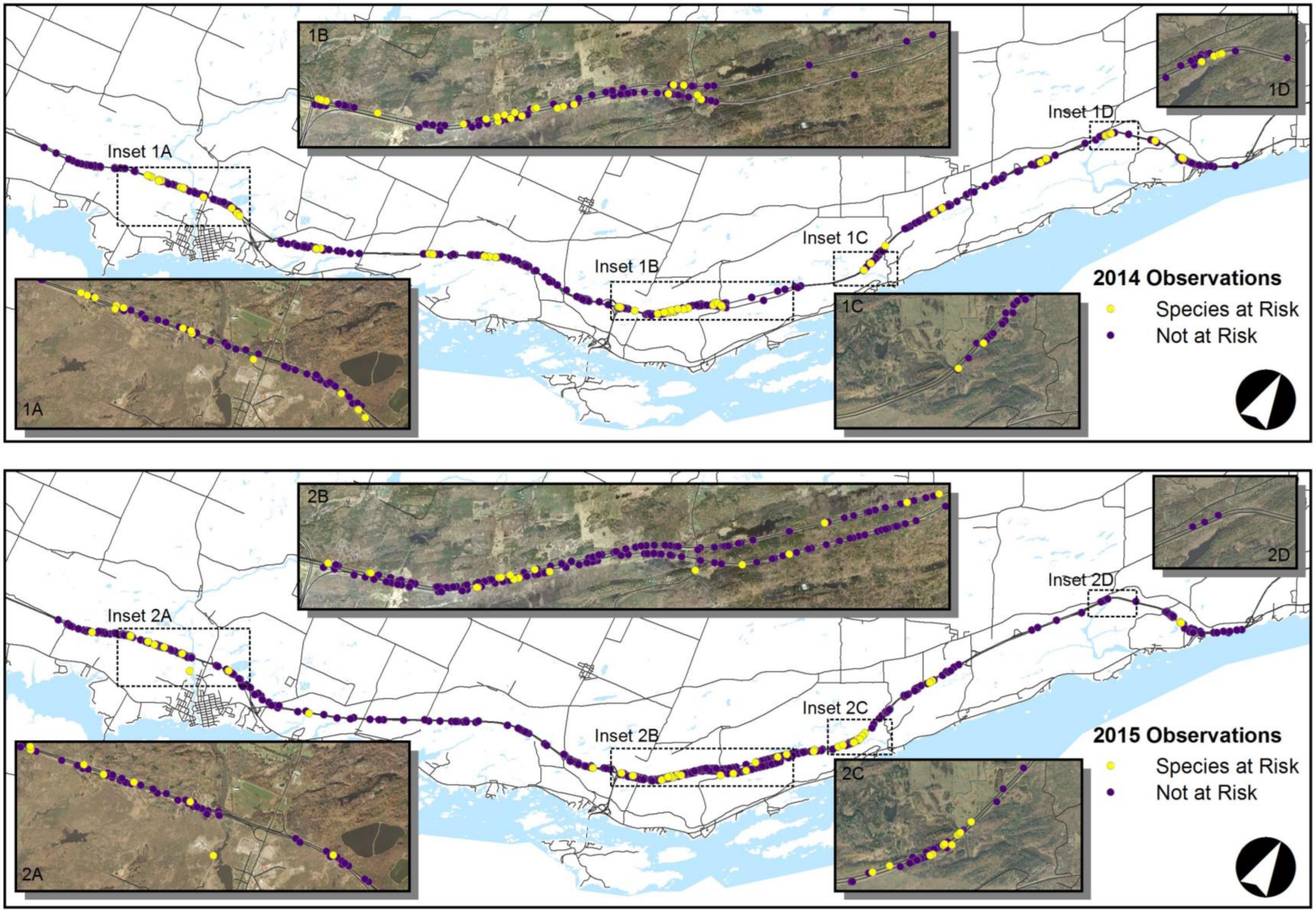

Figure 16. *Distribution of vertebrate observations on Highway 401 in 2014 (top) and 2015 (bottom). (© Ryan Danby)*

Table Ib. *Non-SAR bird species. Individuals not recorded as dead on road (DOR) were found alive on the road or roadside.*

Common Name	Confirmed ID	DOR	Suspected ID	DOR	Total	Total DOR
Unknown	16	14	0	0	**16**	**14**
Duck	14	5	2	2	**16**	**7**
Corvidae (Crow Family)	8	8	0	0	**8**	**8**
Turkey Vulture	7	0	0	0	**7**	**0**
Ruffed Grouse	5	5	4	4	**9**	**9**
Red-winged Black Bird	5	5	0	0	**5**	**5**
Great Blue Heron	4	1	0	0	**4**	**1**
Wild Turkey	4	1	1	1	**5**	**2**
Canada Goose	3	3	2	2	**5**	**5**
Ring-billed Gull	3	3	1	1	**4**	**4**
Barred Owl	2	2	0	0	**2**	**2**
Osprey	2	0	0	0	**2**	**0**
Common Yellowthroat	2	2	1	1	**3**	**3**
Red-tailed Hawk	2	0	0	0	**2**	**0**
Cedar Waxwing	1	1	0	0	**1**	**1**
Blue Jay	1	1	0	0	**1**	**1**
Ovenbird	1	1	0	0	**1**	**1**
Canada Warbler	1	1	0	0	**1**	**1**
Morning Dove	1	1	0	0	**1**	**1**
Total	**82**	**54**	**11**	**11**	**93**	**65**

Table Ic. *Non-SAR amphibian species. Individuals not recorded as dead on road (DOR) were found alive on the road or roadside.*

Common Name	Confirmed ID	DOR	Suspected ID	DOR	Total	Total DOR
Green Frog	14	8	0	0	**14**	**8**
Bullfrog	11	10	0	0	**11**	**10**
Leopard Frog	6	6	0	0	**6**	**6**
Unknown Frog	6	5	0	0	**6**	**5**
Spotted Salamander	2	2	0	0	**2**	**2**
Toad	1	0	0	0	**1**	**0**
Eastern Newt	1	1	1	0	**2**	**1**
Total	**41**	**32**	**1**	**0**	**42**	**32**

Table Id. *Non-SAR reptile species. Individuals not recorded as dead on road (DOR) were found alive on the road or roadside.*

Common Name	Confirmed ID	DOR	Suspected ID	DOR	Total	Total DOR
Painted Turtle	105	104	5	5	**110**	**109**
Garter Snake	75	2	1	1	**76**	**3**
Unknown Turtle	41	36	0	0	**41**	**36**
Dekay's Brown Snake	18	5	1	1	**19**	**6**
Northern Water Snake	16	7	0	0	**16**	**7**
Unknown Snake	9	3	0	0	**9**	**3**
Red-bellied Snake	2	0	0	0	**2**	**0**
Smooth Green Snake	2	1	0	0	**2**	**1**
Total	**268**	**158**	**7**	**7**	**275**	**165**

6.2.2 SAR/Road Interactions

Herpetofauna SAR were the target species of the study. Within the 51 km length of the study area along Highway 401, 120 SAR herpetofauna were recorded, of which 97 were found dead (**Table II**) during the 2014 and 2015 field seasons. Meshing the raw SAR data (Appendix V) with information gleaned from the predictive model resulted in mapping that identified three definite SAR herpetofauna hotspots (**Figures 16 & 17).**

Monarch Butterfly, *Danaus plexippus*, were also recorded during the study (status: Species of Special Concern; Total observed = four DOR).

Hotspot I: A hotspot was identified east of the Highway 137 interchange on the north side of Highway 401 (between: 44.38248, -75.98255 & 44.38411, -75.97530, **Figure 17**). There is a wetland on the north side of the highway that provides suitable SAR turtle habitat. Seven DOR Snapping Turtle (five in 2014 and two in 2015) as well as four Snapping Turtle nest activities were recorded in 2014. There are two culverts within this hotspot (MTO ID: 002204010001, a corrugated steel pipe (CSP) culvert; 101.7 m in length, and MTO ID: 002204010002, a rigid frame open (RFO) culvert; 105.3 m in length, Appendix VI – MTO Culvert Data).

Table II. *SAR herpetofauna data recorded along Highway 401 between Gananoque and Brockville in 2014 and 2015. Individuals not recorded as dead on road (DOR) were found alive on the road or roadside (AOR).*

Species	**2014**				**2015**				**Total**
	AOR	DOR	Shed Skin	Nest Activity	AOR	DOR	Shed Skin	Nest Activity	
Blanding's Turtle	0	3	-	0	1*	2	-	0	**6**
Eastern Ribbonsnake	1	1	0	-	0	0	0	-	**2**
Gray Ratsnake	0	1	1	0	1	1**	0	-	**4**
Milksnake	7	2†	1	0	4	0	1	0	**15**
Snapping Turtle	1	49	-	0	0	38	-	5	**93**
Total	**9**	**56**	**2**	**0**	**6**	**41**	**1**	**5**	**120**

Note: * This Blanding's Turtle was found on Escott-Rockport Rd. just 100 m south from the east-bound Hwy 401 overpass. ** This Gray Rastsnake was found dead in the grass beside the highway due to mowing. † One Milksnake was found on Escott-Rockport Road between the east-bound and west-bound lanes of the Highway 401 overpasses.

Hotspot II: A hotspot was identified east of Darlingside Drive to west of Escott-Rockport Road (between: 44.38718, -75.96538 & 44.39374, -75.95478, **Figure 17**). This hotspot stood out as the area of highest priority to mitigate based on Project field data and the predictive model. In total, twenty-seven SAR representing four SAR species were documented within this one kilometre stretch of Highway 401 (**Table III**). There is Provincially Significant Wetland habitat to the north and south of the highway at this site, and there are three culverts. In the middle of the hotspot is a concrete box culvert (MTO ID: 00230401003, 73 m in length) and there are two CSP culverts, one on each side of the concrete box culvert (MTO ID: 002304010002, 57 m in length & 002304010004, 64 m in length).

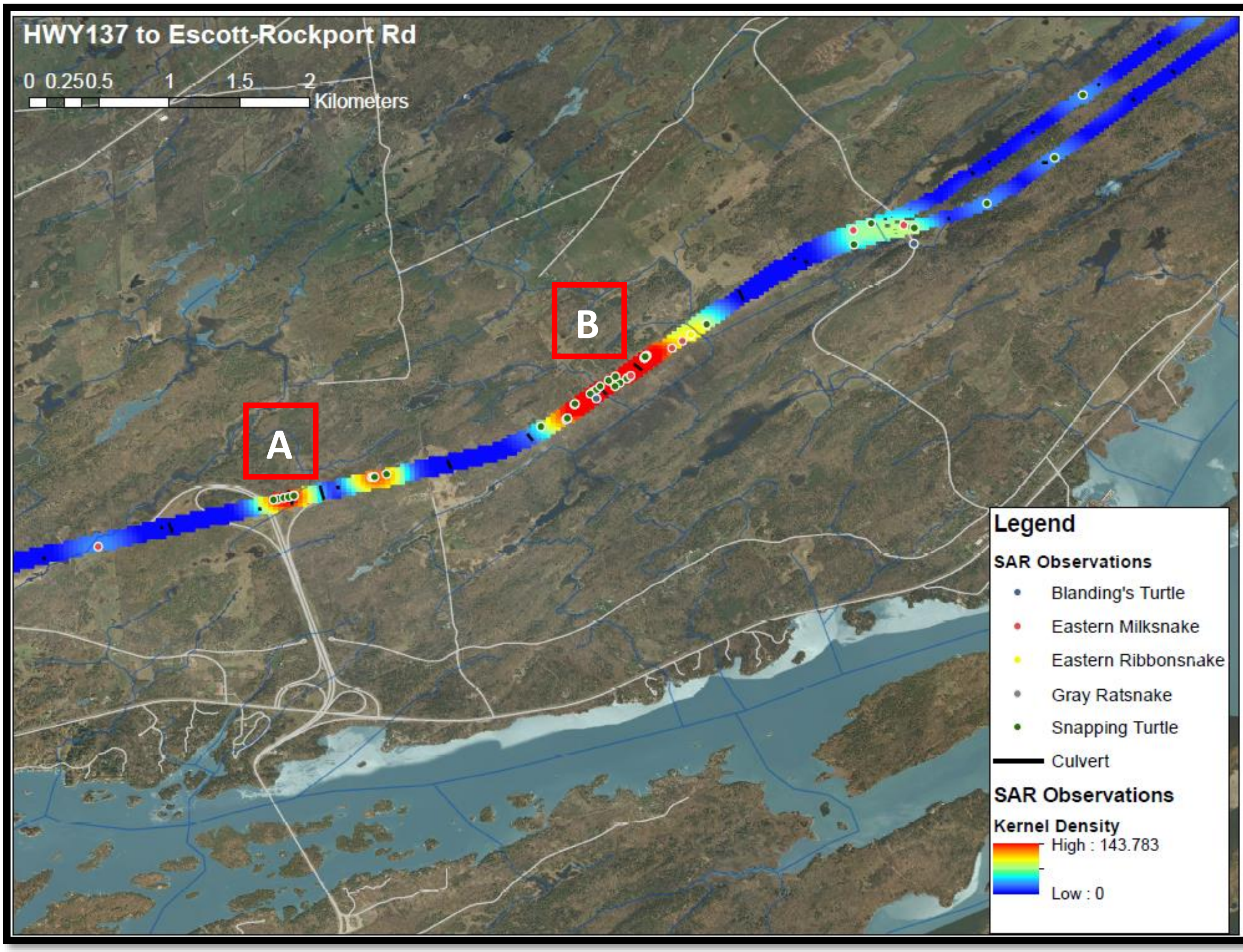

Figure 17. *SAR Herpetofauna Hotspots I (A) and II (B) between the Highway 137 interchange and Escott-Rockport Road. (© Ryan Danby)*

Table III. *SAR herpetofauna data from Hotspot II on Highway 401 between Darlingside Drive and Escott-Rockport Road.*

Species	2014		**2015**		
	AOR	DOR	AOR	DOR	**Total**
Blanding's Turtle	0	1	0	0	**1**
Eastern Ribbonsnake	1	0	0	0	**1**
Milksnake	2	0	1	0	**3**
Snapping Turtle	0	12	0	10	**22**
Total	**3**	**13**	**1**	**10**	**27**

<u>Hotspot III</u>: A hotspot was identified (**Figure 18**) one kilometre west of where Highway 401 crosses LaRue Creek (between 44.42678, -75.90150 and 44.43384, -75.89458). There is a Provincially Significant Wetland complex on the north and south side of the highway at this site. Ten DOR Snapping Turtles were documented in 2015. There are two CSP culverts within this hotspot (MTO ID: 002304010016 & 002304010017). The habitat under the LaRue Creek Bridge (**Figure 19**) is characterized by steep rocky slopes.

