Effectiveness of wildlife mitigation measures for large- to mid-sized animals on Highway 69 and Highway 11 in MTO Northeastern Region, Ontario

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Black Bear and Cubs on Highway 69 Overpass

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1 Executive Summary

1. As part of a large-scale monitoring initiative by the MTO NER, four mitigated sections of highway were evaluated for interactions with large- and mid-sized animals at two study sites: Highway 11 and Highway 69 as part of an Environmental Retainer assignment between the MTO and Eco-Kare International (5013-E—28). Large to mid-sized animals include elk, moose, deer, Black bear, coyote, and red fox.

2. Three mitigated sites occurred within the Highway 11 study area (Callander, Wasi and Sundridge) and varied in length of wildlife exclusion fencing used from 2.2 km to 8.6 km (one side of the highway) and presence of crossing structures (zero to one) between the towns of Callander and Sundridge.

3. The Highway 69 study area had approximately 10 km of wildlife exclusion fencing that connected one wildlife overpass, one underpass, three Reptile tunnels and two creek bridges.

4. The Highway 11 study area was monitored for approximately two years from July 2014 to June 2016 and the Highway 69 study area was monitored for approximately five years from September 2011 to September 2016.

5. Highways 69 and 11 study areas represent two different manners in which mitigation systems can be enacted. On Highway 69, all mitigation for large animals was implemented during a highway upgrade from 2 to 4 lanes and on Highway 11 all mitigation was implemented after the highway was upgraded to 4 lanes. The varying designs with respect to fence-end tie-ins, crossing structure, fencing and escape ramp specifications provide ideal set-up for monitoring evaluations.

6. Mitigation systems were first evaluated using snow-tracking data to measure animal intrusions or presence at both mitigated (Impact) and adjacent unmitigated sections (Control) on all four mitigated sections using a series of Before-After-Control-Impact (BACI) statistical designs. An ACI and a BACI design were used on Highway 69 and a series of ACI on Highway 11.

7. There were fewer deer observations at mitigated (Impact) sections, most notably at Wasi, however none of these relationships were significant.

8. On Highway 69, an ACI evaluation conducted after mitigation was installed showed a significant difference between Control and Impact sections for the ungulate group, but this is most likely attributed to changes in traffic volumes between old Highway 69 and the mitigated sections of highway rather than the mitigation itself.

9. A supplementary BACI evaluation on Highway 69 showed that there was a significant reduction of wolves, deer, and moose observations on the mitigated section than the unmitigated section before and after mitigation when compared to the Control section (Trout Lake Rd. to Makynen Road).

10. Combined results show that animal presence is reduced on mitigated sections of highways in the winter, however better statistical designs that include more years and surveys in each year before and after mitigation installation would greatly increase rigour and confidence in interpretation.

11. Evaluation of mitigation systems was secondly evaluated using both carcass and WVC collision reporting from the highway maintenance patrols (from 2006 to 2015 on Highway 11 and from 2010 to 2015 on Highway 69) and Ontario Provincial Police (OPP) (2000 to 2013) respectively.

12. Similar to analyses with snow-tracking data BACI designs were used for evaluation at each mitigation system at the two study sites when data was available for the two time periods, i.e. before and after exclusion fencing was installed.

13. To assist with interpretation of results, hotspot maps were created both before and after fencing installation at the four mitigated sections using OPP and carcass data when relevant.

14. Siriema software was used that calculates where more WVC occur at a location than expected in a random scenario. The objectives were to assess reduction in WVC before and after fencing and also to assess whether animals are funnelled to fence-ends.

15. At Callander, there was a significant WVC reduction when WVC were excluded from the southern-most section of mitigated highway (300 m) and this indicates that WVC are reduced along the majority of the mitigated highway section after fencing was installed. However, there is a higher than expected risk of WVC at the at-grade interface of Highway 11 and Nosbonsing Road before and after fencing was installed as observed in the hotspot evaluation. The fencing may be extended to Watson Road, with the use of ungulate guards or electric mats to improve the system as a whole.

16. At Wasi, there was a decrease in large animal carcasses in the mitigated section but this was not statistically significant. The hotspots occurred at the north fence-ends prior to installation of fencing and one crossing structure, and persisted at the northern fence-end after installation. The northern fence tie-ins are the most conducive to deer movement and a northern fence extension with ungulate guards or electric mats at Watson Road would improve the mitigated system.

17. Evaluation of the new Sundridge fenced highway is difficult because it is a new alignment. Previously, the highway traversed the semi urban areas of Sundridge and South River and are therefore not directly comparable to the new alignment that traverses a forested area. Further, there was only carcass data available for two years after mitigation was installed. A non-significant decrease in WVC was observed with large animals, and the hotspot analysis showed a small increase in WVC at the SW fence-end.

18. On Highway 69 there was a significant reduction in WVC that were reported by the OPP, in addition to deer and moose carcass pick-ups before and after fencing was installed and a corresponding increase in the control section. Contrary to this, Black bears are able to navigate the one-way gates the wrong way, as well as climb over and go under the wildlife fence and are exposed to an increased risk of WVC. This was supported by WVC data opportunistically collected by the research team as well as a non-significant increase in WVC carcass reports.

19. A detailed summary of OPP data by species showed an overall 71% decrease in Black bear, deer and moose collisions on Highway 69 before and after installation of fencing;

20. It is recommended to complete the above analyses in 2018 when there will be at least 3-4 years of after data at the mitigated sections, namely Highway 69, Wasi and Sundridge. Preliminary results have shown that the mitigation systems are working, albeit there are site and species-specific differences. Highway 69 needs to be improved for Black bear, and fence-end effects are apparent at all three sections on Highway 11.

21. Reconyx motion activated digital cameras were installed at 28 monitoring locations between July 2014 and June 2016 on Highway 11 and between 24 and 31 monitoring locations between September 2011 and September 2016 on Highway 69. Monitoring locations included crossing structures, fence-ends, ungulate guards, one-way gates, and jump-outs and varied on both highways as research objectives were refined with information learned from ongoing monitoring.

22. Camera monitoring was supplemented with snow-tracking data at all mitigation structures on both highways and cross-referenced with camera monitoring to eliminate duplication of information. All independent wildlife interactions with mitigation measures (that occurred 5 minutes of each other) were coded with an ‘action code’ that included ‘cross’ (crossing structure); ‘jump’ (jump-out); ‘passage’ (one-way gate), ‘approach’, ‘repel’, and ‘ignore’. Interactions at fence-ends were recorded as a ‘breach’ and whether the animal moved to or away from the highway.

23. A total of 1,242,400 pictures were processed from cameras on Highway 69. Of these 87,106 or 7.0% were pictures of animals, and 5,080 independent wildlife interactions with mitigation measures were recorded. A total of 501,550 pictures were processed from cameras on Highway 11. Of these 33,319 or 6.6% were pictures of animals, and 1,815 independent large animal interactions with mitigation measures were recorded.

24. All cross + approach at each of the seven types of wildlife crossings were grouped into one class and termed ‘wildlife use’ and compared with repels to calculate passage rates (cross+approach)/(cross+approach+repel) at all crossing structures.

25. Moose, deer, Black bear, coyotes, and Red fox, and one Bobcat (prior to completion of fencing at the overpass) all used the crossing structures at the two study sites combined. Wolves were the least detected species and were not documented at the Highway 11 site. Few Black bears were documented at the Highway 11 site. Deer were detected the most and regularly used the wildlife overpass.

26. Deer used the wildlife overpass 1028 times, comprising 69% of the total wildlife use on the overpass. Moose were detected using the overpass 127 times followed by Black bear (114), Red fox (76), coyote (39), and wolves (18). Elk and lynx (at the time of report preparation) have not yet been detected on the structure, though lynx have been observed twice on the overpass access road.

27. Passage rates and overall frequency of use were highest for deer at the two larger underpass structures (Highway 69 and Wasi underpass). Deer use at Wasi underpass (two year monitoring period) is likely higher than at Highway 69 (four year monitoring period) because of the sheer number of deer in the area, and the presence of grass forage at the entrance of the Wasi underpass.

28. There was increased use at Wasi underpass (Highway 11) by both males and females in the fall, as well as at both the underpass and overpass on Highway 69. This is likely attributed to the fall rut and increased foraging movements prior to winter.

29. Passage rates were significantly higher at the wildlife overpass than the underpass; however, ungulate passages are increasing from 40-60% with each consecutive year.

30. More deer used the jump-outs at Callander than at Sundridge. This is likely because there were fewer deer observed at Sundridge, but also because of structural design. The jump outs at Sundridge did not have an earthern ramp that spanned around the concrete blocks, and the blocks were a barrier for deer moving along the road-side of the fence.

31. One-way gate use on Highway 69 did not improve for ungulates throughout the monitoring period suggesting there is no indication of an adaptation period. Design modifications are required to deter wrong-way use by Black bears, and improve passage by ungulates. However, properly designed jump-outs in other studies have appeared to show more success than gates for providing escape opportunities from exclusion fencing.

32. An additional 45 approach and cross, and 10 repels were documented for all wildlife interactions at the crossing structures with snow-tracking data (Table 9). Wolf use at the Reptile tunnel and Moose use at Wasi underpass was confirmed only with snow-tracking data. Five of six deer repels were confirmed with snow-tracking at the reptile tunnels.

33. Collectively, the evaluation of the exclusion fencing at each mitigation system have shown a decrease in WVC or animal presence on the highway, although this was not always significant. Wildlife overpass is the most used structure by ungulates, however the underpasses are supplementary structures used by large animals. Underpasses should not be smaller than 4 m x 4 m with open medians.

34. Improvements to the Highway 69 mitigation section are required for Black bear that includes burying the fence and an improved design or closure of one-way gates. Closure of gates with additional mesh fencing may be more practical.

35. Jump-outs at Sundridge need to be improved by securing fencing to concrete blocks, improving ramp to allow access for deer walking along fence, and preventing erosion of ramp from concrete blocks.

36. Recommendations for mitigation include improving WVC risk at the Callander southern fence-end and the Wasi northern-fence end by adjoining each mitigation section to each other. The use of ungulate guards or electric mats should be considered at road intersections.

2 Introduction

Roads directly impact wildlife when animals are killed and this further poses a significant safety concern for motorists; especially when a collision involves large animals such as moose (Mountrakis & Gunson 2009). Wildlife interactions with highways can be studied to better understand distribution and occurrence along different road types. For example, hotspots of collisions may occur where favourable habitat for a species exist on both sides of the highway. In addition, wildlife are more likely to cross or use habitat next to a highway as traffic volumes decrease (Beyer et al. 2013; Eco-Kare International 2015). As wildlife interactions are better understood, practical solutions are designed to mitigate the occurrence of collisions on highways (Healy and Gunson 2014; Eco-Kare International 2015).

Two types of mitigation measures are generally used for large animals on highways; wildlife crossing structures (overpasses and underpasses) and wildlife fencing. When combined, they funnel large animals to crossing structures and exclude animals from the highway (Ministry of Transportation 2015). Exclusion fencing does not usually span the entire highway length and typically ranges in length from several kilometres to tens of kilometres. Short sections of fencing (< 5 km) can lead to higher than expected collision hazard at fence ends when wildlife travel along the fence and access the highway at and near where the fence ends (Cserkész et al. 2013; Huijser et al. 2016b). Several mechanisms have been implemented to mitigate this hazard. These include use of:

- One-way (OW) gates, and jump-outs (JOs), along the fence length to provide opportunities for animals to enter back to the safe-side of the fence;
- Supplementary measures such as rock piles, steep highway slopes or strategically placed fence-ends at rock cliffs to deter travel past fence-ends;
- Inclusion of wildlife crossing structures along the length of wildlife fencing to provide crossing opportunities so wildlife do not cross at fence-ends;
- Perpendicular fence extensions away from the road at fence-ends;
- Implementation of Electro-mats or Texas gates at fence-ends where road or driveway interchanges occur.

None of these solutions are designed for all species and some solutions work better in a specific situation than others. For instance, steep inclines have proven to be effective for keeping moose off the highway on Highway 69 (Eco-Kare International 2014). However some animals, e.g. deer, will navigate fence-ends tied into steep inclines. Other animals like wolves and Black bear will walk over ungulate guards, and deer may jump over. Lynx, Black bear and smaller animals will use the one-way gates the wrong way. In all circumstances the animals are now on the road-side of the fence and pose a safety risk to motorists (Eco-Kare International 2014).

This report combines the findings of work completed under contract assignments 5 and 6 of the Retainer Assignment 5013-E-0028 with the Ministry of Transportation (MTO). Combining the findings of the Highway 11 mitigation monitoring with that conducted on Highway 69 will result in a more comprehensive understanding of the effectiveness of Wildlife-Vehicle Collision (WVC) mitigation systems currently in use in the MTO Northeastern Region (NER) in Ontario. Furthermore, it will allow for a comparison of two different strategies for enacting mitigation practices: retrofitting existing road infrastructure (Highway 11) versus including mitigation systems as a component of new construction associated with highway upgrades (Highway 69).

Wildlife-road mitigation systems were evaluated in two ways. First, using a combination of road-side snow-tracking, WVC reporting data collected by the Ontario Provincial Police (OPP) and maintenance crews that remove animal carcasses from road-sides, a reduction in both animal roadside presence and collision rates attributable to the mitigation systems can be measured. Second, using snow-tracking and wildlife camera data the effectiveness of the individual components of the mitigation systems are evaluated to determine if they are used by wildlife as planned and from this provide recommendations for future planned mitigation projects.

3 Study Area

Mitigation monitoring and evaluation took place along two Ontario highways, 69 and 11, in the Ministry of Transportation Northeastern Region (NER). The Highway 11 site spans between the towns of Callander and Sundridge. The Highway 69 study site spans between the towns of Estaire to Delamere. Both highways are important travel corridors between northern and southern Ontario.

There are very few residential inhabitants surrounding the highway and the site is characterized as a recreational cottage country region. Both highway corridors are mixed woodlands, interspersed with extensive wetlands, lakes and rivers. The terrain is dictated by Canadian Shield rock, and is hilly with numerous crags, cliffs. Highway 69 traverses several river valleys such as Lovering creek and Murdock River. The weather is characterized by a humid continental climate with warm-hot summers and long, cold winters with relatively high snow depths.

