HERPETOFAUNA AND ROADS: HOW CAN WE GET ALONG?

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ABSTRACT

Biodiversity provides us with irreplaceable ecosystem services such as clean air and water, productive soils, food, timber and renewable energy. Ontario's people are healthier and their quality of life is better because of its biodiversity (Ontario Ministry of Natural Resources, 2012). Ontario's 53 herpetofauna species provide essential services such as helping maintain wetland health (Ontario Nature, 2013) which subsequently improves Ontario's water quality (Ontario Ministry of Natural Resources, n.d.), limiting diseases such as Lyme's disease by helping control rodent and insect populations (Crowley, 2014), and serving as a vital food source for species such as birds and mammals (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004).

Sixty percent of Ontario's herpetofauna species are at risk of disappearing and face many threats including deliberate killing, poaching/pet trade, loss/fragmentation of habitat, pesticides/contaminants, and road mortality (Ontario Ministry of Natural Resources, 2013). Roads are either directly or indirectly related to all of these threats. Current road design and construction practices are placing unnecessary stress on many herpetofauna species (Ontario Ministry of Natural Resources, 2013) and removal of significant negative road impacts on herpetofauna population and habitat is needed. Ontario's herpetofauna population is in a critical state and there needs to be a co-ordinated strategic push from all directions to tackle the threat of road mortality on these species (Gunson K. , 2014).

The objectives of this paper are to identify:

- root causes of herpetofauna road ecology threats;
- actions which significantly help herpetofauna biodiversity.

Four root causes of herpetofauna road ecology threats were identified:

1. herpetofauna's small stature and low societal value;
2. road resource managers giving biodiversity needs a relatively low priority;
3. a fractured, non-collaborative road ecology approach to a multi-faceted problem; and
4. limited information on where species are and how to develop solutions which preserve biodiversity.

The authors concluded Ontario's 'In Our Nature' biodiversity preservation plan has the strategic framework and general approaches required to address Ontario's herpetofauna road ecology challenges. However, Ontario has systematic deficiencies which are preventing positive change at the pace required to help many of its species at risk. A framework developed by Donella Meadows was used to identify which actions have the greatest ability to create significant change. Two critical actions were recommended: engaging and motivating key stakeholders in Ontario's road ecology network, and incorporating biodiversity preservation into road resource managers mandates. Five additional necessary recommendations were identified:

- enhancing tools governments use to implement change;
- garnering more public awareness of herpetofauna and road ecology issues;
- utilizing more of a land planning approach for road ecology activities;
- developing better solutions through research and monitoring/control and;
- improved information sharing so that information is readily available and used to develop solutions which preserve biodiversity.

Implementing actions which lead to significant positive herpetofauna road ecology change is essential if Ontario is to preserve its herpetofauna biodiversity. Altogether, the report's recommendations highlight opportunities for Ontario to develop significant positive herpetofauna road ecology change which could have a positive impact on the welfare of Ontario's biodiversity and people.

1.0 INTRODUCTION

1.1 The Problem

Ontario has more biodiversity than any other Province in Canada (Gunson K. , 2014). Biodiversity provides us with irreplaceable ecosystem services such as clean air and water, productive soils, food, timber and renewable energy. Ontario's people are healthier, and their quality of life is better because of its biodiversity (Ontario Ministry of Natural Resources, 2012). Of concern is that southern Ontario harbours the most Species at Risk in all of the Canadian provinces and road densities/growth comparable to Europe (Gunson, Ireland, & Schueler, 2012). In 2011 Ontario released its 'In our Nature' plan which contains the following vision: 'A future where biodiversity loss is halted and recovery is advanced. People value, protect and enhance biodiversity and the ecosystem services essential for human health and well-being' (Ontario Ministry of Natural Resources, 2012).

Herpetofauna species, more commonly known as reptiles and amphibians, are a significant part of Ontario's biodiversity with Ontario having 27 reptile species (Canada has 48) (Ontario Ministry of Natural Resources, 2013) and 26 amphibian species (Canada has 47) (Ontario Ministry of Natural Resources, 2013). Herpetofauna contribute to ecosystems in a multitude of ways such as maintaining the health of wetlands (Ontario Nature, 2013) which subsequently improves Ontario's water quality (Ontario Ministry of Natural Resources, n.d.), and limiting diseases such as Lyme's disease by helping control rodent and insect populations (Crowley, 2014). Additionally, herpetofauna are a vital food source for species such as birds and mammals as herpetofauna efficiently convert ingested food into body mass (rather than heat production as herpetofauna are cold blooded) (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004).

Ontario's herpetofauna species face challenges such as deliberate killing, poaching/pet trade, loss and fragmentation of habitat, pesticides and contaminants and road mortality (Ontario Ministry of Natural Resources, 2013). Roads are either directly or indirectly related to all of these challenges. Roads have been identified as a significant threat for many wildlife species in Ontario (Gunson, Ireland, & Schueler, 2012) and current road design and construction practices are placing unnecessary stress on many herpetofauna species (Ontario Ministry of Natural Resources, 2013). Road design and construction can have a significant negative impact on herpetofauna species through road mortality and habitat disruption or loss (Vancouver Island University, 2011). Considering almost 60% of Ontario's herpetofauna species are at risk (Ontario Ministry of Natural Resources, 2013) coupled with growing ecological stresses such as invasive species, climate change and societal population growth, removal of significant negative road impacts on herpetofauna population and habitat is needed.

This report examines whether Ontario's 'In our Nature' plan sufficiently addresses herpetofauna related challenges with a focus on impacts from the interaction of road networks and the natural environment, otherwise known as road ecology (Ontario Road Ecology Group, 2010).

The report's specific objectives are as follows:

1. Provide insight into how effective current herpetofauna road practices preserve biodiversity;
2. Identify root causes of herpetofauna road threats; and
3. Recommend actions which significantly help herpetofauna biodiversity.

The report focuses on Ontario but recommendations are likely applicable to other jurisdictions. It is noted that several report contributions were garnered from resources outside of Ontario.