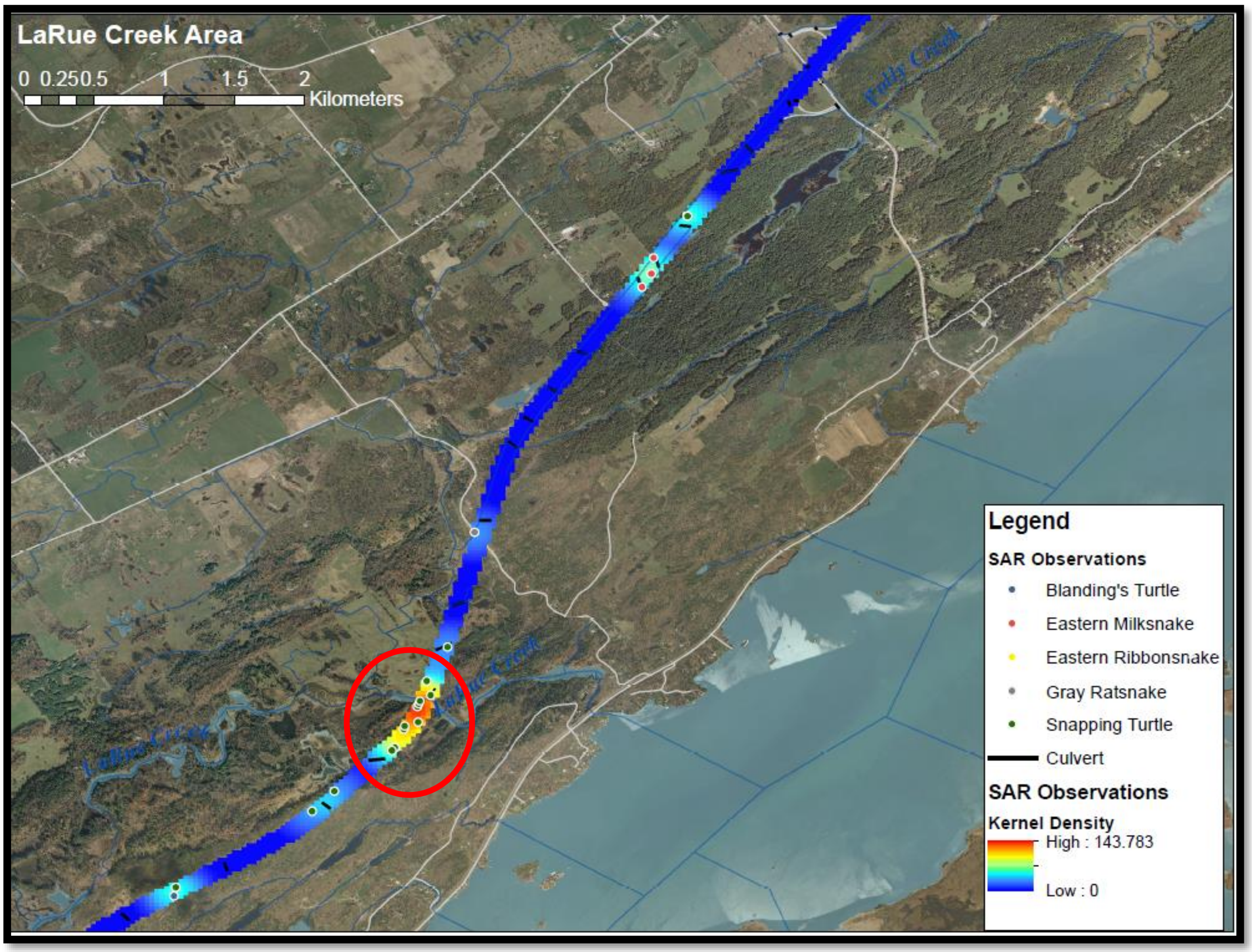

Figure 18. *SAR herpetofauna Hotspot III located at the LaRue Creek crossing (red circle). (© Ryan Danby)*

Figure 19. *LaRue Creek Bridge. (© Clayton Shearer)*

6.3 Areas of Concern

There were segments within the study site that the predictive model yielded moderate hotspot index values and where Project data suggest that mitigation could benefit SAR. In total, there were four areas of interest, and one area of predictive interest, worth considering when examining large-scale habitat connectivity within the Frontenac Arch.

Gananoque River Crossing:

Within two kilometres west and two kilometres east of the Gananoque River crossing four SAR herpetofauna species numbering 20 individuals were documented (**Table IV**). The model and raw field data indicate several sites within this segment of Highway 401 that were areas of concern with a moderate kernel density. Of the two most prominent areas of concern in this segment, one was located to the east of the Gananoque River Crossing, and one to the west (**Figure 20**). Fencing to culverts on the north and south sides of the highway may be a suitable mitigation option to help protect SAR in this area. Gray Ratsnakes (a climbing species) were present and fencing design details should target this SAR (please see Climbing Snake Mitigation protocol – Appendix VII). The installation of fencing would keep this species off the road, but may pose a barrier to habitat connectivity if culverts are not used to cross the highway. Project findings (i.e. of the four Gray Ratsnakes documented during the study one was found dead on a highway overpass and one shed skin was found on an overpass) suggest that this species is more likely to use structures that facilitate climbing over the highway than using a culvert to pass under the highway (versus for example Blanding's Turtle that will move through culverts under the road).

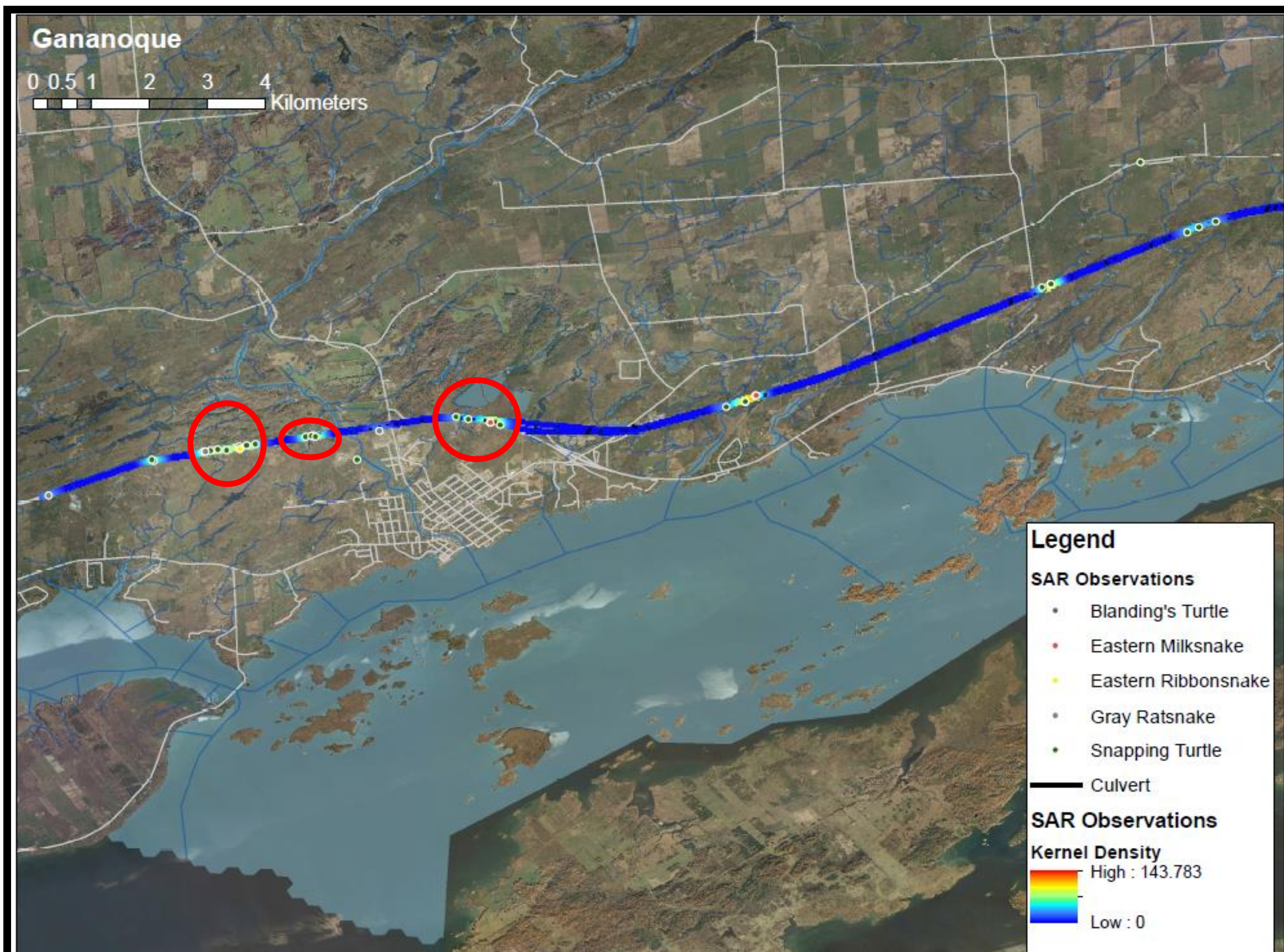

Figure 20. *Gananoque area of concern map. Red circles indicate areas of concern based on field observations and the predictive model. (© Ryan Danby)*

The Gananoque Waterfront Trail – Lions Loop crosses under the Gananoque Bridge on the east side (**Figure 21**). The path width and substrate are suitable for wildlife to cross and nest, but pedestrian traffic may deter wildlife from using the path. A dedicated wildlife corridor separate to the recreational path may be beneficial here as well as a dedicated wildlife corridor under the bridge on the west side of the Gananoque River. The river bank on this side slopes steeply to the water, perhaps a retaining wall could be installed to allow a level path to be established along this side of the river bank.

Table IV. *SAR herpetofauna data from within two kilometres east and two kilometres west of the Highway 401 Gananoque River crossing in 2014 and 2015 field seasons.*

	2014		**2015**		
Species	**AOR**	**DOR**	**AOR**	**DOR**	**Total**
Eastern Ribbonsnake	0	1	0	0	**1**
Gray Ratsnake	0	1	1	0	**2**
Milksnake	3	0	0	0	**3**
Snapping Turtle	1	9	0	4	**14**
Total	**4**	**11**	**1**	**4**	**20**

Figure 21. *Gananoque River Bridge showing the Gananoque Waterfront Trail on the river's east side. (© Clayton Shearer)*

<u>West of Highway 137</u>

The one area of concern of predictive interest, where the computer model indicated there should be a strong presence of SAR and other turtles, but the field data did not support this is immediately west of Highway 137. The predictive model identified a possible hotspot at this location (highlighted in Figures 13 & 14, Map A). It is worthwhile to focus on this area in future monitoring, even though at this point field data have not confirmed it as a hotspot.

Escott-Rockport Road Overpass

The predictive model and field data indicate that there is an area of concern from the Escott-Rockport Road overpass to approximately 300 m west (**Figure 22**). Snapping Turtle (three DOR in 2014), Milksnake (one DOR in 2015) and Blading's Turtle (one AOR in 2015) were all found within the area and there is wetland habitat north, south and within the median of the highway. A box culvert (> three metres in size) connects the wetland complex. Mitigation (e.g. fencing) would be worthwhile for SAR protection along this segment of the study area.

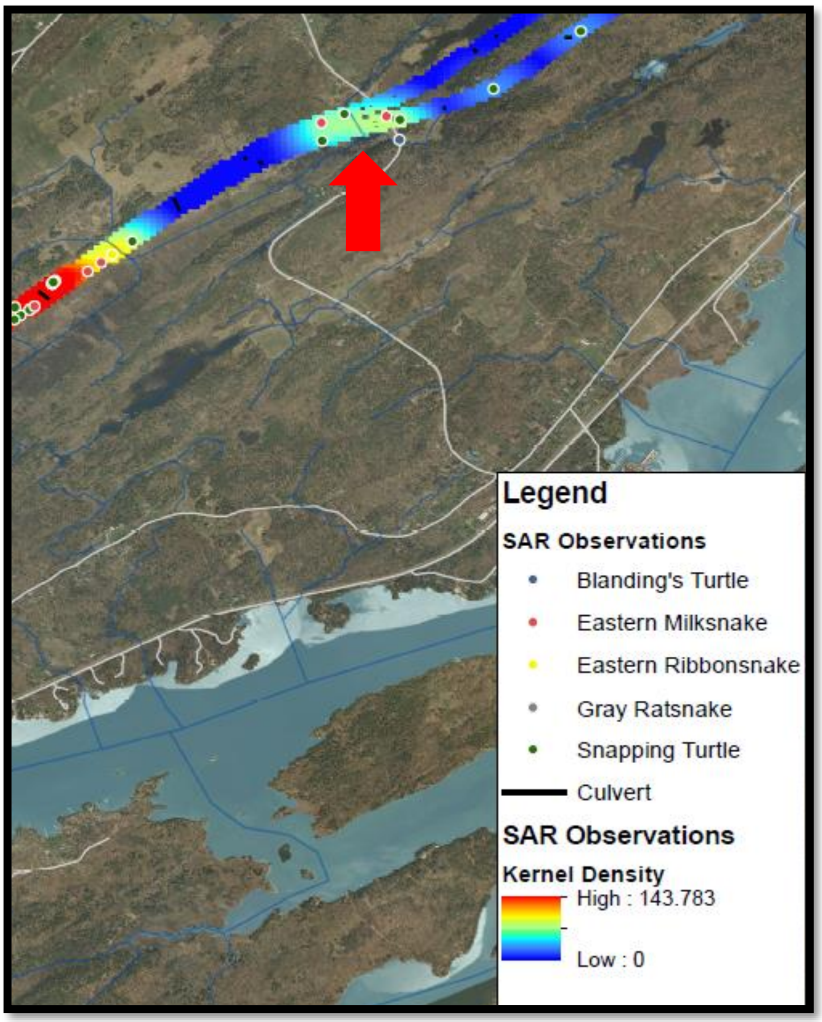

Figure 22. *Area of concern at the Escott-Rockport Road overpass on Highway 401 (red arrow). (© Ryan Danby).*

Jones Creek to Butternut Bay

Where Highway 401 crosses Jones Creek (**Figure 23**) two Blanding's Turtle and three Snapping Turtle were all found DOR in 2014 within approximately 200 m of one another (**Figure 24**). East of Lyn Creek (**Figure 25**) is another area of concern as indicated by the model and Project data (four DOR Snapping Turtle: two in 2014 and two in 2015).