The two study sites are distinct from each other in terms of the manner in which the mitigation systems were put in place. On Highway 69, the mitigation systems were installed as part of a massive upgrade project from two to four lanes of highway as well as construction of a new highway alignment. On Highway 11, mitigation measures were installed in sections, as part of a retro-fit to an already twinned existing highway.

3.1 Highway 11 between North Bay and Sundridge

The study site is comprised of three continuously-fenced sections of Highway 11 called Callander, Wasi, and Sundridge. Callander highway section is associated with the small town of Callander (population 3,800), a bedroom community to North Bay and situated on the southeast shore of Lake Nipissing. This section of highway has an annual average daily traffic volume (AADTV) of 10,700 vehicles (Ministry of Transportation 2010). The second highway section south of Callander is Wasi, where the AADTV is 9,150 vehicles. The closest populated area to the Wasi highway section is Powassan (population 3,378) which is comprised of three small population centres on Highway 11 located 7 km south of Wasi River. Sundridge is the southernmost highway section, with an AADTV of 8,500 vehicles. This new alignment bypasses the towns of Sundridge (population 985) and South River (population 1,000).

3.1.1 Mitigation History

Historically, the MTO in NER have used deer and moose warning signs on highways. Due to lack of known effectiveness, traditional warning signs were upgraded to enhanced signage at five known hotspots in 2005 (Healy & Gunson 2014). Limited effectiveness of signs provided impetus to trial a series of more effective wildlife mitigation measures from 2006 to 2014 along three sections of highway, totalling 14.3 km, between Callander and Sundridge on Highway 11 (Figure 1; Table 1). These three mitigation systems provide a unique experimental set-up because varying components of mitigation measures exist along each section of highway (Figure 1; Table 1). Along all three highway sections: Callander, Wasi and Sundridge mitigated sections, there are secondary roads that intersect Highway 11, where fence ends are below-grade, at-grade, and above-grade fence-ends (Figure 1; Table 1).

Although Callander did not have the highest rates of WVCs, fencing was placed on this section of highway first. This was because the Highway 11 interchange with Derland and Mountain Roads were below-grade, so fence-ends occurred below grade, funnelling animals away from Highway 11 (A. Healy pers. comm., Appendix F). Fencing and associated escape measures in this section were installed in 2006, and repairs and upgrades were conducted and installed in 2009 (Table 1). There were no fence-end treatments at the southern fence-ends. At the north fence ends, the fencing was extended to the top of rock cliffs in 2009.

A Wildlife Detection System (WDS) was installed in 2011 and operational in 2012 near the Wasi Truck Inspection Station where both deer and moose were found to be crossing the highway (2010 winter snow-tracking data; URS Canada 2012). The system was comprised of 2.1 km of wildlife fencing with two 100 m openings where sensors were located. When triggered by moving animals, a flashing beacon mounted on wildlife warning signs was engaged, warning motorists that wildlife may be on the highway (URS Canada 2012). The WDS was determined to be ineffective due to an abundance of false positives, as well as monitoring observations that suggested wildlife entering the 100 m gaps were more likely to remain within the highway ROW than to cross all four lanes. Wildlife that remained in the highway ROW were no longer detected if they travelled north or south of the fence gaps, and could then also become trapped within the fencing. During a highway rehabilitation project in 2013, an open span wildlife underpass was installed at one of the fence gaps, and the other gap was closed with fencing (Table 1).

The north fence-ends at Wasi are associated with a truck stop and grass habitat (Figure 24 i) and forested habitat (Figure 24 j), both ends at the south side were associated with wetland-river habitat (Figure 24 h and k). No road-highway interchanges occur along the fenced section and the north fence end is at grade near the Watson Road intersection while the south fence end is at grade with Hills Siding Road interchange (Figure 1).

Near Sundridge, when the four-lane new alignment was opened in 2012, there was an immediate increase in WVCs. As a result, the Ontario Provincial Police (OPP) requested that wildlife fencing be installed; this was completed in the winter of 2012 through spring 2013 (Table 1). A snowmobile box culvert existed along this section of highway and was used as a joint-use snowmobile and wildlife crossing. This retro-fit consisted of joining wildlife fencing up to the culvert. Three road interchanges occur along this section and the fence-ends are at grade with the Boundary/Tower Road interchange, above grade at Hill Valley Road (Photo 43:), and below grade at Adams Road (Photo 42). The north and south fence-ends are strategically placed at steep highway slopes and are treated with rock piles to deter animals from moving around the fence and along the fenced ROW (Figure 24 l through O).

Table 1: Description of the three mitigated sections and monitoring along Highway 11

Mitigation System Description, Road interchanges, Location, and Installation Year	Unique design features	Implementation	Monitoring data	Impetus for Implementation
Callander				
3.5 km of wildlife fencing from highway 654 (Nosbonsing Road) northward + 4 one-way gates (generation 1, Photo 3, 2006) + 8 Jump outs (Photo 7; installed 2006); Fencing repaired and one way gate design modified (generation 2, Photo 4, 2009). Two below-grade road-highway fence gaps, southern fence-ends at-grade, and northern fence ends on-top of rock cliff.	Spacing between prongs increased at animal height in one-way gate generation 2 (Photo 4); Wildlife fencing 2.8 m high that includes three top wires; wood posts (Photo 2).	Retrofit	4 cameras at Jump out, 2 cameras at one-way gates; In Year 2 cameras moved from gates to selected fence-ends; Snow-tracking and WVC crash and carcass data collection.	Trial section selected because intersecting roads were not at-grade and under the highway to funnel animals under Highway 11.
Wasi				
2.2 km of wildlife fencing from Hills Siding Road northward + Wildlife Detection System (WDS) (2011); fencing + 4 m x 4m x 16 m (WxHxL) twinned concrete open span wildlife underpass (16 m long sections) (2013); At-grade north and south section fence-ends at secondary road intersections.	Wildlife fencing first installed as part of WDS, then gaps closed; fencing 2.4 m high; steel posts; three top wires; not buried (Photo 20: Picture of camera on tree pointing at fence end (FENWWAS).	Fence + WDS retrofit upgraded to fence + wildlife crossing structure during a highway rehabilitation project.	4 cameras at wildlife underpass and 4 at fence-ends; in Year 2 cameras moved from one way gates to fence-ends; snow-tracking and WVC crash and carcass data collection.	High numbers of collisions in the area; Wasi culvert and fencing were integrated during major highway reconstruction of the existing four-lanes.
Sundridge				
8.6 km of wildlife fencing from Highway 124 northward + 22 OW + 22 JO (1.8 m height) + 4	Paired jump out and one way gates installed beside	Retrofit after new alignment	2 cameras at joint-use underpass; 4 at	Ontario Provincial Police (OPP)

m x 4 m x 82 m (WxHxL) joint-use snowmobile and wildlife concrete box tunnel (winter 2012-spring 2013); fence-end gaps at road interchanges below, above and at-grade, north and south fences ends at grade with steep highway slope.	each other; Photo 46), spaced approximately 700 m apart; wildlife fencing 2.8 m high including 3 top wires, steel posts and bottom buried apron.	construction completed in September 2011.	jump out and 4 at one-way gates; in year 2 cameras moved from gates to selected fence-ends; snow-tracking; and WVC crash and carcass data collection.	requested wildlife fencing due to high numbers of collisions after new alignment opened.
Highway 69				
Approximately 10.5 km of wildlife fencing from Trout Lake Road to Lovering Creek Bridge completed in September 2012, and an additional 3.3 km extended to Murdock River Crossing and an additional 2.5 km extended to Crooked Lake Road in 2015; three 2.8 x 3.3 m reptile box culverts, one 5 m x 5m large animal box culvert with open median and wing walls; two creek bridge pathways, and one 50 m wide wildlife overpass.	Two 50 m fence gaps where highway traverses steep terrain; no jump outs but 26 one-way gates; two ungulate guards, e.g. Texas gates used at Highway 637 intersection; wildlife fencing is not buried with an apron; no outrigger fence extension at top.	Fencing installed as part of highway upgrade construction project from two to four lanes and new alignment from Burwash to Highway 637.	24 to 31 cameras installed at crossing structures, one-way gates, fence-ends, and ungulate guards. 6 cameras at overpass, 3 cameras at underpass, 2 cameras at Lovering Creek bridge.	High number of Moose-Vehicle Collisions where new alignment constructed.

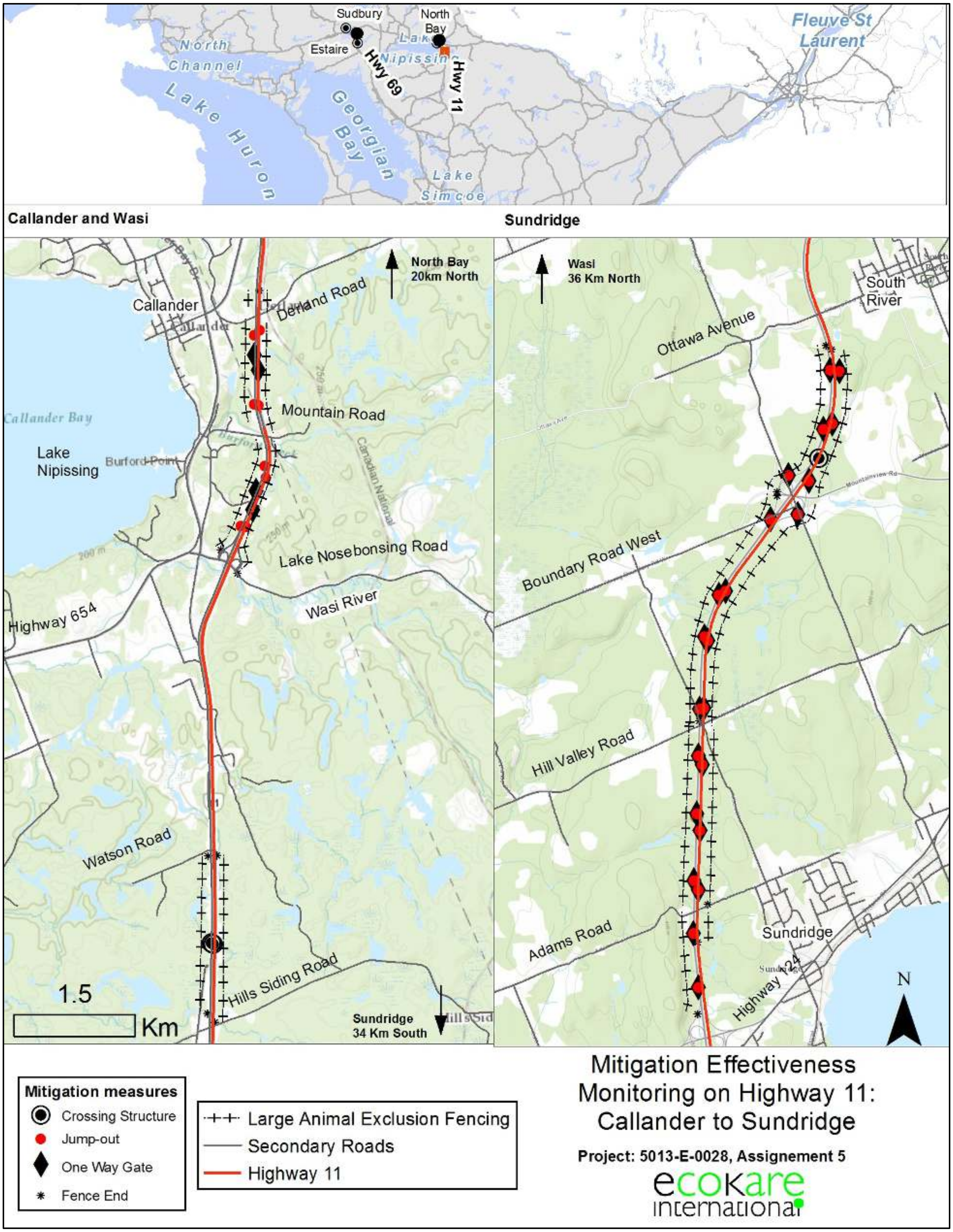


Figure 1: Study area showing the three mitigated sections and associated secondary roads along Highway 11 between Callander and Sundridge.

3.2 Highway 69 between Sudbury and Parry Sound

The study site is comprised of one continuously fenced section of Highway 69 that spans from Trout Lake Road to Murdock River (Figure 2). The uninhabited town of Burwash and unincorporated community of Estaire are the only communities near the study site. Burwash is comprised of abandoned dwellings and much of the land is now used by the Department of Defence and the MNRF. This section of highway has an annual average daily traffic volume (AADTV) of 5,750 vehicles (Ministry of Transportation 2010).

3.2.1 Highway 69 mitigation history

On June 28, 2005, it was officially confirmed that Highway 69 would be expanded to four lanes from Parry Sound north to Highway 17 in Sudbury. Construction began in 2005 on the segment extending southward from Sudbury to just south of Estaire (Nelson Road Interchange), and opened on November 12, 2009. In September 2011 (when our monitoring began), the next southern phase (approximately 10 km) was in construction which included twinning and a new 4-lane alignment (6.8 km) east of the highway (Figure 2).

The new alignment and twinned section opened to traffic in phases in the summer and fall of 2012. First, on June 6th, 2012 two lanes of traffic (now northbound lanes) were opened for vehicle use on the new alignment (where the wildlife crossing structures are located), diverting vehicles away from what is now termed old Highway 69 (Figure 2). Following this, on August 8th, 2012 all lanes of traffic on the new alignment and on the northerly twinned section were open for vehicle use (Figure 2). Further south of the new alignment road twinning was ongoing under Highway Contract MTO 2012-5101, by the Bot Construction Group. This 11.2 section of highway included a new wildlife crossing pathway at Murdock River Bridge and an additional 5.5 km of large animal fencing (11.0 km both side). Large animal fencing now spans to Crooked Lake Road.

Data collected for wildlife road-kill is considered post-construction in November 2012 when the wildlife fencing was continuous and complete. Data collected at the crossing structures is considered post construction as of June 30th 2012, because fencing abutted all the structures, between June 2nd and 12th, 2013 and highway was open for traffic. Landscaping on top of overpass was completed in June 2012

Mitigation measures that are being monitored include 10 km of fencing, 27 one-way gates, one 30 m wide bridge (wildlife overpass), one large wildlife underpass (twin 5m x 5m culverts), three smaller reptile tunnels (twin 3.3m x 2.8m), and two creek-bridge pathways for wildlife under the Lovering Creek bridge and Murdock River bridge. There are 14 one-way gates on the east side, 10 gates on the west side, two gates on Highway 637 near Highway 69, and one gate at the Lovering Creek Bridge (Figure 2). Two fence-ends at Killarney as well as other selected fence-ends have been monitored with cameras and snow-tracking. A detailed description of these measures can be found in Table 1, and their locations in Figure 2.

