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A tool to prioritize high-risk road mortality locations for wetland-forest herpetofauna in southern Ontario, Canada

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Abstract. Roads are more frequently fragmenting natural habitats increasing the likelihood of collisions between wildlife and vehicles. The Canada Species at Risk Act (2002) lists species that are threatened with regional extinction, and roads have been identified as a significant threat for many of these wildlife species in Ontario, e.g. turtles. In response to negative road impacts on wildlife, we developed a GIS modeling tool that predicts high-risk road mortality locations for selected wetland-forest herpetofaunal species that are representative of the landscape. We obtained a habitat suitability index (sum of weighted habitat scores) within a 12.6 hectare buffer surrounding each 15 x 15 m pixel of road in the landscape. Validation of the final model with dead and alive on-road herpetofaunal data showed animals were more at risk of road mortality when roads bisected large areas of wetland-forest habitat. The tool has been effective to promote proactive mitigation planning within government transportation agencies at the municipal and provincial level. Future work will develop species-specific models that identify road mortality locations along roads that re-connect habitat from a local and metapopulation perspective. In addition, the models will be used to prioritize locations along roads for effective mitigation solutions, e.g. turtle crossing signs and wildlife crossing structures.

Keywords: Ontario, herpetofauna, Geographic Information System tool, mitigation, prioritize, landscape.

Introduction

In southern Ontario the total length of major roads has increased fivefold between 1935 and 1995 (Fenech et al. 2005) and there is no point (excluding large lakes and protected areas) that is more than 1.5 km from a road. Along with an increasing road network and associated traffic volumes, southern Ontario harbours the highest biodiversity of plants and animals in Canada.

As more and more species become threatened by human activities they are added to the Species at Risk (SAR) list in Canada by the Committee of the Status of Endangered Wildlife in Canada. A SAR is any naturally occurring plant or animal in danger of extinction or of disappearing from a region. As of January 2007, there were 534 SAR in Canada and Ontario is home to 182 of these species, the highest percentage of species at risk among the provinces (Environment Canada 2007). Today, the negative impacts of roads are widely seen as a contributing factor leading to SAR designation. For example, seven of Ontario's eight turtle species are listed as SAR and roads have been identified as one of the most significant threats for five of these species (Seburn 2007).

For motorists, the most obvious impact of roads on biodiversity is a direct collision with an animal crossing or moving along roads. Less obvious, but significant nonetheless, are the effects of landscape fragmentation as roads bisect remaining patches of natural habitat (Trombulak & Frissell 2000). A fragmented landscape caused by roads has increasingly been a major concern for decreasing species richness, genetic diversity, and species abundance in Ontario and elsewhere (Fahrig et al. 1995, Findlay & Houlahan 1997, Vos & Chardon 1998, Eigenbrod et al. 2008).

Studies that have evaluated the spatial distribution of road-kill along roads have demonstrated that they are not random occurrences but spatially clustered for large mammals and small-vertebrate fauna (Clevenger et al. 2003, Mountrakis & Gunson 2009). These spatially clustered hotspots

are intuitive locations to prioritize efforts to mitigate road impacts on wildlife. Common examples of mitigation measures used for smaller wildlife such as turtles, are wildlife underpasses and or retro-fitted culverts (Dodd et al. 2004; Caverhill et al. 2011), and wildlife warning signage (Gunson et al. 2012).

Often road-kill data are not available on a road by road basis e.g. for new road extensions or across regions with dense road networks; therefore, research has begun to develop predictive models that identify potentially significant wildlife corridors and habitat linkage zones bisected by roads. Research is more developed for large animal groups e.g. Black Bears and are typically based on expert opinion, available literature, and are more rigorous if validated with empirical data (Boone & Hunter 1996; Clevenger et al. 2002, Larkin et al. 2004).

In this study we describe a methodology developed in a Geographic Information System (GIS) that identifies high-risk mortality locations for wetland-forest herpetofaunal species along roads in southern Ontario. We then describe new initiatives for model development and application to road planning projects in Ontario.