Figure 23. *Jones Creek underpass at Highway 401. (© Clayton Shearer)*

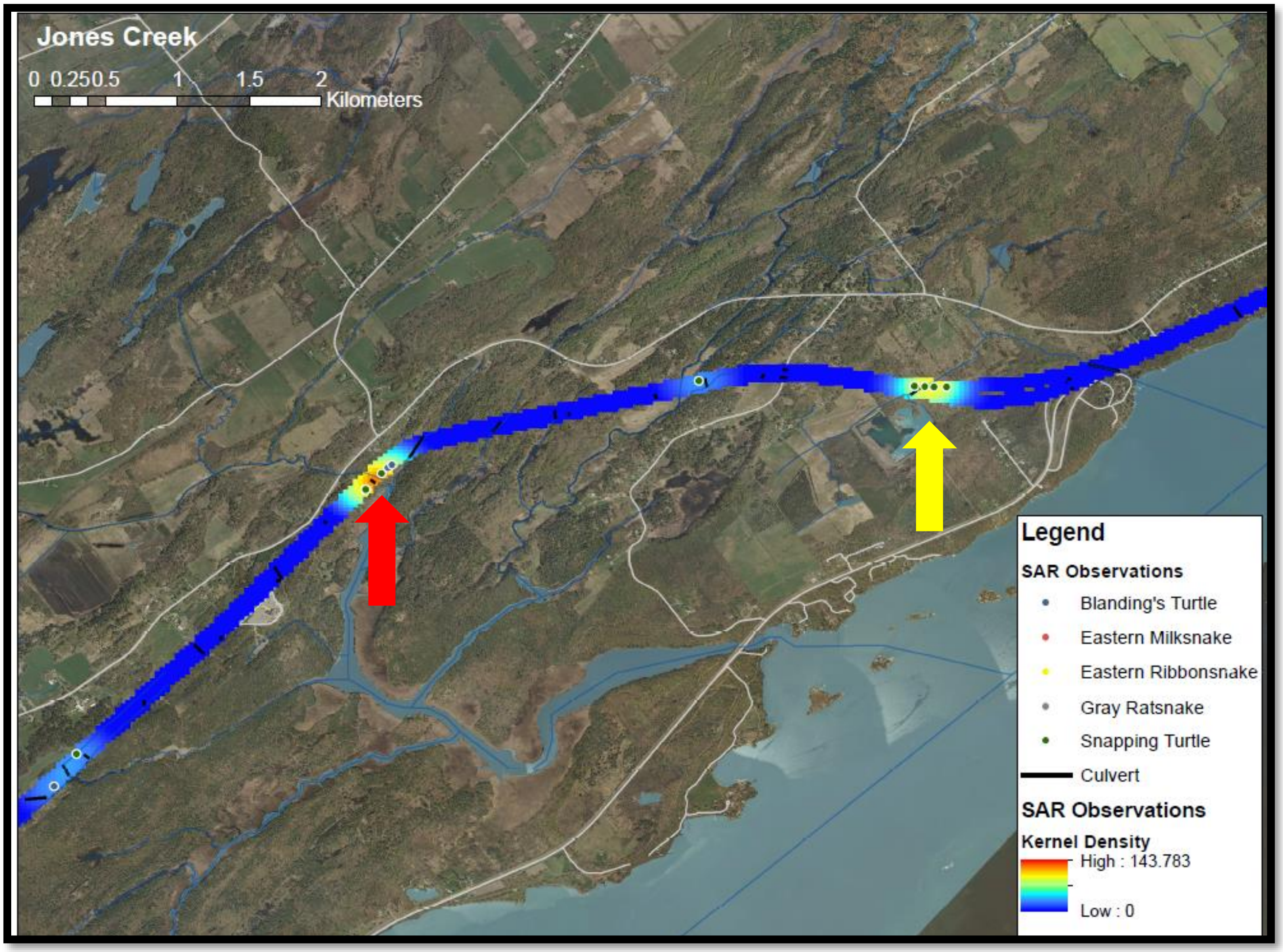

Figure 24. *Two areas of concern along Highway 401 (Jones Creek - red arrow, and east of Lyn Creek - yellow arrow) as indicated by Project data and the predictive model. (© Ryan Danby)*

Figure 25. *Highway 401 crossing over Lyn Creek. (© Clayton Shearer)*

7.0 HOTSPOT MITIGIATION RECOMMENDATIONS

7.1 Mitigation Measures

Large-scale habitat connectivity is the ultimate goal for protecting SAR and helping in their recovery, as well as for protecting non-SAR wildlife, maintaining a robust level of biodiversity in the Frontenac Arch, and improving driver safety on Highway 401. In the meantime, strategies are necessary to lessen mortality among target SAR herpetofauna. Therefore, we recommend:

1. A preliminary mitigation strategy where field data and the predictive model indicate hotspots. Mitigation should consist of:
   - fencing
   - creation of nesting beaches
   - installation of light shafts in medians
   - creating pathways under bridges
   - revising mowing practices to avoid killing SAR herpetofauna
   - retrofitting culverts where immediately feasible
   - maximizing opportunities for undertaking improvements during routine highway maintenance and repair

2. Longer-term strategies of:
   - widening spans of bridges
   - retrofitting culverts to provide more suitable dedicated wildlife culverts
   - finalizing the identification of connectivity corridors
   - creating one or more wildlife overpasses
   - improving habitat

Specific details of each strategy will need to be discussed and approved by OMNRF, MTO, and the Project Team.

7.2 Specific Hotspot Mitigation Recommendations

We recommend that fencing be installed at Hotspot I, II, and III to guide wildlife to culverts. There are examples where MTO has done this to protect SAR turtles (e.g. Highway 24 in Brant County, Highway 7 east of Peterborough – please see Case Study Box). Properly designed fencing works. There are documented cases of turtles using culverts after being directed there by fencing (**Figure 26**). The design for fencing should target Snapping Turtles because of their tendency to climb. Fence ends should curve back into the habitat to avoid creating hotspots at either end. If a culvert does not extend across a median, fencing should be added to guide target SAR herpetofauna to the culvert under the opposing traffic lanes.

If a culvert extends across a median, the potential to add light shafts should be considered to create a more attractive environment inside the culvert and to promote successful wildlife crossings.

Figure 26. *Snapping Turtle moving through using a drainage culvert on Highway 7. (© Eco-Kare International)*

Case Study Box: Highway 7, Hastings County, Ontario

Species at Risk turtle hotspots were identified and treated with temporary geotextile exclusion fencing in 2012. In 2015, one kilometre of permanent fencing was installed to pre-existing drainage culverts at the primary hotspot (Image1). Animex® Reusable Animal Exclusion Fencing was the chosen product because it is:

- Animal safe - No netting or mesh to cause entrapment or lacerations
- Low maintenance – Withstands vegetation clearance impacts
- Manufactured from recycled & post-consumer materials
- Comprised of a solid barrier - Can be perforated to allow water flow
- UV stabilized for 10+ years
- Durable and reusable
- Recycled at end of life – no land fill
- One-way escape options
- Available in safety orange, white, black and more.
- Multiple species exclusion
- Modular system
- No residual materials left on site (no metal clips or hog rings)

Image 1. Animex® fencing installed on Highway 7 to protect SAR Turtles. (© Eco-Kare International)

Hotspot I: Fencing (approximately 650 m in length) is recommended east of the Highway 137 interchange on the north side of Highway 401 (between: 44.38248, -75.98255 & 44.38411, -75.97530, **Figure 17**, **Figure 27**) to direct wildlife to the two culverts within the recommended mitigation area.

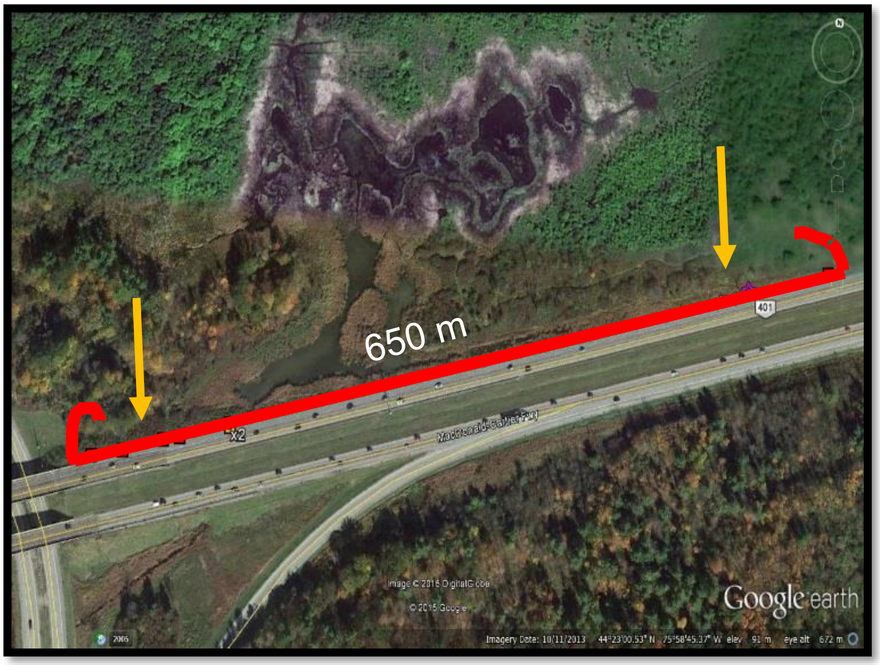

Figure 27. *Proposed mitigation fence location (red) and nesting beach habitat (orange arrows) to prevent target SAR turtles from entering the road at Hotspot I.*

Turtle nesting habitat creation is also recommended here based on the nesting activity documented in 2014. We suggest two sites, one near 44.38283, -75.98185 where the six DOR Snapping Turtle were recorded, and one near 44.38394, -75.97613 where the nesting activity was found. South-west facing slopes in secure areas (i.e. away from human recreation trails, etc.) should be selected for nesting habitat. (For guidelines, please consult the Toronto Zoo's Turtle Nesting Beach Design protocol).

It should be noted that MTO has scheduled bridge rehabilitation for this coming summer on the Highway 137 overpasses (Southern Highways Program 2015-2019). In proceeding with this work, MTO should consider the data presented in this report to ensure protection of local SAR, and to maximize habitat enhancement opportunities.

Hotspot II: Mitigation efforts are highly recommended east of Darlingside Drive to west of Escott-Rockport Road (between: 44.38718, -75.96538 & 44.39374, -75.95478, **Figure 17**). As the area of highest priority to mitigate within the study area, we recommend one kilometre of fencing on both the north and south side of the highway (**Figure 28**). Fencing should guide wildlife to the three culverts within the site. The middle culvert (MTO ID: 00230401003) is a concrete box culvert and may be the most suitable (existing) passageway for wildlife.

Figure 27. *Recommended location for mitigation fencing (in red) for Hotspot II.*

<u>**Hotspot III**</u>**:** A hotspot was identified (**Figure 18**) extending west from the Highway 401 bridge over LaRue Creek for about one kilometre. We recommend one kilometre of fencing on the north and south sides of the highway that will direct wildlife to two CSP culverts (MTO ID: 002304010016 & 002304010017, **Figure 29**).

Wildlife pathways should be created on each side of LaRue Creek under the Highway 401 bridge, and nesting beach habitat for SAR turtles should be added to both the north and south sides of the creek east of the bridge (44.43383, -75.89486 and 44.43370, -75.89394 respectively). The habitat under the LaRue Creek Bridge is not suitable for turtle nesting due to the lack of direct sunlight.

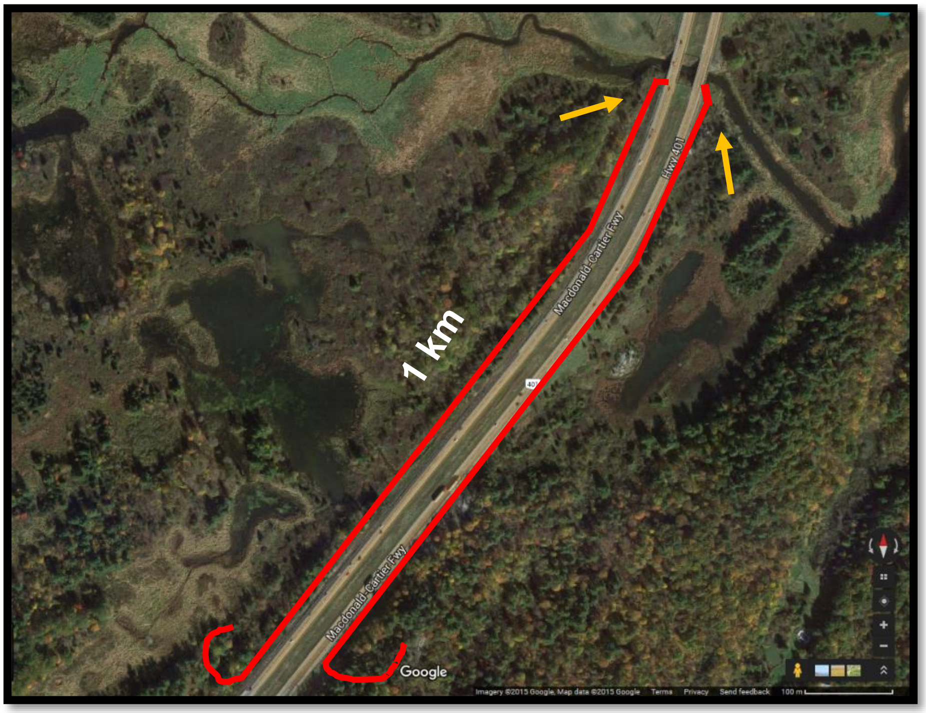

Figure 29. *Recommended fencing (in red) and nesting beach creation locations (yellow arrows) for Hotspot III.*

The areas of concern are priority sites that merit further monitoring of habitat availability and quality as well as SAR/road interactions to assess future mitigation measure needs. If closer examination of these sites support the model and Circuitscape predictions of good habitat availability and high probability of use by moving animals, even if current wildlife/road interactions are low, these sites could prove critical to mitigate to help restore SAR populations that have been reduced by past traffic-related mortality (Eberhardt *et al*. 2013).

7.3 Monitoring of Mitigation Measures

Monitoring mitigation measures following installation is necessary to ensure the strategy is functioning as intended to achieve the goals of : 1) reduction in road mortality; 2) maintenance of habitat connectivity and access to critical habitats; 3) maintenance of dispersal routes and continuity of metapopulation processes; 4) prevention of prey-trap formation; 5) preservation of habitat quality, including minimization of habitat loss; and 6) preservation of gene flow throughout populations (Baxter-Gilbert and Litzgus 2014). Monitoring should assess how wildlife are responding to the strategy (i.e.

using/avoiding the structures) and if maintenance is required (i.e. ensure fencing is intact with no gaps for wildlife to escape onto the road or to be trapped).

7.4 Routine Highway Maintenance Protocols

As part of a comprehensive SAR protection and recovery strategy, routine highway maintenance protocols should be reviewed.

1) Mowing: Project data report two SAR killed by mowing practices (**Figure 30**). The juvenile Snapping Turtle had clear straight cut marks on the ventral side and the Gray Ratsnake was found in segments with cut marks and frayed edges – all evidence that the blades of a mower were responsible for the direct mortality. Field researchers also noted other dead non-SAR wildlife tangled in the cut grass (e.g. garter snake). MTO informed field researchers that crews were sent to cut grass once it reached two feet in height and that blades were set to cut grass down to four or five inches in height. On the highway shoulder, the mowers span a distance of seven feet, and thirty feet within the median (fifteen feet on either side). To reduce death caused by highway mowing practices, we encourage ceasing or reducing the mowing schedule during peak herpetofauna movement periods and raising the height of the blades.

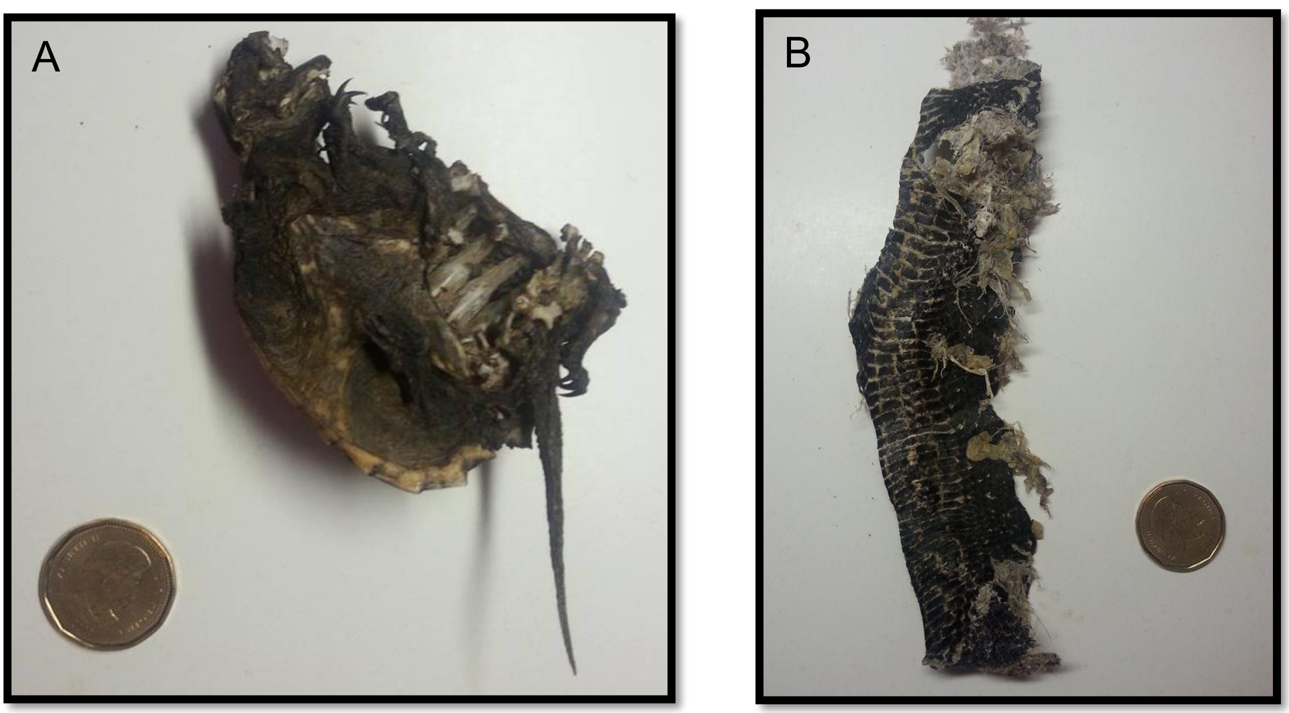

Figure 30. *A juvenile Snapping Turtle (A) and a segment of a Gray Ratsnake (B) likely killed by mowing practices on Highway 401. (© Clayton Shearer)*

2) Re-surfacing: Any work involving laying new material on the road or shoulder should consider turtle nesting/hatching times (June to October). This will help protect the adult females as well as the nests and hatchlings. Turtles often nest in roadside habitat because it is warm, well drained, easy to excavate soil (Langen *et al.* 2015). If a nest is buried under additional material, the nest will likely fail.