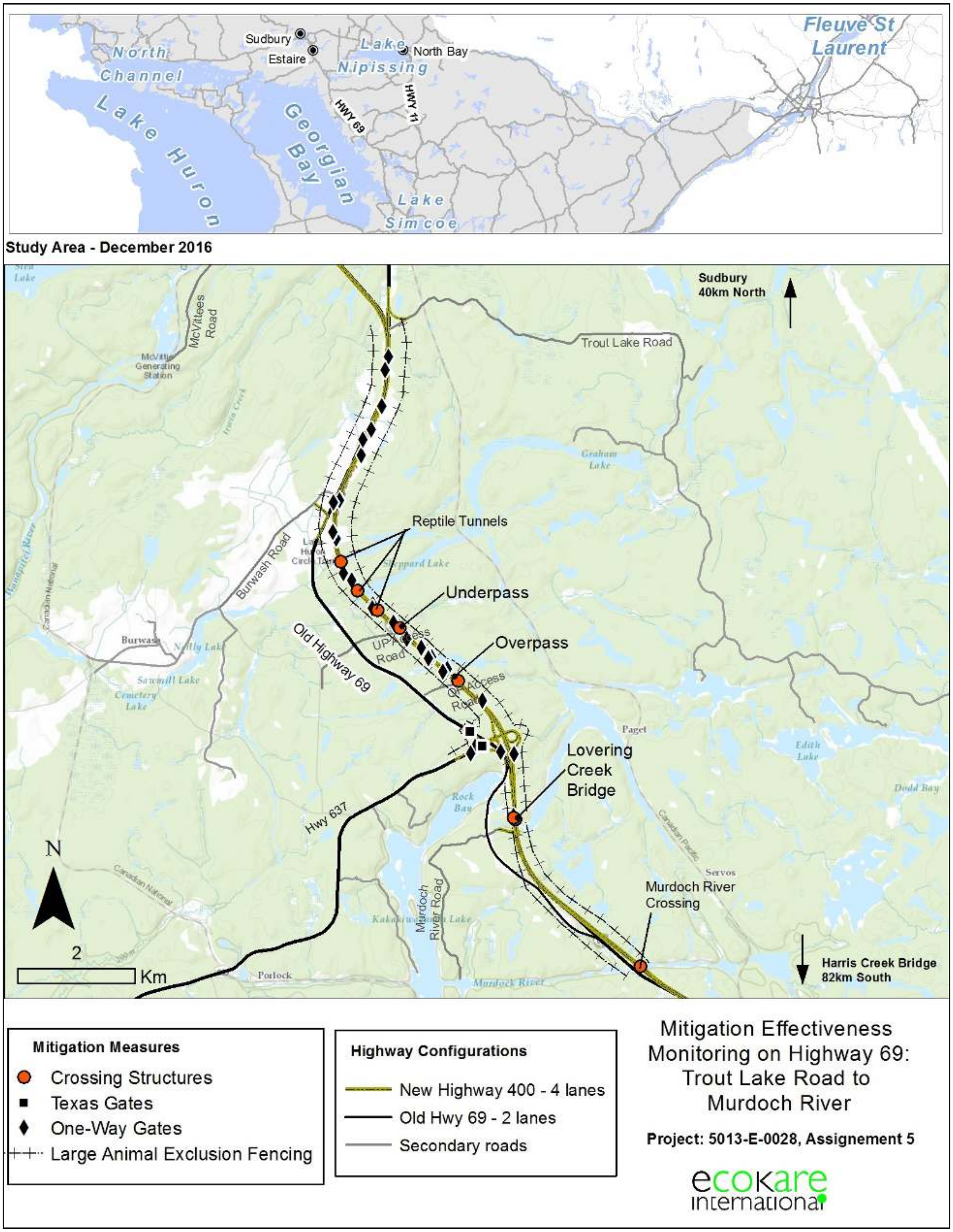


Figure 2: Highway 69 study site between Trout Lake Road and Murdock River that were monitored from 2011 to 2016

3.3 Highways 69 and 11 comparison

Highways 69 and 11 represent two different manners in which mitigation systems can be enacted. On Highway 69 all mitigation for large animals was implemented during a highway upgrade from 2 to 4 lanes and on Highway 11 all mitigation (fencing and one crossing structure) was implemented after the highway was upgraded to four lanes.

Installing wildlife fencing at an existing highway (retro-fit) is more challenging due to issues of property ownership, utilities, and at-grade entrances. Fence placement and fence- end treatments are easier to deal with during the design and construction phases for a new highway or during major road reconstruction. Perhaps the greatest challenge when retro-fitting wildlife fencing on existing highways, is finding locations where wildlife can cross the road, e.g. existing underpass. Without wildlife crossing opportunities there is an increased risk of WVCs at fence-ends (McCollister & Manen 2010; Healy & Gunson 2014).

The variety of mitigation measures on both Highway 11 and Highway 69 provide an ideal experimental set-up. These measures include varying fence height, design, and length. Fence-ends vary in placement above- below- and at-grade of the Highway; and vary in tie-ins to rocky cliffs, and steep highway slopes; in some cases rocky boulders were also added to fence-ends (Figure 24). There are several crossing structure types such as one overpass, four varying dimensions of box tunnels, and two creek bridge pathways. Varying designs of one-way gates and jump outs have been used on both highways (Table 1).

Monitoring the effectiveness of the mitigation measures with a consistent, and rigorous approach on both Highway 69 (Eco-Kare International 2014) and Highway 11 combined can provide insight on what measures work best under specific circumstances for large animals.

4 Effectiveness of mitigation systems at excluding animals from the road

4.1 Evaluation of mitigation using snow-tracking

Wildlife-Vehicle Collisions (WVC) are a function of both animal roadside presence and traffic properties. Mitigation systems such as exclusion fencing and crossing structures are meant to reduce WVCs by reducing the frequency of animal intrusions onto the road. Therefore, this section first looks at whether animal roadside presence measured from snow-tracking data is reduced within fenced sections of road of varying lengths. Next, two datasets that contain locations of WVCs were used to evaluate whether there was a reduction in WVCs within the same fenced sections as above.

4.1.1 Methods

Systematic road-side presence surveys using snow-tracking were conducted between November 1 and April 31 within 24-48 hours of a major snowfall, i.e. enough to cover old tracks. Roadside presence surveys were conducted on Highway 69 in 2011-2012, 2012-2013, 2013-2014 and in 2015-2016. On Highway 11 only one year of data was obtained in 2015-2016. On Highway 11 snow-tracking transects were completed from the start of Sundridge mitigated section to 5 km north of the end of the mitigated section. Following this, a transect was completed 5 km south of Wasi mitigated section and was completed at the north end of Callander mitigated section (Appendix D).

Snow-tracking is a low cost and non-invasive sampling method that can inform animal movements, distribution and behaviour in the landscape and near roads (Bowman et al. 2010; Schuster et al. 2013). Snow-tracking surveys at both study sites consisted of a vehicle travelling at 80 km/h along the edge of the road with one to two observers. When tracks were observed, the observers exited the vehicle to record the wildlife track locations using a handheld Geographic Positioning System (GPS) and other information such as the species, date, time, snow conditions, direction of travel, whether the animal crossed or turned around at the road edge were collected. All treatment sections along the highway were surveyed on the same day and in a few cases over two consecutive days to reduce bias between mitigation structures due to varying weather and snow condition.

Statistical analyses

The effectiveness of the mitigation systems at excluding animals from the road-side was conducted on Highway 69 and Highway 11 by comparing road-side presence between mitigated (fencing with or without crossing structures) and adjacent unmitigated treatment sections. When the road characteristics such as, topography and adjacent vegetation, are similar between treatment sections, it is likely that the difference in animal roadside presence can be attributed to the effectiveness of the mitigation systems in place. A Before-After-Control-Impact (BACI) study was done on Highway 69 and a series of After-Control-Impact (ACI) study designs were used on both Highway 69 and 11 when no data prior to mitigation was available.

The snow-tracking locations were compiled in a Geographic Information System (GIS) and prepared for statistical analysis. Multiple set of tracks of the same species was counted as one observation. This approach was taken because it is often difficult to accurately identify the number of animals in a tracking sequence and because animals in groups are often not moving independently and following a lead animal. Observations of the same species, in the canid or ungulate group that were within 300 m of each other were removed to identify independent snow-tracking events (Schuster et al. 2013).

On Highway 11, because the mitigated and unmitigated sections differed in length, the total number of independent tracks in each treatment section was divided by the treatment section length to (presence/km) to allow standardized comparisons. Each mitigated section was paired with an adjacent unmitigated treatment section (Appendix D) and a paired t-test was used to evaluate the effectiveness of the mitigation systems at excluding animals on roads using 2015-2016 data. Only deer data were used for the analysis.

In the case of Highway 69, data were collected across multiple years and the number of surveys varied each year, the results were standardized by survey effort using the following formula:

*Presences = # independent presences / (length of transect * number of surveys)*

Two analyses were conducted on Highway 69. First, a one-way Analysis of Variance (ANOVA) was used to test whether road-side presence between mitigated (Impact) and unmitigated (Control) treatment sections after mitigation installation (ACI; survey years 2012-2013, 2013-2014, and 2015-2016) differed. Tests were conducted for individual species (deer, moose and wolves) as well as species groups (canids and ungulates) to determine if mean presence differed between treatment sections. Two mitigated treatment sections (new alignment and new alignment northerly to Trout Lake Road) and two unmitigated sections (old Highway 69 and Trout Lake Road northerly to Makynen Road) were included in this analysis (Figure 2). To identify pair-wise differences a Tukey-Kramer *post hoc* test was used.

Second, for each year the difference in presence/km*surveys between Control and Impact sections were calculated and a one-sample t-test was used to test whether roadside presence between Impact and Control treatments differed before and after mitigation was installed (BACI, before period 2011-2012 and after period (2012-2013, 2013-2014 and 2015-2016). Similar to above, Trout Lake Road to Makynen Road was the unmitigated section and the Highway 69 new alignment was the mitigated section. However, old Highway 69 was now the before mitigation section. The mitigated section from the new alignment to Trout Lake Road was not included in the analysis because this section was undergoing construction during the 2011-2012 before period. Tests were conducted for individual species (deer, moose and wolves) as well as species groups (canids and ungulates).

4.1.2 Results

4.1.2.1 Highway 11

There were 36 independent observations of animals found along Highway 11 during 14 snow-tracking surveys conducted between November 2015 and April 2016. Of those the majority were deer (n = 27). The remainder consisted of Red fox (n = 2), small canids (n = 5) and unidentifiable species (n = 2). Only deer potentially had a large enough sample size for statistical analyses.

While mitigated treatment sections showed lower values of deer road-side presence (presences/km, Figure 3), most notably at the Wasi section, this relationship was not significant ($t = -3.1837$, $df = 2$, $p = 0.086$). This lack of significance may be due to the lower sample size, as well as only one unmitigated control section used for comparison with each mitigated section. A replication of mitigated and unmitigated sections are ideal for rigorous evaluation using ACI or BACI analyses (Roedenbeck et al. 2007). Future studies could include multiple adjacent transects both north and south of the mitigated zones. In addition, with multiple years of data snow-tracking may prove to be a reliable estimator of the effect of mitigation at excluding animals from the road-sides.

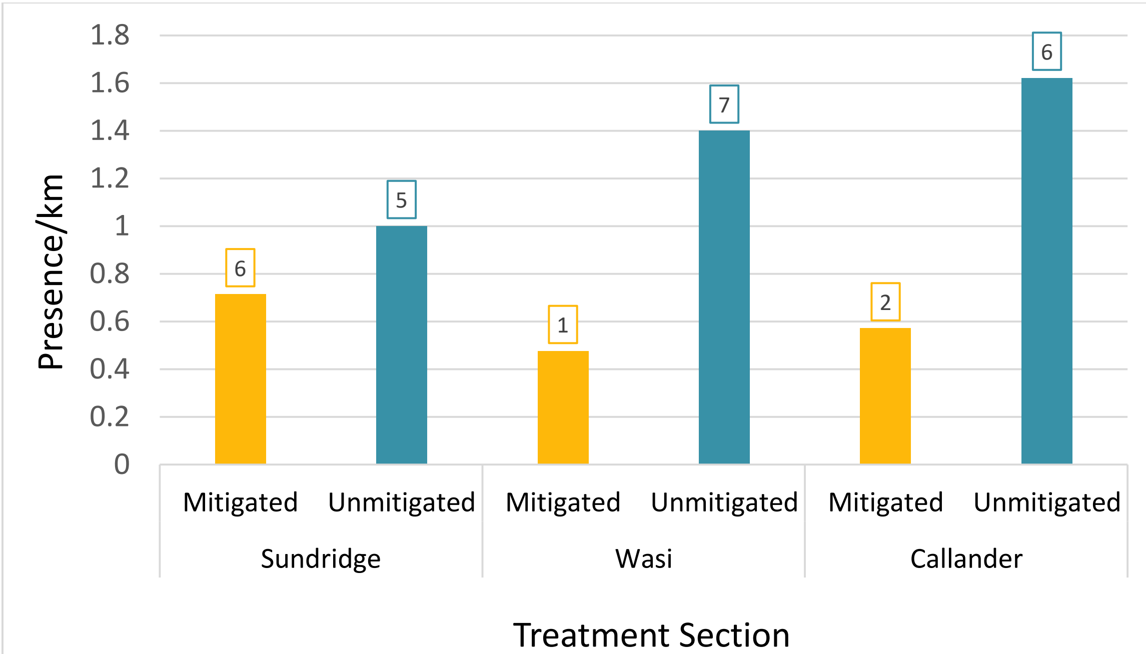


Figure 3: Deer presence per kilometre of surveyed road at paired mitigated and unmitigated sections of Highway 11. The numbers above the bars represent the absolute number of presence detected in each section

4.1.2.2 Highway 69

There were 284 independent observations of animals found along the treatment sections (between Lovering Creek and Makynen Road on Highway 69 and old Highway 69) during 51 surveys in the four snow-tracking seasons (2011-2012, 2012-2013, 2013-2014 and 2015-2016). The most common species detected included coyotes (n = 85), elk (n = 71), moose (n = 31), Red fox (n = 23), wolves (n = 23), deer (n = 12) and lynx (n = 12). The remainder of observations consisted of species with only a few individual occurrences or tracks that could only be identified to group. Two species groups were created. Ungulates (n =48) consisted of deer, moose and non-species specific ungulate tracks. Elk were excluded from all analyses as they are unevenly distributed across the study area. Canids (n = 145) included wolves, coyotes and Red fox as well as non-species specific canid tracks.

