2018

USING WILDLIFE ECOPASSAGES TO REDUCE TURTLE ROAD MORTALITY IN THE LAKE SIMCOE WATERSHED

Lake Simcoe Region
conservation authority

Table of Contents

1.0 Executive Summary

Roads and other transportation infrastructure, such as bridges, have been shown to negatively affect wildlife populations on both small scales (e.g. vehicle-wildlife collisions) and more broadly (e.g. habitat fragmentation). However, research has shown that these effects can be mitigated through the implementation of wildlife ecopassages, which restrict wildlife access to roadways while allowing safe passage across them.

To address this issue, the Lake Simcoe Conservation Authority (LSRCA) initiated the Wildlife Safe Passage Project with the goal of installing wildlife ecopassages to mitigate the negative impacts of roads on turtle populations. To this end, the LSRCA installed five ecopassages in 2015, which consisted of wildlife exclusion fencing attached to existing crossing infrastructure. The five sites were monitored along with four control sites for three years (one year pre-fencing and two years post-fencing) to assess the effectiveness of the ecopassages at both reducing turtle road mortality and allowing safe passage under the road.

Results showed that the ecopassages reduced total turtle road mortality by 81% compared to control sites with no fencing and that adult turtle road mortality was reduced by 87%. The fencing was not as effective at reducing roadkill of other non-target species including snakes and amphibians. There was a peak in all wildlife killed on the roads in September, highlighting this important period for wildlife migration. Additionally, it was shown that roads with higher traffic rates had higher rates of roadkill, which could direct future road management decisions. An estimated 39% of the turtles observed at the sites used the ecopassages to cross under the roads, and 18 turtles were observed using artificial nesting structures.

Of the eight turtles killed at the ecopassage sites post-installation, five occurred near gaps in the fencing and three occurred at the fence ends. This highlights the importance of maintaining continuous fencing to the greatest extent possible, and ensuring fence ends do not allow wildlife to pass around them. Overall, the fencing used proved to be robust and withstood all weather conditions experienced; the only maintenance issue experienced was some damage from roadside mowing.

This study demonstrated that relatively inexpensive solutions (i.e. under $60,000) can be built to address road impacts on wildlife populations and existing infrastructure can be retrofitted to enable safe road passage for wildlife. Several lessons were learned during the course of the study and recommendations are presented within this report.

2.0 Introduction

2.1 Background

The impacts of roads on wildlife populations are well documented throughout the world (Andrews et al., 2008; Forman and Alexander, 1998; Jackson, 2000; Jochimsen et al., 2004). The ecological effects are generally negative and can range from habitat loss and degradation, to population fragmentation and disruption of gene flow, and direct road mortality (Forman et al., 2003). In general, roads negatively affect wildlife populations and there is a lot of research on how to mitigate these impacts. Rytwinski et al. (2016) conducted a meta-analysis of the effectiveness of road mitigation measures at reducing roadkill. This study found that crossing structures paired with exclusion fencing (i.e. ecopassages) reduced road mortality by 51%, compared to controls.

Reptiles and amphibians (collectively called herpetiles) display behavioral and life history traits that make them particularly susceptible to the impacts of roads. For example, turtles are known to bask on warm roads, migrate between various habitat types throughout the year, are slow moving, and can be difficult to see on roads (Fahrig and Rytwinski, 2009). These factors combine to make roads a serious threat to turtle population persistence. Additionally, since female turtles migrate more than males due to their need to find suitable nesting habitat, they are disproportionately killed on roads. This creates male-biased sex ratios which can accelerate population decline (Steen and Gibbs, 2004; DeCatanzaro and Chow-Fraser, 2010).

Road mortality can also impair populations by removing a higher rate of breeding adults from the population. Turtles are adapted to mature later (up to 19 years in Ontario), live longer (up to 75 years) and produce many offspring per year (Ontario Nature, 2018). As more adults are removed from the population, this reproductive strategy which has served them well for millions of years puts them at a disadvantage. Over time, fewer eggs are laid, recruitment decreases and populations shrink.

There are eight turtle species found in Ontario. Of these, seven are listed as species at risk under the provincial *Endangered Species Act* (MNRF, 2007), and according to the Committee on the Status of Endangered Wildlife in Canada, all eight species are at risk (COSEWIC, 2018). Four of these turtle species are known to occur within the Lake Simcoe watershed, as described in the following table.

Table 1. Turtle species occurring in the Lake Simcoe watershed.

Common Name	Scientific Name	Provincial Status	Federal Status
Midland painted turtle	*Chrysemys picta picta*	Not at risk	Special concern
Snapping turtle	*Chelydra serpentina*	Special concern	Special concern
Northern map turtle	*Graptemys geographica*	Special concern	Special concern
Blanding's turtle	*Emydoidea blandingii*	Threatened	Endangered

* Status listings according to the Species at Risk in Ontario list (MNRF, 2018) and the Committee on the Status of Endangered Wildlife in Canada list (COSEWIC, 2018).

2.2 Purpose

Despite the current policies protecting the natural heritage features in the Lake Simcoe watershed from potential development (e.g. Lake Simcoe Protection Plan, Provincial Policy Statement, Greenbelt Plan, Oak Ridges Moraine Conservation Plan, and municipal official plans), projected population and employment growth are expected to increase demand for roads and other transportation infrastructure. The Growth Plan for the Greater Golden Horseshoe (MMAH, 2017) suggests that urban development could increase by 50% in the watershed by 2041, which will increase road density and the frequency with which roads are located between remaining natural features. Further, as municipal infrastructure is not subject to the *Planning Act*, the protection of natural heritage features is not as stringent for the development of roads and other infrastructure. This shift from rural and natural heritage features to urban land use and the associated increased road density can impact connectivity between wildlife habitats. This can have significant impacts on Ontario's native biodiversity, particularly those species which migrate throughout their breeding cycle.

To address these impacts, the Wildlife Safe Passage Project was initiated by the Lake Simcoe Region Conservation Authority (LSRCA) in 2015 with the goal of mitigating the anticipated increase in wildlife mortality resulting from roads and vehicular traffic. Because of the relatively high threat of roads on turtle populations, as discussed above, this study focused on reducing negative road impacts on turtles.

