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INCORPORATING ROAD-MORTALITY HOTSPOT MODELING AND CONNECTIVITY ANALYSES INTO ROAD MITIGATION PLANNING IN ONTARIO

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ABSTRACT

In Ontario and world-wide, wildlife are increasingly involved in collisions with motor-vehicles, providing a real threat to human and wildlife safety on roads. This is particularly evident in Ontario due to its increasing human density, and traffic volumes along with its high biodiversity. The Committee on the Status of Endangered Wildlife in Canada has listed seven of Ontario's eight turtle species as endangered or of special concern and roads have been identified as a major threat for five of these species.

Ontario is planning to extend a number of 400 series expressways across Ontario over the next 20 years, some of which are currently underway. With increasing threats of a severely fragmented landscape, provincial and municipal transportation agencies are currently integrating transportation mitigation solutions e.g. wildlife overpasses and underpasses, within the environmental assessment study (EAS) process. To assist in providing cutting-edge road ecology science in this decision-making process a group of non-government, government, scientists, educators, and transportation planners collectively called the Ontario Road Ecology Group (OREG) formed at the Toronto Zoo in 2007.

This paper discusses two initiatives adopted by the OREG. We first discuss the development of a GIS habitat mapping model for wetland-forest animals in southern Ontario. Model development entailed weighting a land-use layer, and summing the land-use within 200 m buffers surrounding each 15 x 15 m pixel in the landscape. A Habitat Suitability Index (HSI) was then attached to each road pixel. Opportunistic validation using Chi-squared statistics showed that HSI's on roads with a score greater than 30,000 had higher numbers of road mortality than expected by chance. Alternatively, HSI scores less than 10,000 had significantly fewer road mortality. Ongoing work entails a systematic rigorous validation collecting road mortality data along random, and hot and cold spot locations in predefined circuits to regress dead and alive on road animal abundance with HSI scores.

The second initiative entails combining the validated road hotspot model with natural heritage systems to incorporate landscape connectivity into the final model. Natural heritage modeling is an on-going process adopted by the Ministry of Natural Resources and Conservation Authorities to map and connect natural core habitat areas across southern Ontario and within watersheds. We show examples of the preliminary application of the hotspot model to already developed natural heritages systems e.g. the Greenbelt in the Project 400 study area. This type of integration in addition to species at risk habitat mapping can assist in prioritizing areas where mitigation measures such as crossing structures will be most effective to maintain connectivity for species at risk, e.g. turtles in addition to reducing wildlife road mortality. Once complete, these analyses can be used as leverage to bring together key stakeholders to determine a strategy to

ensure province-wide landscape-level planning is adopted into policy by transportation agencies in Ontario.

INTRODUCTION

Ontario has the highest number of roads, vehicles, and species of animals in Canada. As a result wildlife is increasingly involved in collisions with motor-vehicles, providing a real threat for wildlife and human safety on roads. Based on 2004 statistics, roughly 6% of all motor-vehicle collisions involve wildlife (14,000/year) and this has increased by 83% over a 10 year period. Ontario statistics from 2004, show motor-vehicle collisions with moose and deer resulted in 7 fatalities, and 542 injuries for motorists (Ontario Ministry of Transportation, NE Division, personal communication).

For some species continued trends of increased road mortality has contributed to significant declines in population numbers in Ontario. For example, seven of eight turtle species are listed by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) as threatened, endangered or special concern and road mortality has been identified as one of the most direct, significant threats to five of these turtle species.

In 2007 a group of scientists, academics, consultants, and government planners assembled at an Ecopassages forum at the Toronto Zoo to begin to tackle some of the negative impacts associated with roads and wildlife in Ontario. As a result a group of individuals banded together and formed the ‘Ontario Road Ecology Group’-OREG. Its goal is to raise awareness about the threat of roads to biodiversity in Ontario, and to research and apply solutions to these threats.