The ACI evaluation conducted after mitigation was installed showed a significant difference between the mitigation and unmitigated road sections for the ungulate group ($F_{3,8}$ = 8.758, df=3, p = 0.007) and for moose ($F_{3,8}$ = 8.7961, df=3, p = 0.009) (Figure 4). It is likely that moose are driving this pattern within the ungulate group because moose comprised the majority of the ungulate sample (31 of 48 observations) and there was not a significant result for deer. There was not a significant difference in mean road-side presence between treatment sections for the Canid group or for deer and wolves.

The Tukey-Kramer *post hoc* test showed that the significant differences between mitigated and unmitigated sections were between old Highway 69 and Trout Lake Road northerly to Makynen Road (both unmitigated sections), between old Highway 69 and new alignment northerly to Trout Lake Road (unmitigated and mitigated), and between old Highway 69 and the new alignment (unmitigated and mitigated) (Figure 2). Collectively, there are significantly more tracks on old Highway 69 than at both the unmitigated and mitigated highway sections, likely because old Highway 69 had little to no traffic volumes after highway construction was finished.

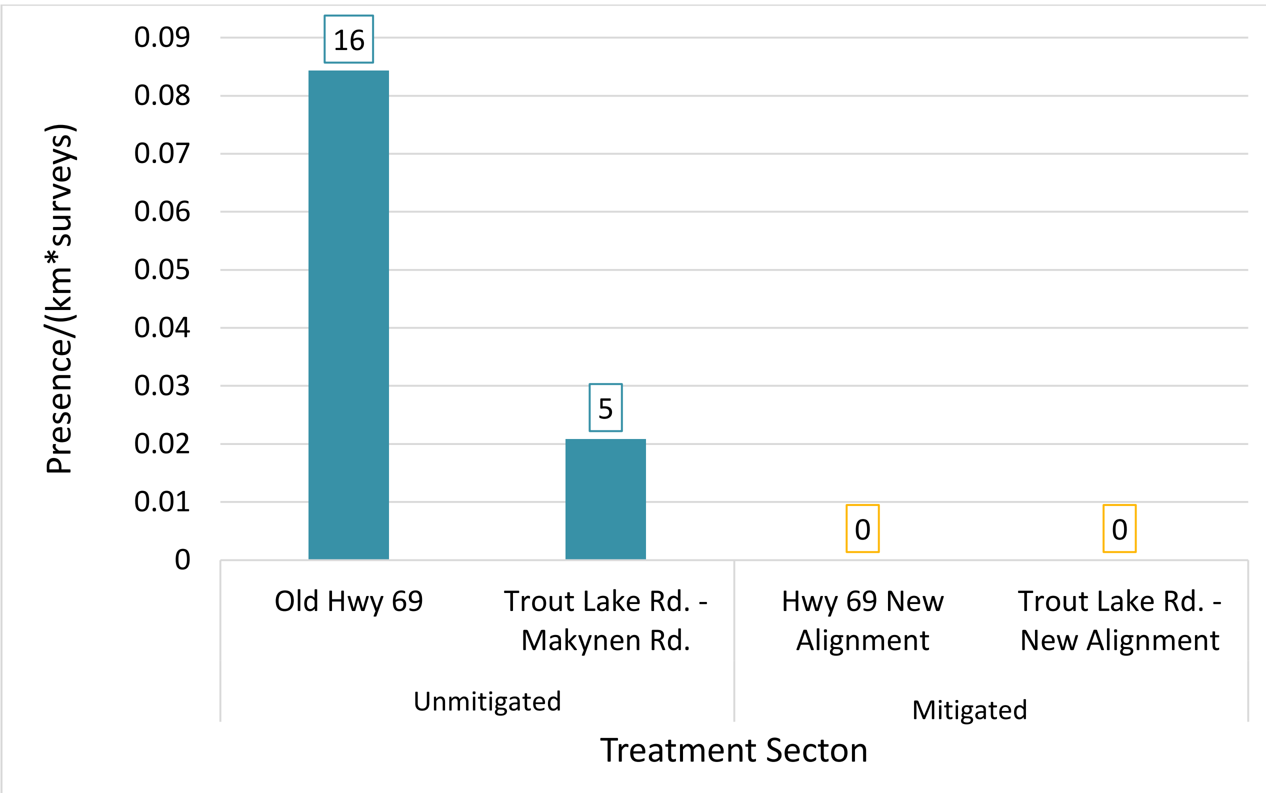
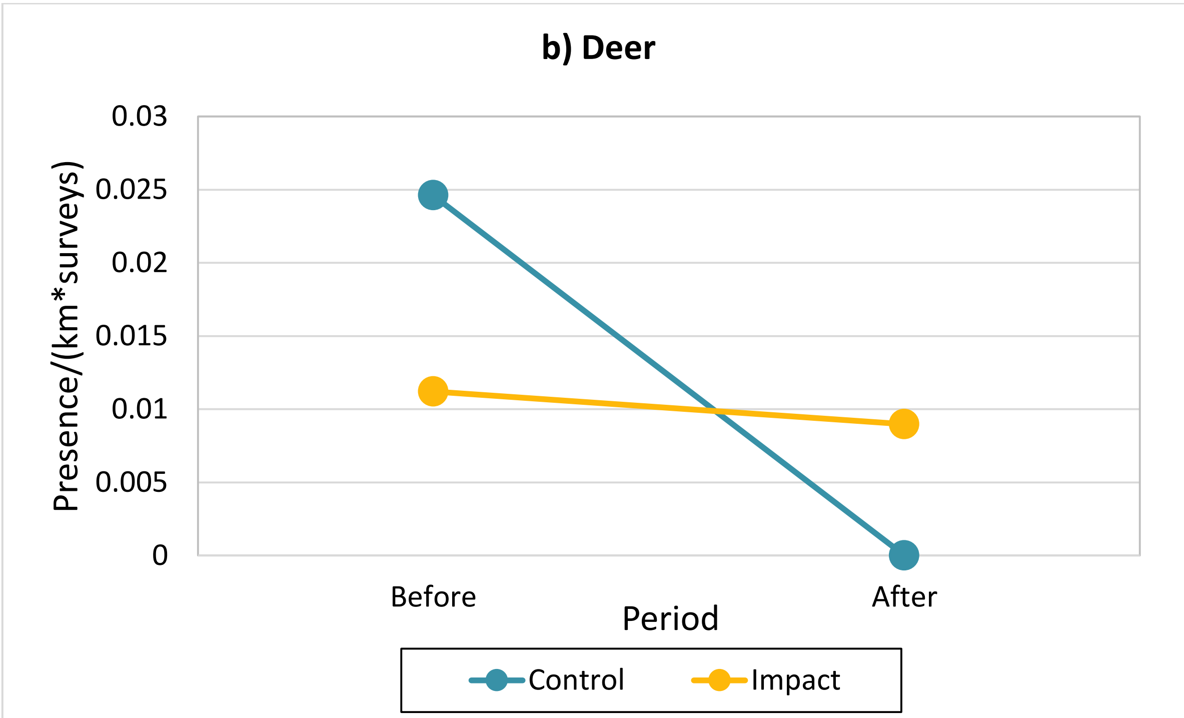
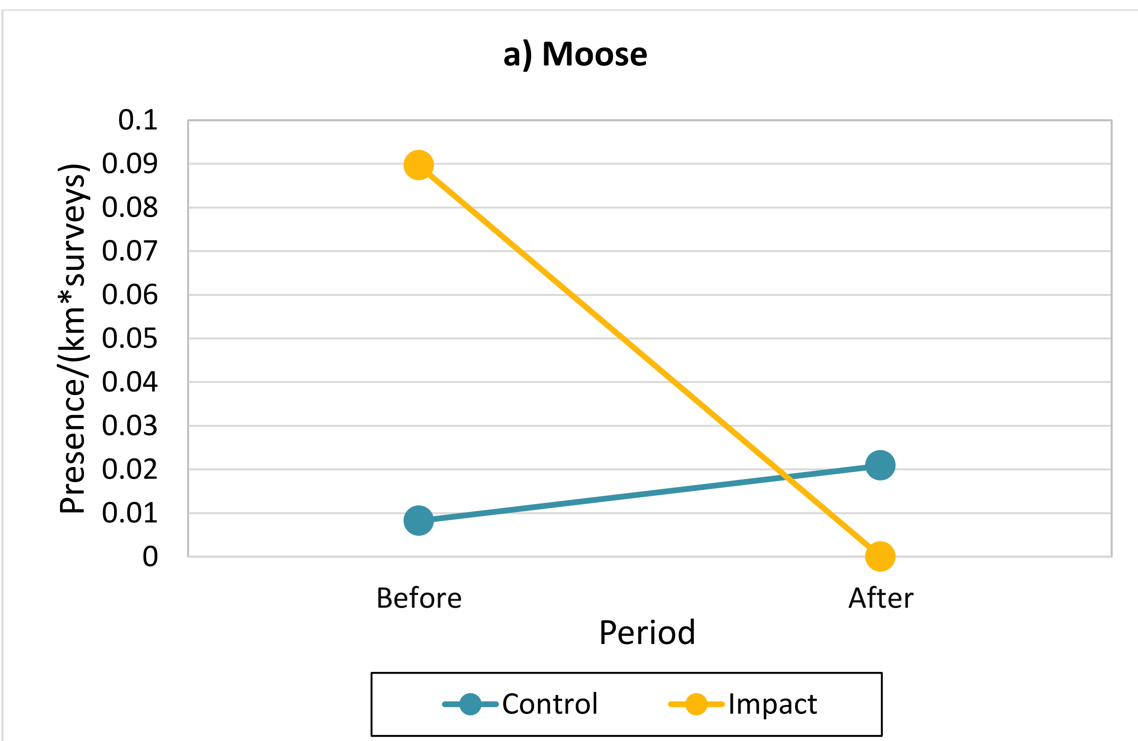


Figure 4: Moose presence/(km*surveys) at mitigated and unmitigated sections on Highway 69 based on snow-tracking data collected after mitigation (2012-2013, 2013-2014 and 2015-2016). Numbers above the bars represent the absolute number of independent presences detected per treatment section.

The one sample t-tests that compared the difference in road-side presence between the mitigated (Impact) and unmitigated (Control) sections varied significantly between the before and after periods for deer (t_2 = -4.86, p = 0.040; Figure 5a), moose (t_2 = 6.37, p = 0.024; Figure 5b), wolves (t_2 = 7.96, p = 0.015; Figure 5c) and the ungulate group (t_2 = 12.21, p = 0.007; Figure 5d).


b) Deer
0.03
0.025
0.02
0.015
0.01
0.005
0
Presence/(km*surveys)
Before
After
Period
Control
Impact


a) Moose
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Presence/(km*surveys)
Before
After
Period
Control
Impact

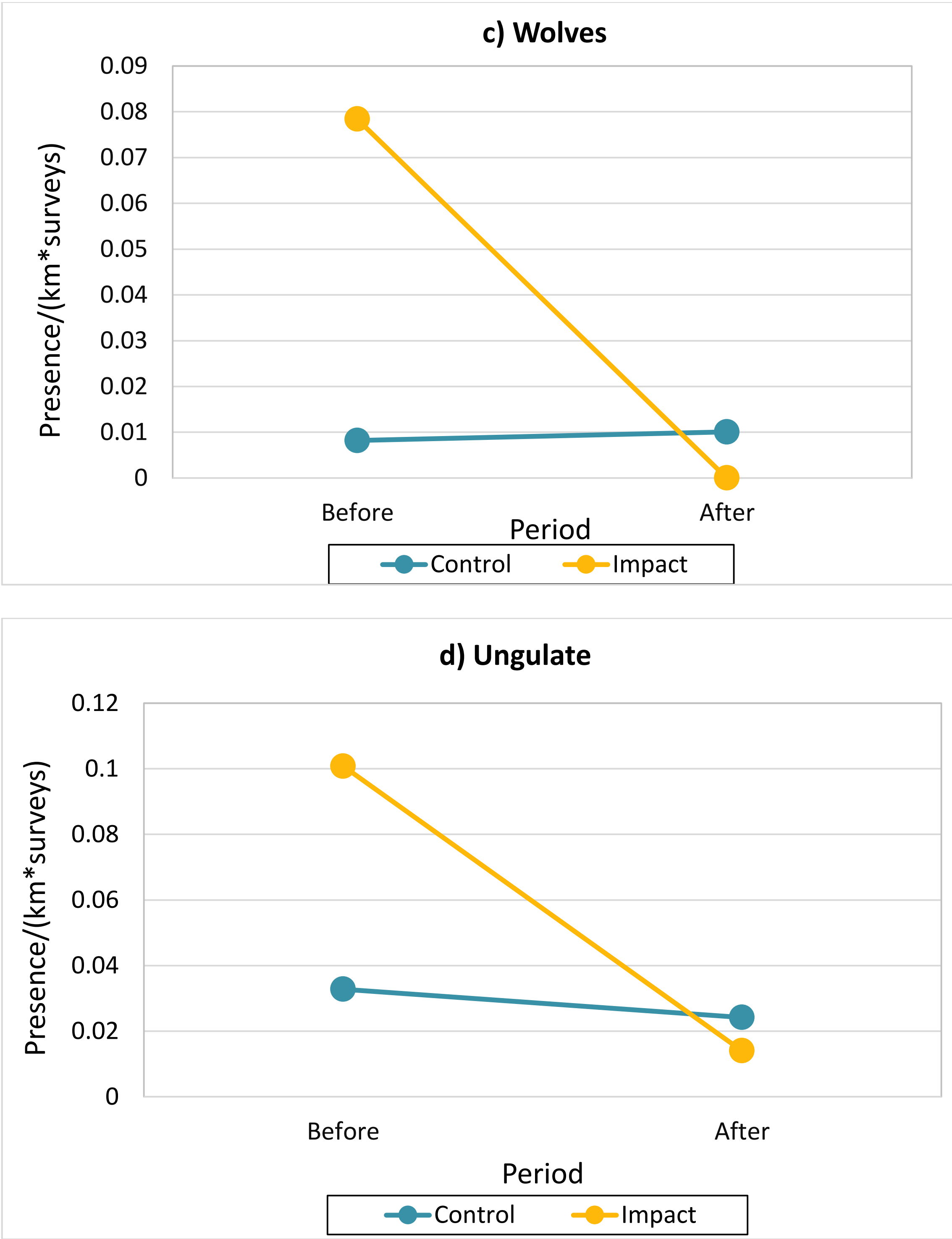


Figure 5: Mean presence per kilometre of surveyed road standardized for sampling effort (presence/(km*surveys)) during the before and after periods at the Control (Trout Lake Road to Makynen Rd) and Impact (Old Hwy 69/Hwy 69 New Alignment) sections on Highway 69 using snow-tracking data.