1.2 Approach

Information was collected from existing literature and complimented with interviews from a variety of herpetofauna road ecology stakeholders. Literature was collected from Canadian and International sources while interviews were conducted with personnel from Canada with a particular focus on Ontario. A list of interviewees is found in Appendix 1. It is noted that First Nations input has not been integrated into the report. Several attempts were made to reach out to various First Nations but no input was received.

Emphasis was placed on understanding higher level systematic items such as why herpetofauna biodiversity preservation is not effectively integrated into road design and construction. To enhance this perspective the problem was viewed through a sustainability (environmental, social and economic aspects) lens.

1.3 Background Information

The following is a summary of current herpetofauna road ecology based on literature and stakeholder interviews.

1.3.1 Environmental Aspects:

North America's road footprint on wildlife is substantial when one considers a road's impact on ecosystems from light pollution, invasive species, human access, pollution, noise, hydrological, etc. Ecosystem impacts extend 100 m to 800 m beyond the road edge resulting in roads having an influence on 15% to 73% of the United States landmass (Andrews, Gibbons, & Jochimsen, 2007). Road salt impacts extend more than 800 m beyond road edge (Penny, 2014).

Direct Road Impacts: Direct road mortality is defined as 'injury or mortality that occurs during road construction or subsequent contact with vehicles' (Andrews, Gibbons, & Jochimsen, 2007, p. 568). Migrating amphibians and reptiles are highly vulnerable to road mortality (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004). For example, on a busier highway in North Florida as few as 2% of turtles attempting to cross the road did so successfully (Aresco, 2005). Paved roads can also be an attractive trap for reptiles that use the roads to raise their body temperature (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004); (Vancouver Island University, 2011, p. 41). The effect of road mortality is especially severe where 'roads are close to snake hibernacula or turtle nesting sites' (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004, p. 27) as softer road shoulders are at times an attractive nesting site. Bernardino and Dalrymple; Kline and Swann (as cited in (Andrews, Gibbons, & Jochimsen, 2007, p. 568)) suggest that road mortality is considered to be 'the greatest non-natural source of vertebrate death in protected areas.' Evidence supports the conclusion that herpetofauna road mortality of herpetofauna can result in significant loss of species and threaten the sustainability of populations (Andrews, Gibbons, & Jochimsen, 2007). For instance, the state of turtles in Ontario is a particularly telling story of how significant the impact of roads can be on a species. In Ontario, seven of eight turtle native species are currently at risk of disappearing (Ontario Ministry of Natural Resources, 2013). Many turtles, such as the Blanding turtle, can survive in the wild for more than 75 years and do not reach breeding age until their teens or twenties. Turtles have a very low probability of reaching adulthood with only 1% of eggs turning into adult turtles. However, once turtles reach adult age they have extremely low naturally occurring mortality rates with over 99% of the adult population surviving each year. Very small increases in mortality rates, such as increases in road kill, can quickly result in a population crash and eventual extinction (Kawartha Turtle Trauma Centre, n.d.). This is just one example of how roads are a contributor to the high number of herpetofauna species at risk in Ontario.

Construction impacts can be significant and care needs to be taken not to disturb nesting species such as turtles and salamanders. For instance, it is recommended construction be halted during turtle nesting season in regions where herpetofauna may be impacted. In Ontario, nesting season occurs from late May to early July (Kawartha Turtle Trauma Centre, n.d.). During nesting/migration season, species are more vulnerable to getting hit by vehicles and disturbed by construction as they leave the wetlands and may cross roads to find suitable nesting areas (Vancouver Island University, 2011). However, this recommendation results in potentially significant complications for some construction activities such as paving or earthworks, which are typically only done in warmer weather (May through

early October). Not constructing in half of this time would have significant cost and schedule impacts on some projects.

Indirect Road Impacts: The report, Best Management Practices for Amphibians and Reptiles in Urban and Rural Environments in British Columbia (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004) identifies more than twenty categorical effects on herpetofauna, several of which are indirect. Highlights are as follows:

Chemical: pollutants, de-icing salts and dust suppression chemicals have long-term negative effects (Andrews, Gibbons, & Jochimsen, 2007, p. 570). The concern is highlighted for amphibians as their permeable skins and eggs are sensitive to environmental pollutants.

Hydrological and Microhabitat: Amphibians must maintain optimal moisture levels in order to survive (Andrews, Gibbons, & Jochimsen, 2007). Hydrological changes such as alterations in precipitation runoff, fluctuations in flow velocities, and flooding in adjacent wetlands occurring within a road's footprint can destroy livable herpetofauna habitats (Jones et al., as cited in (Andrews, Gibbons, & Jochimsen, 2007)).

Habitat Loss: Richter and Azous (as cited in (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004)) found that where urbanization took up more than forty percent of the land area in Washington State, amphibian species richness in watersheds significant decreased.

1.3.2 Social Aspects

There are several examples of society fearing and persecuting herpetofauna despite many of these species providing societal (Crowley, 2014) and ecological benefits such as sources of food, medicine and raw material (Ceriaco, 2012). Society's negative bias and human preference for more aesthetically pleasing species like dolphins and bears has tilted conservation efforts in an unfavourable manner for reptiles and amphibians (Ceriaco, 2012). Minimal research was found on the impacts of societal bias towards herpetofauna species but research has concluded some drivers intentionally drive out of their way to strike snakes and turtles, with one justification being reptiles eating 'beneficial' wildlife such as ducklings (Ashley, Kosloski, & Petrie, 2007).

The influence of European folklore and Christianity is noteworthy as much of North America's population descends from European origin (European-Canadians, n.d.) and Christianity is North America's dominate religion (PEW Research, n.d.). Snakes, toads and frogs are commonly associated with powerful negative symbolism. First Nation views of herpetofauna vary across North America with snakes commonly regarded as being dangerous but powerful spirits (Native American Snake Mythology, n.d.) and frogs being associated as guardians of fresh water (Anderson, 1996). One noteworthy legend is the Story of Turtle Island, which tells the tale of how the land from the sea was placed on the back of the turtle and how this land became the Americas (Turtle Island Native Network, n.d.).