8.0 MITIGATION DESIGN OPTIONS

As mitigation measures intended to protect wildlife from the threats of roads have become more prevalent, the options (products, materials, installation methods, etc.) have become more diverse. It is important to install appropriate mitigation measures that address the target species and work as intended in the environment and within the immediate landscape. Ideally, mitigation (i.e. fencing, dedicated wildlife passages, habitat protection/restoration) should keep wildlife off the road while maintaining high quality habitat connectivity.

8.1 Fencing

Exclusion fencing is necessary to keep wildlife off the road and guide it to passages (Cunnington *et al.* 2014). Fences need to be durable to withstand environmental conditions (e.g. UV light, snow, and snowplough piling) and maintain structural integrity to function as intended (Baxter-Gilbert and Litzgus 2014). If fencing is near, or in water, accommodation should be made for spring thaw water levels to ensure the height remains an effective barrier (Woltz *et al*. 2008). Up-dated reptile and amphibian fencing best management practices will soon be available from the OMNRF. Recent research and in –field observations (Baxter-Gilbert and Litzgus 2014; Long Point Causeway Improvement Project, OREG List-Serve communication, February 24, 2016) suggest that the OMNRF 2013 best practices recommendation of using 1/8" mesh wire hardware is not ideal due to the material rusting away and the formation of gaps in the fence.

Fencing design details must target climbing species (e.g. Gray Ratsnake and Snapping Turtle). Fence height should be at least two metres high, have a 200 mm 45-90^{o} overhanging lip at the top facing towards the habitat (OMNRF 2013, **Figure 31a, b**). Supporting stakes should be approximately two metres apart and secured on the road side to avoid wildlife climbing the fence. Fencing material should be taut between stakes. To prevent creating hotspots at either end of the fence, the fence should curve inward toward the habitat directing wildlife back and reducing access to the roadway. Where feasible, the fence should end at natural barriers (e.g. rock cuts). Fences should extend for approximately 60 m from each side of the mouth of a culvert and lead into the tunnel at a 45^{o} angle (**Figure 32**; Jackson 2003). Installation should occur prior to emergence from hibernacula and over-wintering sites.

Figure 31a. *Exclusion fencing targeting SAR snakes and turtles. (© Eco-Kare International)*

Figure 31b. *Exclusion fencing on Hwy 10 targeted to protect SAR turtles. Red circle highlights overhang away from road to discourage climbing species. (© Mandy Karch)*

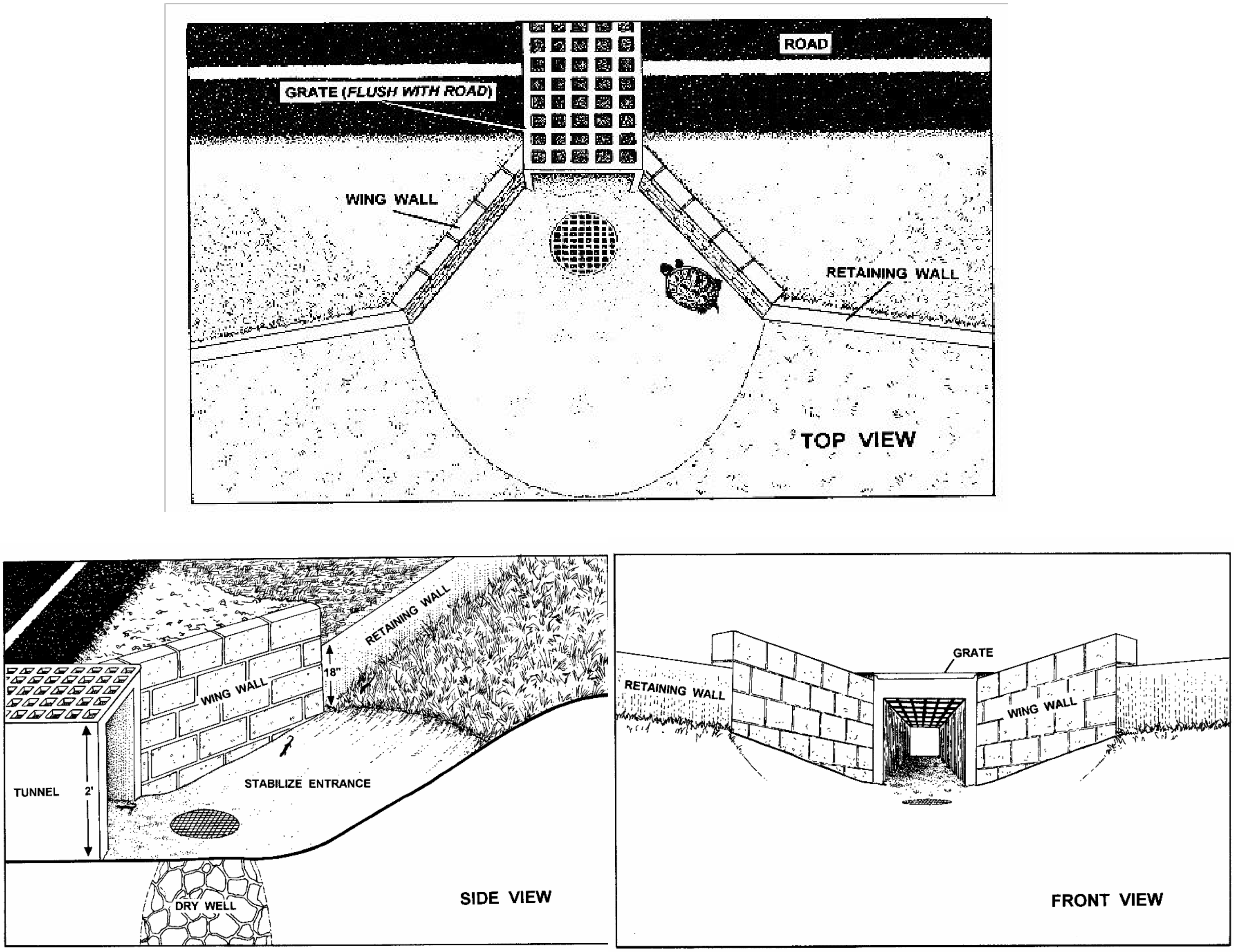

Figure 32. *Underpass design proposal to promote reptile and amphibian passage. (Taken from Jackson 2003)*

Maintenance is imperative. Holes in the fence undermine the purpose of fencing and could harm wildlife that attempt to pass through. Fences should be checked in the early spring and throughout the active season, particularly after a heavy rain to ensure backfill is still in place. Any damage or repair should be immediate to keep the fence in proper working order. Vegetation near the fence that wildlife could climb should be cut back to prevent creatures from getting over the fence.

Geotextile fences are generally not recommended when targeting snakes because as the product wears, animals may get caught in the frayed material. New fencing products and materials are entering the market (e.g. ACO Wildlife, Animex®; **Figure 33a, b, c, d**) and should be considered on a site by site basis.

Monitoring mitigation sites is essential, whichever fencing material is used, to ensure wildlife is protected and to indicate when/where maintenance is required. Monitoring also provides information regarding materials used, installation techniques, and effectiveness, and this can be helpful in designing future mitigation projects.

Figure 33a. *ACO one-way fence panels to guide and protect wildlife. (© ACO Wildlife)*

Figure 33b. *ACO polymer concrete guide wall with dual protective rim to deter wildlife climbing over the top. (© ACO Wildlife)*

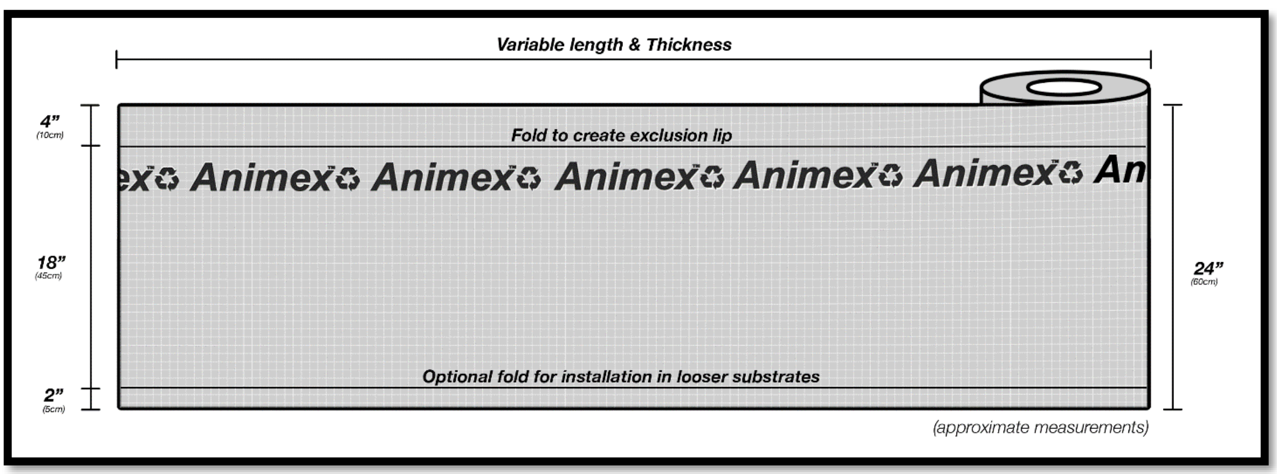

Figure 33c. *Turtle fencing exclusion product. (© Animex®)*

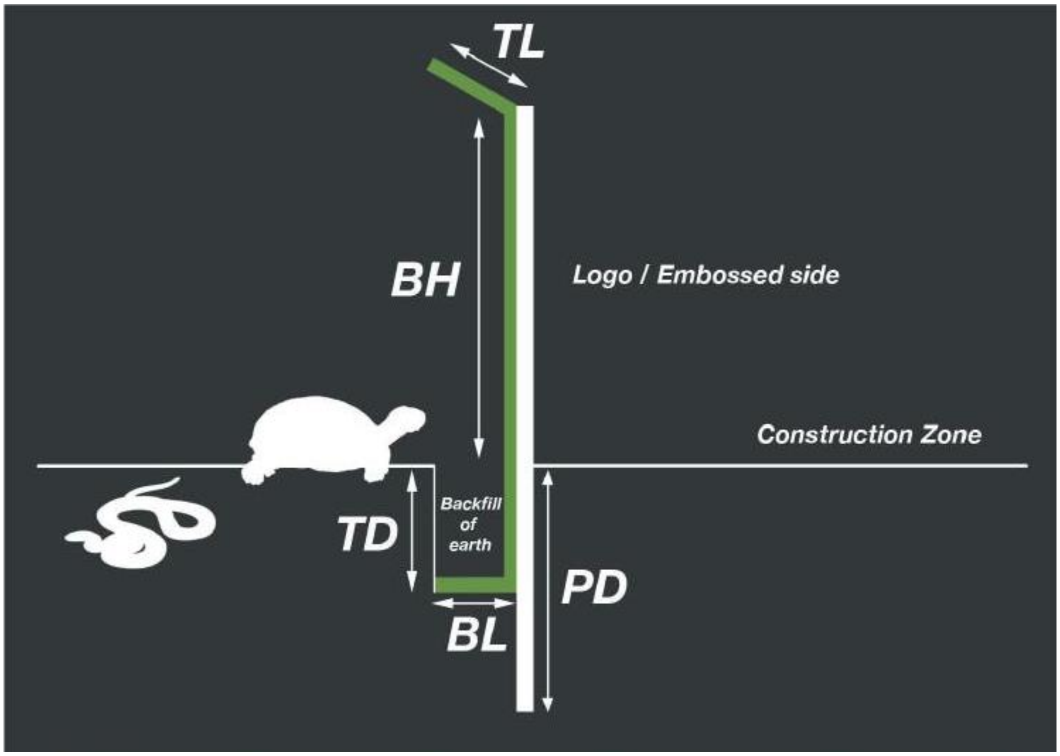

Figure 33d. *The road side of the fence is embossed/textured to facilitate wildlife climbing up and entering the habitat side. The habitat side of the fence has an exclusion lip and is a glossy surface that prevents wildlife from climbing and gaining access to the road. (BH = Barrier Height, TD = Trench Depth, TL = Top Lip, BL = Bottom Lip, PD = Post Type) (© Animex®)*

8.2 Culverts/Ecopassages

Culvert characteristics may attract or repel wildlife. In the study site where the independent MTO culvert research recommends culvert replacement and Project data suggest a crossing hotspot, the new culvert should promote herpetofauna passage. Installation of large tunnels (e.g. oversized concrete box culvert) that maintain good airflow and natural light throughout or smaller tunnels specifically designed for reptiles and amphibians that enhance ambient light and moisture conditions through a grated slot system that lies flush with the road surface are recommended (**Figure 34**; Clevenger and Huijser 2011). A drawback of the grated slot system is that wildlife may be exposed to pollution and road runoff (Kintsch and Cramer 2011). Installing two shorter culverts (i.e. one culvert that spans east-bound lanes and a separate culvert that spans west-bound lanes) that terminate in the median will also enhance preferred light and moisture levels (add guiding walls where the culverts ends to continue directing animals through to the other side; City of Edmonton 2010). As the tunnel length increases, so should the width/opening of the culvert to bring in more natural light/moisture conditions. Concrete or polymer concrete culverts should be chosen over corrugated steel structures that are cold and may repel herpetofauna due to the un-favourable micro-climate created inside the tunnel. Where MTO's culvert report recommends a new insert, a PVC pipe is an improvement over a CSP.

Figure 34. *ACO polymer concrete tunnel that maintains more natural ambient light, temperature and moisture conditions through a grate system that lies flush with the road surface. (© ACO Wildlife)*

Where there are known movement corridors, reptiles and amphibians require that mitigation measures be installed. For mitigation to be effective for low-movement mobility species, such as some herpetofauna species, a culvert with exclusion fencing should occur every 45 metre (Clevenger and Huijser 2011).

If a hotspot is identified and culvert replacement is not currently an option, culverts could be retro-fitted to encourage herpetofauna use. Bottom substrate could be added to help insulate CSP culverts and provide a more natural crossing terrain. Local soil/material would be preferred, but sandy loam could also be used (Jackson 2003). Smaller diameter PVC pipes that provide protective cover may also be added to improve passage options for smaller individuals (**Figure 35**). Where culverts are wet all year long, consider adding a ramp that leads to a dry ledge made of wood, rock, concrete or galvanized steel that runs the length of the culvert (**Figure 36**; Clevenger and Huijser 2011).