The relationship for the ungulate group, moose and wolves all showed evidence that the fencing and crossing structures were effective at excluding animals from the highway (Figure 5 b, c and d). In all three cases animal road-side observations decreased where mitigation was installed, and for moose and wolves road-side observations slightly increased in the unmitigated control sections after mitigation. Deer showed the opposite trend where road-side observations decreased in unmitigated sections, but remained approximately constant where fencing was installed over the study period.

4.1.2.3 Discussion

No significant differences in snow-tracking on Highway 11 between mitigated and unmitigated sections is likely a result of using only one year of data, as well as only having one replication of both mitigated and unmitigated sections for comparison. Furthermore, there are some limitations with using snow-tracking data for this type of analysis because it only represents movements of animals in the winter that may be reduced due to increased amounts of snow-fall.

However, when the results are examined collectively on both highways there is a consistent reduction in animal presence along the four mitigated sections monitored when compared with unmitigated sections. On Highway 69, the BACI result also showed a significant reduction in moose and wolves before and after fencing was installed when compared to unmitigated sections. The results suggest that there is some reduction in deer presence (Highway 11), and that fencing is working to reduce moose and wolf presence on Highway 69.

There are limitations to the BACI Highway 69 evaluation because the before period is only based on one year of information collected prior to installation of wildlife mitigation. The After period is based on three years. This unbalanced sampling and low sample size introduces variation into the statistical design and results should be interpreted with caution. Wolf presence was low and sporadic along the highway and during the monitoring period, therefore monitoring results for this species should be interpreted with caution.

The After-Control-Impact evaluation on Highway 69 showed significant results that were driven by the relationship between greater animal presence on old Highway 69 (unmitigated) and less presence (observed tracks) on the other sections of Highway. This is more than likely due to the reduction in traffic volumes present on old Highway 69 in the 2012-2013, 2013-2014 and in 2015-2016 snow-tracking periods. This result lends support to previous findings that animal movement at and across highways is reduced when AADTV exceed 5,750 vehicles (Eco-Kare International 2014).

4.2 Evaluation of mitigation using wildlife-vehicle collision reporting

4.2.1 Methods

4.2.1.1 Data sources

Two different datasets were used to evaluate the effectiveness of the mitigation systems at reducing Wildlife-Vehicle Collisions (WVC) on Highways 11 and 69. Complete records of all WVC from 2000 to 2013 were received from the MTO NER office that was originally collected from the Ontario Provincial Police (OPP) (Table 3). Herein this data is referred to as OPP data. In addition to this data, records of animal carcass removal were obtained from provincial highway maintenance road crews. The carcass data are reported for 2006 to 2015 on Highway 11 and from 2010 to 2015 on Highway 69 (Table 3). Herein this data is referred to as carcass data.

The greatest advantage of the OPP data is that it is consistently collected across the province with the same procedures, due to mandatory reporting requirements for collisions that result in property damage greater than $1,000 or when death and injury occur. Three major limitations is that the data is not species-specific, however it is likely that >90% of the reports are with large animals. Secondly, there is spatial error inherent in the data that occurs when translating the OPP distance measurement to the closest landmark, then referencing the location to the MTO Linear Highway Referencing System (LHRS) that then extracts decimal degrees to the data (Table 2). Spatial accuracy of this type of data has been reported up to 2,000 m with high variability ± 1,620 m (Gunson et al. 2003). Third, the data likely contains 30% fewer accounts of WVC than what actually occurs (Vanlaar et al. 2012).

Carcass data supplements the OPP data for several reasons (A. Healy, email communication). First, the carcass records include the species of animal involved in the collision and in some cases the age and sex are recorded. Second, not all WVC are reported to the OPP, and third there is at least a three year time lag with obtaining OPP data as opposed to one to two years with the carcass data (Table 2). However, in general, the carcass data is not collected as consistently as the OPP data because the effort involved in managing data records vary among patrols and lack of data collection efforts is not enforced by an individual or agency.

Spatial inaccuracies are derived from transcribing the descriptive locations to decimal degrees using Google Earth and has been estimated previously at an average 516 m ± 808 m (Gunson et al. 2009). It is likely that data collected after 2010 was more accurate because new MTO contracts included the requirement to report locations using GPS installed in trucks.

In light of the differences in the two types of data, examining both independently at the two highways will allow a complete evaluation of wildlife mitigation systems, and provide insight on the most optimal data set to be used for the evaluation of future mitigation projects.

Table 2: A summary of wildlife road mortality data sets collected along Highway 11 that will be used to assess pre and post mitigation effectiveness.

Dataset holder	How collected	Data description	Limitations and Advantages
1) MTO NER maintenance department (carcass data)	Area Maintenance Contractor (AMC) carcass pick-up; sometimes measure location with GPS in trucks, alternatively the location is described to closest landmark, recorded bi-weekly for each patrol zone and data transferred to MTO NER office.	Data compiled and cleaned (January 2016) in MTO Retainer Assignment 7 (5013-E-0028) for Powassan and Rutter Patrol Zones	-Species specific -Spatial accuracy reported at 516 ± 808 m (Gunson et al. 2009) -Collected 2006 to present (one to two year time lag) -Decimal degrees manually obtained from Google Earth for majority of records -Sampling effort not consistent across patrol zones
2) Ontario Provincial Police (OPP); Road User Safety (RUS) division (OPP data)	OPP personnel file a collision report (over $1,000 damage) and describe location to the nearest land mark or side road that is then translated to a Provincial Linear Highway Referencing System by the MTO	Data received in shapefile for all of Ontario from Traffic Safety Office (Zoe Lam) from Jan 01 2001 to Dec 03 2010; all provincial highways: data from 2010 to 2014 received from NER geomatics office – Steve Simpson.	-Not species specific -Spatial accuracy varies up to 2,000 m with high variability ± 1,620 m (Gunson et al. 2003); -In 2016 data available from 2001-2013 (three year time lag); -Sampling effort more consistent; -Available in decimal degrees

4.2.1.2 Statistical analyses

A Before-After-Control-Impact (BACI) study design was used that compare WVC counts in mitigated areas (Impact) with adjacent unmitigated areas (Control) both before and after the mitigation systems were installed. BACI designs are robust because when only a before and after comparison is evaluated, it is not known whether WVCs increased or decreased as a result of the mitigation or other factors such as, climate, population abundance or land use changes.

A consistent sampling framework and statistical methodology was used to evaluate a reduction in WVC within each mitigation system: three on Highway 11 and one on Highway 69, using both OPP and carcass data (Table 3). Each mitigation system is comprised of several unique characteristics in terms of when mitigation was installed (Table 3), and fencing design features such as length, height, and fence-end tie-ins (Section 5.5), as well as inclusion of other measures such as escape structures: one-way gates and jump-outs, and inclusion of crossing structure opportunities: underpass, creek bridge pathways, and overpass (Section 5). Data processing methodology is described below:

- Carcass data was obtained from hardcopy datasheets and excel spreadsheets and all converted to decimal degrees as part of another MTO assignment (Environmental Retainer 5013-E0028, Assignment 7);
- OPP collision data were obtained from MTO head office and NER traffic office and mapped using a GIS add on tool for the two highways;
- The Powassan and Rutter Patrol Zones were used to define highway extents for Highway 69 and Highway 11 respectively.
- The length of each mitigated fenced section of highway (Impact) was measured and the adjacent unmitigated (Control) highway was divided into sections of equal length; the different lengths of the mitigated sections as well as different spatial extent for crash and carcass data resulted in a different number of corresponding Control sections (Table 4);
- Impact and Control Sections are within Rutter and Powassan Patrol Zones on Highway 69 and Highway 11 respectively (Appendix D);
- Standardization of counts, e.g. WVCs per km, was not required because all WVC were counted for each year within each Control and Impact section that were of equal length;
- Full years of WVC counts were used that were obtained from Impact and Control treatment sections of equal length;
- When highway sections overlapped with other mitigation sections on Highway 11 or Highway 69, these were not used.
- The WVC data before and after installation of mitigation on Highway 69 and Sundridge was obtained from the old and new highway sections respectively, to account for the construction of new highway alignments (Figure 2);
- The carcass data was examined using Large Animal (bear, moose and deer) and also examined by species: deer, bear and or moose when sufficient sample size was available.
- There was no OPP data available during the after mitigation period at Sundridge or Carcass data available during the before mitigation period at Callander (Table 3).

Table 3 shows the before and after time periods for each of the OPP and carcass WVC reporting data sets. The Wasi construction period was between 2011 and 2013 to account for use of a detection system (WDS) in 2011 and subsequent construction of fencing and a crossing structure in 2013. OPP data for year 2014 was not used because the MTO had not received complete records (Steve Simpson, MTO NER, *pers. comm.*).

Table 3: A summary of duration of construction period and years of data used for before and after time periods for the OPP and Carcass WVC data.

Section	Construction period	OPP data (Count of Year)		Carcass data (Year count)	
		Before	After	Before	After
Callander	2006	2000-2005 (6)	2007-2013 (7)	(0)	2007-2015 (9)
Wasi	2011-2013	2000-2010 (11)	(0)	2006-2010 (5)	2014-2015 (2)
Sundridge	2012-2013	2000-2011 (12)	(0)	2006-2011 (6)	2014-2015 (2)
Highway 69	2011-2012	2000-2010 (11)	2013 (1)	2010 (1)	2013-2015 (3)

Table 4: Length of mitigation and number of Control sections for each of the four mitigated sections on Highway 11 and Highway 69.

Section-Highway	Impact Section	Length of exclusion fencing (km); one side of highway	Number of Control sections
Callander	Retro-fit on existing highway	3.5	13
Wasi	Integrated with new highway rehabilitation project	2.1	18
Sundridge	Retro-fit on new alignment	8.4	3
Highway 69	Installed on new alignment with road upgrade project	10.0	5 using OPP data/*4 using Carcass data

*An additional Control section on Hwy 69 north of the mitigated section was used for crash data but not carcass because it was not within the Rutter Patrol Zone.

A linear mixed effects model (Zuur et al. 2009) was used to test for mitigation effectiveness using the count of annual OPP and carcass reports. Preliminary analysis showed that WVC count varied significantly by both year and treatment sections; therefore, year and each mitigated section were included as random effects to control for this variation across sampling units and to isolate the influence of mitigation on numbers of WVC occurring. The model is as follows:

$$Count \sim Period + Treatment + (Period \times Treatment) + Year + Section$$

where *Count* is the summed OPP and carcass count per treatment section per year, *Period* is the time period in which the WVC occurred (before vs. after mitigation), *Treatment* is the mitigation status of the section of highway (mitigated (Impact) vs. unmitigated (Control)), *Period x Treatment* is the interaction between the two terms, *Year* is the calendar year and *Section* is the uniquely identified treatment section.

Mitigation effectiveness (reduction in WVC or carcass) was evaluated using the significance of the interaction between Period and Treatment (Hejda 2012; Baxter-Gilbert et al. 2015). Histograms and residual plots of WVC and carcass counts for each Period-Treatment group were used to assess normality of the data and homogeneity of variance. When necessary the count data was log-transformed to meet the assumptions of the linear mixed effects model.

Supplemental analyses were conducted with the OPP reports in the Callander section to assess concerns regarding a potentially biased increase in WVC reporting by the OPP within the fence section (A. Healy, MTO NER, *pers. comm.*). The southern terminus of the fence is at Lake Nosbonsing Road and Wasi River that likely funnels animals to Highway 11 increasing the risk of WVC (Cserkész et al. 2013). This coupled with the OPP reporting system that report WVC to the nearest landmark which in this case is Nosbonsing Road, may incorrectly place some WVC within the fenced section that occurred south of the intersection where there was no fencing (this type of reporting error is also noted in Huijser et al. (2016)).

Close examination of the WVC that occurred in the Callander mitigation section showed that 18 of the 53 WVCs were reported in the first 300 m of fencing north of the Lake Nosbonsing intersection. Furthermore, six WVC occurred exactly at the fence-end and Lake Nosbonsing intersection. Two possibilities were put forth to explain these high WVC counts. First, WVC may be occurring outside of the mitigated section but are located within the section due to reporting errors. Second, there is already a high risk of WVC at this road intersection and additionally, animals may be funneled to this location creating a fence-end effect. To address these concerns two supplemental models were used that first removed the six WVC that occurred exactly at the fence-end, and second, WVC that occurred within 300 m northerly of the fence end were removed and the lengths of the control and impact sections were adjusted.

4.2.1.3 Supplementary hotspot analyses

Statistical significance of a reduction of WVC is only one element of effectiveness. Fencing and crossing structures may also affect where animals move in relation to the road and this is commonly seen in a fence-end effect. For example, the presence of short sections of fence (< 5k km) likely funnels animals to a fence end and if able to do so wildlife will access the highway right-of-way (ROW) and either cross the road or follow the fence inside the ROW (Cserkész et al. 2013; Huijser et al. 2016b). To assist with interpretation of results, hotspot maps were created both before and after fencing installation at the four mitigated sections using OPP and carcass data when relevant.

A Linear HotSpot Identification tool (LHIT) in Siriema software (Coelho et al. 2014) was used for defining hotspots and ArcMap 10.4 was used to prepare and map the results from Siriema. The Siriema tool uses kernel density. Kernel density searches and counts WVC within a user defined search distance and WVCs closest to the marker are weighted more heavily (Gunson & Teixeira 2015). For consistent comparisons, all iterations used the same user defined parameters of 300 m for the search distance with 500 road divisions.