The goals of this project were as follows:

1. To decrease direct road mortality of turtles and other wildlife by preventing their access to roadways;
2. To reduce habitat fragmentation by upgrading existing culverts into ecopassages and encouraging turtles to pass through these in order to access their various habitat needs; and
3. To create demonstration sites of ecopassages in the Lake Simcoe watershed in order to build capacity and provide road managers with a functional example of road-wildlife hazard mitigation.

To achieve these goals, the LSRCA installed wildlife exclusion fencing in five areas of high turtle road mortality and attached it to existing road crossing infrastructure to create wildlife ecopassages. The three-year study investigated the effectiveness of the ecopassages in reducing turtle road mortality and in facilitating movement across the roadways in comparison to control sites.

3.0 Methods

3.1 Site selection

Five sites were selected throughout the Lake Simcoe watershed in April 2015 to serve as ecopassage treatment sites. These sites were chosen based on the potential road mortality hotspot mapping completed by the LSRCA (LSRCA, 2015). Sites were then further narrowed down by the following criteria: (i) relatively small sites (i.e. less than 300 m long), (ii) documented turtle road mortality, (iii) crossing infrastructure that was suitable for ecopassages (i.e. good condition, high openness ratio), (iv) appropriate turtle habitat, and (vi) located in different municipalities.

In addition to these sites, four control sites were also selected based on their close proximity and similarity to the treatment sites (i.e. similar habitat and crossing infrastructure). A map showing the locations of the hotspots as well as treatment and control sites is shown in Figure 1.

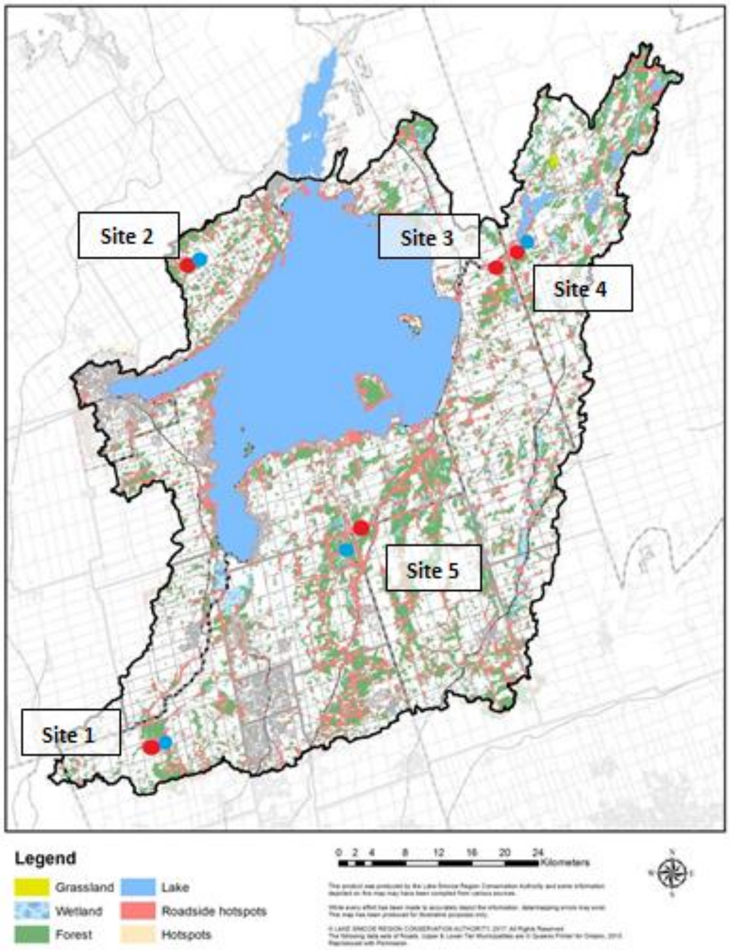

Figure 1. Map of potential road mortality hotspots in the Lake Simcoe watershed, and the locations of the five ecopassage treatment sites (red dots) and four control sites (blue dots).

3.2 Site descriptions

An overview of each of the ecopassage sites is provided in the following subsections.

Site 1 – Lloydtown-Aurora Road

This site is located on Lloydtown-Aurora Road, just west of Pottageville in the Township of King. The road is maintained by the Regional Municipality of York and is a paved two-lane road with a speed limit of 80 km/hr at this location. Traffic is moderate, with an average of 5.4 vehicles per minute.

The South Schomberg River crosses under the road at two locations at this site. One crossing consists of a flared corrugated steel pipe (CSP) measuring 4.3 m in diameter and approximately 24.8 m long, corresponding to an openness ratio[1] of 0.58. The second crossing is a 1.2 m diameter CSP, measuring approximately 28.4 m long, with an openness ratio of 0.04. Openness ratio refers to the amount of light visible at the end of a crossing structure and determines the permeability or attractiveness of a structure for wildlife to cross through. A higher value means a more attractive crossing structure, and an openness ratio greater than 0.25 is recommended for turtles, but no less than 0.1.

Habitat types at this site include meadow marsh, thicket swamp, cultural meadow, cultural thicket and coniferous forest. Most of these natural heritage features represent suitable turtle habitat.

Figure 2. Photos of Site 1, clockwise from top left: view of larger culvert, looking north; view of road, looking east; South Schomberg River, looking south; view of smaller culvert, looking north

[1] Openness ratio for a CSP = (πr^2) / Length

Site 2 – Line 7

This site is located on Line 7 North in the Township of Oro-Medonte, in Simcoe County. The road is maintained by the Township and is a paved two-lane road with a speed limit of 60 km/hr. The traffic volume is low, with an average of 2.0 vehicles per minute, and the majority of vehicles are gravel trucks.

The road crosses through the Hawkestone wetland complex, and at this site Hawkestone Creek flows under the road through a bridge with an opening measuring approximately 1.82 m high, 8.58 m wide, and 12.5 m long (openness ratio[2] of 1.25).

Habitat types at this site include a thicket swamp on the west side of the road, and a mixed swamp on the east side.

Figure 3. Photos of Site 2, clockwise from top left: wetland west of the site; crossing structure, looking west; view of site, looking south; snapping turtle in wetland on west side

[2] Openness ratio for a box culvert or similar structure = (Height x Width) / Length

Site 3 – Highway 48 West

This site is located on Durham Regional Road 48, in the Township of Brock. The road is maintained by the Regional Municipality of Durham and is a paved two-lane road with a speed limit of 80 km/hr. The traffic volume is moderate with an average of 4.7 vehicles per minute.