Model Methods and Results

We selected herpetofauna as our target group because several of these species are identified as 'At Risk' and road mortality is well documented regionally in Ontario and in upstate New York (Fahrig et al. 1995, Ashley and Robinson 1996, Langen et al. 2009). In addition, for some turtle species road mortality may threaten population persistence (Gibbs & Shriver 2002) and bias sex-ratios (Steen & Gibbs 2004) in areas of sufficient road density and traffic volumes.

We used herpetofaunal species that rely on forests and wetlands as compulsory landscape elements during some portion of their life-cycle, e.g. for breeding, and overwintering. These individuals are susceptible to road mortality as they disperse and migrate between wetlands and forests to overwinter, breed or forage (Ashley & Robinson 1996, Smith & Dodd 2003, Aresco 2005, Langen et al. 2009, Andrews et al. 2008). Species in Ontario include pond-breeding amphibians: Spotted Salamander (*Ambystoma maculatum*), Wood Frog (*Lithobates sylvaticus*), Gray Tree Frog (*Hyla versicolor*), Eastern American Toad, (*Anaxyrus americanus*), Red-spotted Newt (*Notophtalmus viridescens*), Jefferson Salamander complex (*Ambystoma jeffersonianum* complex), Jefferson Salamander (*Ambystoma jeffersonianum*) and semiaquatic freshwater turtles: Painted Turtle (*Chrysemys picta*), Snapping Turtle (*Chelydra serpentina*), and Blanding's turtles (*Emydoidea blandingii*). The Jefferson Salamander, Snapping Turtle and Blanding's turtles are classified as SAR in Canada.

We then used the Southern Ontario Land Resource Information System (SOLRIS) to map wetland-forest habitat associated with our target species. The layer represents the landscape in 15 x 15 m pixels from 2000-2003, and is derived from a combination of satellite imagery, topographic maps, and aerial photography (Ontario Ministry of Natural Resources 2007). All wetland pixels (swamps, fens, bogs, marshes, and open water) received a score of 100, all forest pixels (forest, mixed-forest, deciduous forest, and plantations) received a score of 50 and all other land-use pixels (open, agriculture, and built-up) received a score of 0.

We calculated a Habitat Suitability Index (HSI), the sum of weighted pixels, within a 12.6 ha area (buffer radius 200 m) surrounding each road pixel in the Ontario Road Network (ORN). The ORN has over 234,000 kilometers of provincial, municipal and recreation roads with a positional accuracy of 10 meters or less (Ontario Ministry of Natural Resources, unpublished data). The final HSI scores for each road pixel ranged from 0-55,000.

We selected 12.6 hectares as our buffer measurement because several studies have shown that this area encompasses the 'core terrestrial zone' defined as integral for maintaining amphibian and reptile diversity (see Porej et al. 2004). Joyal (1996) also found total wetland area utilized by spotted turtles in Maine was within a radius of 250 m. Furthermore, Semlitsch and Bodie (2003) found core terrestrial habitat ranged from 159 to 290 m for amphibians and from 127 to 289 m for reptiles from the edge of the aquatic site.

To evaluate the road pixel scores or segments (grouped into 5,000 intervals) that identified high-risk road mortality locations we used Chi-squared statistics to compare a count of observed herpetofauna on roads to what was expected for each score class. The expected counts were based on the proportional road length assigned to each score class. We then used Bailey`s confidence intervals to evaluate what score class was significant ($p<$