Figure 35. *PVC pipes placed in a corrugated steel pipe culvert to provide passage options for herpetofauna and other small wildlife. (© Tony Clevenger)*

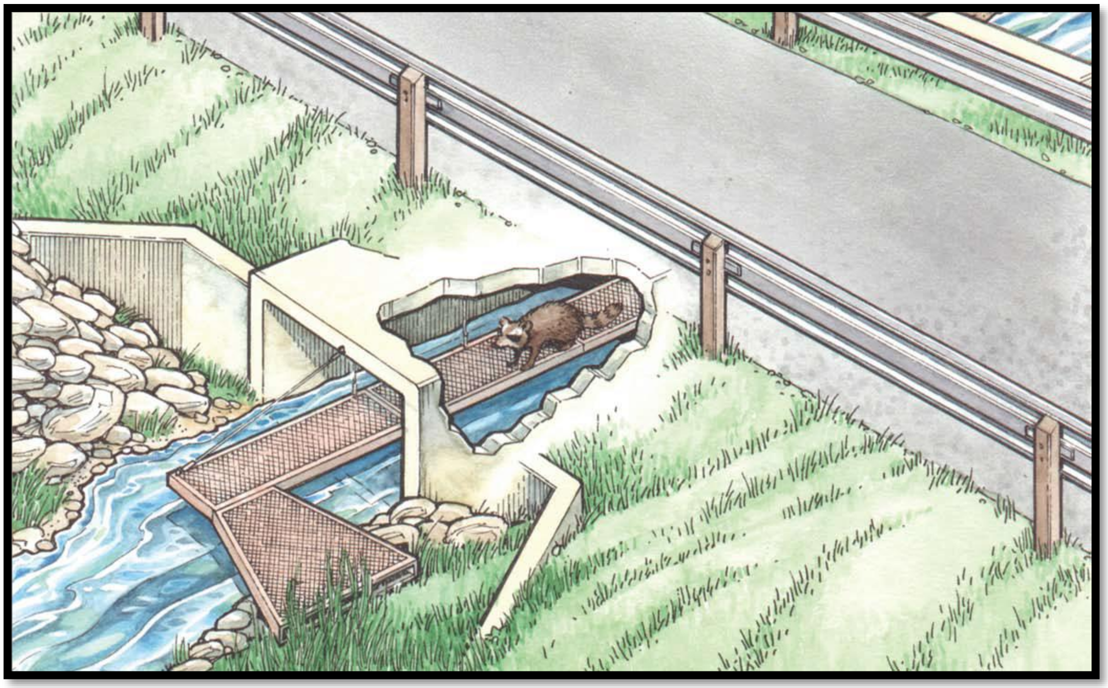

Figure 36. *Critter-Crossing TM Animal Access Shelves provide small wildlife with passage options through culverts. (© Roscoe Culvert)*

Follow-up monitoring and maintenance are necessary for new and retro-fitted culverts to determine if target SAR are using the passages. Monitoring should occur for a minimum of two years following installation. The use of remote wildlife cameras has been successful in the past to determine if/how wildlife are using the infrastructure (**Figure 37**). Regular maintenance is necessary to ensure vegetation around the mouth of the culvert is clear. Overgrowth may: prevent access to the entrance, provide places for predators to hide, and provide wildlife a means of climbing to the top of the culvert and on to the roadway (Environmental Guide for Wildlife in the Oak Ridges Moraine 2006). Monitoring will also ensure that the culvert is accessible to wildlife. For instance, if the entrance is at ground level, it should be kept clear of debris, and any erosion damage should be repaired.

Figure 37. *Image taken by a motion sensor-triggered camera of a Snapping Turtle exiting a dedicated wildlife tunnel. (© Long Point Causeway Improvement Project)*

8.3 Bridge Design & Extended Stream Crossings

Bridges over watercourses provide an opportunity to reconnect the landscape for a diversity of wildlife by widening the bridge span so that banks on both sides of watercourses are widened (referred to in the literature as Extended Stream Crossings (ESC); **Figure 38**). Generally the width of the ESC should be approximately five times the width of the stream at high water, to ensure dry passage for wildlife. The height of the structure should accommodate the passage of the largest local wildlife (e.g. deer, moose, etc.). ESC are probably the most cost-effective way to improve landscape connectivity across roads (Lesbarrères and Fahrig 2012).

Figure 38. *Example of an extended stream crossing (ESC) in Canada. (© Lenore Fahrig)*

8.4 Median Design

The efficacy of perforated median barrier design in facilitating wildlife passage is largely unknown (California Department of Transportation 2007). However, installing medians with holes or overlapping concrete median barriers to create gaps at least offers wildlife a crossing option if trapped on the highway (Ontario Ministry of Transportation 2013).

8.5 Habitat Creation

Herpetofauna follow migratory and dispersal routes to access critical habitat. Creating habitat may negate the need for some individuals to move across the highway or into the highway right-of-way, where for instance, Snapping Turtles often lay eggs in gravel shoulders. SAR turtles have successfully used constructed nesting sites (Kiviat *et al*. 2000, Toronto Zoo Adopt-A-Pond Conservation Programme, personal communication) and habitat creation (i.e. nesting beaches, hibernacula, basking sites), may be a useful component of a mitigation strategy. The Toronto Zoo provides guidelines for how to construct reptile habitat:
www.torontozoo.com/adoptapond/turtleresources.asp?opx=5&sopx=2
www.torontozoo.com/adoptapond/snakehibernacula.asp

9.0 OVERPASS CONSIDERATIONS

Wildlife crossing structures are diverse in design, shape and size. Heretofore our recommendations have focused on underpasses for allowing animals to move under the road, combined with fencing to funnel animals toward these passageways. These measures range in size from the retrofit of specific culverts to make them more usable by snakes, turtles and other small and medium sized animals, to the improvement of bridges at the Gananoque River, and LaRue Creek and Jones Creek, the latter of which will also be of benefit to facilitate movement of larger animals including white-tailed deer and coyote.

In addition to these recommended underpasses, we recommend that an overpass be considered along this stretch of highway. Overpasses have several benefits beyond those of underpasses. Apart from underpasses associated with large bridges, overpasses are the only mechanism that could provide reliable safe passage of large animals across Highway 401. The movement of these animals is critical for large-scale ecological integrity of the Frontenac Arch and the entire A2A region as a whole, particularly since these species disperse over much larger distances. In light of the barrier imposed by Highway 401 to the movement and dispersal of large mammals, construction of an overpass would be a significant tool for restoring ecological connectivity to eastern North America.

Given the 4-lane divided nature of Highway 401, the required underpasses will be long; sometimes in excess of 100 metres. This means that these environments are usually dark and frequently wet. An overpass would be of significant benefit to species that might avoid these conditions, including several of the SAR identified in our field surveys. Indeed, a number of best-practices recommend strategies to increase natural lighting for crossing structures (Bissonette and Cramer 2008). An overpass would also be capable of supporting natural vegetation, a feature that would help ensure its efficacy.

Smith *et al*. (2015) identify two scales of overpasses. “Landscape bridges” (also called ecoducts or land bridges) are wide structures (usually >50m) without interruption constructed across a road. The second scale, “wildlife overpasses”, are narrower than landscape bridges (sometimes <20m). Experience with both types is relatively recent, but growing quickly. One of the fundamental conclusions of a recent review by Smith *et al*. (2015) is that detailed design, including attention to appropriate siting, is critical for their success. To this end, we recommend a systematic assessment be undertaken to determine the best location for an overpass along Highway 401 along with a comprehensive list of design considerations. The following concepts and approaches should be used to guide this process.

The overpass must be located at an ecologically optimum site. Clearly, it will be ineffective in a location where there is little potential for use and it would be excessive where small underpasses could achieve the same level of connectivity. Ostensibly this would be in an area where the most roadkill occurs. However, there are many reasons why an area could be a worthy location for an overpass despite not exhibiting particularly high levels of mortality. As mentioned previously, areas with moderate or low wildlife road mortality may be indicative of areas that were once hot spots but where roadkill has reduced populations to such an extent that they are no longer hotspots. In these locations suitable habitat likely still exists and an overpass would serve to reconnect habitats and restore landscape connectivity. As such, a combination of both road survey results and habitat-based modeling should be used in evaluating potential locations. Such habitat modeling should emphasize landscape and regional scales of analysis, rather than local scale considerations. At a landscape scale an overpass could serve as a corridor between critical habitat types or natural area complexes. At a regional scale, strong consideration should be given to situating an overpass where it could play a role in improving the capacity of the Thousand Islands to facilitate connectivity across the St. Lawrence River.

Data used in this analysis would include the field data collected in this project and along the 1000 Islands Parkway, but also any other available data that documents movement and habitat requirements of focal species in the region. Such habitat requirements may need to be determined using a resource selection approach. Techniques such as least cost path modeling and circuit theory have been used to guide identification of potential wildlife crossings elsewhere (e.g. Cushman *et al*. 2013) and such an exercise is critical for the Highway 401.

Despite ecological requirements, there is a suite of socio-economic and engineering considerations as well. Foremost among these are the long-term prospects for conservation of lands on either side of the overpass. This is critical to ensure when undertaking a large infrastructure siting and design process. Luckily, several properties that are part of 1000 Islands National Park abut the south side of Highway 401 and may prove worthy of consideration.

Clevenger and Huijser (2011) assert that landscape bridges and wildlife overpasses are best designed without human use in mind, and they highly recommend against any human-related activities of the structures. However, van der Ree and van der Grift (2015) argue that multi-use structures can support some recreational activities if appropriately planned and designed. Moreover, they argue that conveyance of humans across highways could serve as a secondary rationale for the financial investment required for this infrastructure.

Ideally, an overpass would be positioned at a wildlife movement corridor, and we have identified five areas that could possibly act as corridors (**Table V, Figures 39a-e**) within the study area by synthesizing data from:

- Fieldwork undertaken for this Project
- Evelyn Garrah 2012 M.E.S. thesis SAR herpetofauna data (**Figures 40, 41**)
- MTO Wildlife/Vehicle Collision data (Appendix VIII)
- Predictive hot spot model developed for this Project
- Natural Heritage Information Centre data (Appendix IX)
- Circuitscape analysis (Koen *et al.* 2014, **Figure 7**)
- Sustaining What We Value habitat mapping project (together with updates commissioned by A2A)
- Thousand Island National Park (TINP) property locations (**Figure 42**)

At this stage, these are only hypothesized corridors. Once the locations are confirmed, land-use management practices that involve habitat protection, and rehabilitation and creation (e.g. SAR herpetofauna nesting beaches, hibernacula, basking sites) will be paramount. In addition, when confirmed corridors are combined with data from fieldwork monitoring over the next two years, it will be possible to identify where an overpass, or overpasses, should be located.

Table V. *Details of possible wildlife movement corridors (sources: Figures 7,17, 18, 20, 24, 39, 40,41, 42, Appendices V, VIII, IX, Southern Highway Program 2015-2019).*

Corridor ID	**1**	**2**	**3**	**4**	**5**
Area	Gananoque west (2.5 km west of the Gananoque River crossing)	Gananoque east (Cliffe Rd. to Reynolds Rd. - focus on connectivity through TIP lands between Keys Rd. and Fitzsimmons Rd.)	Hwy 137 to Escott-Rockport Rd.	LaRue Creek crossing	Jones Creek crossing
Project SAR Data	Yes	Yes	Yes (Hotspot II)	Yes (Hotspot III)	Yes
TIP SAR Data	N/A	Yes	Yes	Yes	Yes
Project Model	Moderate	Moderate	Very High	High	Moderate
Circuitscape	High (to the north)	Moderate-High	Moderate	High	Moderate
MTO Data: # WVC	16	6	7	25	26
TINP Property	No	Yes	Yes	Yes	Yes
NHIC Data	No	Yes	No	Yes	Yes
Mitigation Recommendations	Dedicated wildlife culverts, Gananoque River Bridge Habitat creation	Dedicated wildlife culverts, Habitat creation	Dedication wildlife culverts, Wildlife overpass, Habitat creation	Extended stream crossing, Dedicated wildlife culverts, Habitat creation	Extended stream crossing, Dedicated wildlife culverts, Habitat creation
Relation MTO Scheduled Work	None	None	Hwy 401 – Hwy 137 overpasses, Bridge Rehabilitation 2017	Hwy 401 – LaRue Mills Rd. underpass, Bridge Rehabilitation 2017-2019	TIP – Jones Creek and Jones Creek Trail bridges, Bridge Replacement 2017 ~ *Note: Hwy 401 Bridge Rehabilitation (2017-2019) at Lyn Rd. overpass*

*Note: Deer crossing signs are used only where it is known that deer are accustomed to crossing the road (established through field observations) and thereby present a hazard to drivers (OTM 2001). The study site segment of Highway 401 where the deer signs were documented is eight km in length and according to guidelines, this implies that at least one deer collision has occurred in this area for a minimum of five years (OTM 2001).