In response to the Ministry of Transportation’s (MTO) plans to extend a number of 400 series highways as well as other provincial highways over the next 20 years, OREG initiated Project 400. This project entails working with the provincial transportation government to evaluate and provide solutions to minimize potential environmental and wildlife impacts such as wildlife-vehicle collisions (WVCs) along roads, specifically 400-level expressways. Possible solutions include the use of mitigation measures such as reptile tunnels (Aresco 2005; Dodd et al. 2004), overpasses and underpasses, culverts and other structures that have been successful in alleviating road mortality (Forman et.al. 2003).

This paper describes two components of Project 400:

1) The development, validation and application of a GIS-based, road-mortality hotspot model. This model prioritizes where there will be mortality sinks for wildlife on current and proposed roads.

2) The development and integration of connectivity and species at risk (SAR) presence data into road planning procedures. This model predicts where there roads will behave as barriers for movement of wildlife, most specifically SAR.

STUDY AREA:

Ontario is divided into northern Ontario, the landmass of, and north of, the Canadian Shield, and southern Ontario the portion of the province south of the Canadian Shield (Figure 1). The study area for Project 400 is composed mainly of the central portion of Southern Ontario (Figure 1). There are several planned routes (blue lines) where a proposed route has been defined and the Environmental Assessment Study (EAS) is nearing completion. In addition there are conceptual routes (grey lines) where a proposed route has not been defined and the EAS process is in its early stages if at all. These highways are being developed in response to the population and employment growth expected in the major urban centres across the Greater Golden Horseshoe (GGH) (Ministry of Public Infrastructure Renewal 2006).