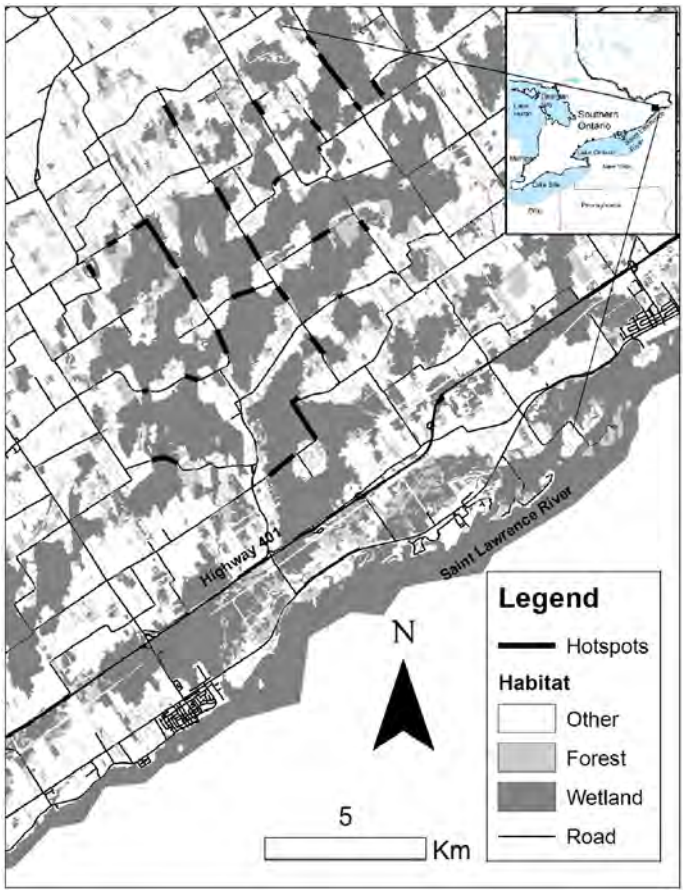

Figure 1. Map displaying road segments with scores greater than 30,000 (Hotspots) and surrounding wetland-forest habitat within a zoomed in area of Southern Ontario.

0.05), i.e. where more herpetofauna encounters were expected as compared to chance (Cherry 1996).

We obtained an on-road presence (alive or dead on road) database for the selected wetland-forest amphibians and reptiles for eastern Ontario from 1970 to 2005 (Bishop Mills Natural History Centre and Ontario Ministry of Natural Resources, unpublished data). To address spatial autocorrelation (see Dormann et al. 2007) we reduced multiple mortality events within 500 m of each other, occurring on the same day, and for the same species to only one event. We considered locations 500 m apart to be independent events as road mortality hotspots have occurred on segments less than or equal to 500 m for salamanders and turtles in North America (Clevenger et al. 2003; Langen et al. in review). We only included events that were within 500 m of a road, and the final collated data set had 446 road data events.

Table 1. Summary of observed and expected values for each score class using Bailey's confidence intervals to test for significance ($p < 0.05$).

Score Class	Observed	Expected	Type
0-5,000	54	158	Coldspot
5,001-10,000	56	85	Coldspot
10,001-15,000	73	62	No significance
15,001-20,000	42	48	No significance
20,001-25,000	63	38	No significance
25,001-30,000	36	26	No significance
30,001-35,000	47	15	Hotspot
35,001-40,000	36	8	Hotspot
40,001-45,000	21	3	Hotspot
45,001-50,000	18	3	Hotspot
Total	446	446	

Table 1 shows the results of the validation exercise to determine what score class represents more or less on-road encounters with herpetofauna than expected by chance. Road pixels with scores greater than 30,000 were classified as hot-

spots because there were more on-road encounters than expected by chance, and road pixels with scores less than 10,001 were classified as coldspots because there were less on-road encounters than expected by chance. Figure 1 shows an example of the model output in a zoomed in area of southern Ontario. Road pixels that scored greater than 30,000 are depicted with black lines along with shaded wetland-forest habitat surrounding roads.

Application and Future Work

The GIS model was assessed and applied to a new four-lane freeway extension (approximately 50 km) in south-central Ontario (Gunson & Seburn 2010). The model application was successful for two reasons. It identified the same major wetland-forest drainages that had been prioritized for wildlife mitigation in the Individual Environmental Assessment (IEA) process (Gartner Lee and EcoPlans Ltd. 2009). In addition, the modeling was viewed as an important tool for regional wildlife and transportation planning and facilitated discussion between government, and non-government agencies.

Currently, the model is being refined to identify 'high risk' turtle road mortality locations for placement of mitigation strategies, such as turtle signage. Furthermore, the success of the modeling process has been recognized by continued funding from municipal agencies to further develop tools for regional wildlife-transportation mitigation planning in Ontario.