A tributary of the Talbot River flows under the road at this site. The crossing infrastructure consists of a CSP measuring 2.92 m in diameter and approximately 32.9 m in length (openness ratio of 0.2).

Habitat types at this site include a thicket swamp on the north side of the road and a shallow marsh on the south side, as well as both mixed and deciduous forests.

Figure 4. Photos of Site 3, clockwise from top left: view of culvert and wetland south of site; culvert, looking northwest; culvert and wetland on north side; view of road, looking west

Site 4 – Highway 48 East

This site is located on Durham Regional Road 48, in the Township of Brock. The road is maintained by the Regional Municipality of Durham and is a paved two-lane road with a speed limit of 80 km/hr. The traffic volume is moderate with an average of 4.7 vehicles per minute.

A tributary of the Talbot River flows under the road at this site. The crossing infrastructure consists of a CSP with a diameter of 2.95 m and a length of 31.5 m (openness ratio of 0.21).

Habitat types at this site include open water and a cultural thicket.

Figure 5. Photos of Site 4, clockwise from top left: view of culvert, looking northwest; open water and cultural thicket, looking southeast; open water (Talbot River), looking north; view of road, looking east

Site 5 – Ravenshoe Road

This site is located on Ravenshoe Road, between the towns of East Gwillimbury and Georgina. The road is maintained by the Regional Municipality of York and is a paved two-lane road with a speed limit of 60 km/hr. The traffic volume is high with an average of 7.1 vehicles per minute.

The Black River flows under the road through a bridge with an opening approximately 4.25 m high and 30.95 m wide, and a road width of 12 m (openness ratio of 11).

Habitat types at this site include a shallow marsh on the north side and thicket swamp on the south side.

Figure 5. Photos of Site 5, clockwise from top left: view of thicket swamp, looking southeast; thicket swamp, looking southwest; shallow marsh, looking north; view or road, looking east

3.3 Stakeholder consultation and permitting

Following site selection, the road managers (i.e. municipal roads departments) for each site were contacted to inform them of the project, outline the project design, and request approval to proceed. Each municipality was provided with detailed site designs, an overview of the scheduled construction and monitoring plan. Municipal staff attended a site visit at each location to determine constraints and approve the fencing placement. Prior to the project initiation, a road occupancy permit was acquired from each municipality, as required.

Additionally, as all sites were located in or adjacent to sensitive areas, permits were acquired from the LSRCA regulations department, in accordance with Ontario Regulation 179/06, for the installation of the fencing and artificial nesting structures.

Where possible, landowners adjacent to the ecopassage sites were also contacted to inform them of the upcoming project, as well as its purpose and design.

3.4 Ecopassage installation

In April 2016, the ecopassages were installed at the five treatment sites. The ecopassages consist of Animex wildlife exclusion fencing installed alongside the roadway and attached to existing crossing infrastructure (culverts and bridges). The fencing is 41 cm high with a 10 cm angled lip at the top to prevent animals from climbing over. In order to meet the conditions of the LSRCA permit, the fencing was dug into the slope so that the top is even with the grade. With this design, the fencing does not interfere with road drainage, snow removal, or driver sight lines.

The fencing extends past the road crossing infrastructure on either side and runs parallel along the roadside, extending through wetland habitat and into adjacent forest habitat. At each end, the fence turns back on itself to orient turtles back towards the crossing infrastructure. Fence length at each site was determined based on the site characteristics and extended past the wetland habitat into adjacent natural features (e.g. forest). Images of the ecopassages and fencing are shown in Figure 6.

In order to provide safe nesting areas for female turtles, artificial nesting structures (ANSs) were installed at each of the ecopassage sites. The ANSs consist of a base layer of pea gravel overlain with brick sand, and were dug into the south-facing slope to maximize sun exposure and drainage. One to three ANSs were installed at each treatment site, depending on space availability. An image of an ANS is also shown in Figure 6. The lengths of fencing at each site are listed in Table 2, as well as the approximate cost of materials to create the ecopassages (fencing and ANSs).

Figure 6. Ecopassage fence installation showing the below-grade design and artificial nesting structure (left), and the connection to existing road crossing infrastructure (right).

Table 2. Length of Animex fencing installed at each treatment site and cost of ecopassage materials

Site Number	Site Name	Length of Fencing (m)	Approximate Ecopassage Cost ($)
1	Lloydtown-Aurora	275	17,400
2	Line 7	100	11,300
3	Highway 48 West	50	7,500
4	Highway 48 East	105	8,800
5	Ravenshoe	120	6,900

3.5 Monitoring

In order to assess the effectiveness of the ecopassages at reducing road mortality, a before-after-control-impact (BACI) study was completed. Monitoring of both treatment and control sites was conducted for one year before the ecopassages were installed (2015) and for two years after installation (2016-2017).

Monitoring of all sites was completed twice a week during the peaks in turtle migration - in the spring when turtles are emerging from hibernation and females are searching for nests, and in the fall when hatchlings are emerging and turtles are moving back to hibernation ponds. The actual monitoring dates and number of visits are shown in Table 3. Monitoring began once reports of turtles emerging from hibernation in Ontario were received, and ended after three consecutive monitoring days of no observed roadkill, implying that the active migration season had finished.

Table 3. Dates of completed monitoring at the ecopassage and control sites.

Year	Monitoring period	Date started	Date completed	Number of visits
2015	Spring	May 20	June 29	11
	Fall	August 31	October 13	12
2016	Spring	May 19	July 4	13
	Fall	August 23	October 6	14
2017	Spring	May 8	June 29	16
	Fall	August 14	October 13	18

Road mortality was assessed through walking surveys of the sites. Surveys were completed at each treatment and control site twice a week between 9:00 am and 4:30 pm. During the surveys, two LSRCA staff walked the entire length of each site on both sides of the road, scanning for wildlife on the road or adjacent lands. When any wildlife was encountered, staff noted the species (where possible), location (UTM waypoint and description), and state of the individual (alive on road, dead on road, alive beside road, dead beside road). Where live animals were encountered, a description of their behaviour was also noted. For the purposes of the surveys, the term 'road' encompassed the entire roadway (driving lanes and shoulders). Other parameters such as time, weather and a 2-minute traffic count were also collected during each survey.