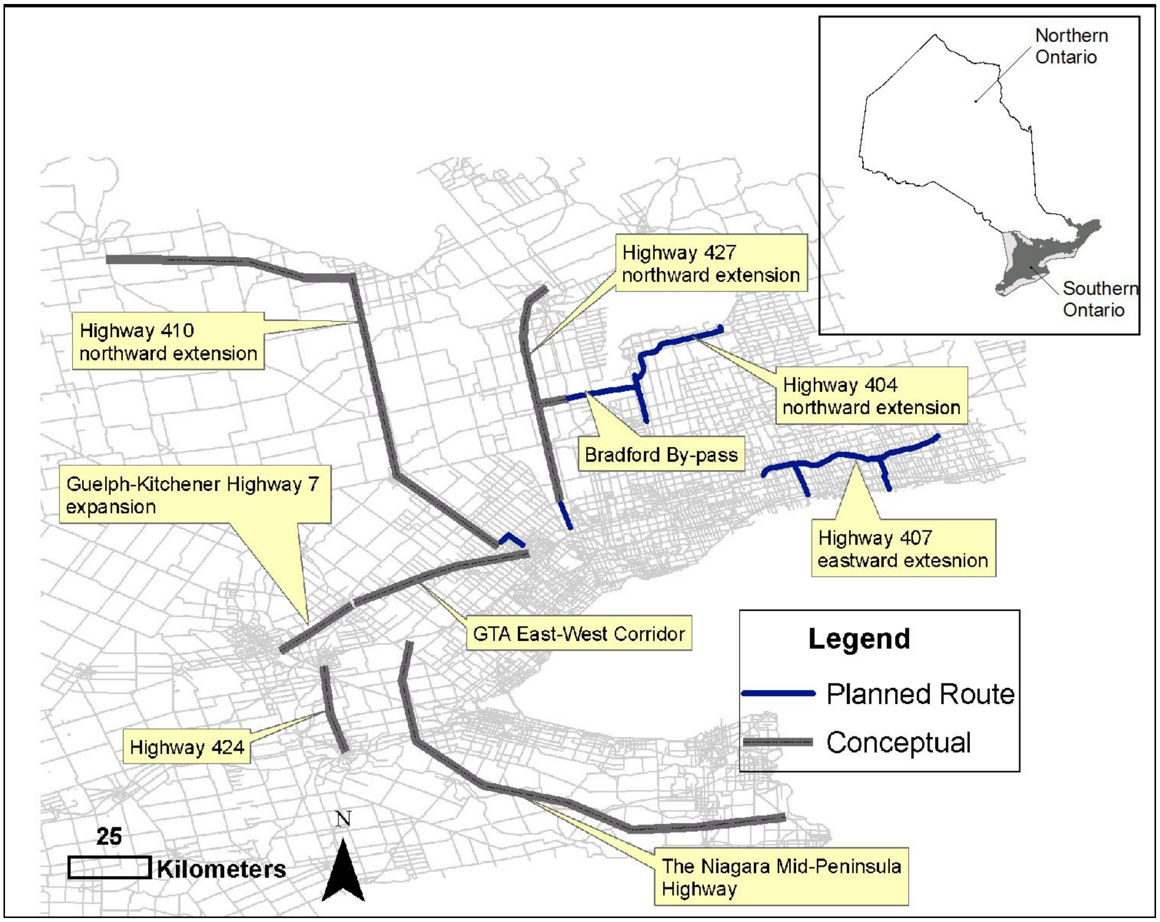

Figure 1. Study area for Project 400 showing the planned and conceptual routes in south-central Ontario. Note: The best available Information was used to complete this map as of September 2008.

METHODS

Road-mortality Hotspot Model

Development

After completing a review of the literature and available expert opinion we selected forest-wetland habitat to be associated with the distribution of the majority of SAR and other animals in southern Ontario. For example published literature has shown that ungulate (mainly deer) road mortalities are positively correlated to the amount of forest cover or have occurred close to forest cover in six published studies (Bahsore et al. 1985, Finder et al. 1999, Hubbard et al. 2000, Malo et al. 2004, Seiler 2005, Gunson et al. 2009). In addition, herpetofauna road mortalities (amphibians and reptiles), have been correlated to a mosaic of wetland-forest habitat (deMaynadier and Hunter 1999, Joyal et al. 2001 Guerry and Hunter 2002, Gibbs and Shriver 2005, Hermann et al. 2005, Langen et al. 2008) and at locations where roads bisect wetlands (Langen et al. 2008).

We then used the available regional geospatial layers for model development. The Southern Ontario Land Resource Information System (SOLRIS), and the Ministry of Natural Resources (MNR) road network were used for habitat identification and roads respectively. To produce a habitat map a score was applied to every habitat type within the SOLRIS layer. Wetland (swamps, fens, bogs, marshes, and open water) received the highest score (100), forest habitat (forest, mixed forest, deciduous forest, and plantations) received a score of 50, and all other features (agriculture, and built-up) received a score of zero.

We then summed the score of the newly classed pixels within a 200 m radius buffer surrounding every 15 x 15 m pixel within the study extent of the SOLRIS layer. This created an output layer herein called habitat suitability, where each 15 x 15 m pixel had a habitat suitability index (HSI) (range 0-55,000) associated with it. We then converted the vector-type MNR roads layer to a raster data-type with 15 x 15 m pixels and registered it with the habitat suitability layer so the two layers spatially overlapped. This allowed the summation of the two layers so an HSI could be attached to each road pixel in the landscape. We used ArcMap 9.2 for all spatial analyses using a Geographic Information Sytem (ESRI, Redlands California).

Opportunistic Validation

We obtained a road mortality database for all wetland-forest amphibians and reptiles for southern Ontario collected by two organizations, the Bishop Mills Natural History Centre, and the Natural Heritage Information Centre from 1970 to 2005. We selected eastern Ontario-UTM Zone 18T as our study area because this region had the vast majority of road mortalities and was a spatial extent that could be easily manipulated to perform spatial analysis in a GIS. We filtered the database for species of herpetofauna that are typically found hibernating and breeding in wetland-forest complexes as per the literature and internet search (Gibbs 1998, Glista et al. 2007, Langen et al. 2008). These included the American toad (*Bufo americanus)*, Gray tree frog (*Hyla versicolor*), Wood frog (*Rana sylvatica*), Spring peeper (*Pseudacris crucifer*), Spotted salamander (*Ambystoma maculatum*), Painted turtle (*Chrysemys picta*), Snapping turtle (*Chelydra serpentine*), Blandings turtle (*Emydoidea blandingii*), Map turtle (*Graptemys geographica*), Musk turtle (*Sternotherus* odoratus), and the Spotted turtle (*Clemmys guttata*). To address spatial autocorrelation we reduced multiple mortality events within 500 m of each other, occurring on the same day, for the same species to only one event. From these data we only included events that were within 500 m of a road. The final collated data set had 447 road mortality data points.