Future work includes collecting standardized and consistent on-road encounter data for herpetofaunal species across Ontario for continuous and rigorous validation. This will entail seasonal data collection along a cross-section of 200 m road segments with varying scores defined from the model (Schueler & Gunson 2011). In addition, we will focus model development on long-term regional persistence by prioritizing road impacts at both a local (migration and dispersal) and landscape (meta-population) scale (Van der grift 2006; Semlitsch 2008). Lessons learned from these various initiatives have been integrated into a series of workshops and meetings with provincial and municipal planners to facilitate integration of road ecology planning tools and solutions into policy.

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References

Andrews, K.M., Whitfield, J.W., Jochimsen, D.M. (2008): Ecological effects of roads on amphibians and reptiles: a literature review. pp. 121-143. In Mitchell, R.E., Brown, J., Bartholomew, B. (eds.) Urban Herpetology. Society for the Study of Amphibians and Reptiles.

Aresco, M.J. (2005): Mitigation measures to reduce highway mortality of turtles and other herpetofauna at a North Florida Lake. Journal of Wildlife Management 69: 540-551.

Ashley, E.P., Robinson, J.T. (1996): Road mortality of amphibians, reptiles and other wildlife on the Long Point Causeway, Lake Erie, Ontario. Canadian Field Naturalist 110: 403-412.

Boone, R.B., Hunter, M.L. (1996): Using diffusion models to simulate the effects of land use on grizzly bear dispersal in the Rocky Mountains. Landscape Ecology 11: 51-64.

Caverhill, B. Johnson, B., Phillips, J., Nadeau, E., Kula, M., Holmes, R. (2011): Blanding's turtle (Emydoidea blandingii) and Snapping turtle (Chelydra serpentina) habitat use and movements in the Oakland Swamp wetland complex, Ontario, Canada, and their response to the Provincial Highway 24 exclusion fence and aquatic culvert ecopassage from 2010-2011. Report prepared by the Toronto Zoo, Adopt-A-Pond Programme.

Cherry, S. (1996): A comparison of confidence intervals for habitat use-availability studies. Journal of Wildlife Management 60: 653-658.

Clevenger, A.P., Chruszcz, B., Gunson, K.E. (2001): Highway mitigation fencing reduces wildlife-vehicle collisions 29: 646-653.

Clevenger, A.P., Wierzchowski, J., Chruszcz, B., Gunson, K. (2002): GIS-generated expert based models for identifying wildlife habitat linkages and mitigation passage planning. Conservation Biology 16: 503-514.

Clevenger, A.P., Chruszcz, B., Gunson, K. (2003): Spatial patterns and factors influencing small vertebrate fauna road-kill aggregations. Biological Conservation 109: 15-26.

Dodd, C.K., Barichivich, W.J. Smith, L.L. (2004): Effectiveness of a barrier wall and culverts in reducing wildlife mortality on a heavily traveled highway in Florida. Biological Conservation 118:619-631.

Dormann, C.F., McPherson, J.M., Arau' jo, M.B., Bivand, R., Bolliger, J., Carl, G., Davies, R.G., Hirzel, A., Jetz, W., Kissling, W.D., Ku¨hn, I., Ohlemu¨ ller, R., Peres-Neto, P.R., Reineking, B.,

Schro¨der, B., Schurr, F.M., Wilson, R. (2007): Methods to account for spatial autocorrelation in the analysis of species distributional data: a review. Ecography 30: 609-628.

Eigenbrod, F., Hecnar, S.J., Fahrig, L. (2008): Accessible habitat: an improved measure of the effects of habitat loss and roads on wildlife populations. Landscape Ecology 23: 159-169.

Environment Canada (2007): Species at Risk Act in Ontario: Facts. Canadian Wildlife Service. Ontario, Canada.

Fahrig, L., Pedlar, J.H., Pope, S.E., Taylor, P.D., Wegner, J.F. (1995): Effect of road traffic on amphibian density. Biological Conservation 74: 177-182.

Fenech, A., Taylor, B., Hansell, R. Whitelaw, G. (2005): Major road changes in southern Ontario 1935-1995: Implications for protected areas. www.utoronto.ca/imap/papers/major_road_changes.pdf.

Findlay, C.S., Houlahan, J. (1997): Anthropogenic correlates of species richness in southeastern Ontario wetlands. Conservation Biology 11: 1000-1009.