The use of the ecopassages and ANSs was monitored through the use of wildlife cameras. Cuddeback Long Range IR trail cameras were installed onto U-posts facing either the culvert or the ANS (Figure 3). The cameras were set with the time-lapse function and took a photo every minute continuously during the monitoring period. The photos were then uploaded onto a computer and manually checked for evidence of wildlife using the ecopassages or ANSs. Due to timing and personnel constraints, only 55% of these photos (a randomized subsection) were manually checked by LSRCA staff and volunteers for the presence of turtles and other wildlife. These results were then extrapolated out to the entire data set to estimate total wildlife occurrences. Where possible, the species as well as their behaviour was identified.

Figure 7. Trail cameras set to capture wildlife passing through the ecopassages (left) and using the artificial nesting structures (right)

3.6 Data analysis

The total observed live and roadkilled wildlife was summed over each monitoring year per site and was then normalized by dividing by the length of each site, giving an observed rate per km of road. This allowed comparison between sites as the lengths of each varied.

Rates of observed wildlife (live and roadkilled) were compared before (2015) and after (2016 and 2017) ecopassage installation using a t-test (for normal data) or a Mann-Whitney rank sum test (for non-normal normal data). Normality was assessed using a Shapiro-Wilks test. Traffic rates between years were compared using an analysis of variance and a comparison of traffic rates and observed roadkill was completed using linear regression. All data analysis was completed in SigmaPlot (version 13).

4.0 Results

Throughout the three years of monitoring, a total of 61 species were identified at the treatment and control sites. A list of species is shown in Table 4 below. This list contains all identifiable species, however there were numerous occasions where staff were not able to accurately identify the species of roadkilled animals. In this case, they were simply identified by general wildlife group (e.g. snake, frog).

Table 4. Wildlife species observed at the ecopassage and control sites.

Common name	Scientific name	Alive	Roadkilled
Reptiles			
Painted turtle	*Chrysemys picta*	x	x
Snapping turtle	*Chelydra serpentina*	x	x
Common gartersnake	*Thamnophis sirtalis*	x	x

Common name	Scientific name	Alive	Roadkilled
Eastern ribbonsnake	*Thamnophis sauritus*	x	
Red-bellied snake	*Storeria occipitomaculata*	x	x
Milksnake	*Lampropeltis triangulum*	x	x
Amphibians			
American toad	*Anaxyrus americanus*	x	
Gray treefog	*Hyla versicolor*	x	
Western chorus frog	*Pseudacris triseriata*	x	
Wood frog	*Lithobates sylvatica*	x	
Northern leopard frog	*Lithobates pipiens*	x	x
Green frog	*Lithobates clamitans*	x	x
Mink frog	*Lithobates septentrionalis*	x	
Spring peeper	*Pseudracris crucifer*	x	
Eastern newt	*Notophthalamus viridescens*		x
Salamander	(unknown species)		x
Mammals			
Beaver	*Castor canadensis*	x	
Coyote	*Canis latrans*	x	
Eastern chipmunk	*Tamias striatus*		x
Eastern cottontail	*Sylvilagus floridanus*	x	
Eastern grey squirrel	*Sciurus carolinensis*	x	x
Deer mouse	*Peromyscus maniculatus*	x	x
Least weasel	*Mustela nivalis*		x
Meadow vole	*Microtus pennsylvanicus*	x	
Mink	*Mustela vison*		x
Muskrat	*Ondatra ziebethicus*	x	x
Northern river otter	*Lontra canadensis*	x	
Porcupine	*Erethizon dorsatum*		x
Racoon	*Procyon lotor*	x	x
Red fox	*Vulpes vulpes*	x	
Red squirrel	*Tamiasciurus hudsonicus*		x
Shrew	*Sorex spp.*		x
Star-nosed mole	*Condylura cristata*		x
Virginia opossum	*Didelphis virginiana*		x
White-tailed deer	*Odocoileus virginianus*	x	
Birds			
American crow	*Corvus brachyrhynchos*		x
American redstart	*Setophaga ruticilla*		x
American robin	*Turdus migratorius*		x
Barn swallow	*Hirundo rustica*	x	
Belted kingfisher	*Megaceryle alcyon*	x	
Blue jay	*Cyanocitta cristata*	x	
Canada goose	*Branta canadensis*	x	
Cedar waxwing	*Bombycilla cedrorum*	x	x
Common yellowthroat	*Geothlypis trichas*		x
Dark-eyed junco	*Junco hyemalis*		x

Common name	Scientific name	Alive	Roadkilled
Eastern kingbird	*Tyrannus tyrannus*	x	
European starling	*Sturnus vulgaris*		x
Great blue heron	*Ardea herodias*	x	
Great egret	*Ardea alba*	x	
Green heron	*Butorides virescens*	x	
Grey catbird	*Dumetella carolinensis*		x
Hairy woodpecker	*Picoides villosus*		x
Hooded merganser	*Lophodytes cucullatus*	x	
Killdeer	*Charadrius vociferus*	x	
Mallard	*Anas platyrhynchos*	x	
Northern cardinal	*Cardinalis cardinalis*		x
Osprey	*Pandion haliaetus*	x	
Owl	(unknown species)		x
Red-winged blackbird	*Agelaius phoeniceus*	x	
Wood duck	*Aix sponsa*	x	
Yellow warbler	*Setophaga petechia*		x

During the entire monitoring period, a total of 47 live turtles and 92 roadkilled turtles were observed (Table 5). All identifiable species were either midland painted turtles or snapping turtles. Overall, the majority (75%) of observed roadkilled turtles were hatchlings or juveniles. Conversely, most of the live turtles observed (80%) were adults.

Table 5. Number of turtles observed at all sites (treatments and controls) from 2015 to 2017

Number of turtles observed	2015		2016		2017	
	Live	Roadkilled	Live	Roadkilled	Live	Roadkilled
Snapping turtle	7	30	5	1	11	35
Midland painted turtle	7	5	6	3	10	14
Unknown	1	4	0	0	0	0
Total	15	39	11	4	21	49

4.1 Effectiveness of the ecopassages

The ecopassages reduced the road mortality of all turtles at the treatment sites by 81% (Mann-Whitney, $p=0.016$), compared to a 127% increase at the control (unfenced) sites (Figure 8). There was also a corresponding 87% decrease in adult turtle road mortality at the treatment sites (one-tailed t-test, $p=0.0012$), compared to no significant change at the control sites before and after the fencing was installed (Figure 8).