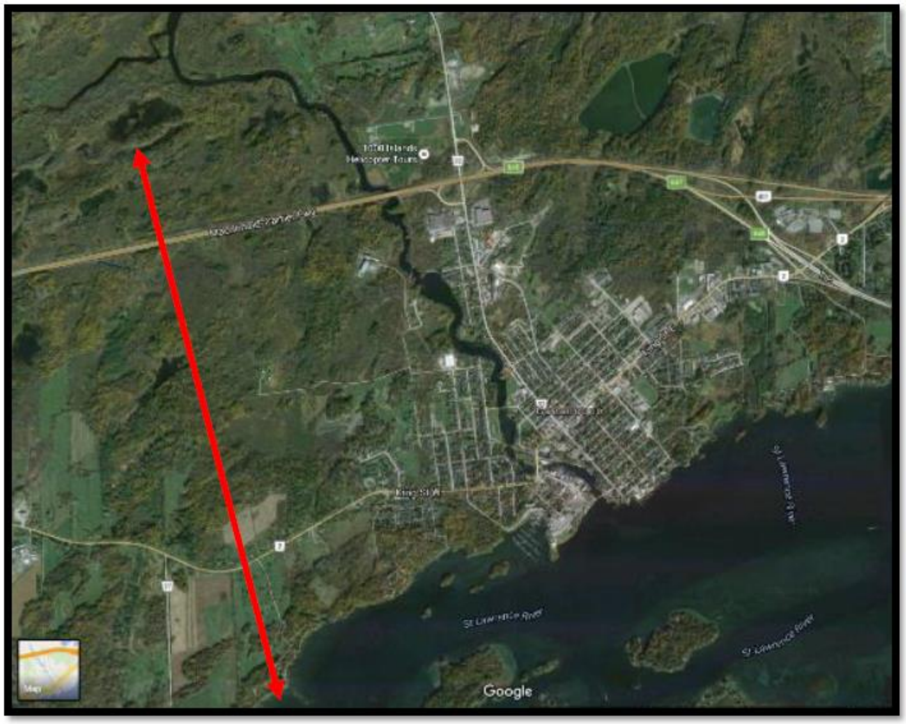

Figure 39a. *Corridor 1, Gananoque west.*

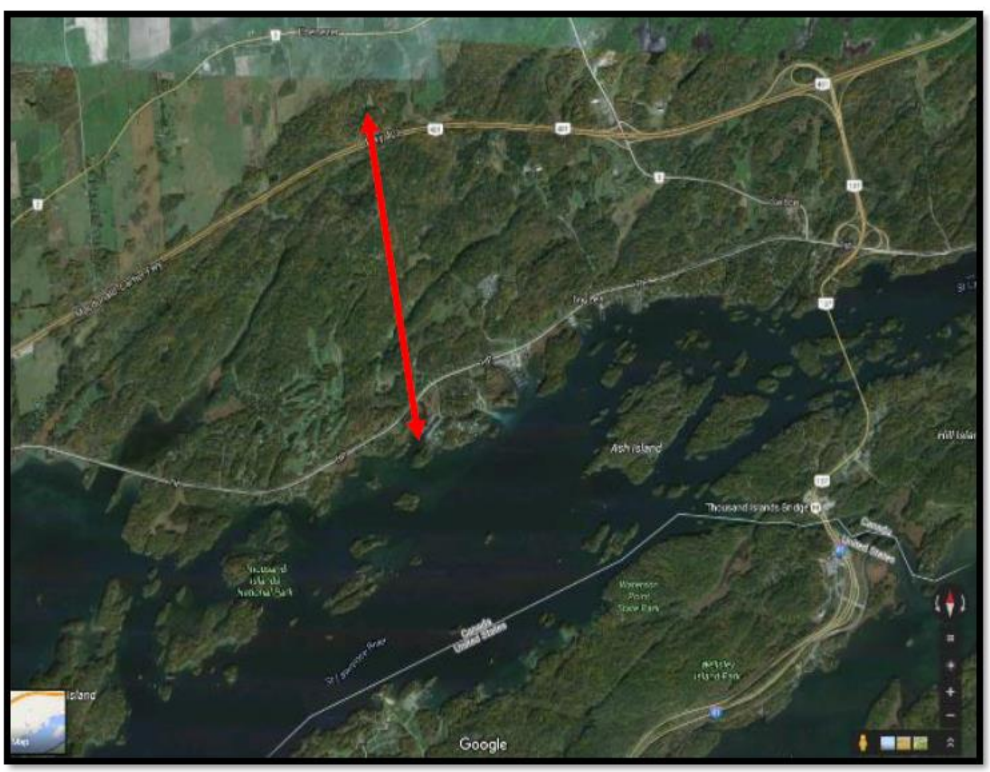

Figure 39b. *Corridor 2 – Gananoque east.*

Figure 39c. *Corridor 3 – Hwy 137- Escott-Rockport Road.*

Figure 39d. *Corridor 4 – LaRue Creek.*

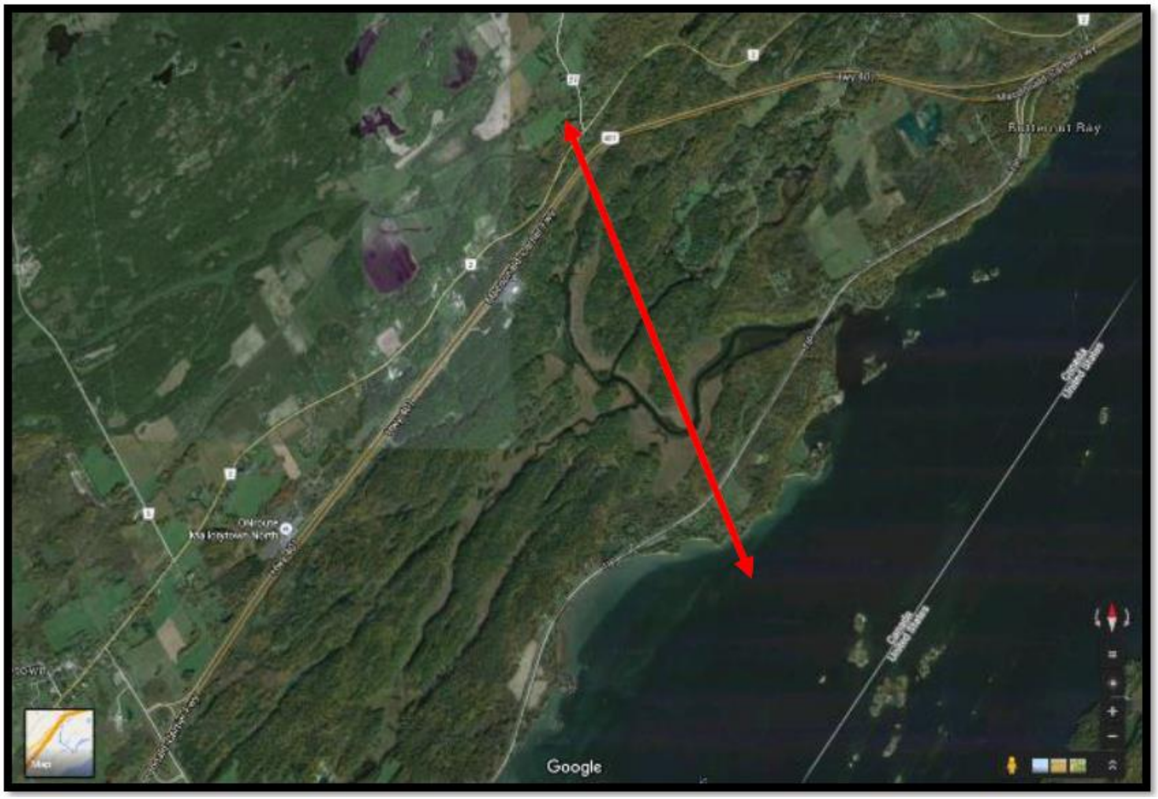

Figure 39e. *Corridor 5 – Jones Creek.*

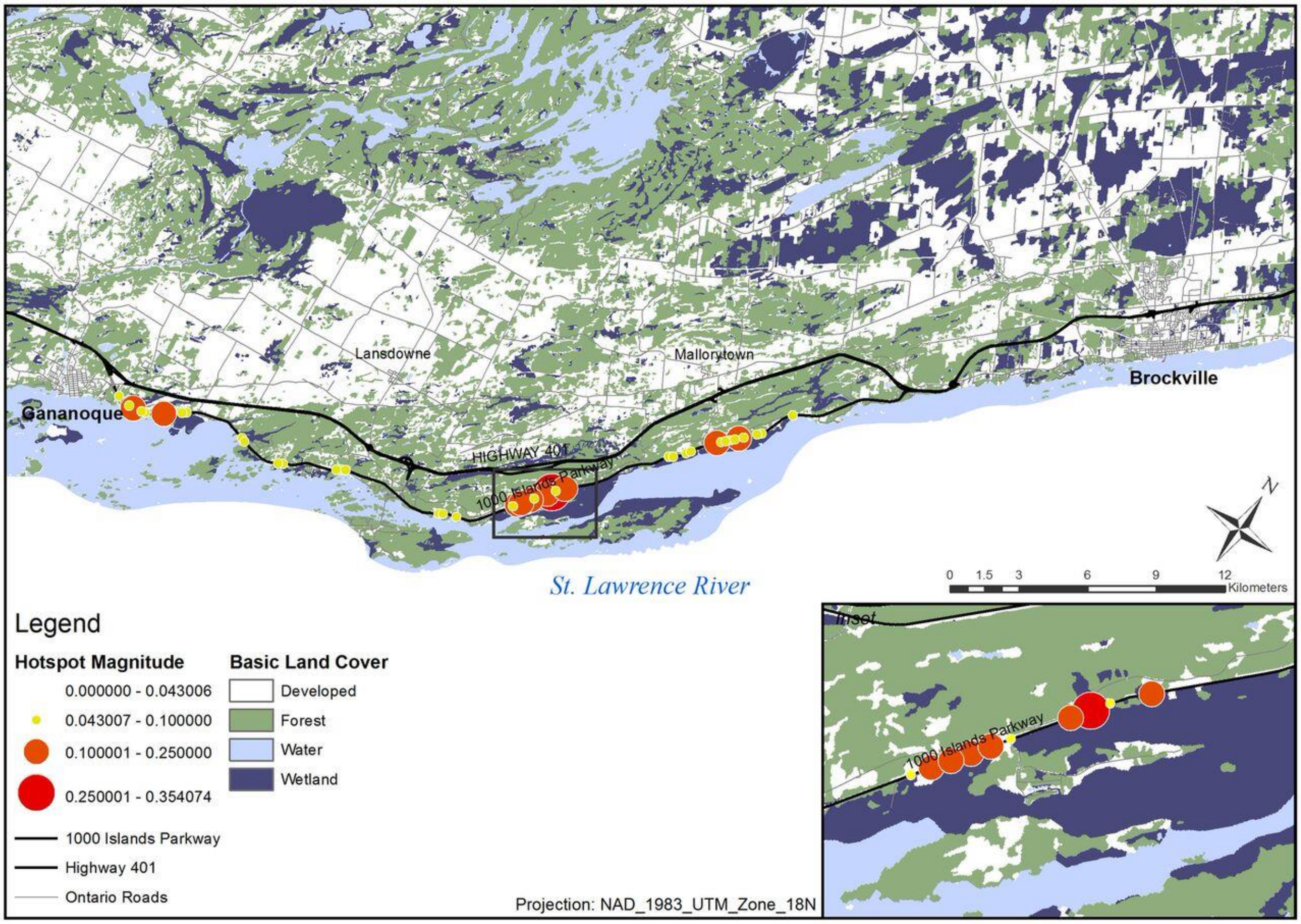

Figure 40. *Hot spots of wildlife mortality on the 1000 Islands Parkway. Variation in circle size is representative of variation in the relative importance value of each hot spot as calculated using the Hot Spot Importance Index, which is integrated across species (see Methods). Hot spots shown here are those identified using α=0.10 (based on data in Garrah 2012). (© Ryan Danby)*

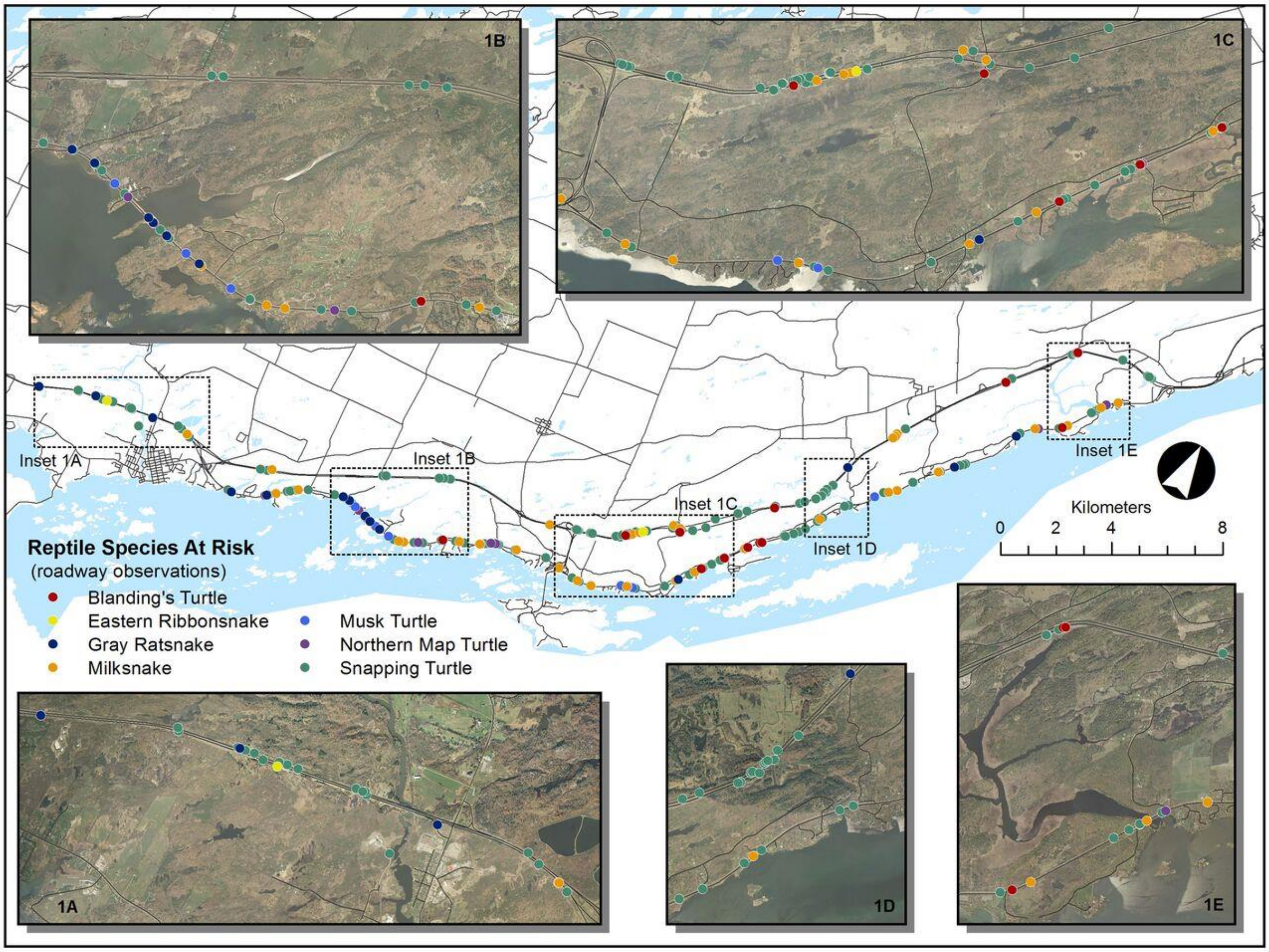

Figure 41. *Distribution of species at risk reptiles observed on Highway 401 (2014-2015) and 1000 Islands Parkway (2008-2011). (© Ryan Danby)*

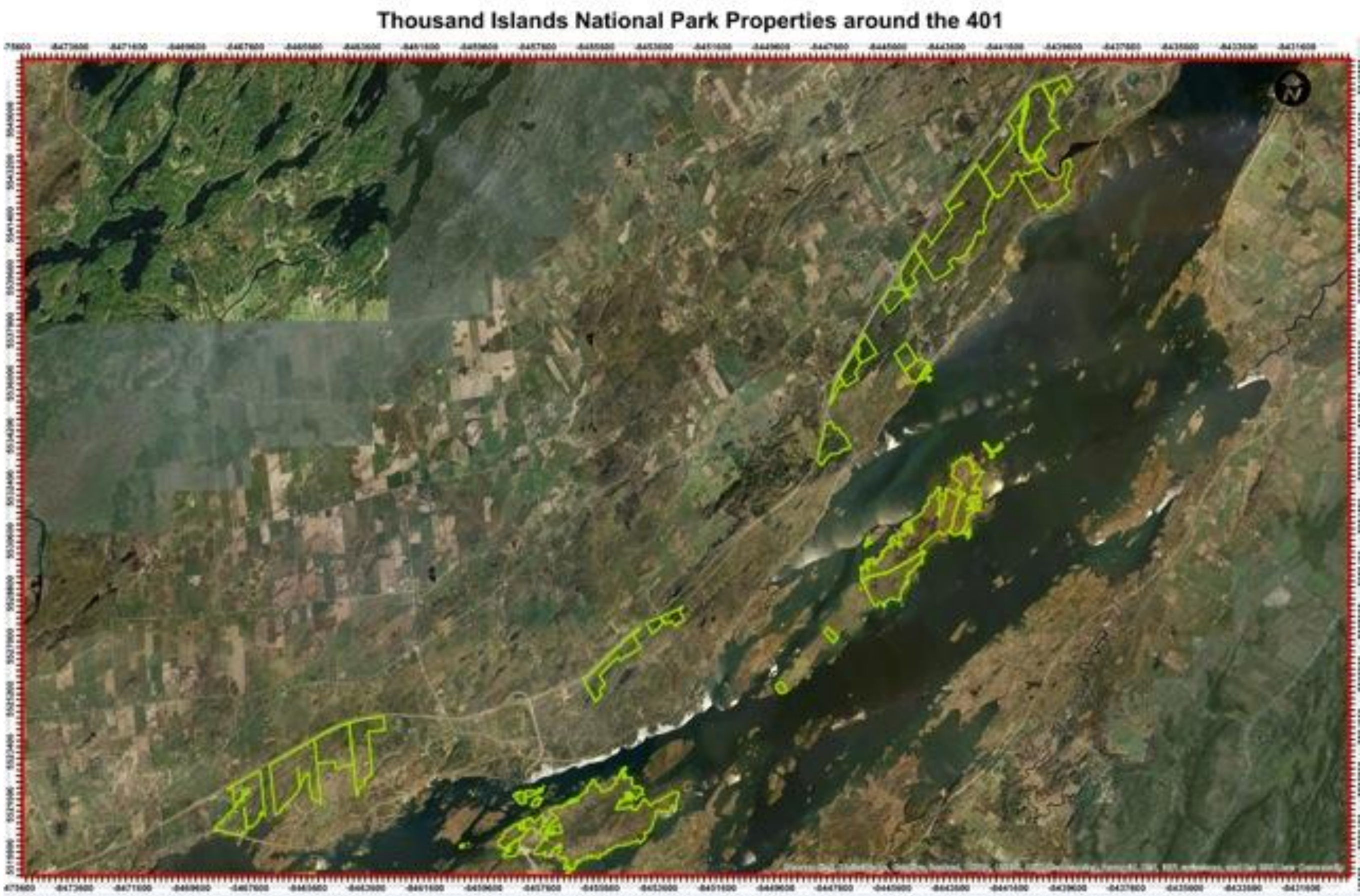

Figure 42. *Thousand Islands National Park property locations. (© Parks Canada)*

10.0 CONCLUSION

It became obvious early in this project that the problem posed by Highway 401 extended far beyond road mortality for species at risk. What we found ourselves facing was a major crisis in ecological integrity, because the highway completely severs connectivity north and south across the St. Lawrence River via the Thousand Islands.