In addition to calculating kernel density, the LHIT also calculates the upper and lower confidence levels. The kernel density that is above the upper confidence level was defined as a significant hotspot, i.e. more WVC occur at this location than expected by chance, and was mapped for interpretation. Both the before and after scenarios for each mitigated section were mapped side by side for visual comparison.

4.2.2 Results

A summary of the results from the linear effects model: Period (Before) x Treatment (Impact) for all analyses using carcass and OPP data at all mitigation sites are presented in Table 5. Following this, detailed assessments of each mitigation system are presented in a sub-sections of the report. This includes Before-After-Control-Impact (BACI) charts that illustrate mean WVC counts for each period for both treatments (Control and Impact). Hotspot analysis was completed for Callander, Wasi, and Highway 69 OPP data because this data was the most spatially accurate and complete. As a supplementary analysis, hotspot analyses were also conducted for Highway 69 all carcasses and for deer and moose specific data to assist in interpretation of significant results from the linear effects models.

The annual WVC count for all the mitigated (Impact) and unmitigated (Control) treatment sections during the before, after, and during periods of mitigation construction are presented in line charts in Appendix C. These charts compare mean counts for each year in all Control sections with counts in the corresponding Impact section. In general WVCs in the mitigated impact sections varied considerably more than in the control sections.

The charts in Appendix C are also useful to compare differences between the OPP and carcass data in each mitigation section. For example, in the Wasi fence section (Impact) from 2007 to 2013 there were zero deer carcasses reported. In contrast, the OPP reported several WVCs in these years and the discrepancy is likely due to a bias in reporting effort in the two data types. In the Highway 69 mitigated site there was a drop in WVC in the after period for both the OPP reports (2013) and the carcass reports (2013-2015) that is likely attributed to a reduction in WVCs (Appendix C).

Table 5 shows there were significantly less WVC reported by the OPP on Highway 11 in the Callander (truncated fence section) and in the Wasi fenced sections; albeit the relationship at Wasi was marginally significant at 0.0514. There were significantly less ($p<0.05$) WVC reported by the OPP and less Moose and Deer carcasses reported by the maintenance workers at the Highway 69 fenced section (Table 5).

Table 5: An overview the Parameter estimates (β), standard errors (SE) and p-values (*P*) from the linear mixed effects model conducted for Callander, Wasi, Sundridge and Hwy 69 mitigated sections using OPP and Carcass data. Green shaded cells are significant (p<0.05) or marginally significant (p=0.05).

Hwy	Section	OPP or Carcass data	Period (Before) x Treatment (Impact))		
			β	SE	*P*
11	Callander	OPP all	0.3974	0.3017	0.1879
11	Callander	OPP less 300 m	2.2109	1.0454	0.0358
11	Callander	OPP less WVC at Nosbonsing (Hwy 654) intersection	0.5274	0.3171	0.0963
11	Wasi	Carcass (deer)	0.1944	1.0981	0.8598
11	Wasi	Carcass (bear, deer, and moose)	0.7778	1.3041	0.5520
11	Sundridge	Carcass (deer)	0.8333	2.1059	0.7081
11	Sundridge	Carcass (bear, deer, and moose)	2.278	2.258	0.3302
69	Hwy 69	OPP all	0.94647	0.20626	<0.0001
69	Hwy 69	Carcass (deer)	0.62292	0.18660	0.0066
69	Hwy 69	Carcass (moose)	2.7500	1.0633	0.0253
69	Hwy 69	Carcass (bear)	-0.3053	0.3032	0.3350
69	Hwy 69	Carcass (deer, moose, bear)	0.9234	0.6199	0.1360

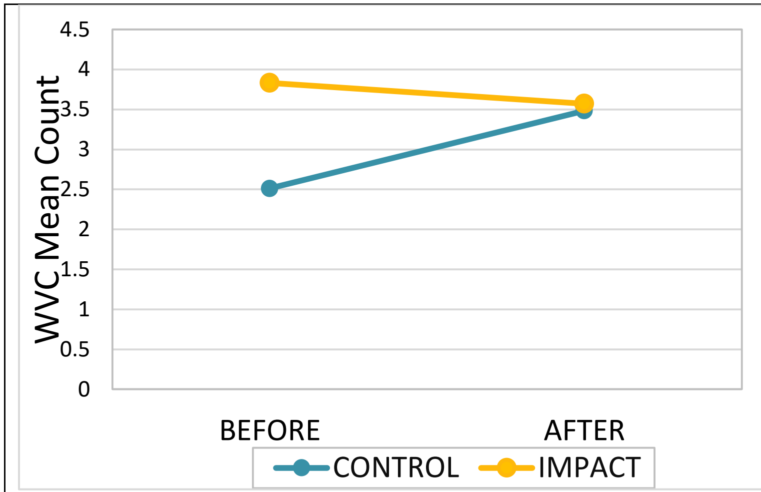
Shaded cells are significant

4.2.2.1 Callander mitigated section

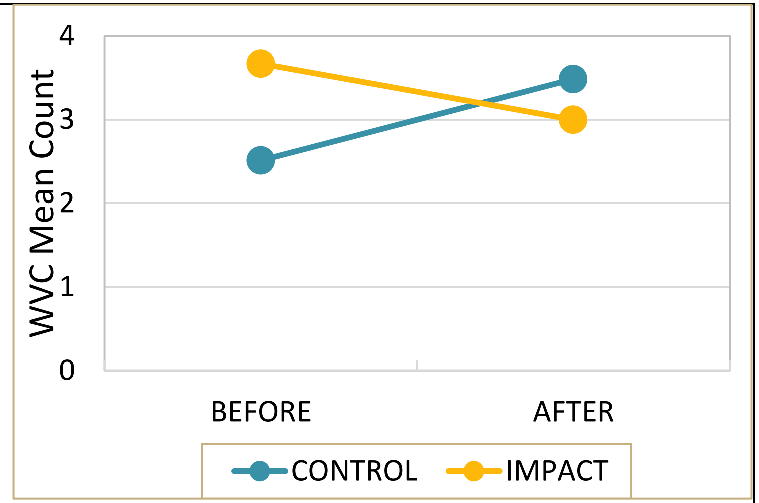
Only OPP reported WVCs were used because WVC carcass reports were not available prior to mitigation installation. All three BACI figures showed that WVC decreased in the mitigated section and increased in the control section, however there was only a significant reduction in

WVCs when WVC were excluded from the 300 m southern end (Figure 6, Table 5). The annual WVC count showed that there were peaks in WVC prior to mitigation and again in 2012 after mitigation was installed (Appendix C).

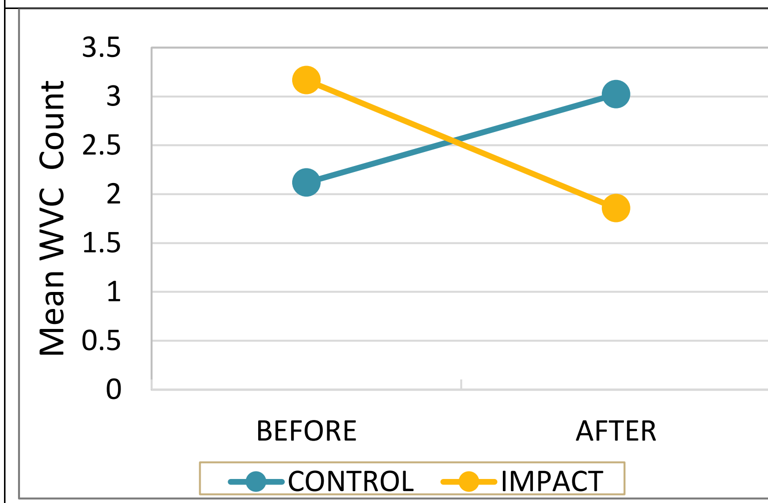
The significant WVC reduction when WVC were excluded from the souther-most section of mitigated highway (300 m) indicates that WVC are reduced along the majority of the mitigated highway section after fencing was installed. However, there is a higher than expected risk of WVC at the at-grade interface of Highway 11 and Nosbonsing Road before and after fencing was installed (Figure 7). This is likely attributed to animals following Nosbonsing Road and or Wasi River to Highway 11, and after fencing was installed animals were also funneled to this location. Collectively, these results suggest that there is an overall WVC reduction, but a fence-end modification is required to improve the system. A 100 m fence extension into the forest following Lake Nobonsing Road. A fence extension to Watson Road is also recommended and ungulate guards or fence extensions away from Highway 11 should be used at Nosbonsing Road.



All OPP reported WVC at Callander



OPP excluding WVC at Nobonsing Lake Road



All OPP excluding WVC within 300 m southern fenced section

Figure 6: Before-After-Control-Impact summary charts illustrating mean WVC count before and after installation of wildlife mitigation in the mitigated and control section of highway

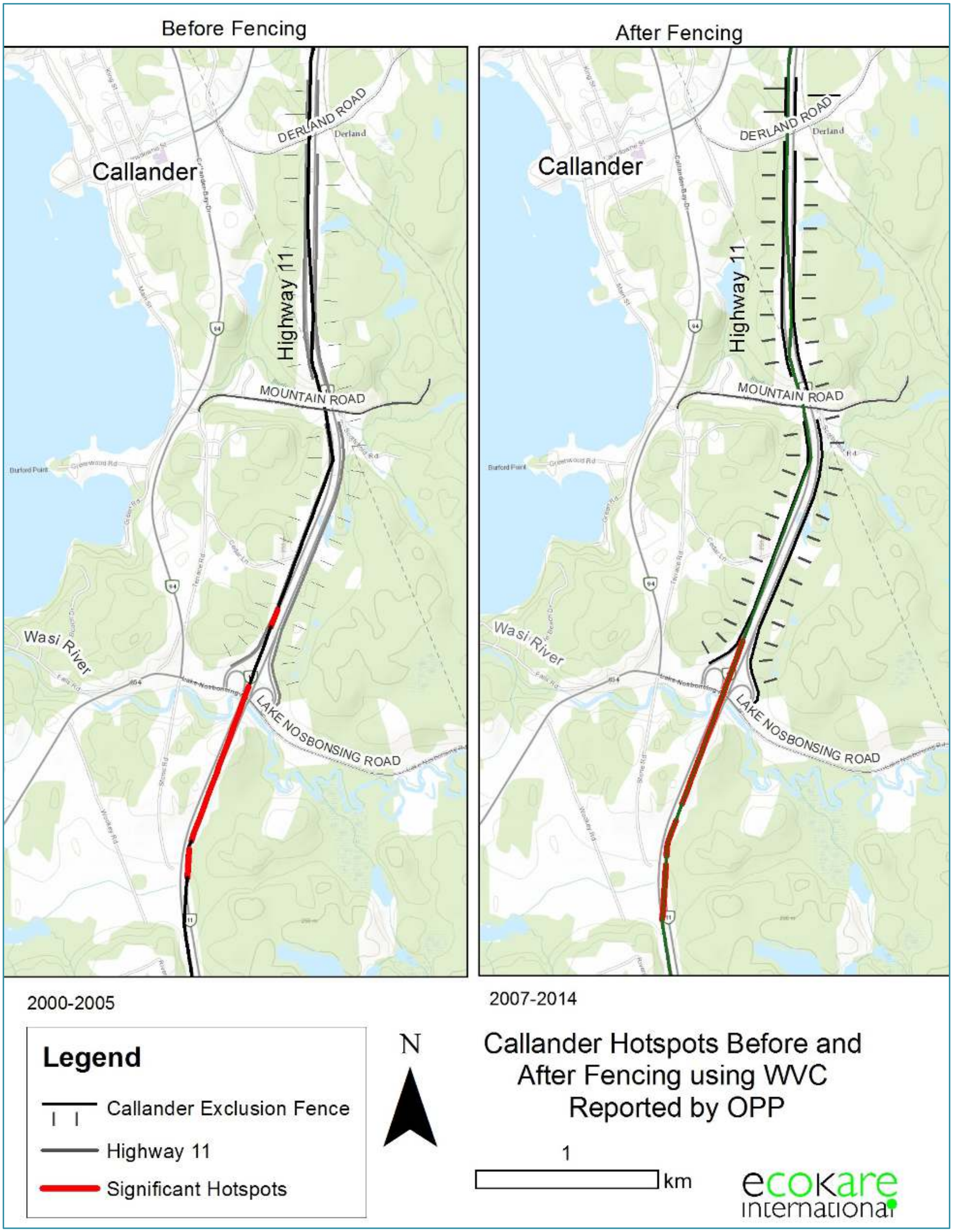


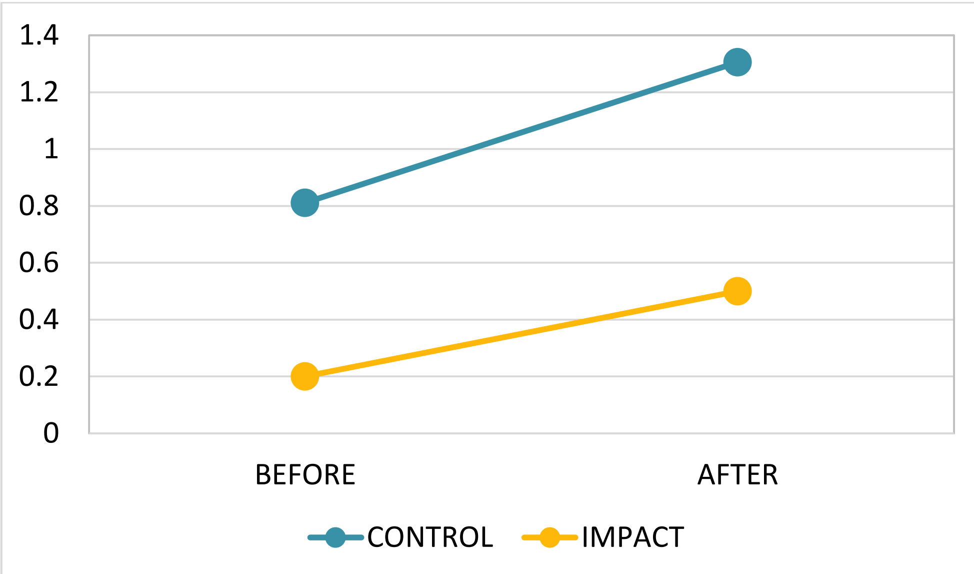
Figure 7: Hotspots on Highway 11 in the Callander mitigated section before and after fencing using WVC reported by OPP.