Looking at other non-target species, road mortality of amphibians and snakes at all sites (treatment and control) remained relatively unchanged between 2015 (before ecopassage installation) and 2016 (after ecopassage installation). However, there was a significant increase in road mortality at all sites in 2017 (second year after ecopassage installation) (Figure 10 and 11). This increase was more pronounced at the control sites for amphibians, and at the treatment sites for snakes.

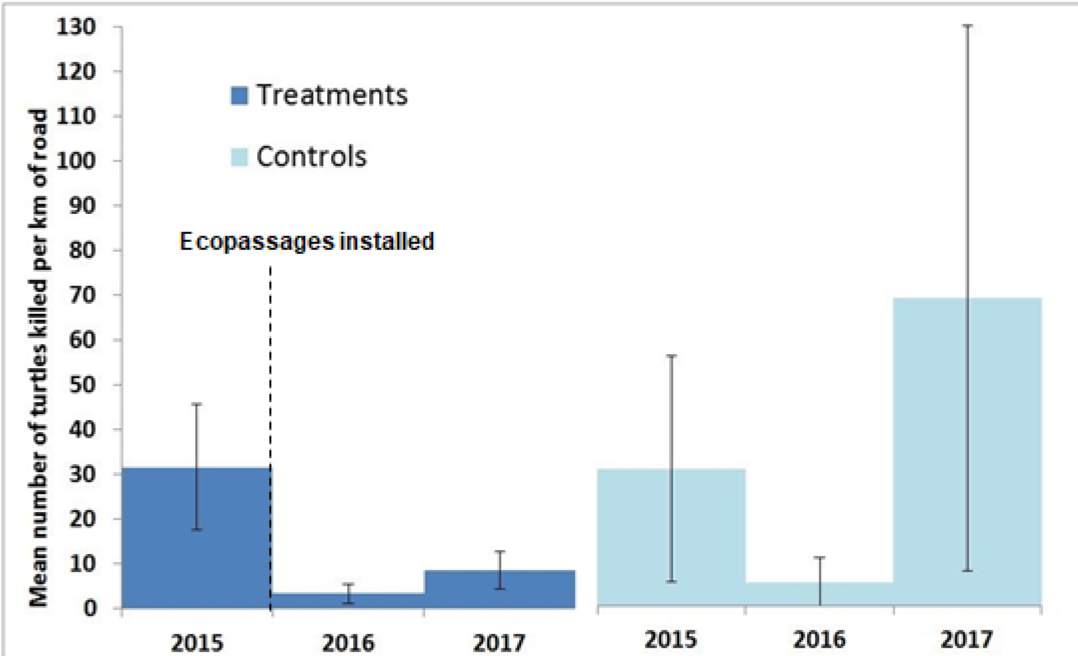

Figure 8. The mean number of turtles killed per km of road at treatment and control sites from 2015-2017. The ecopassages were installed in early 2016, so 2015 represents pre-fencing data and 2016/2017 represent post-fencing data. Error bars represent the standard error of the mean.

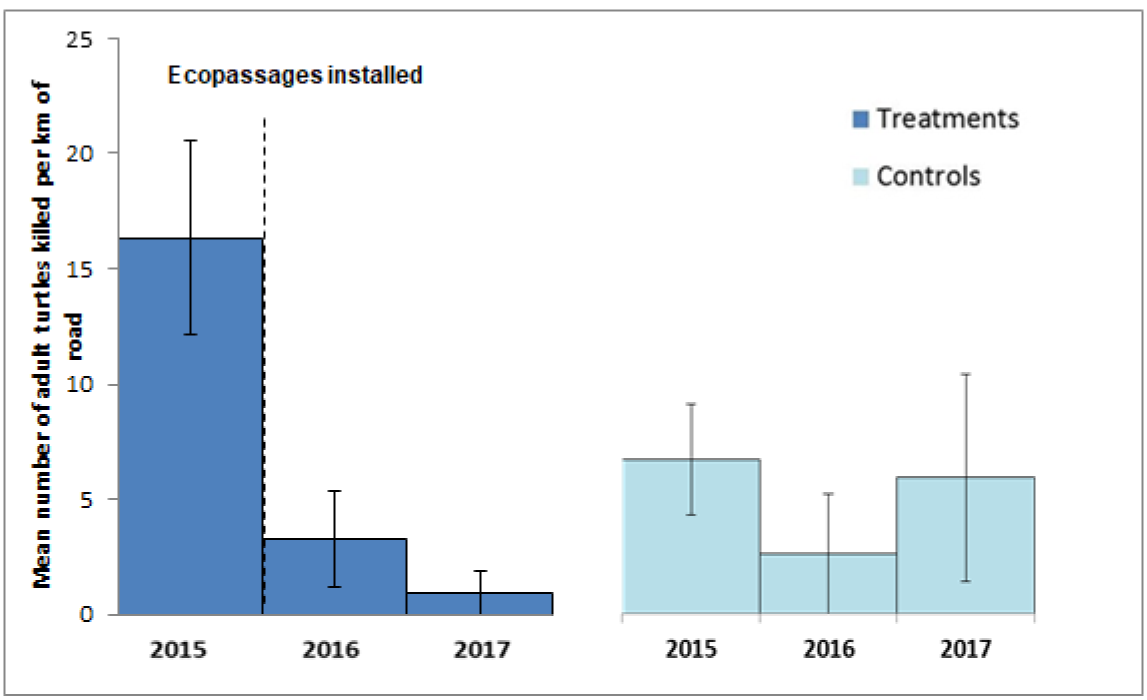

Figure 9. The mean number of adult turtles killed per km of road at treatment and control sites from 2015-2017. The ecopassages were installed in early 2016, so 2015 represents pre-fencing data and 2016/2017 represent post-fencing data. Error bars represent the standard error of the mean.