We overlaid the observed road mortalities on the final output layer and attached the closest HSI score to each one. We grouped the HSI scores into groups of 5,000 starting with 0-5,000, etc. up to 50,000, and counted the number of observed turtle mortalities that were located within each class interval (Table 1). We did not include the final interval, 50,000 to 55,000 since there were no observed mortalities that were located on road segments with this score class. We calculated the expected count distribution for wetland-forest road mortalities at each score interval based on the proportional road length assigned to each score class (Table 1). We then used Chi-square statistics to compare the count of the observed mortalities to what was expected for each score class. We used Bailey's confidence intervals to determine if the difference between the observed and expected values were significant ($p<0.05$) (Cherry 1996) (Table 1). For interpretation we calculated the observed to expected ratio to obtain a percentage of observed kills to what was expected.

Systematic Validation

We selected a 232 km circuit along County Roads (and short stretches of connecting municipal roads) around Leeds & Grenville United Counties in eastern Ontario, from the Rideau River south to the St Lawrence River, straddling the Frontenac Axis/limestone boundary (Fig. 2). In the circuit there were 18 hotspots (score > 30,000) and 23 coldspot stations (score < 10,000) (Fig. 2, see Results section).

We obtained geographical coordinates for all dead on road (DOR) vertebrates, and nonvolant alive on road (AOR) vertebrates, seen in driving the circuit, stopping for all that may be SAR or related species (Snakes or Turtles). At each station we stopped at the station stretch, and each of two surveyors walked one way, gathering or counting carcasses and AOR animals until our GPS unit read 100 m distant from the station, returning on the other side of the road. We picked up all cm-scale roadkills seen on the pavement or gravel shoulders, and recorded nonvolant species seen alive on the pavement and shoulders. We also recorded Turtle nest excavations and predation, and various incidental road-related phenomena (including Anuran calling, and invasive plants & Gastropods.

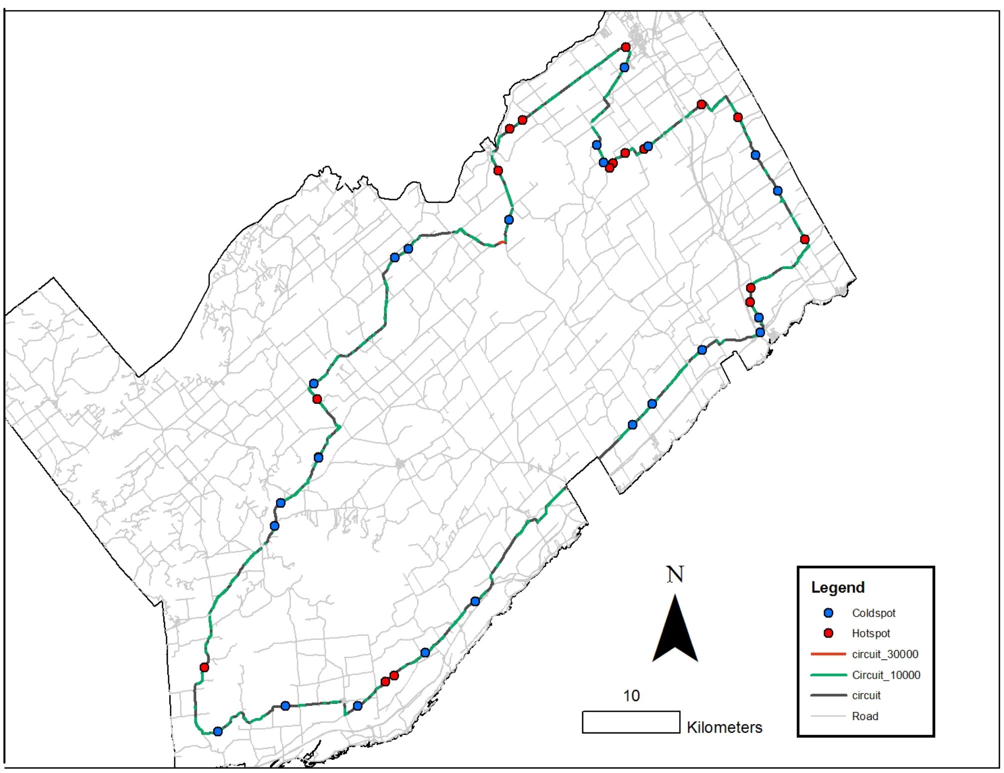

Figure 2. Surveyed circuit in Leeds & Grenville United Counties in eastern Ontario showing hot- and coldspot stations used to systematically validate the predefined hotspot model.