4.2.2.2 Wasi mitigated section

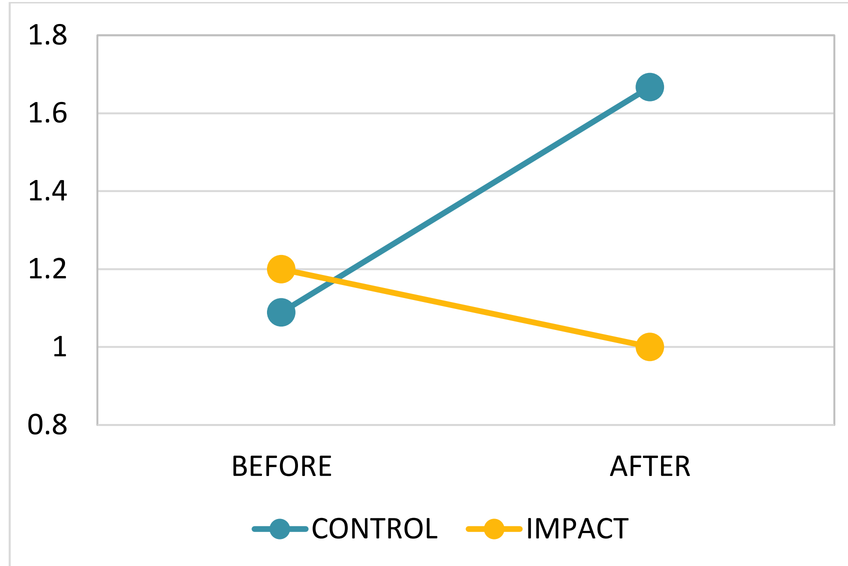
A linear mixed effect model could not be conducted for the Wasi mitigated site using OPP reports because the 2014 data were not complete. However, the 2014 OPP reports (30 records) were used to generate a preliminary hotspot analysis to illustrate where WVCs were occurring in relation to the fence before and after mitigation was installed.

There was not a significant reduction in WVC carcasses at the Wasi site (p-value > 0.05) likely due to only having two years of information after mitigation was installed (Table 5). The BACI chart shows an increase in deer carcasses found in both the Control and Impact highway sections before and after fencing was installed (Figure 8, Left). There is a decrease in WVC large animal carcasses at the Impact highway section with a corresponding increase at the Control sections (Figure 8, Right).

There is an obvious decrease in significant hotspots that occurred along the Wasi fenced section using OPP reports after mitigation was installed (Figure 10). In the before period hotspots were primarily along the northern half of the fenced section, and there was another hotspot at the southern fence end at Hills Siding Road. The carcass reports illustrates that this hotspot is comprised of all large animal species (bear, deer, moose and wolf, Figure 9). In the After period, the hotspot at the northern fence-end is still existing in the crash data, and there were two road-kill at the southern end in the carcass data (Figure 9, Figure 10). Comparison between the two periods using OPP data should be used with caution because there was only one year of OPP reports after mitigation (30 records in 2014) as opposed to 341 reports before mitigation (2000 to 2010).



Deer carcasses at Wasi



Large animal carcasses at Wasi

Figure 8: Mean count of deer carcasses (left) and large animal (right) carcasses, before (2006 to 2012) and after (2014 and 2015) fencing and an underpass was constructed at the Impact and adjacent Control sections of highway.

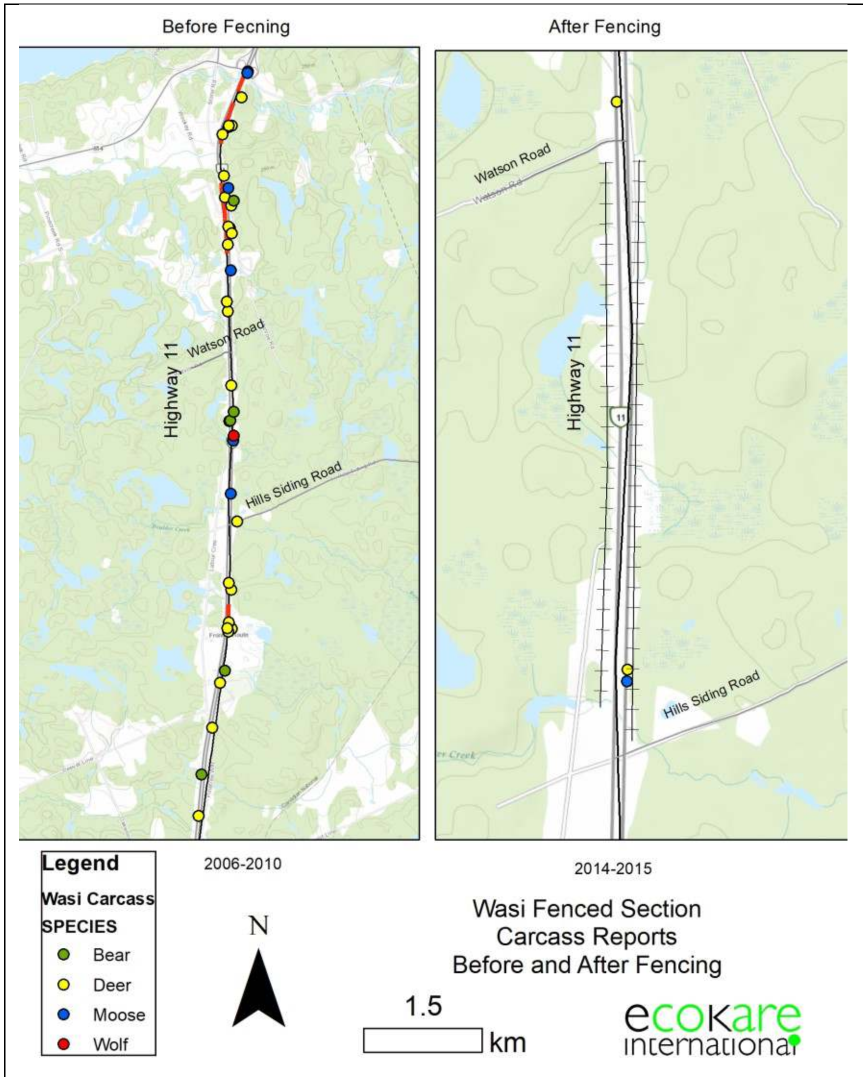


Figure 9: Location of carcasses found at the Wasi mitigated section before and after fencing

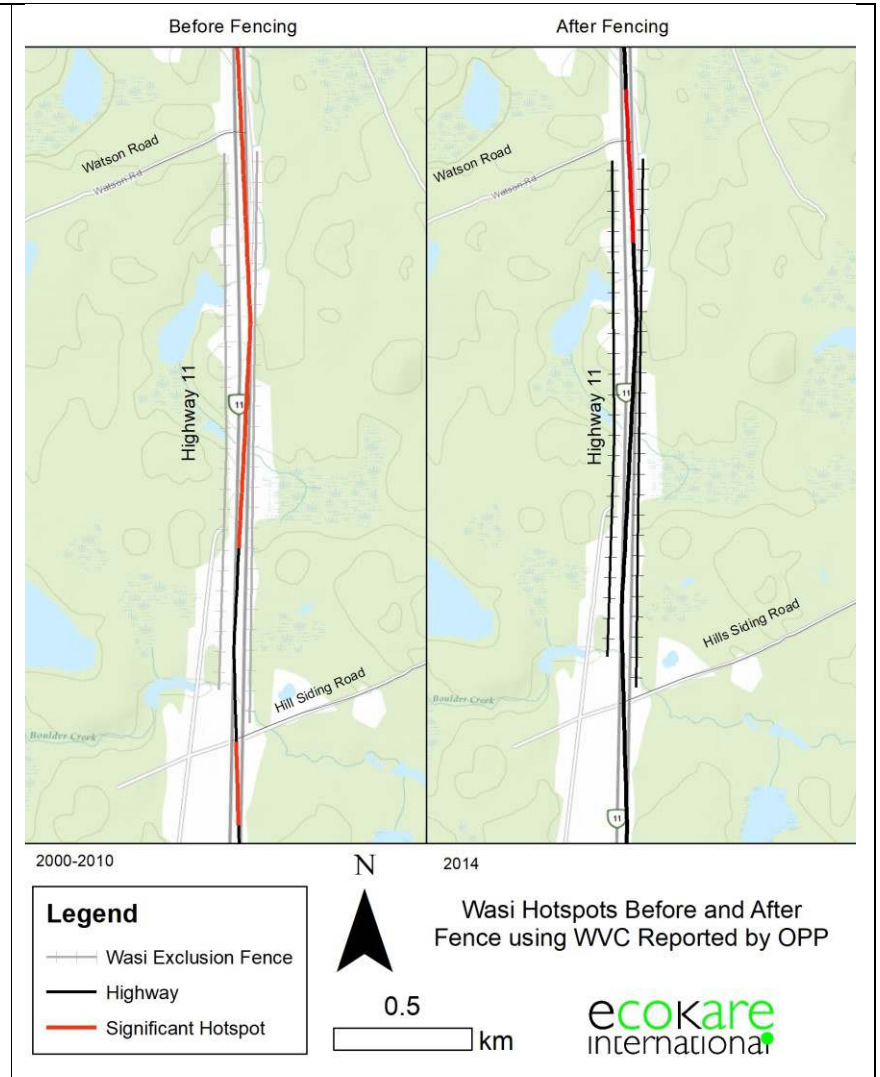


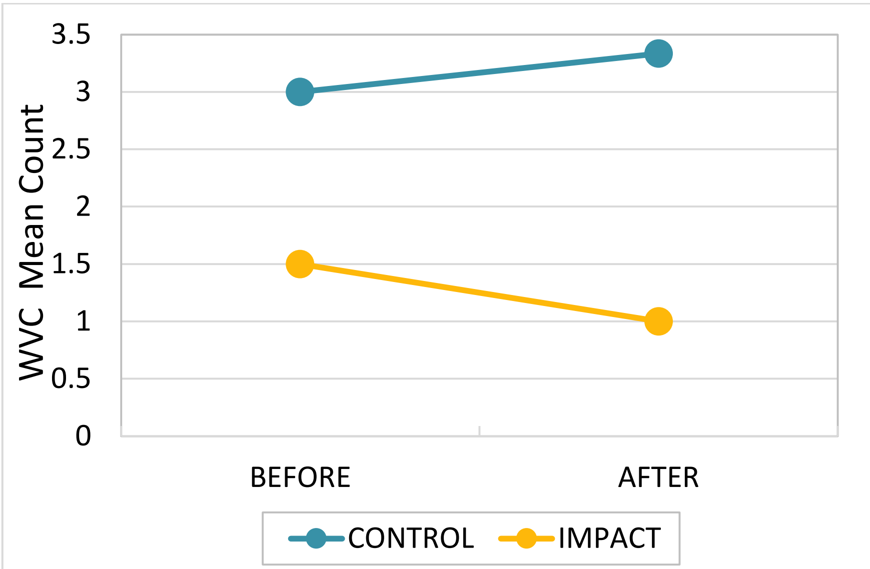
Figure 10: Location significant hotspots found at the Wasi mitigated section before and after fencing using OPP reports

4.2.2.3 Sundridge mitigated section

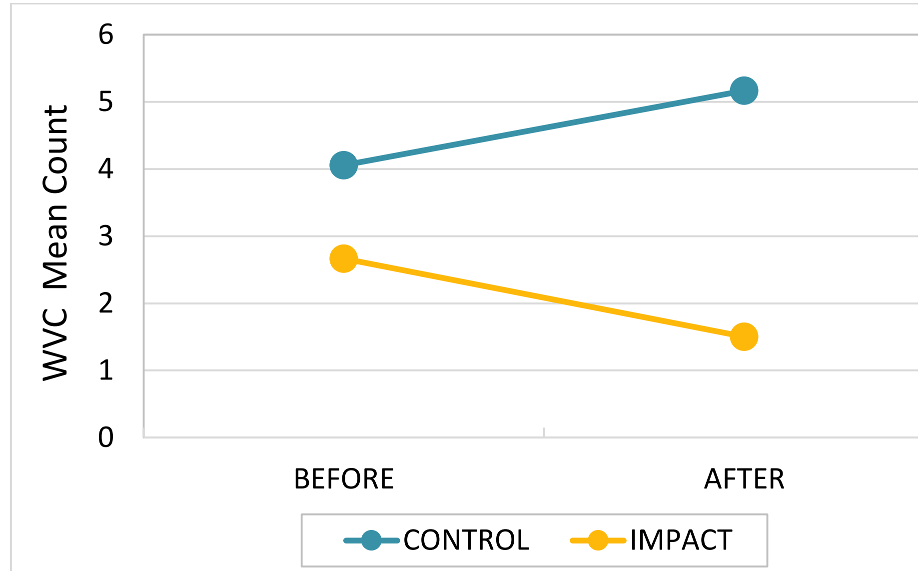
Fencing was installed at Sundridge in 2012 and 2013 on a new highway alignment; therefore, before and after analyses compare two highway sections. Further, there was only one incomplete year of OPP reports (2014) for statistical analysis so a linear model in a BACI design was only conducted using carcass reports. A hotspot analysis was completed using the records obtained from the OPP with only one year of WVC data (2014) available after fencing was installed.

Similar to the Wasi mitigation section, the carcass reports for both deer and large animals (deer, moose and Black bear) were used to evaluate the Sundridge mitigation system. The annual carcass count (Appendix C) showed a decline in both deer and large animals in the fenced section in 2015. In addition, there was a decline in the mean carcass count for both deer and large animals, while concurrently the carcass count in adjacent fenced sections increased (Figure 11), however this relationship was not significant (Table 5).

There were two primary hotspots on the old Highway 11 near South River and near the intersection with Adam's Road from 2000 to 2012 (Figure 13). The southern hotspot is likely comprised of deer and the hotspots in the north is likely several species: deer, wolf, moose, and bear (Figure 12). On the new highway alignment after fencing was installed (OPP reports from August 2013 to 2014) there is one hotspot just north of Adams Road. A paired jump-out and one-way gate is located near this hotspot and it is possible that deer are breaching the fence system at these structures. Again these results should be interpreted with caution because there were only 33 OPP reports after mitigation was installed as compared to 327 reports prior to mitigation.



Deer Carcasses at Sundridge



Large Animal Carcasses at Sundridge

Figure 11: Mean count of deer (left) and large animal (right) carcasses before and after fencing and an underpass was constructed at the Impact and adjacent Control sections of highway.