Consequently, we decided to take advantage of the opportunity presented under our species-at-risk funding to broaden the scope of our research to include road mortality of all wildlife. We were able to accomplish this thanks to an enormous amount of volunteer time donated by our field researchers, Clayton Shearer in particular, and by Prof. Ryan Danby of Queen's University. As a result, we have been able to present comprehensive recommendations, not only with respect to species at risk, but to all wildlife, and in general terms, to biodiversity throughout eastern North America, for which connectivity across the Frontenac Arch is a critical link.

We were advised by officials of the Ontario Ministry of Transportation that they need to schedule remedial work on culverts three years in advance. Therefore, we have recommended preliminary strategies to protect SAR which entail modifications that can be undertaken immediately. And we have recommended longer-term strategies that, if implemented in full, will re-establish the ecological link across the Frontenac Arch.

Public engagement and cooperation among stakeholders, especially property owners will be required to achieve large-scale landscape connectivity within the study area. Among our partners in this project are Parks Canada, Frontenac Arch Biosphere Reserve, Algonquin Park, Adirondack Park, the Royal Ontario Museum (ROM), Cataraqui Region Conservation Authority, Nature Conservancy of Canada, Ontario Nature, Save the River, Mohawks of Akwesasne, and Plenty Canada. They will play an important role in reaching out to inform and empower a diverse public audience.

Moving forward with this initiative will require a multi-disciplinary approach and continued commitment and collaboration among government and non-government planners. Engaging members of the public and seeking guidance from local First Nations about traditional ecological knowledge will assist in reaching the goals of protecting SAR and re-establishing ecological integrity through the Frontenac Arch.

In the Project we collected and assembled Project field data, Thousand Island Parkway SAR herpetofauna data, MTO wildlife/vehicle collision data, Natural Heritage Information Centre data, and Thousand Islands National Park SAR data. A predictive computer model was created, hotspot maps were generated, partnerships were facilitated, and the public was informed and engaged (e.g. ROM Partners in Protection outreach event. Facebook, www.facebook.com/hashtag/fieldreportfriday?source=feed_text&story_id=845766678874315).

An application for funding has been made to OMNRF to help finance SAR herpetofauna research on Highway 2 within the study area. If funding is granted, research will begin in early Spring 2016, and will build on this Project's findings and recommendations, and will contribute to the goal of protecting SAR and re-establishing ecological integrity. Highway 2 runs parallel and close to Highway 401 and the Thousand Islands Parkway. At the time of writing of this report, we are seeking funding that will allow us to continue monitoring road mortality on Highway 401.

11.0 ACKNOWLEDGMENTS

The Algonquin to Adirondacks Collaborative together with the Ontario Road Ecology Group would like to thank the Ontario Ministry of Natural Resources Species at Risk Stewardship Fund for financially supporting the Project. We are grateful to the Ministry of Transportation of Ontario, specifically Dan MacMartin, Ryan Vandenberg and Louis Tay for assisting with the Encroachment Permit and logistics that allowed data collection on Highway 401 and to Brenda Carruthers and Dawn Irish for their support.

Data collection on Highway 401 requires a unique skill set. Project success is owed to the expertise and guidance of Field Supervisor Dr. Fred Schueler and Aleta Karstad and the dedication of Field Researchers Clay Shearer, Rory Tanner, Jamie Graham, Christena Kube, Ben Shearer, Emma Terrel and Adam Zieleman. Success is equally due to GIS assistance from Marian Kremer and Laura Kitchen, and statistical assistance from Dr. Michelle Bowman. Local expert advice from Parks Canada greatly assisted with the Project. Thank you to all who contributed.

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APPENDIX I

MTO 2013 TRAFFIC VOLUME DATA
HIGHWAY 401 (KINGSTON TO BROCKVILLE)

Location	AADT	SADT
1.6 km west of Hwy 15, IC 623	48,912	54,292
5.2 km west of Cty Rd 2, IC 645	23,551	29,439
0.6 km west of Cty Rd 2, 648	24,579	29,249
1.9 km west of Reynolds Rd, IC 659	25,419	30,249
1.8 km west of Hwy 137, IC 661	27,059	32,200
14.0 km west of Mallorytown Rd, IC 675	26,160	31,130
0.8 km west of Cty Rd, IC 687	26,000	30,940
0.5 km west of North Augusta Rd, IC 698	28,849	34,331
1.1 km west of Maitland Rd, IC 705	28,874	34,360

AADT = Annual Average Daily Traffic
SADT = Summer Average Daily Traffic

In summary, east of Kingston there are approximately 30,000 vehicles per day on Highway 401, of which approximately 30% are commercial vehicles (i.e. trucks).

APPENDIX II

List of independent variables associated with each point in the GIS. Data were relevant to four scales: (i) 0m data was extracted at the exact location of a point; (ii) 50m data was indicative of conditions within a 50m radius around the point; (iii) 250m data was indicative of conditions within a 250m radius around the point; (iv) 500m data was indicative of conditions within a 500m radius around the point. 'W' in the parameter name is short for "Whole", meaning that the entire radius is measured; 'NS' is short for "North South", meaning that the difference between both sides of the road is measured.

Name (GIS Shorthand)	**Scale**	**Parameter Description**
Point_Culvert_Dist	0m	Distance to nearest culvert
Point_DEM	0m	Point terrain elevation
Point_Elev_Diff	0m	Difference in elevation between road and adjacent areas
Point_ForestInt_Dist	0m	Distance to nearest patch of interior forest (defined with 100m buffer)
Point_Intersect_Dist	0m	Distance to nearest road intersection
Point_Slope	0m	Point terrain slope
Point_WaterBody_Dist	0m	Distance to nearest waterbody
Point_WaterCross_Dist	0m	Distance to nearest road stream crossing
Point_WetlandInt_Dist	0m	Distance to nearest patch of interior wetland (defined with 100m buffer)
W50m_Sinuosity	50m	Road sinuosity (within 50m distance)
W50m_BuildCount	50m	Number of buildings within 50m radius
W50m_CulvertCount	50m	Number of culverts within 50m raduis
W50m_IntersectCount	50m	Number of road intersections within 50m radius
W50m_WaterCount	50m	Number of waterbodies within 50m radius
W50m_Land_Aggregates	50m	Aggregate extraction landcover (%)
W50m_Land_Agriculture	50m	Agriculture landcover (%)
W50m_Land_Aquatic	50m	Aquatic, open water, wetland landcover (%)
W50m_Land_ForConifer	50m	Coniferous forest landcover (%)
W50m_Land_ForDeciduous	50m	Deciduous forest landcover (%)
W50m_Land_ForMixed	50m	Mixed forest landcover (%)
W50m_Land_ForUndifferentiated	50m	Undifferentiated forest landcover (%)

W50m_Land_Marsh	50m	Marsh landcover (%)
W50m_Land_Road	50m	Roadways (%)
W50m_Land_Swamp	50m	Swamp landcover (%)
W50m_Land_Urban	50m	Urban landcover (%)
W50m_Land_Water	50m	Open water bodies (%)
W50m_Land_WETLAND	50m	Total wetland (aquatic+marsh+swamp)(%)
W50m_Land_FOREST	50m	Total forest (coniferous, deciduous, mixed, undifferentiated) (%)
W50m_Land_DIVERSITY	50m	Landcover diversity (Shannon Index score)
W50_Circuit_Mean	50m	Habitat connectivity (average Circuitscape score)
NS50_Elev_Diff	50m	Difference in mean elevation between north and south side of road
NS50_Slope_Diff	50m	Difference in mean slope between north and south side of road
NS50_Land_Dissimilar	50m	Sorenson's dissimilarity metric between north and south side of road
NS50_Water_Diff	50m	Difference in the amount of water between north and south side of road
NS50_Wetland_Diff	50m	Difference in the amount of total wetland between north and south side of road
NS50_Forest_Diff	50m	Difference in the amount of total forest between north and south side of road
W250m_Sinuosity	250m	Road sinuosity (within 250m distance)
W250m_BuildCount	250m	Number of buildings within 250m radius
W250m_CulvertCount	250m	Number of culverts within 250m radius
W250m_IntersectCount	250m	Number of road intersections within 250m radius
W250m_WaterCount	250m	Number of water crossings within 250m radius
W250m_Land_Aggregates	250m	Aggregate extraction landcover (%)
W250m_Land_Agriculture	250m	Agriculture landcover (%)
W250m_Land_Aquatic	250m	Aquatic, open water, wetland landcover (%)
W250m_Land_ForConifer	250m	Coniferous forest landcover (%)
W250m_Land_ForDeciduous	250m	Deciduous forest landcover (%)
W250m_Land_ForMixed	250m	Mixed forest landcover (%)

W250m_Land_ForUndifferentiated	250m	Undifferentiated forest landcover (%)
W250m_Land_Marsh	250m	Marsh landcover (%)
W250m_Land_Road	250m	Roadways (%)
W250m_Land_Swamp	250m	Swamp landcover (%)
W250m_Land_Urban	250m	Urban landcover (%)
W250m_Land_Water	250m	Open water bodies (%)
W250m_Land_WETLAND	250m	Total wetland (aquatic+marsh+swamp)(%)
W250m_Land_FOREST	250m	Total forest (coniferous+deciduous+mixed+undifferentiated) (%)
W250m_Land_DIVERSITY	250m	Landcover diversity (Shannon Index score)
W250m_Circuit_MEAN	250m	Habitat connectivity (average Circuitscape score)
NS250_Elev_Diff	250m	Difference in mean elevation between north and south side of road
NS250_Slope_Diff	250m	Difference in mean slope between north and south side of road
NS250_Land_Dissimilar	250m	Sorenson's dissimilarity metric between north and south side of road
NS250_Water_Diff	250m	Difference in the amount of water between north and south side of road
NS250_Wetland_Diff	250m	Difference in the amount of total wetland between north and south side of road
NS250_Forest_Diff	250m	Difference in the amount of total forest between north and south side of road
W500m_Sinuosity	500m	Road sinuosity (within 500m distance)
W500_BuildCount	500m	Number of buildings within 500m radius
W500_CulvertCount	500m	Number of culverts within 500m radius
W500_IntersectCount	500m	Number of road intersections within 500m radius
W500_WaterCount	500m	Number of water crossings within 500m radius
W500_Land_Aggregates	500m	Aggregate extraction landcover (%)
W500_Land_Agriculture	500m	Agriculture landcover (%)
W500_Land_Aquatic	500m	Aquatic, open water, wetland landcover (%)
W500_Land_ForConifer	500m	Coniferous forest landcover (%)
W500_Land_ForDeciduous	500m	Deciduous forest landcover (%)

W500_Land_ForMixed	500m	Mixed forest landcover (%)
W500_Land_ForUndifferentiated	500m	Undifferentiated forest landcover (%)
W500_Land_Marsh	500m	Marsh landcover (%)
W500_Land_Road	500m	Roadways (%)
W500_Land_Swamp	500m	Swamp landcover (%)
W500_Land_Urban	500m	Urban landcover (%)
W500_Land_Water	500m	Open water bodies (%)
W500m_Land_WETLAND	500m	Total wetland (aquatic+marsh+swamp)(%)
W500m_Land_FOREST	500m	Total forest (coniferous+deciduous+mixed+undifferentiated) (%)
W500m_Land_DIVERSITY	500m	Landcover diversity (Shannon Index score)
W500_Circuit_MEAN	500m	Habitat connectivity (average Circuitscape score)
NS500_Elev_Diff	500m	Difference in mean elevation between north and south side of road
NS500_Slope_Diff	500m	Difference in mean slope between north and south side of road
NS500_Land_Dissimilar	500m	Sorenson's dissimilarity metric between north and south side of road
NS500_Water_Diff	500m	Difference in the amount of water between north and south side of road
NS500_Wetland_Diff	500m	Difference in the amount of total wetland between north and south side of road
NS500_Forest_Diff	500m	Difference in the amount of total forest between north and south side of road

APPENDIX III

SAFETY & SURVEY PROTOCOL

Project: Highway 401 (Gananoque to Brockville) Species at Risk Ecology Project 2014-2016 MNR SAR Stewardship Fund (MTO Encroachment Permit: EC-2014-420-17).

Goal: Improve habitat connectivity by identifying key sites in the study area to mitigate and increase highway permeability for SAR movements.

Objectives:

1. Record study site culvert conditions (dimensions, water flow regimes, approach).
2. Describe habitat and suitability for SAR presence.
3. Record opportunistic SAR and wildlife presence.
4. Record opportunistic wildlife/road interactions (dead or alive on /near road).
5. Develop a specific habitat/SAR hotspot model for the study site to predict and prioritize mitigation.

Method:

Walk the Highway 401 study site and document all evidence of wildlife/road interactions, and habitat and culvert characteristics.

Personnel:

1 Field Supervisor; 2 Field Researchers

Responsibilities:

Field Supervisor Responsibilities:

- Adhere to safety and survey protocol, review Ontario Traffic Manual Book 7, Encroachment Permit: EC-2014-420-17
- Collect data
- Liaise with Field Researchers and coordinate survey schedule (ensure survey protocol is adhered to and Researchers work in pairs)
- Enter all data into a project specific database
- Summarize data and participate in data reporting

Field Research Responsibilities:

- Adhere to safety and survey protocol, review Ontario Traffic Manual Book 7, Encroachment Permit: EC-2014-420-17
- Collect data
- Liaise with Field Supervisor and report any study complications/recommendations
- Submit data (including photos) to Field Supervisor each week during the study period
- Project outreach and education

Safety Protocol

- Safety protocol training must be received prior to entering the field
- Signed waivers and emergency contact information must be received prior to entering the field
- Adhere to MTO Encroachment Permit: EC-2014-420-17
- Review Ontario Traffic Manual (Book 7)
- Surveys must be conducted in pairs
- Researchers must walk opposing traffic
- Researchers must never enter the roadway
- Personal safety equipment must be worn at all times in the field
    - Safety vest
    - Hard hat
    - Nitrile gloves
    - Leather work gloves (when required)
    - Close-toed shoes
- Dress weather appropriate (hat, sunscreen, sun glasses, rain gear, sweater, drink water, etc.)
- No ear bud or listening to music – always be aware of your environment and traffic
- Park on cross roads to access the study site
- Carry a cell phone (to be used in the field for emergencies only)

Survey Protocol

- Your safety is paramount and comes FIRST
- Park the vehicle at a safe location to access the study site
- Never enter the roadway or impede/distract traffic
- Document all evidence of wildlife/road interactions (remains/carcasses (e.g. feathers, fur, bones), prints, scat, nests, live specimens)
- Discard remains into the roadside habitat to avoid data collection redundancies
- Walk opposing traffic
- Scan the road from the median to the guard rail and from the guard rail into the roadside habitat (e.g. down ditches, etc.)
- GPS and photograph ALL wildlife observations (alive or dead near or on road)
- Collect a full dataset for each specimen (e.g. date, time, observer, GPS location, weather conditions, specimen details (fresh kill, size, age class, sex, gravid, behaviour, direction traveling, etc.), location details, comments, etc.)
- Complete the data card each for each individual sighting entry – please review and ensure all fields are filled in
- Record study site culvert conditions (dimensions, water flow regimes, approach, debris, wildlife interaction evidence e.g. scat)
- Record roadside habitat characteristics
- Please write clearly

Please note: Do not discuss Species at Risk presence data with the general public.