Road-connectivity Model

In the 1990's the Ministry of Natural Resources incorporated a natural heritage system (NHS) strategy into its policy (Ministry of Natural Resources 1999), and other agencies such as Ontario's Conservation Authorities are adopting a natural heritage approach to defining and connecting significant natural wildlands in their watersheds (e.g. Toronto Region Conservation Authority 2007). We integrated available NHS with our habitat models to incorporate connectivity in model output. First, we filtered the final output from the habitat suitability model for scored pixels greater than 30,000 which were previously defined hotspots for road mortality. We then overlaid this with the NHS models in the study area for Project 400, e.g. the greenbelt NHS. The Greenbelt zone is a previously designated 'green zone' made up of key natural, agricultural, and rural areas that wrap around the golden horseshoe from Niagara to areas east of the Greater Toronto Area (The Greenbelt Plan, Ministry of Municipal Affairs and Housing, 2005). The natural heritage system contains connected natural areas within the green zone. The Ministry of Transportation 407 planning team invited OREG to assist in prioritizing where wildlife mitigation would be most effective along the highway corridor. We used the results from the validated hotspot model and the Greenbelt NHS to apply the model to the Highway 407 east extension.

RESULTS:
Road-mortality Hotspot Model
Opportunistic Validation

Table 1 below shows that sections of road that receive a score between 0 and 10,000 will have significantly less road mortality with wetland-forest animals than expected, herein deemed a coldspot. Sections of road that receive a score between 30,000 and 50,000 will have significantly more road mortality than expected, herein deemed a hotspot.

Table 1. Summary of Chi-square and Bailey's confidence interval analyses using road-kill data from 1970 to 2005 for wetland-forest animals in eastern Ontario. Coldspots refer to sections of roads with significantly less road-kill than expected, and hotspots refer to road sections with significantly more road-kill than expected.

Score Class	Observed	Expected	Observed/ Expected	Type
5,000	54	158	34	Coldspot
10,000	56	85	66	Coldspot
15,000	73	62	117	n/a
20,000	42	48	88	n/a
25,000	63	38	166	n/a
30,000	36	26	138	n/a
35,000	47	15	313	Hotspot
40,000	36	8	450	Hotspot
45,000	22	3	733	Hotspot
50,000	18	4	450	Hotspot

Total	**447**	**447**		

Systematic Validation

We completed one circuit on June 18th and June 19th, 2009 as a pilot test run to determine the time, cost, and methodological requirements for a rigorous and systematic study design. Wetland-forest herpetofaunal species found dead and alive on the road at the surveyed transects were: Snapping turtle, Painted turtle, Gray treefrog, American toad, Blanding's turtle, and the Wood frog. Other herpetofaunal species were the Water snake (*Nerodia sipedon*), Milk snake (*Lampropeltis triangulum*), Green frog (*Rana clamitans*), Leopard frog (*Rana pipiens*), and the Bull frog (*Rana catesbeiana*). Road-killed queen Bumble Bees (Bombus) were the most conspicuous invertebrates.