One of the reasons for society's limited awareness of herpetofauna is herpetofauna are not seen very often, possibly creating an out of sight out of mind mindset (Busby, 2014). However, it is believed society's perception of herpetofauna, in particular snakes and turtles, has become more ecologically sensitive over the decades; for example, blatantly killing rattle snakes and snapping turtles has become less socially acceptable (Penny, 2014).

The significance of herpetofauna species for First Nation populations and their ability to utilize their treaty rights to influence herpetofauna road ecology practices is not well researched. However, for reference, a noteworthy fish oriented road ecology case involving First Nation fish rights and Washington State has resulted in a $2.4 billion rehabilitation project for Washington State to restore damaged fish habitats (Lovvas, 2013).

1.3.3 Economic Aspects

Canada has more than a million kilometers of (two-lane equivalent) roads, and in terms of value transported, roads are the most important transportation mode for passenger/freight transportation, intra-city/intra-provincial transportation activities, and trade between Canada/United States (Transport Canada, 2012). North American

society's dependency on roads is not only a matter of convenience but is often an absolute essential part of North American societal needs such as commuting to work, daycare and appointments all in the same day (Transport Canada, 2008).

Minimal information was found on the direct economic cost associated with integrating herpetofauna road impact mitigation measures for new and existing roads though it was estimated a forestry road in Algonquin Park required 15 – 20% of the road's operational budget to be allocated to turtle mitigation efforts (Laflamme, 2014). In another county, it was estimated typical additional cost for herpetofauna mitigation on capital works projects was less than 1% (Sheperd, 2014). However, it was noted this number could increase for projects such as paving a large stretch of road fencing represent a larger portion of cost and shortening construction windows to avoid nesting concerns could increase the number of seasons construction occurs over.

Limited research was found on the economic value of herpetofauna. Economic value falls into one of two classifications: direct value (such as the economic value of lumber derived from a forest) and indirect value (such as the value of replicating the oxygen production of a forest). Direct value is typically more obvious than indirect value. Much of apparent herptefauna's value is indirect such as helping maintain wetlands though species such as snapping turtles offer direct value to some through hunting and eating. It is noted MNR is currently developing information on the indirect value of herpetofauna. An example is defining the savings to the health care system as a result of snakes eating rodents and insects which are carriers for Lyme disease (Crowley, 2014).

1.3.4 Herpetofauna Road Design and Construction Related Challenges

During the planning or operational stages road practitioners assess a multitude of economic, societal, environmental and performance requirements. When wildlife mitigation requirements are considered, a significant challenge is the majority of road and construction practices lack proper road ecology guidelines and collaboration between road and natural resource practitioners is limited. Inadequate Ontario road ecology guidelines result in road practitioners sourcing information from regions outside Ontario (Burdett, 2014) which may not align with practices best suited for Ontario's herpetofauna challenges.

'Cost benefits rather than ecological benefits strongly influence crossing design' (Clevenger, 2005, p. 127) and 'rarely are there monitoring programs planned or budgeted post-construction' (Clevenger, 2005, p. 124). Post construction monitoring is needed to assess the success of mitigation efforts. Glista et al. (Glista, DeVault, & DeWoody, 2009) adds to that point by noting most studies report on the effectiveness of mitigation efforts has on reducing road mortality but few research the ecological success rate of the structures and whether mitigation efforts actually help herpetofauna populations. Cumulative effects on biodiversity such as road mitigation impacts are not instantaneous and results may take decades to be seen. As a result, long-term research is needed to evaluate the impact of mitigation efforts on populations (Andrews, Gibbons, & Jochimsen, 2007). Studies are best designed if they monitor mitigation measure effectiveness through pre-and-post-construction monitoring (Clevenger, 2005).

1.3.5 The Ontario Story

All literature and interview summary themes are relevant to Ontario. However, Ontario has a noteworthy difference from most other jurisdictions in that it has an Endangered Species Act (ESA). The 2007 Endangered Species Act created a major shift in the way road managers operated; for instance, the Ministry of Transportation of Ontario (MTO) indicates the Act added additional wildlife considerations which previously were not considered on projects (Carruthers, MTO, Senior Policy Analyst, 2014). The Act has helped change the conversation on some projects from 'why should herpetofauna issues be considered?' to 'what herpetofauna impacts do we need to consider and how do we address them?' (Crowley, 2014).

Both the MTO and Ministry of Natural Resources (MNR) are actively addressing herpetofauna road ecology challenges. The MTO has developed a wildlife habitat awareness sign policy (2012) that is currently being tested for effectiveness and is developing a Wildlife Mitigation Strategy (Carruthers, Municipal Road Ecology Symposium: Town of Oakville, 2013). The MNR has developed recovery strategies for several herpetofauna

species at risk (Ontario Ministry of Natural Resources, 2013) and is developing a Best Management Guideline for Mitigating Road Impacts on Herpetofauna for new construction (Ontario Ministry of Natural Resources, 2013). The guideline may also address rehabilitation construction. Two other organizations are influencing Ontario's herpetofauna road ecology: the Ontario Road Ecology Group, a non-government organization focused on road ecology, and Eco-Kare, a consulting service focused on integrating science into practical road mitigation solutions for provincial governments as well as municipalities in Ontario (Gunson K. , 2014). Although these activities are a step forward, their limitations are worth noting as:

- which the MNR's Best Management Guideline will support, is restricted in its application to new road construction (though other construction projects still need to be mitigated according to MNR provisions);
- MTO manages only 0.68% of roads in Ontario (Carruthers, Municipal Road Ecology Symposium: Town of Oakville, 2013) .

In summary, active mitigation of negative road impacts on herpetofauna outside off MTO and MNR is low and regulatory considerations do not proactively address existing problem areas.

2.0 ROOT CAUSE ANALYSIS

Herpetofauna road ecology literature indicates proper road planning and design helps mitigate vehicle-wildlife collisions (Coffin & Alsia, 2007). However, the literature falls short on identifying effective means to achieve this goal. An assessment of reviewed literature and conducted interviews suggest four root causes of negative herpetofauna road impacts.