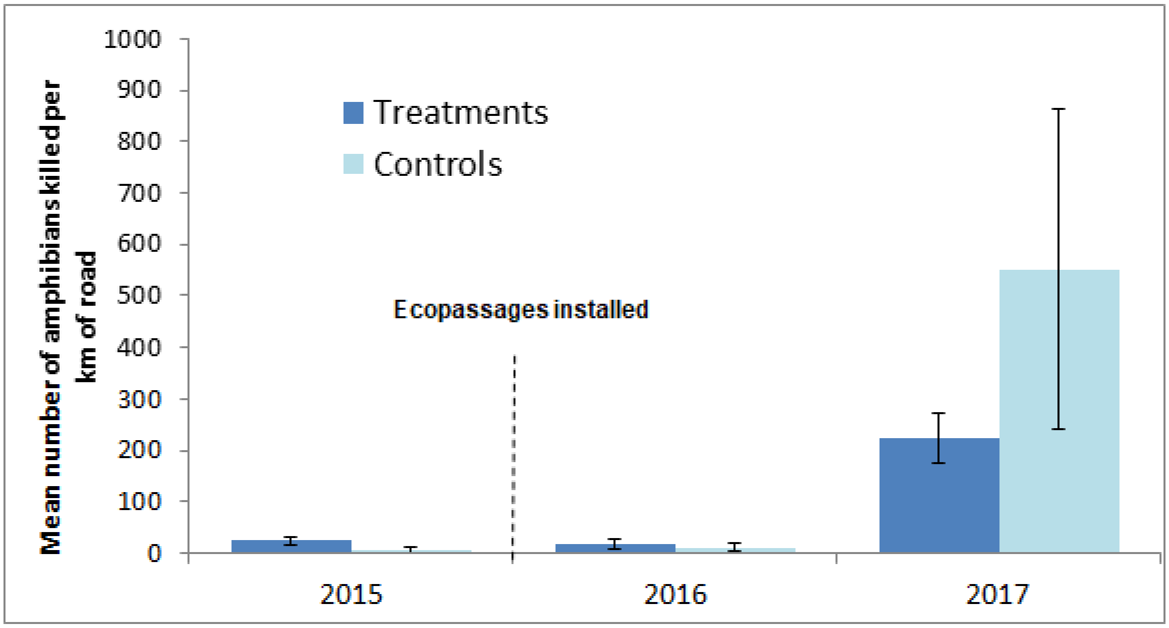

Figure 10. The mean number of amphibians killed per km of road at treatment and control sites from 2015-2017. The ecopassages were installed in early 2016, so 2015 represents pre-fencing data and 2016/2017 represent post-fencing data. Error bars represent the standard error of the mean.

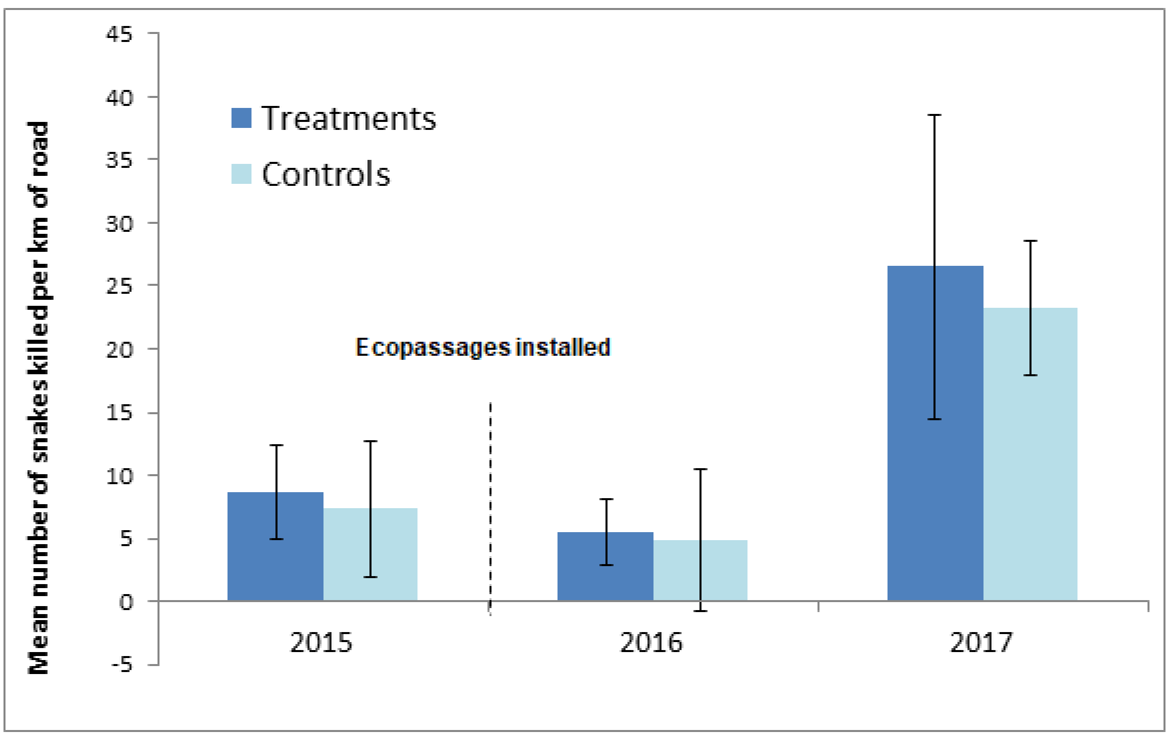

Figure 11. The mean number of snakes killed per km of road at treatment and control sites from 2015-2017. The ecopassages were installed in early 2016, so 2015 represents pre-fencing data and 2016/2017 represent post-fencing data. Error bars represent the standard error of the mean.

To ensure that any of the observed changes in road mortality were not caused by changes in traffic volume, a two-minute traffic count was conducted during each survey. An analysis of variance revealed that there were no significant changes in traffic volume during site visits at any of the sites over the three survey years ($p>0.05$).

When looking at the number of animals (all species combined), there were more killed at sites with higher traffic volumes (normalized per km of road), than those sites with less traffic (Figure 12). However, the relationship was not statistically significant (linear regression, $p=0.06$).