Gartner Lee, EcoPlans Ltd. (2009): 407 East Individual Environmental Assessment and Preliminary Design Study-Natural Environmental (Terrestrial) Impact Assessment of the Recommended Design. Report to the Ministry of Transportation, Ontario, Canada.

Gibbs, J.P., Shriver, W.G. (2002): Estimating the effects of road mortality on turtle populations. Conservation Biology 62: 1647-1652.

Gunson, K.E., Ireland, D., Schueler, F. (2009): Incorporating road-mortality hotspot modeling and connectivity analyses into road mitigation planning in Ontario. Proceedings of the International Conference on Ecology and Transportation. Duluth, Minnesota. September, 2009.

Gunson, K.E., Seburn, D.C. (2010): A review of proposed wildlife mitigation along the 407 east extension. Report submitted to the Canadian Environmental Assessment Agency.

Gunson, K.E., Middleton, J., Schueler, F.W. (2012): Placement of Species at Risk Crossing Signs. Final Report to the Ontario Ministry of Transportation.

Joyal, L.A., McCollough, M., Hunter, M.L. (1996): Landscape ecology approaches to wetland species conservation: a case study of two turtle species in southern Maine. Conservation Biology 15: 1755-1762.

Langen, T.A., Ogden, K.M., Schwarting, L.L. (2009): Predicting hot spots of herpetofauna road mortality along highway networks. Journal of Wildlife Management 73: 104-114.

Larkin, J.L., Maehr, D.S., Hoctor, T.S., Orlando, M.A., Whitney, K. (2004). Landscape linkages and conservation planning for the black bear in west-central Florida. Animal Conservation 7: 23-34.

Mata, C., Hervás, I., Herranz, J., Suárez, F., Malo, J.E. (2008): Are motorway wildlife passages worth building? Vertebrate use of road-crossing structures on a Spanish motorway. Journal of Environmental Management 88: 407-415.

Mountrakis, G., Gunson, K.E. (2009): Multi-scale spatiotemporal analyses of moose-vehicle collisions: a case study in northern Vermont. International Journal of Geographic Information Systems 23: 1389-1412.

Ontario Ministry of Natural Resources (2007): SOLRIS: Accuracy Assessment Report. Report submitted to the Inventory Monitoring and Assessment Section, Ontario, Canda.

Porej, D., Micacchion, M., Hetherington, T.E. (2004): Core terrestrial habitat for conservation of local populations of salamanders and wood frogs in agricultural landscapes. Biological Conservation 120: 399-409.

Schueler, F.W., Gunson, K.E. (2011): The road ecology circuit in Leeds & Genville. Trails and Landscapes 45: 155-161.

Seburn, D.C. (2007): Recovery strategy for Species at Risk turtles in Ontario. Ontario Multi-Species Turtles at Risk Recovery Team.

Semlitsch, R.D., Bodie, J.R. (2003): Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17: 1219-1228.

Semlitsch, R.D. (2008): Principles for management of aquatic-breeding amphibians. Journal of Wildlife Management 64: 615-631.

Smith, L.L., Dodd Jr., C.K. (2003): Wildlife mortality on highway US 441 across Paynes Prairie, Alachua County, Florida. Florida Scientist 66:128-140.

Steen, D.A., Gibbs, J.P. (2004): Effects of roads on the structure of freshwater turtle populations. Conservation Biology 18: 1143-1148.

Trombulak, S.C., Fissell, C.A. (2000): Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14: 18-30.

van der Grift, E., Pouwels, F. (2006): Restoring habitat connectivity across transport corridors: identigying high-priority locations for de-fragmentation with the use of an expert-based model. pp. 205-231. In Davenport, J., Davenport J.L. (eds.), The Ecology of Transportation: Managing Mobility for the Environment. Springer, Netherlands.

Vos, C.C., Chardon, J.P. (1998): Effects of habitat fragmentation and road density on the distribution pattern of the moor frog *Rana arvalis*. Journal of Applied Ecology 35: 44-56.

*** Langen, T.A., Gunson, K.E., Scheiner, C. (in review): Biodiversity and Conservation. Road mortality in freshwater turtles: identifying causes of spatial patterns to optimize road planning and mitigation.