2.1 Herpetofauna Visibility and Societal Value

Herpetofauna are not highly visible or valued to society (Busby, 2014) and the adage 'out of sight, out of mind' is appropriate when it comes to society's understanding of the need to mitigate herpetofauna road impacts. Herpetofauna do not receive the same level of attention as other wildlife species yet play a vital role in our ecological system as both predator and prey, and are an important component of biodiversity wildlife (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004). Reasons for herpetofauna's low visibility include their physically small stature (vehicle collisions with herpetofauna have less driver safety impact than larger animals such as deer (Burdett, 2014)), low direct economic valuation (as opposed to fish (Penny, 2014)) and negative societal bias resulting in conservation efforts which tend to favour more aesthetically pleasing species (Ceriaco, 2012). There are a multitude of misconceptions about herpetofauna, in particular snakes (Crowley, 2014), and these misconceptions can have negative impacts on society's treatment and valuation of these species.

As herpetofauna have low visibility and societal value, awareness of herpetofauna challenges and public pressure to address the challenges is low.

2.2 Road Manager's Mandate

A typical road resource manager's mandate is to provide and maintain safe, efficient transportation networks. Consideration towards biodiversity preservation is normally only given when legally required or when excessive public pressure is exerted (Busby, 2014). As a result, road resource managers have limited funds budgeted for wildlife mitigation construction, operation or research. When wildlife mitigation is considered the objective is to only comply with legal requirements or address notable public pressure (Busby, 2014). When road ecologists argue on the precautionary principle, road resource managers consider biodiversity needs of secondary importance in comparison to road infrastructure safety and economic requirements (Lesbarreres & Fahrig, 2012). As a result, consideration and funding of biodiversity preservation in road planning is lacking. Roads in National Parks are a notable exemption as a Park's mandate is to preserve the region's ecology (McGuire, 2014).

In Ontario, herpetofauna considerations are only legally required when a species noted as extirpated, endangered or threatened on the Species at Risk in Ontario List (SARO) may be negatively impacted by a road. However, the practicality is that SARO considerations are only considered during construction and disruptive maintenance as 'when a new road is constructed, the onus is on the agency constructing the road to consider all of the potential impacts on species at risk, including mortality that will occur during the operation of the road. However, a situation such as an existing road that is resulting in high mortality of a species at risk is difficult to mitigate because the onus not to harm or harass the species is on individual drivers, and that is very difficult to effectively implement' (Crowley, 2014). It is noted construction/maintenance projects deemed as having significant social or economic benefit may receive SARO exemptions (Ontario Ministry of Natural Resources, 2013). Overall, herpetofauna road ecology considerations are only required on some new construction projects and maintenance activities, a relatively small portion of Ontario's road network.

As a road resource manager's mandate does not include biodiversity preservation, existing negative herpetofauna impacts often remain.

2.3 Road Ecology Approach

Collaboration between road planners and ecologists is rare (Lesbarreres and Fahrig, 2012). In Ontario, collaboration between road owners, natural resource managers, ecologists, and various Provincial Government Branches is limited (Gunson K. , 2014). However, herpetofauna habitats are complex systems, and protecting them requires a 'collaborative, multi-disciplinary approach, including biology, ecology, hydrology, land use planning, and engineering' (Vancouver Island University, 2011, p. 7).

There are two schools of thought on how to appropriately address road ecology. Both require a collaborative, multi-disciplinary approach. The first has road ecologists involved throughout projects with road ecology research considered at the earliest stages of planning (Lesbarreres & Fahrig, 2012, p. 377). Alternatively, (Lesbarreres & Fahrig, 2012, p. 378) suggest if quality wildlife movement data was available upfront along with knowledge of road ecology solutions which preserve biodiversity, 'eco passages and other design features for wildlife could be included in the road project without direct involvement of road ecologists in road planning.' MTO has taken the latter path as it wishes to be more strategic at selecting and mitigating wildlife impacts through having a better understanding of where is the best to mitigate (Carruthers, Municipal Road Ecology Symposium: Town of Oakville, 2013). MTO is implementing mitigation efforts on a project by project basis, usually through an Environmental Assessment (Carruthers, Municipal Road Ecology Symposium: Town of Oakville, 2013). However, MTO only operates a small portion of roads in the province and when one considers the varying rules for design, construction and operation stages in addition to Ontario's multiple road owners (e.g. MTO, Municipal, Parks, private), a complicated and inconsistent approach for herpetofauna management in an ecosystem is likely.

Ontario's approach to road ecology is fragmented due to multiple road owners taking a project by project approach while often working ineffectively with necessary multi-disciplinary stakeholders. The result is an inconsistent approach throughout many ecosystems.

2.4 Herpetofauna Road Ecology Knowledge

When road ecology is considered, Glista et al. (Glista, DeVault, & DeWoody, 2009, p. 2) indicate 'economic factors often dictate the choice of road mortality mitigation measures that are implemented' and 'the frequency at which road mortality mitigation measures are implemented does not correlate with their perceived effectiveness; the most promising measures often are the least used.'

'Adequate inventory data and an understanding of the ecology of the species are lacking for amphibians and reptiles' (Biolinx Environmental Research Ltd. and E. Wind Consulting, 2004). Information on herpetofauna populations is generally unavailable unless an Environmental Assessment is conducted for a specific project. Information about species which are threatened by poaching is subject to strict distribution regulations; however this also hampers its use among road ecology practitioners that need to plan and design road mitigation solutions (Gunson K. , 2014).

Not knowing what species are where makes it difficult for practitioners to mitigate negative road impacts and help preserve biodiversity.

Today, much of Ontario's focus is given to limiting direct impacts such as road kill and minimal attention is given to indirect impacts such as road salt impacts (Burdett, 2014). Limited knowledge on direct and indirect road related herpetofauna impacts exist, making it difficult to assess a road's influence on a species survival and determine how to best mitigate their impacts. (Andrews, Gibbons, & Jochimsen, 2007, p. 568) state 'a better understanding of how roads affect herpetofauna and the subsequent application of this knowledge will minimize detrimental effects.' Having an understanding of what mitigation efforts work optimizes the use of limited resources. For example, road owners do not have information to be able to answer questions such as 'is it better to have a highly effective mitigation effort in one region to support habitat banking but have marginal mitigation elsewhere or vice versa?' (Carruthers, MTO, Senior Policy Analyst, 2014).