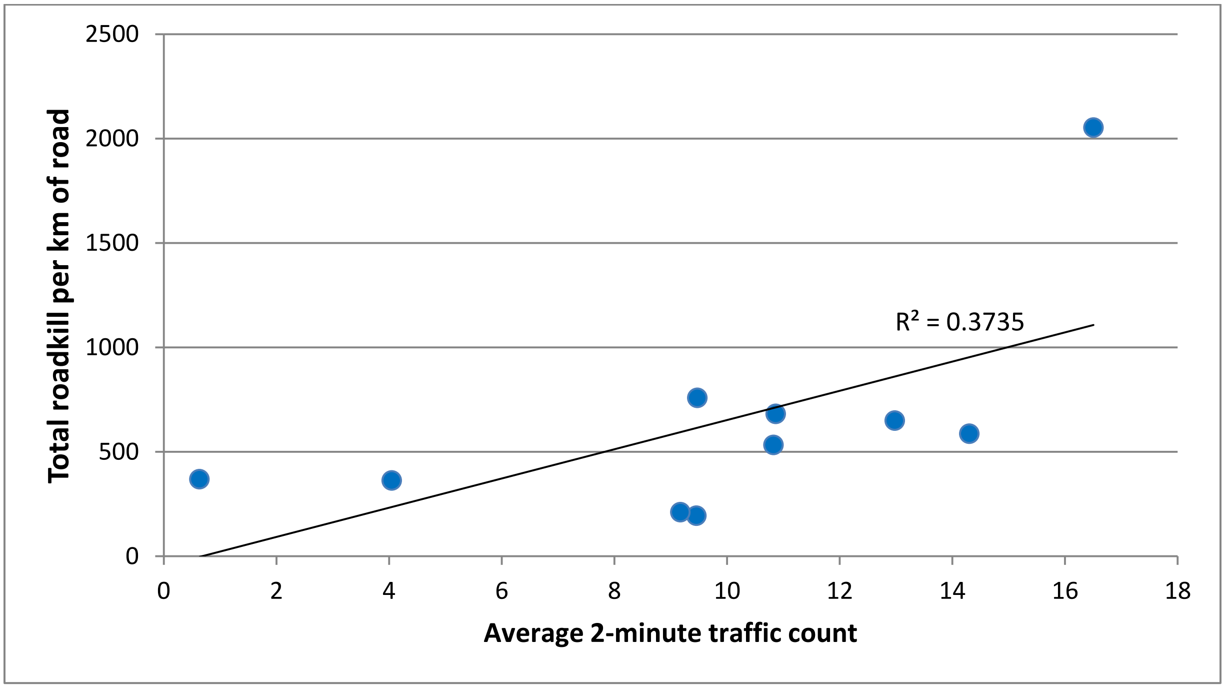

Figure 12. The amount of roadkill per km of road increases with traffic volume.

The majority (60%) of all observed roadkill occurred in September throughout the monitoring period. Road mortality of all wildlife groups except birds peaked in September (Figure 13). Although the majority of turtles were killed in September, most (75%) of these were hatchlings. There was another smaller peak in turtles killed in June, which were all adults and likely females in search of a nest. Both of these periods are important for turtle migration and represent periods when seasonal road ecology BMPs (e.g. road closures, signage, temporary fencing) could be implemented.

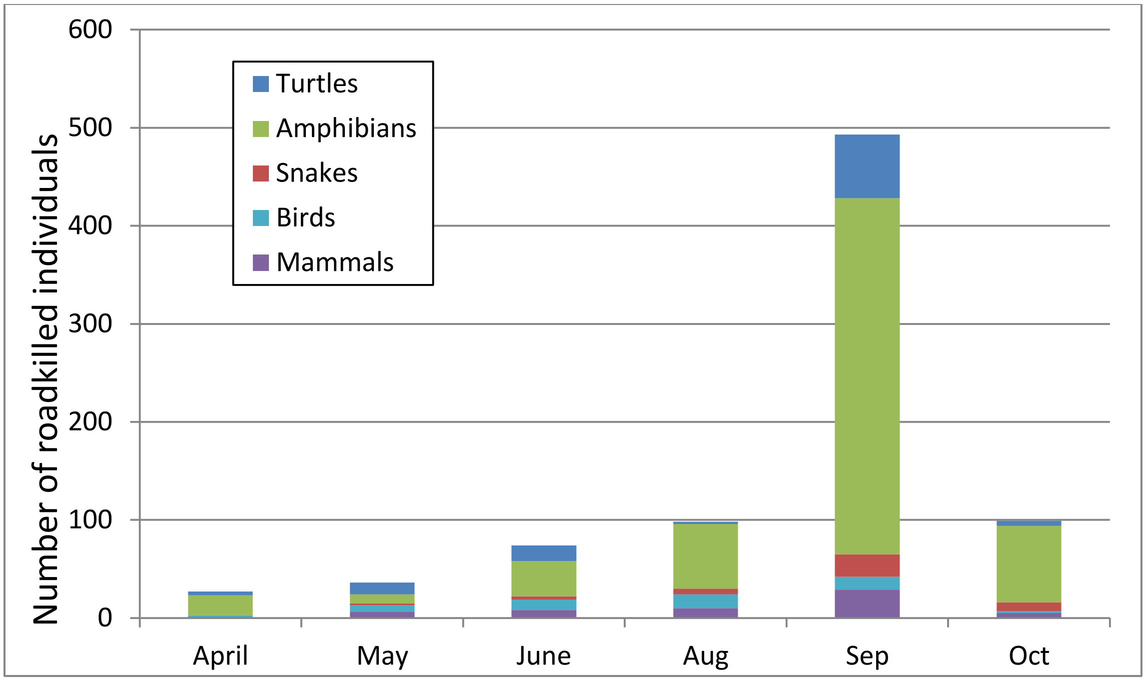

Figure 13. Monthly distribution of observed wildlife roadkill at all sites

4.2 Use of ecopassages and artificial nesting structures (ANSs)

In order to assess wildlife use of the ecopassages and ANSs, trail cameras were used to determine how often they were accessed by turtles and other wildlife. In 2016, six cameras were used to observe three ecopassages and two cameras were used to observe ANSs. Use of ecopassages was observed at the sites with CSPs (sites 1, 3 and 4), and use of ANSs was observed at the sites with bridges (sites 2 and 5) since the crossing area at these sites was too large to monitor with cameras. In 2017, the two cameras observing the ANSs were stolen, and the remaining six were left to observe ecopassages.

Over 1.7 million photos were recorded over 1400 days (all cameras combined). Over the study period, there were an estimated 200 occurrences of turtles crossing through the ecopassages and 18 turtles were actually observed using the ANSs. It is important to note that some of these occurrences could represent the same individuals at different times. A summary of the trail camera data is shown in Table 6. Some example photos of turtles observed during the study period are shown in Figure 14.