The circuit required 2 people ~ 9 hours to complete and has an estimated cost of $2,000 per circuit which includes mileage costs, and labour (set-up, surveying, and data entry). Ideally the circuit should be completed from early spring through summer for a number of years to obtain data on all species throughout their specific seasonal life-cycle requirements, e.g., breeding, egg-laying, and juvenile dispersal. The following questions and methodological considerations were formulated as a result of the pilot survey:

- Results can determine the best cut-off score to apply to a coldspot and a hotspot
- Results can determine if the land-use layer SOLRIS is appropriate to determine wetland-forest complexes as hotspots
- Seasonal replicates are required to produce species-specific models that will incorporate different seasonal movements for each species or species group
- Results (number of AOR and DOR animals) can be regressed against each scored class to determine appropriate scores for hotspots and coldspots
- The surveys will provide valuable insights on the death rate of animals on eastern Ontario county roads

Road-connectivity Model

Figure 3 shows twelve areas (yellow dots) where high quality habitat (black and white areas, score > 30,000) detected by the hotspot model, bisect the 407 east highway extension. These are plausible areas for attempted mitigation since they are contained in the Greenbelt natural heritage system. This means that these are probable wildlife movement corridors as well as probable sites of initially high wildlife road mortality, before dispersal attempts cease or the populations become extinct.

The 407 transportation planning team finalized the detail design phase of the EAS and there will be 55 wildlife crossings associated with watercourses, the majority of which will accommodate ungulates, and 6 wildlife underpasses not related to watercourses. Five out of the 6 wildlife underpasses are for small animals only. OREG's modeling efforts were used to support and corroborate the Study Team's pervious connectivity and linkage analysis and eco-passage system recommendations.