Mitigation efforts on some projects have been found to have minimal benefit (inadequate design, improper construction or inadequate maintenance). This frustrates road owners in particular and raises the question of whether future resources should be spent on potentially ineffective mitigation efforts rather than transportation safety and efficiency. Road practitioners have suggested an Ontario based resource which provides users means to develop herpetofauna mitigation solutions which preserve biodiversity is needed (Burdett, 2014) and without this, solutions being developed may be inadequate or focus on ineffective aspects. It is noted MNR's Best Management Guideline development (Ontario Ministry of Natural Resources, 2013) may address some of these challenges.

In summary, herpetofauna road ecology challenges stem from:

- herpetofauna's small stature and low societal value;
- road resource managers giving biodiversity needs a relatively low priority;
- a fractured, non-collaborative road ecology approach to a multi-faceted problem; and
- limited information on where species are and how to develop solutions which preserve biodiversity.

3.0 SITUATIONAL ANALYSIS

A situational analysis is defined as 'the process of finding a strategic fit between external opportunities and internal strengths while working around external and internal weaknesses' (Clarke, n.d.). A situational analysis was conducted to find a strategic fit between the Provincial Government and external stakeholders which address challenges roads pose to Ontario's herpetofauna species.

3.1 Stakeholders

TABLE 1 summarizes the various stakeholders and their associated level of influence as it pertains to the Ontario Government and herpetofauna road ecology.

- Centre: The Ontario Government is responsible for managing Ontario's biodiversity and developing/implementing a strategy to preserve it.
- Primary Stakeholders: Stakeholders directly responsible for managing roads and herpetofauna in Ontario.
- Secondary Stakeholders: Those who work directly with primary stakeholders on herpetofauna road ecology items.
- Other Stakeholders: Those who have interest and influence in road ecology and/or road construction and may work directly with secondary stakeholders.

TABLE 1 STAKEHOLDERS

Stakeholder Level	Stakeholder
Centre	Ontario Government
Primary	Natural Resource Managers (MNR, Conservation Authorities, Parks Organizations), Road Resource Managers (MTO, Municipalities, Private resource, Parks Organizations), First Nations
Secondary	Road industry (consultants, contractors), Ecology industry (MOE, road ecologists, environmental groups), Government finance organizations (MOI)
Other	Media, Environmental groups, educational institutions, Government, Public, suppliers.

3.2 Ontario Biodiversity Strategy Analysis

In 2011 the Government of Ontario released a revised strategy 'Biodiversity: It's In Our Nature' (Ontario Ministry of Natural Resources, 2012) on biodiversity protection which is intended to 'set out the means by which the government will realize the strategy's vision, goals and targets'. The document's vision is 'a future where biodiversity loss is halted and recovery is advanced. People value, protect and enhance biodiversity and the ecosystem services essential for human health and well-being'. Three goals are outlined:

- Mainstream biodiversity;
- Protect and restore Ontario's biodiversity; and
- Use Ontario's biological assets sustainably.

The following situational analysis uses a SWOT (Strength, Weakness, Opportunities, Threats) and TOWS (strategies based on SWOT) matrix (Mindtools, 2013, p. 1) to evaluate whether Ontario's 'In Our Nature' plan contains objectives and actions which could address herpetofauna road ecology issues.

TABLE 2 SWOT ANALYSIS OF ONTARIO GOVERNMENT HERPETOFAUNA ROAD ECOLOGY

Strengths 1. Multi-government discipline commitment to biodiversity vision and strategy; 2. Endangered Species Act (ESA) which offers a level of protection to species at risk; 3. MTO and MNR are addressing some road ecology challenges.	Weaknesses 1. Only MTO/MNR Provincial Gov't branches actively engaged on the issue; 2. Herpetofauna protection: Non endangered species not protected and ESA is challenging to enforce on existing roads not being developed; 3. MTO only manages less than 1% of roads in Ontario and many other road owners are less engaged on herpetofauna issues; 4. Prioritizing herpetofauna mitigation with infrastructure resource demands.
Opportunities 1. Stakeholder engagement of industry knowledge and resources; 2. Grassroots support; 3. Societal engagement; 4. Information and data sharing to facilitate evidenced based policy development.	Threats 1. A multitude of stakeholders not engaged/focused; 2. Limited road ecology information; 3. Poor construction and maintenance practices; 4. Negative societal perceptions; 5. Lack of research and continuous improvement.

TABLE 3 TOWS MATRIX OF ONTARIO GOVERNMENT HERPETOFAUNA ROAD ECOLOGY

Strength & Opportunity Strategies 1. Gov't branch leading a stakeholder engagement; 2. Information from all stakeholders pooled and shared.	Weakness and Opportunity Strategies 1. Other Provincial Government branches facilitating change; 2. Private industry or grassroots support complimenting limited resources.
Strength and Threat Strategies 1. Utilize Ontario's biodiversity strategy commitments to engage stakeholder; 2. Utilize MTO/MNR efforts to advance stakeholder's solution knowledge.	Weakness and Threat Strategies 1. Build positive feedback loops to build on successes.

To understand whether Ontario's 'In Our Nature' plan covers themes identified in the situational analysis a comparison was made between the situational analysis and action items listed in the 'In Our Nature' plan. The comparison is summarized in TABLE 4.

TABLE 4 COVERAGE OF STRATEGIC THEMES IN ONTARIO BIODIVERSITY STRATEGY

Strategic Theme	Action (Ontario Ministry of Natural Resources, 2012)
Engage herpetofauna road ecology stakeholders.	Yes in the engage people and enhance resilience actions (e.g. 4, 17, 20, 21).
Leverage resources and knowledge in the secondary/other stakeholder level.	Yes in the engage people actions (e.g. 4, 6).
Information sharing.	Yes, several in the engage people and improve knowledge actions
Build positive feedback loops.	Yes, in the improve knowledge actions (e.g. 23, 24).