Survey Schedule *(proposed)*

Days: Monday, Wednesday, Friday

Start Time: 9:00 a.m.

Field Equipment

- A plastic tub with air holes drilled into the top (to transport an injured animal)
- Safety vests
- Hard hats
- GPS units
- Digital camera
- Nitrile gloves
- Leather work gloves
- Clip board, pen and data cards
- Clear plastic bag (to protect data cards rainy weather)
- Towels
- Measuring tape
- Hand sanitizer*
- Hard hats
- Safety vests
- Psychrometer (temperature and moisture reading)
- Binoculars
- 1st Aid kit
- Emergency contact information
- Herpetofauna Identification cards

**note: please do not handle wildlife after applying chemicals to your hands (e.g. sunscreen, hand sanitizer, etc.)*

Injured Wildlife

In the case that an injured animal is discovered due to a wildlife/vehicle collision please call for assistance and procedure:

1. Gananoque Veterinarian Clinic: 613-382-3429
2. After hours - Kingston Regional Pet Hospital: 613-634-5370
3. Canadian Cooperative Wildlife Health Centre: 1-866-532-3161
4. Kawartha Turtle Trauma Centre: 705-741-5000

Project Contacts:

Dr. Fred Schueler, Field Supervisor: Cell – 613-299-3107
Home – 613-258-3107

Mandy Karch, OREG Coordinator: 416-726-9900

Cameron Smith, A2A Secretary: 613-387-3889

Dr. Ryan Danby, Queen's University: 613-533-6000 Ext. 77105

Dan MacMartin, Corridor Management Officer, MTO: 613-742-5324

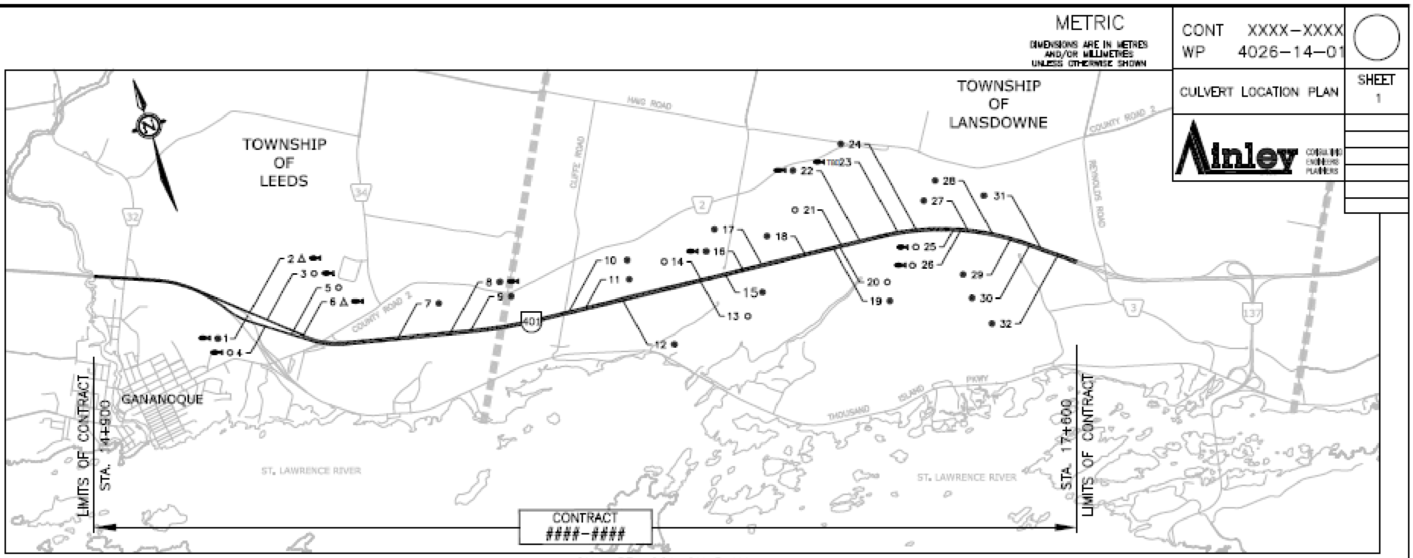
Shaun Thompson, Management Biologist, MNR: 613-258-8235

Gananoque Veterinarian Clinic: 613-382-3429

Emergency – Kingston Regional Pet Hospital: 613-634-5370

APPENDIX VI

MTO CULVERT DATASET & HOTSPOT CULVERT PHOTOS



CULVERT LOCATION PLAN

N.T.S.

CULVERT REPLACEMENTS AND RELINES

CONTRACT CULVERT #	CULVERT ID	HIGHWAY	LOCATION	LANE	TOWNSHIP	STATION	TYPE	EXISTING SIZE	EXISTING LENGTH
1	002104010046	401	Ramp	WBL	Leeds	10+500 (MED)	NRFO	1219 x 1219	45.22
2	002104010017	401	Centreline	WBL	Leeds	17+185 (WBL)	NRFO	1200 x 1260	34.34
3	002104010018	401	Centreline	WBL	Leeds	17+444 (WBL)	SPCSP	900	37.28
4	002104010019	401	Centreline	EBL	Leeds	17+461 (EBL)	SPCSP	900	25.81
5	002104010020	401	Centreline	EBL	Leeds	17+837 (EBL)	SPCSP	900	37.06
6	002104010021	401	Centreline	EBL/WBL	Leeds	18+002 (EBL)	NRFO	1200 x 1240	70.54
7*	002104010040	401	Centreline	EBL	Leeds	19+330 (MED)	CSP	300	28.80
8*	002104010041	401	Centreline	EBL	Leeds	20+054 (MED)	CSP	305	31.63
9*	002204010018	401	Centreline	WBL	Lansdowne	20+335 (MED)	CSP	300	34.12
10*	002204010019	401	Centreline	WBL	Lansdowne	10+391 (WBL)	CSP	300	30.05
11*	002204010020	401	Centreline	WBL	Lansdowne	10+636 (WBL)	CSP	305	33.00
12*	002204010021	401	Centreline	EBL/Ramp	Lansdowne	11+153 (EBL)	CSP	300	30.45
13*	002204010016A	401	Centreline	EBL	Lansdowne	12+257 (EBL)	SPCSP	750	34.61
14*	002204010016B	401	Centreline	WBL	Lansdowne	12+269 (WBL)	SPCSP	750	31.23
15*	002204010023	401	Centreline	EBL	Lansdowne	12+616 (EBL)	CSP	300	36.33
16*	002204010024	401	Centreline	WBL	Lansdowne	12+860 (WBL)	CSP	450	31.47

* CULVERTS FOUND TO BE COATED WITH ASBESTOS

CULVERT REPLACEMENTS AND RELINES

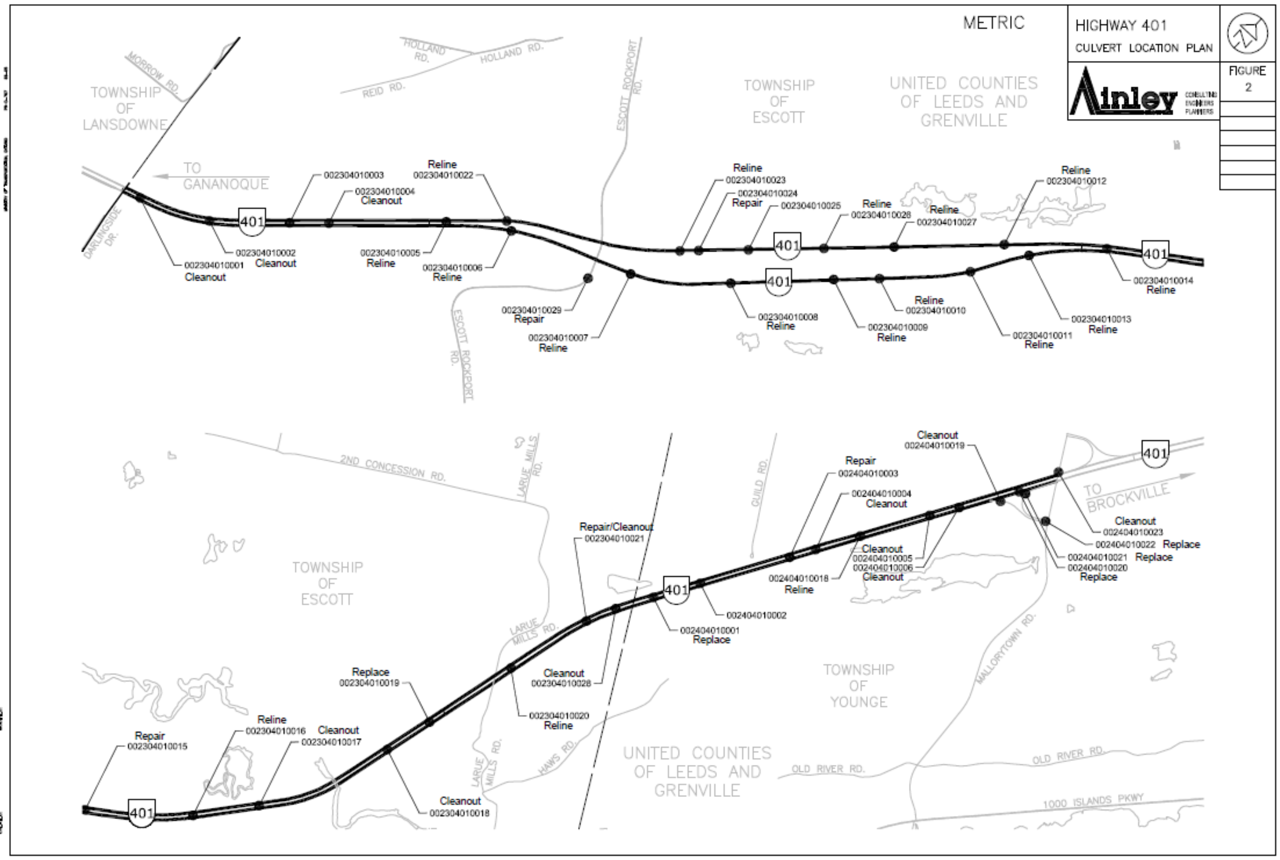
CONTRACT CULVERT #	CULVERT ID	HIGHWAY	LOCATION	LANE	TOWNSHIP	STATION	TYPE	EXISTING SIZE	EXISTING LENGTH
17*	002204010025	401	Centreline	WBL	Lansdowne	13+129 (WBL)	CSP	450	31.98
18*	002204010026	401	Centreline	WBL	Lansdowne	13+744 (WBL)	CSP	450	27.78
19*	002204010027	401	Centreline	EBL	Lansdowne	14+148 (EBL)	CSP	450	31.27
20*	002204010005A	401	Centreline	EBL	Lansdowne	14+237 (EBL)	SPCSP	900	37.29
21*	002204010005B	401	Centreline	WBL	Lansdowne	14+262 (WBL)	SPCSP	900	38.20
22*	002204010028	401	Centreline	WBL	Lansdowne	14+521 (WBL)	CSP	450	28.60
23*	002204010029	401	Centreline	WBL	Lansdowne	15+060 (WBL)	SPCSP	300	28.54
24*	002204010030	401	Centreline	EBL	Lansdowne	15+326 (EBL)	SPCSP	600	28.39
25*	002204010007	401	Centreline	EBL/WBL	Lansdowne	15+808 (EBL)	SPCSP	1200	107.42
26*	002204010008	401	Centreline	EBL/WBL	Lansdowne	15+916 (EBL)	SPCSP	1200	78.06
27*	002204010031	401	Centreline	WBL	Lansdowne	16+027 (WBL)	SPCSP	450	29.29
28*	002204010032	401	Centreline	WBL	Lansdowne	16+371 (WBL)	SPCSP	450	28.78
29*	002204010033	401	Centreline	EBL	Lansdowne	16+623 (EBL)	SPCSP	450	28.53
30*	002204010034	401	Centreline	EBL	Lansdowne	16+895 (EBL)	CSP	450	31.73
31*	002204010035	401	Centreline	WBL	Lansdowne	17+074 (WBL)	CSP	450	28.71
32*	002204010036	401	Centreline	WBL	Lansdowne	17+333 (WBL)	CSP	300	39.35

LEGEND

- ● CULVERT TO BE REPLACED
- ○ CULVERT TO BE RELINED
- □ CULVERT TO BE ABANDONED
- △ CULVERT TO BE BRACED AND MONITORED
- FISHERIES CULVERT
- TBD TO BE DETERMINED

N.T.S.

Culvert locations from the Gananoque River Bridge to Reynolds Road. (Prepared by Ainley Group for MTO)



Culvert locations from east of Highway 137 to Mallorytown. (Prepared by Ainley Group for MTO)

Hotspot I

MTO ID#: 002204010001

- Corrugated Steel Pipe, 101.7m long
- Habitat at the site of the culvert. The culvert is not shown.

MTO ID#: 002204010002

- Rigid Frame Open, 105.3 m long
- Habitat at the site of the culvert. The culvert is at the bottom right of photo.

Hotspot II

MTO ID#: 002304010002

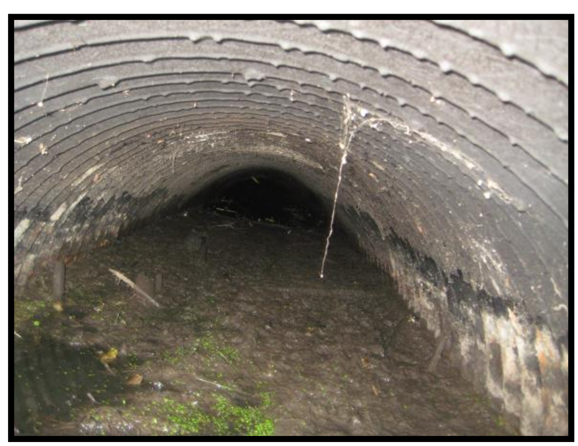
- Corrugated Steel Pipe, 57 m long

MTO ID#: 002304010003

- Concrete Box Culvert, 73 m long

MTO ID#: 002304010004

- Corrugated Steel Pipe, 64 m long



Hotspot III

MTO ID#: 002304010016

- Corrugated Steel Pipe

MTO ID#: 002304010017

- Corrugated Steel Pipe

The culverts are designed to convey water and are inadequate for wildlife passage. Some individuals of some species (e.g. Blanding's Turtles) may opportunistically use the culverts, especially with the addition of fencing, but many species, particularly those that seek dry passage, will not enter.

In 2016, MTO will be conducting routine maintenance of the culverts within the study area. Within the hotspots, the scheduled work will involve cleaning out culverts (MTO ID #: 002304010002 and 002304010004 from Hotspot II, and MTO ID#: 002304010017 from Hotspot III) and relining culverts (MTO ID#: 002304010016). Cleaning out and relining culverts may function to improve hydrological conditions, but these efforts will not effectively improve wildlife passage. Monitoring the culverts with cameras will inform how to modify current conditions to benefit wildlife, but in the development of a large-scale habitat connectivity strategy, an integral component will be the addition of dedicated wildlife culverts to Highway 401.