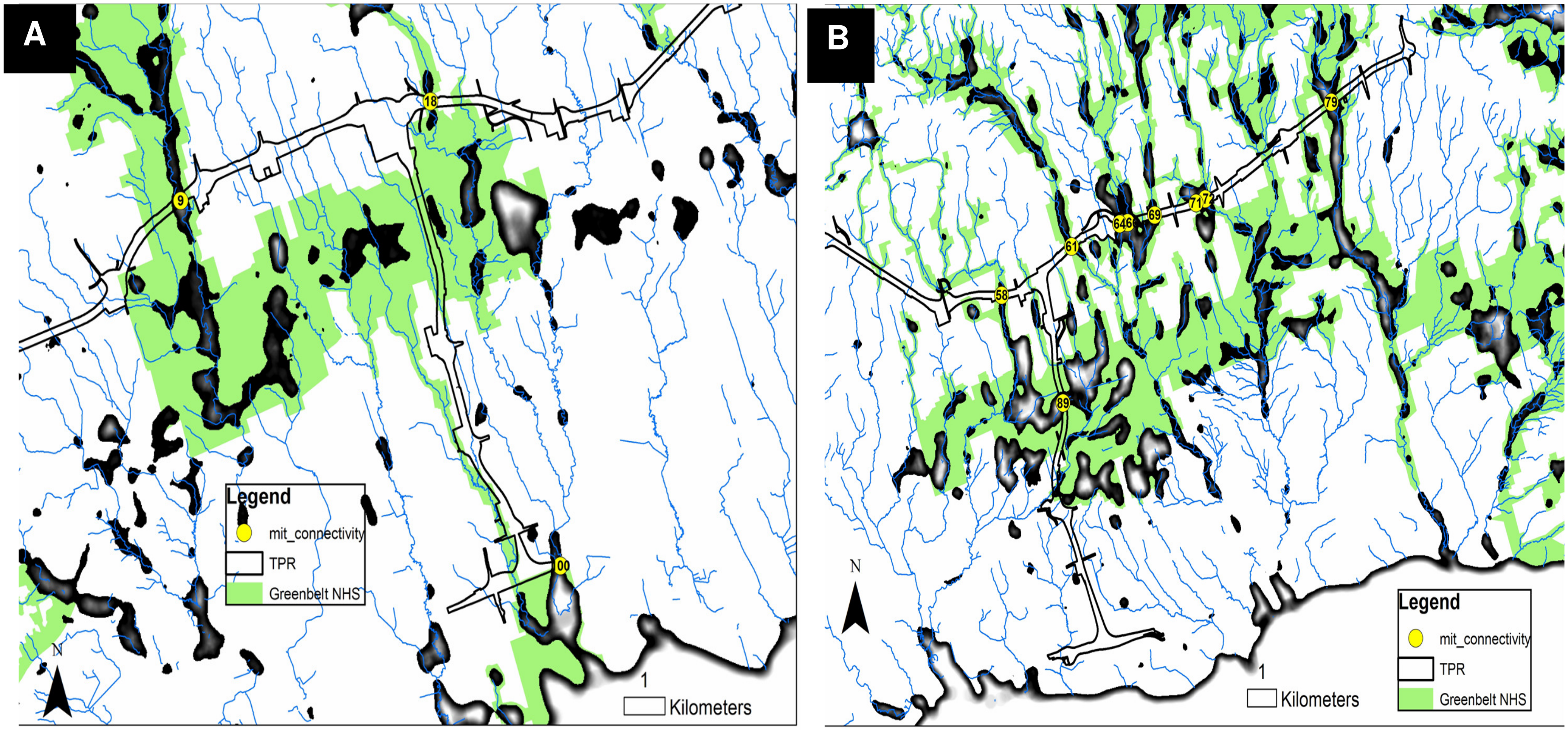

Figure 3. A. The 407 east extension with the west link B. The 407 east extension with the east link combined with the hotspot model and the greenbelt natural heritage system. Yellow dots show where the hotspot model predicts high road mortality all contained within the natural heritage system.

CONCLUSIONS AND FUTURE WORK:

On-going validation and refinement of the road-mortality hotspot model can be achieved by engaging local citizens, conservation authorities and naturalist groups to report and collect locations of wildlife-vehicle collisions within their communities. This type of data collection requires a coordinated effort to sample road mortality across each watershed in southern Ontario. Local citizens can repeatedly monitor sections of roads falling under a larger project such as–'Adopt-A-Crossing' (Schueler and Karstad 2009). Collectively, the GIS modeling and data collation can work towards evaluating the model and providing a landscape-level blueprint for prioritizing mitigation efforts for wildlife in southern Ontario. This will ensure a validated hotspot model at a regional scale required to maintain population persistence for species at risk that are increasingly subjected to road-related threats, namely road mortality and landscape fragmentation.

The road mortality model will be applied to the Project 400 study area along with applicable natural heritage system models. When available, the model will be manipulated to incorporate the most up to date, high resolution, and validated habitat layers, e.g. the ecological land classification layers in specific watersheds. In addition, species at risk presence data will be used to develop species-specific models that incorporate other habitat characteristics such as stream crossings, traffic volumes and topography. SAR presence data can also assist in prioritizing areas for mitigation. However caution will be exercised since the data has been opportunistically collected and SAR can easily exist in areas not yet sampled.

These types of applications- hotspot modeling, and connectivity analyses will be applied to all 400-level roads by OREG and other roads in southern Ontario. At this point these applications are preliminary and a strategy needs to be defined to ensure long-term support to further test the models and to ensure their application into the planning stages of large-scale transportation projects at both the municipal and provincial level.

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BIOGRAPHICAL SKETCH

Kari Gunson holds a BSc. in Zoology and Ecology from the University of Calgary, MSc. in Conservation Biology from the University of Cape Town, and another MSc. in Geospatial Technologies from the State University of New York. She has eleven years experience in road ecology focusing mainly on the interactions of roads and wildlife, and has co-authored eight peer-reviewed articles in this area of research. She worked six years as a research associate on the Banff Crossings Project in Banff National Park and she is a co-founder of the Ontario Road Ecology Group initiated in the Toronto Zoo.

Dave Ireland is the Curator of Conservation Programs at Toronto Zoo and, among other duties, Chairs the Ontario Road Ecology Group. Dave works closely with local, regional and international organizations to collaboratively develop programs to conserve biodiversity. Dave has extensive experience in herpetology in Ontario where he received an MSc in herpetology from Trent University and published 2 peer-reviewed papers in this field.

Dr. Fred Schueler obtained his bachelor degree from Cornell in 1970 in Wildlife Management, his Ph.D. dealt with geographic variation in Northern Leopard Frogs (Rana pipiens; University of Toronto, Zoology, 1979). He presently styles himself Research Curator at the Bishops Mills Natural History Centre, a family research & conservation institute in eastern Ontario http://pinicola.ca. He is also a co-founder of the Ontario Road Ecology Group and he has collected over 35 years of road mortality data that has been instrumental in validating the efforts of the OREG.

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