All situational analysis themes are addressed through various actions in Ontario's 'In our Nature' plan. As a result, it is concluded Ontario's 'In our Nature' plan has a strategic framework which in theory, could address Ontario's herpetofauna road ecology challenges. However, Ontario's herpetofauna population is in a critical state and although there has been some positive momentum in the last seven years, there is a significant risk that changes are not substantial enough or occurring as quickly as needed to alleviate the road mortality threat for Species at Risk (Gunson K. , 2014). A plan which effectively preserves herpetofauna biodiversity is needed to address Ontario's herpetofauna road ecology challenges in a faster and significant manner.

4.0 SYSTEMATIC CHANGES

Four root causes of Ontario's current herpetofauna road ecology challenges have been identified:

1. herpetofauna's small stature and low societal value;
2. road resource managers giving biodiversity needs a relatively low priority;
3. a fractured, non-collaborative road ecology approach to a multi-faceted problem; and
4. limited information on where species are and how to develop solutions which preserve biodiversity.

Action items with the potential to produce positive herpetofauna road ecology change were developed based on the literature review, interviews with key stakeholders, and information analysis. A framework developed by Donella Meadows (Meadows, 1999) was used to evaluate which actions are more likely to produce positive herpetofauna

road ecology change. The framework divides changes into three categories: physical changes, information changes, and directional changes and ranks the ability of each category to implement change. Physical changes such as the modifying the number of species on the SARO list has a low impact compared to sharing information such having road ecology practitioners aware of where SARO species are. Directional changes such as expecting road resource managers to be responsible for biodiversity health and road ecology have the most significant impact.

Current MTO and MNR activities underway are associated with information changes or mid-level change levers. However, as the MTO's activities only pertain to a small portion of roads in Ontario their impact is limited. More substantial change is quickly needed to remove the road mortality threat for Species at Risk (Gunson K. , 2014).

4.1 Recommended Actions

To support Ontario's 'In our Nature' plan, proposed changes to address Ontario's herpetofauna road ecology challenges are summarized in TABLE 5. The overall goal is to change the conversation amongst stakeholders from 'why care' about herpetofauna road impacts to 'how can we mitigate a road threats and preserve herpetofauna biodiversity?'

TABLE 5 RECOMMENDED ACTIONS

Item	Recommended Action	Lead	Support	Relative Priority
1	Stakeholder Engagement	MNR	Primary & secondary stakeholders	Critical
2	Road Resource Manager Mandates	MGS	MNR, MTO, MMAH	Critical
3	Enhance Government Change Tools	MGS	MTO, MOI, MMAH, ORBA, OREG	Necessary
4	Public Awareness	MNR	Media, EDU, OREG, Ontario Nature, MTO	Necessary
5	Ecosystem Based Approach to Transportation Planning	MTO	Ontario Nature, ORBA, MOE, MMAH	Necessary
6	Information Sharing	MNR	MTO, OREG, ORBA	Necessary
7	Monitor and Control	MNR	MNR, MTO, ORBA	Necessary

4.2 Stakeholder Engagement

Action: Have key stakeholders aware of herpetofauna road ecology challenges and actively engaged in attempting to mitigate negative road impacts.

Rationale: Ontario's 'In our Nature' plan has a strategy for addressing herpetofauna road ecology challenges. Current negative road impacts are significant and although there are pockets of positive change, change is not occurring in a manner substantial or quick enough to alleviate road mortality threats for Species at Risk. Engaging key stakeholders is the only way to rapidly develop and deploy actions which mitigate herpetofauna road ecology challenges in a meaningful manner.

Next Steps: The MNR is to develop a stakeholder engagement plan with reference to a stakeholder engagement process such as the AA1000 Stakeholder Engagement Standard (AccountAbility, 2011). Stakeholder engagement has many challenges, several of which can be identified and managed through planning (Johannson, n.d.). The first step is to plan the engagement by answering the following:

- Why engage (purpose): Ontario's health and prosperity is dependent upon the health of its biodiversity; herpetofauna are an essential part of this but road impacts are putting many herpetofauna species at risk. Road ecology stakeholders need to be engaged to address herpetofauna road ecology challenges.

- What are we trying to do (scope): Establish a stakeholder group which offers comprehensive coverage of Ontario's road network and have the group convert strategic herpetofauna road ecology opportunities into results.
- Who needs to be there (stakeholders): Road and natural resource managers, their direct support team, and key influencers (primary and secondary stakeholders).

After formalizing an engagement plan, MNR needs to implement and lead the plan and continually review and improve the engagement plan on an ongoing basis.

4.3 Road Resource Manager Mandates

Action: Have road resource managers responsible for biodiversity health/impacts of their corridors (as opposed to merely complying with environmental legislative criteria). The MNR would be involved in auditing the biodiversity health/impact of road corridors.

Rationale: Currently, the ESA is only applicable to development, which annually covers a small portion of Ontario roads. Little attention is given towards existing herpetofauna road ecology problems. A change in road resource manager's mandate would empower road resource managers to better determine how and where to allocate resources to address biodiversity concerns more strategically. For instance, on low volume roads (in particular private roads) driver education programs were noted as having a significantly greater ecological (and lower cost) compared to installing and maintaining fencing (Laflamme, 2014). Eliminating fencing expenditures with questionable benefit but adding turtle nesting sites along existing portions of the road may also yield more ecological benefit for available resources. It is noted a mandate change would need to be complimented with government change tools and/or budgetary support to help offset increased responsibilities.

Next Steps: Update road resource manager mandate to reflect the need for developing and maintaining safe, efficient transportation systems in corridors with strong biodiversity. The Ministry of Government Services (MGS), who was established to reduce the environmental footprint of the government services and build a green culture (Ontario Ministry of Natural Resources, 2012), is recommended as the most appropriate government branch to facilitate this change.

4.4 Enhance Government Change Tools

Action: Government to develop and use measures to invoke herpetofauna road ecology change outside of regulatory methods.

Rationale: Regulation (the ESA) is currently the primary tool used to invoke herpetofauna road ecology change. However, many other tools which are often more effective are currently available (Treasury Board of Canada Secretariat, 2007). Complementing the ESA with a more comprehensive approach is likely to yield more positive results. Examples of change tools are illustrated in FIGURE 1.