Table 6. Summary of turtles observed at the ecopassage sites using trail cameras

Activity	Count
Number of days of data collected (all cameras combined)	1,412
Number of photos taken (all cameras combined)	1,724,120
Number of photos analyzed	958,507
Estimated number of turtles observed*	515
Estimated number of turtles observed using ecopassages*	200
Number of turtles observed using ANSs	18
Percentage of recorded days where turtles were observed*	18.2

*Based on extrapolated data

Figure 14. Snapping turtles observed at the sites during the project, clockwise from top left: crossing through an ecopassage, nesting beside the exclusion fencing, two females using an ANS, a hatchling emerging from a nest

5.0 Discussion

The average observed turtle road mortality on un-mitigated roads was 31/km/year, which is comparable to similar road ecology studies in North America (Ashley and Robinson, 1996; Enge and Wood, 2002; MacKinnon et al., 2005). A previous LSRCA study mapped expected hotspots for wildlife-vehicle collisions in the Lake Simcoe watershed (LSRCA, 2015). This study estimated that over 37% of roads (or 1,800 km) are in areas where herpetiles are more likely to be killed. Extrapolating these results based on the hotspot mapping, it is expected that over 55,000 turtles are killed on un-mitigated road stretches in the watershed each year. Our study showed that ecopassages can reduce turtle road mortality by over 80%. Expanding their use throughout the watershed could have significant impacts on local populations.

While the fencing aspect of an ecopassage is important for reducing road mortality, it is equally important to provide safe passage across the road to ensure connectivity between habitats is maintained or enhanced. The ecopassages in this study were also effective at providing connectivity for turtles since 39% of the turtles observed with the trail cameras used the existing culverts or bridges to cross under the road. This demonstrates that ecopassages do not have to be expensive purpose-built structures, and existing infrastructure can be retrofitted to enable safe road passage for wildlife.

For any ecopassage project, maintaining a continuous exclusion fence is the most important factor to decrease road mortality. Studies on the effectiveness of exclusion fencing have shown that gaps in fencing can undermine its purpose and in some cases is no better than areas without fencing (Baxter-Gilbert et al., 2015; Rytwinski et al. 2016; Markle et al., 2017). In our case, the study sites had mostly continuous fencing with only two exceptions. Site 4 had a gap in the fencing to allow for a driveway and Site 1 developed a gap in 2017 due to a road washout repair. Of the eight turtles killed at the ecopassage sites post-installation, five occurred near these gaps and three occurred at the fence ends. Future ecopassage projects should strive to maintain continuous fencing to the greatest extent possible.

Additionally, the initial fencing used was 41 cm high with a 10 cm angled lip at the top. This fencing proved effective at reducing turtle access to the roadway, but was not tall enough for some snakes and amphibians. It is recommended that in future projects, taller fencing should be used, where feasible, to exclude as many species as possible from the roadway.

The artificial nesting structures proved to be extremely useful at providing safe nesting habitat. Overall, 18 females were observed using the nests, and over 50 hatchlings were seen emerging from one nest and moving directly into the adjacent wetland since they were restricted from the road. This was extremely promising because very high rates of roadkilled hatchlings were observed only a few metres from their nest at unmitigated sites. And while mortality of hatchlings and juveniles is generally naturally high (Congdon et al., 1994; Janzen et al., 2000), improving the survivorship of these newly-emerged turtles can improve overall population recruitment rates and long-term population persistence.

While the ecopassage fencing proved to be robust and able to withstand all seasonal conditions (e.g. winter plowing, spring runoff, winds, etc.), the only maintenance issue encountered was with roadside mowing. At Sites 1 and 5, sections of fencing were located too close to the road and were damaged by the mower blades during regular municipal mowing activities. Due to the at-grade design of the fencing, operators have difficulty seeing it and it can easily be damaged and destroyed by the heavy-duty machinery used by municipal staff. However, this issue is easily avoided by ensuring that fencing is placed far enough from the roadside in future installations. Where the fencing was damaged in this study, it was replaced with new, taller (66 cm) Animex fencing which was placed further away from the road to avoid any future impacts from mowers.

During the course of the study, two of the wildlife trail cameras were stolen from one site. While efforts were made to secure the cameras, more could have been done to disguise them. Trail cameras are popular with hunters and other groups, and are expensive enough to warrant taking where an opportunity occurs. All efforts should be used to both secure cameras to the landscape and disguise their purpose to avoid losing both materials and potential data.

The total cost of ecopassage installation for this project (fence materials and installation) was under $52,000. This does not include project management / supervision or monitoring fees. The actual cost of a similar project would depend on local site conditions and fence length (affecting the price of installation) as well as the actual cost of products used. However, the overall cost of this type of ecopassage project is relatively inexpensive compared to the total cost of an infrastructure project.

6.0 Summary

This project demonstrated that relatively simple and inexpensive wildlife ecopassages, incorporated into existing road infrastructure, can decrease turtle road mortality by over 80%. Given the current high rates of road mortality, the sensitivity of turtles to road impacts and the ever expanding road network, implementing similar mitigation measures in targeted areas can greatly improve the persistence of turtle populations in the Lake Simcoe watershed and beyond.

7.0 Recommendations

Through the process of installing the ecopassages and subsequent monitoring of the sites, several lessons were learned which would aid in the success of future ecopassages. The LSRCA recommends that the following points be considered for similar future projects:

1. Consider road ecology and conduct pre-consultation with stakeholders early in the road design process.
2. Project design may need to be revised to meet applicable permits and regulations (e.g. from municipalities, MTO and/or the LSRCA).
3. Conduct site meetings with those responsible for road maintenance to ensure that any fencing is installed entirely out of the way of any and all road maintenance activities. This will avoid any fencing damage from standard road maintenance machines (e.g. graders, mowers, snow plows).
4. Use the tallest fencing possible to exclude as many species as possible.
5. Do not underestimate the amount of time and labour required to install exclusion fencing. For this study, installation took several weeks.
6. Plan ahead for the long-term maintenance of ecopassages and fencing and include it in the project budget. Consider who will be responsible, how often it will be inspected / maintained and what may need to be done (e.g. cutting vegetation, fence repairs, clearing culverts, etc.).
7. Order extra fencing, posts or other ecopassage materials to store and have on hand for repairs.
8. If monitoring ecopassages with wildlife cameras, ensure they are securely attached to permanent fixtures and if possible hidden from view to avoid any theft.
9. Consult and inform nearby landowners of the project and its purpose early on in the process. Interested landowners may volunteer to keep an eye on the site and report any wildlife observed. In some cases, they may also volunteer to assist with regular site monitoring.
10. Seek out advice from others in the field, including the conservation authority – there is a lot of knowledge and experience available.

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