FIGURE 1 GOVERNMENT CHANGE TOOL KIT (Treasury Board of Canada Secretariat, 2007)

Next Steps: Develop and promote the use of additional tools. Examples are provided:

- Contracts: The MTO and municipalities (for MOI funded project at minimum) integrate beyond ESA compliance measurement criteria in tender documents of capital projects. An example outcome is contractors proposing to build turtle nesting sites adjacent to construction sites. These nesting sites may attract turtles away from the road, alleviating future fencing maintenance;
- Information & Education: Implement driver education programs in regions where roads have high negative SAR impacts. Driver education was found to be the most successful and cost effective approach for some forestry roads (Laflamme, 2014);
- Performance Based Regulation: Herpetofauna road ecology performance criteria for applications such as crossing structures, road drainage, and fencing be established. Tenders are to be written in a manner which encourages the development of more economically/ecologically viable solutions (e.g. – lower installation cost and/or operation cost) and eliminate the use of ineffective methods.

4.5 Public Awareness

Action: Develop an information sharing system which educates the public on herpetofauna value, concerns, and the risks associated with roads and builds herpetofauna. The goal is to build herpetofauna awareness and empathy through education, which may drive more support for mitigation efforts.

Rationale: An example of the potential impact of a public campaign is the case of drinking and driving. Laws were in place since World War I to dissuade people from drinking and driving. However, no significant drop in incidence occurred until the 1980's when public education campaigns, federal and provincial intervention, and community/non-government organization involvement shifted the social norm and turned drinking and driving into a socially unacceptable behaviour (Treasury Board of Canada Secretariat, 2007). A change in the social norm towards herpetofauna is needed. Examples of such changes taking place in smaller pockets were given during the interview with Joe Crowley from the MNR. Instances of groups such as Ontario Nature and the MNR discussing the current state of herpetofauna and addressing species misconceptions helped develop herpetofauna empathy and motivated people to take action to help herpetofauna were given (Crowley, 2014). Co-ordinating these efforts and complimenting them with additional resources is needed to change the social norm towards herpetofauna and road impacts.

Next Steps: Integrate public awareness into the stakeholder engagement discussion to develop a co-ordinated multi-faceted approach. It is expected the MNR, Ministry of Education, community and non-government organizations will be able to contribute significantly to this initiative.

4.6 Ecosystem Based Approach to Transportation Planning

Action: Have transportation and project planning based on an eco-system based planning perspective (develop plans considering where wildlife movement is) rather than a project specific planning perspective (consider how to mitigate wildlife impacts of the chosen location).

Rationale: Improving wildlife mitigation based on a project specific basis rather than an ecosystem basis may be economically efficient but is not ecologically efficient (Clevenger, 2005). Considering there are a multitude of road managers in an ecosystem, having projects and road planning completed from an eco-system basis rather than a road manager perspective will increase ecological connectivity and allow road practitioners to be more strategic in their mitigation efforts. MTO has already identified a 'need to integrate road ecology into long-term transportation and natural heritage planning' (Carruthers, Municipal Road Ecology Symposium: Town of Oakville, 2013). However, it is noted as MTO only manages a small percentage of roads in Ontario a collaborative effort between stakeholders would be needed to achieve this.

Next Steps: Transportation relevant herpetofauna ecosystem information is to be developed for all regions with a priority on ecosystem known to have a high number of negative road impacts. MTO is to complete its 1st generation Wildlife Mitigation Strategy and continue to evolve this and integrate with Municipalities and Parks road managers.

4.7 Information Sharing

Action: Develop a go-to resource for Ontario herpetofauna road ecology which helps users develop and implement solutions which preserve herpetofauna biodiversity.

Rationale: Mitigating road impacts on herpetofauna is a relatively new requirement in Ontario and stakeholders are learning what works partly through a non-standard approach which involves trying various approaches and monitoring them before adopting them as a standard (Carruthers, MTO, Senior Policy Analyst, 2014). The road ecology industry would benefit if there was a go-to resource road ecology information so practitioners could understand what mitigation requirements are needed (e.g. – species, mitigation requirements & priorities) and understanding which solutions work well and which ones do not for certain applications (topography, volume of traffic, frequency of crossings, fencing criteria, etc.). A forum which identifies research needs and publishes relevant research would also benefit.

Currently, much of the mitigation information appears to be housed by MTO and MNR. Rapid deployment of lessons learned and best management practices to all road and natural resource is needed to advance Ontario's road ecology approach. Sharing of this information, such as where high priority SARO needs are, or what approaches work well on high volume or low volume roads, will help species on the SARO list receive mitigation measures more quickly.

Next Steps: MNR to prioritize the development of the go-to information sharing resource for herpetofauna road ecology in Ontario. It is proposed a non-government organization such as the Ontario Road Ecology Group could lead this activity and development initiatives such as MTO's Wildlife Mitigation Strategy and MNR's Best Management Practice guideline could be used for support. It is recommended emphasis be placed on enabling effective, rapid information transfer and connecting people in a manner resulting in information being continually updated and rapidly deployed (e.g. http://www.ted.com/talks/jennifer_pahlka_coding_a_better_government) such that solutions are continually improving from an ecological and economic perspective.

4.8 Monitor and Control

Action: Increase the likelihood that what was planned is what was constructed and maintained.

Rationale: Monitoring and controlling construction quality and operational practices is equally important as deficient construction or operational impacts such as fallen trees on fencing can negate mitigation benefits (Baxter-Gilbert, 2014).

Next Steps: It is recommended MNR add monitoring and control criteria to issued parties applying for ESA permits. For example, the MNR could develop an approach comparable to the Quality Verification Engineer (QVE) approach used by the MTO. The QVE process requires contractors to have a QVE issue a Certificate of Conformance which provides written confirmation the specified components of the Work are in General Conformance with contract document requirements. In other words, mitigation efforts have been constructed in a manner which results in a product performing as intended and if specified in the contract, indicates work can proceed to the next stage (Nasiruddin Engineering Limited, 2007).

5.0 CONCLUSIONS

This report summarizes the current status of herpetofauna populations and herpetofauna road ecology in Ontario. It also identifies the root causes of herpetofauna road ecology challenges and recommends actions which address herpetofauna road ecology challenges in a more meaningful manner.

5.1 Herpetofauna Road Ecology in Ontario:

Currently, almost 60% of Ontario's herpetofauna species are at risk. Herpetofauna face challenges such as deliberate killing, poaching/pet trade, loss and fragmentation of habitat, pesticides and contaminants and road mortality. Roads are either directly or indirectly to all of these challenges. Efforts to mitigate negative herpetofauna road impacts are not being implemented on a scale large enough to save many species. MTO and MNR are working on efforts to improve herpetofauna mitigation efforts though these efforts are limited and a co-ordinated strategic push from all directions to tackle the threat of road mortality is needed to save some herpetofauna species.

5.2 Identify root causes of herpetofauna and road conflicts:

Four root causes for ongoing herpetofauna road ecology challenges were derived from information collected through a literature review and interviews with key stakeholders. It is believed herpetofauna road ecology challenges stem from:

- herpetofauna's small stature and low societal value;
- road resource managers giving biodiversity needs a relatively low priority;
- a fractured, non-collaborative road ecology approach to a multi-faceted problem; and
- limited information on where species are and how to develop solutions which preserve biodiversity.

5.3 Recommend systematic changes that will reduce conflict between herpetofauna and roads:

To help realize the goals of Ontario's 'In our Nature' plan, seven actions intended to address herpetofauna road ecology threats are presented.

TABLE 6 RECOMMENDED ACTIONS

Item	Recommended Action	Lead	Support	Relative Priority
1	Stakeholders Engaged in Herpetofauna Road Ecology Challenges	MNR	Primary & secondary stakeholders	Critical
2	Road Resource Manager Mandate Incorporates Biodiversity	MGS	MNR, MTO, MMAH	Critical
3	Enhance Government Change Tools to Implement Change	MGS	MTO, MOI, MMAH, ORBA, OREG	Necessary
4	Build Public Awareness of Herpetofauna Importance and Challenges	MNR	Media, EDU, OREG, Ontario Nature, MTO	Necessary
5	Use an Ecosystem instead of Fragmented Road Manager Based Approach to Transportation Planning	MTO	Ontario Nature, ORBA, MOE, MMAH	Necessary
6	Facilitate Sharing of Herpetofauna Road Ecology Information	MNR	MTO, OREG, ORBA	Necessary
7	Monitor, Control and Improve Herpetofauna Road Ecology Approaches	MNR	MNR, MTO, ORBA	Necessary

5.4 Next Steps

Focusing on actions which lead to significant positive systematic change for herpetofauna is essential if Ontario is to preserve its herpetofauna biodiversity. Addressing critical issues is the necessary first step. For this, the MNR is to develop a stakeholder engagement plan and lead an engagement with key stakeholders from the Provincial and Municipal government as well as key ecological and road resource stakeholders (road ecologists, OREG and road consultants). Their first objective is to develop government change tools which result in more substantial herpetofauna road ecology mitigation. In parallel with this activity the Ministry of Government Services (MGS) is to investigate and if appropriate, modify road resource manager's mandate such that it recognizes biodiversity and road ecology as their responsibility.

Items four through seven are to be integrated into the engagement. In support of addressing the problem in the timelier manner, when possible, stakeholder leads are to advance their action as far as possible before integrating the action into the stakeholder engagement process.

Altogether, the report's recommendations highlight opportunities for Ontario to develop significant positive herpetofauna road ecology change, creating a positive impact on the welfare of Ontario's biodiversity and its people.

6.0 BIOGRAPHICAL SKETCH OF AUTHORS

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Kevin is a Senior Design Engineer for Atlantic Industries Limited (AIL) and leads AIL's technical efforts to research, develop and design innovative culvert and buried bridge solutions. Kevin is involved in the development of national design and material specifications for culverts and buried bridges and actively participates in AASHTO, ASTM, and CSA standards. He has designed a variety of wildlife crossings and is actively involved in efforts to improve the use and performance of culvert and buried bridge wildlife crossings. Kevin is a professional civil engineer with a Bachelor of Applied Science from the University of Waterloo and has worked in the transportation infrastructure industry for 13 years. This paper is the result of a final project completed as part of the Masters of Environment and Business program at the University of Waterloo.

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APPENDIX A

LIST OF INTERVIEWEES

The following is a list of key stakeholders interviewed.

- Bob Burdett: Bob is a Senior Environmental Manager in the Planning and Environmental Design division for the MMM Group Limited.

- Brenda Carruthers: Brenda is a Senior Policy Analyst for MTO's Environmental Policy Office.

- Dave Penny: Dave is the Director Emeritus of the Corrugated Steel Pipe Institute (CSPI), the Association of Canadian corrugated steel pipe manufacturers.

- Joe Crowley: Joe is a Herpetology Species at Risk Specialists for the MNR.

- Kari Gunson: Kari is a Road Ecologist/Principal at Eco-Kare, a consulting service focused on integrating science into practical road mitigation solutions for provincial governments as well as municipalities in Ontario.

- Les Shepard: Les is the Director of Public Works for United Counties of Leeds and Grenville.

- Martin Laflamme: Martin is the Acting Woodlands Supervisor for the Algonquin Forestry Authority.

- Oliver Busby: Oliver is a Principal for EBB Environmental Consulting Inc., which provides professional, ethical, and quality service in the environmental resource sector, primarily in Western Canada.

- Terry McGuire, P.Eng.: Terry is currently a consultant and contractor for McGuire Consulting and Contracting. Prior to this, Terry was the Director of the Western Asset Management Service Centre for the West and North Region of Parks Canada.

APPENDIX B

LIST OF ABBREVIATIONS

MGS = Ontario Ministry of Government Services

MNR = Ontario Ministry of Natural Resources

MOI = Ontario Ministry of Infrastructure

MTO = Ontario Ministry of Transportation

ECO = Environmental Commissioner of Ontario

EDU = Ontario Ministry of Education

ESA = Endangered Species Act

SARO = Species at Risk in Ontario List

ORBA = Ontario Road Builders Association

OREG = Ontario Road Ecology Group

SWOT = Strengths, weaknesses, opportunities, threats

TOWS = Threats, opportunities, weaknesses threats