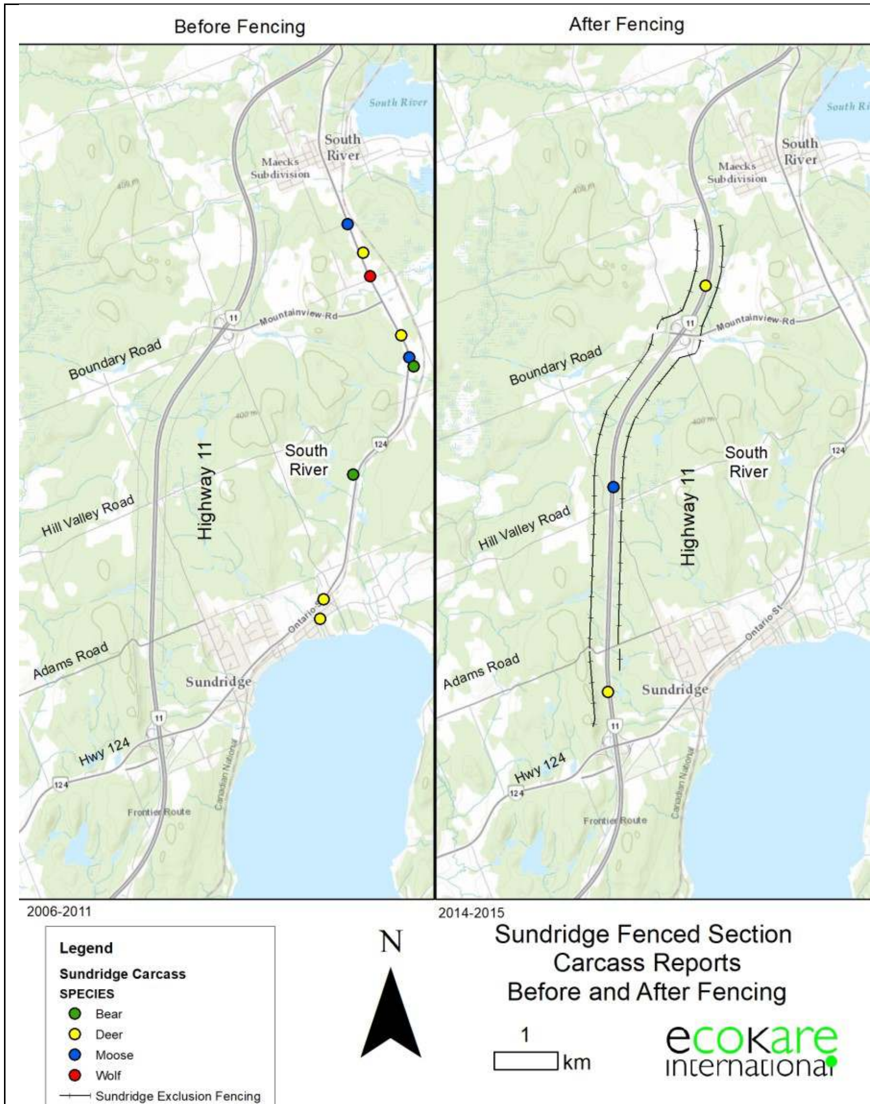


Figure 12: Location of carcasses found at the Sundridge mitigated section before and after fencing

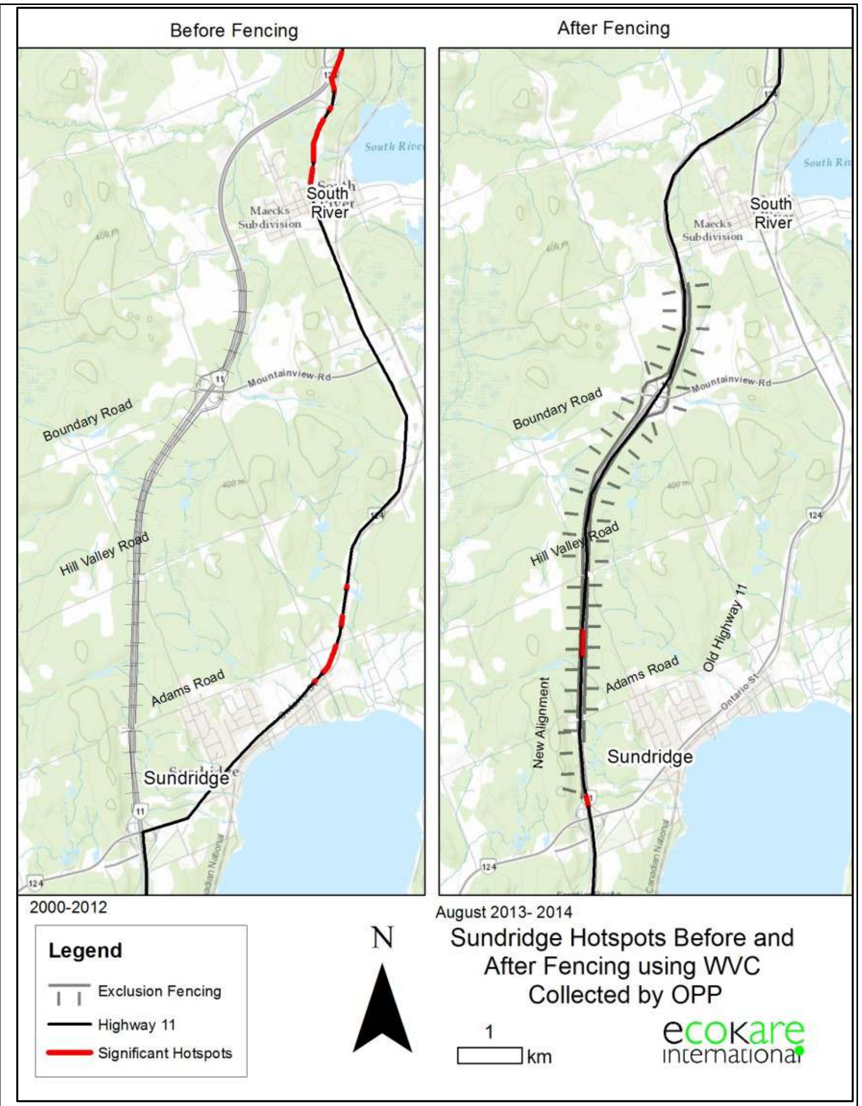


Figure 13: Location of hotspots found at the Sundridge mitigated section before and after fencing using OPP reports

4.2.2.4 Highway 69 mitigated section

Both the OPP and carcass reports (deer, moose, bear, and large animal) were used to evaluate fence effectiveness on Highway 69. The OPP WVC and deer carcass mean counts were log-transformed to normalize the data for statistical analysis. Elk were not used in the analysis because their distribution was clustered north of the mitigated section (Eco-Kare International 2014). Both 2011 and 2012 years were considered construction years because fencing existed from the new alignment to Trout Lake Road and this highway section was under construction.

There was a significant reduction in WVC that were reported by the OPP, in addition to deer and moose carcass pick-ups before and after fencing was installed (Table 5). There was a significant decrease in mean WVC carcasses (deer, moose, and large animal) and OPP reports at the mitigated impact section and a corresponding increase in the adjacent control sections after fencing was installed on Highway 69 (Figure 14). It is important to note that there was only one year of information available to assess WVC reduction using OPP reports. It is recommended to conduct a more balanced mitigation effectiveness evaluation when more data are available.

The occurrence of bear carcasses collected by the maintenance crew varied considerably over time and peaked in 2014 after mitigation was in place (Appendix C). For example, there were six bears in the before period as opposed to 16 in the after period. The BACI summary shows a clear increase within the mitigated Impact section without a corresponding increase in the unmitigated Control sections (Figure 14, bottom middle). Although this trend was not significant, the results suggest that bears are behaving differently to the mitigation than the other large animals. Bears are able to navigate the one-way gates the wrong way, as well as go under the wildlife fence and are exposed to increased risk of WVC. This trend was also seen in the WVC data opportunistically collected by the research team (Appendix D).

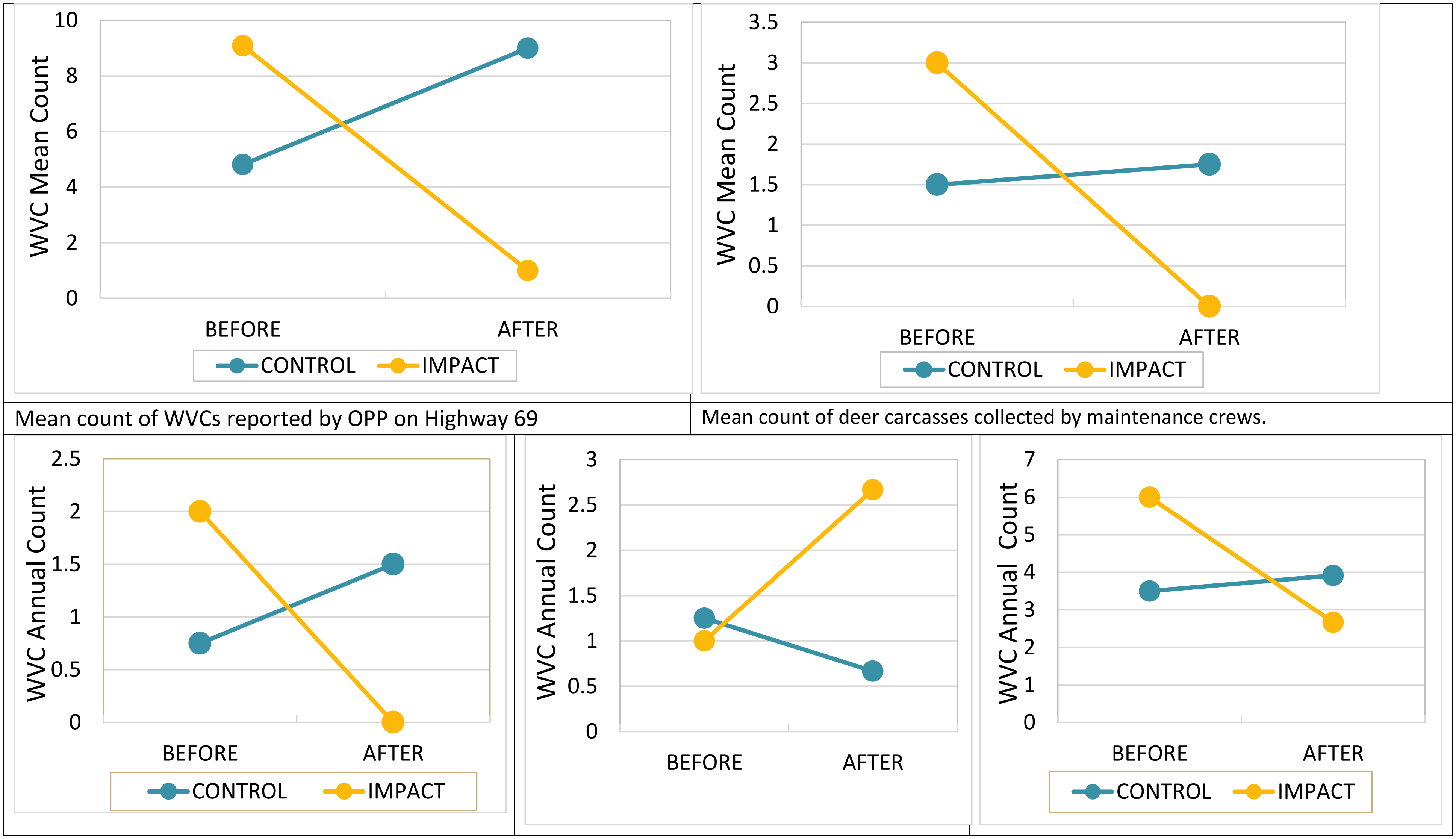
Both WVC carcass and OPP reports were used to illustrate significant hotspots both before and after fencing was completed within the Rutter Patrol Zone. Similar to the Sundridge section WVCs on the old Highway 69 were used to compare to WVC on an adjacent new highway alignment. Reports with dates prior to June 2012 were used for the before period and those after October 31st, 2012 for the after period.

Prior to June 2012, more than expected WVC (OPP reports) were primarily along old Highway 69 and were not apparent on the new alignment after fencing and crossing structures were installed (Figure 15, Left). Using carcass reports (Figure 15, Right), there were two hotspots one at the southern end of the new alignment after fencing was completed and one at the southern fence-end. The hotspot on the new alignment was from three carcass reports of young black bear at the same location in May 2014. The hotspot at the southern fence end was from deer and moose WVC. Again, interpretation is limited because there is only one year of complete data in 2013 and one year of incomplete data in 2014.

A post-hoc summary of OPP WVC data was compiled by the MTO NER office for Highway 69. This summary showed that overall, there was a 71% reduction in Black bear, moose and deer collisions after fencing and crossing structures were functional (Table 6, MTO unpublished data). A species-specific evaluation shows that deer and moose collisions were reduced by 87%, while Black bear increased by 25% (Table 6, MTO unpublished data). These results combined with significant BACI result shows that the wildlife fencing is effective in reducing WVC.

Table 6: A summary of wildlife-vehicle collisions from 2003 to 2015 before and after large animal fencing was installed

Before Fencing				
Year	**Moose**	**Deer**	**Black bear**	**Total**
2003	7	3	1	11
2004	6	3	1	10
2005	12	3	0	15
2006	2	3	0	5
2007	0	3	0	3
2008	7	3	0	10
2009	4	2	2	8
2010	4	3	2	9
2011	3	1	1	5
2012	5	1	1	7
Average	**5**	**2.5**	**0.8**	**8.3**
After Fencing				
2013	0	0	1	1
2014	1	1	1	4
2015	1	0	1	2
Average	**0.7**	**0.3**	**1**	**2.3**
Change	**87% decrease**	**87% decrease**	**25% increase**	**71% decrease**
Data Source: Ministry of Transportation				



Mean count of WVCs reported by OPP on Highway 69

Mean count of deer carcasses collected by maintenance crews.

Mean count of moose carcasses

Mean count of bear carcasses

Mean count of large animal carcasses

Figure 14: Mean count of WVC reported by OPP (top left) and carcasses reported by maintenance crews for deer (top right) and moose (bottom left), bear (bottom middle) and large animal (bottom right), before and after mitigation for control and impact sections on Hwy 69.

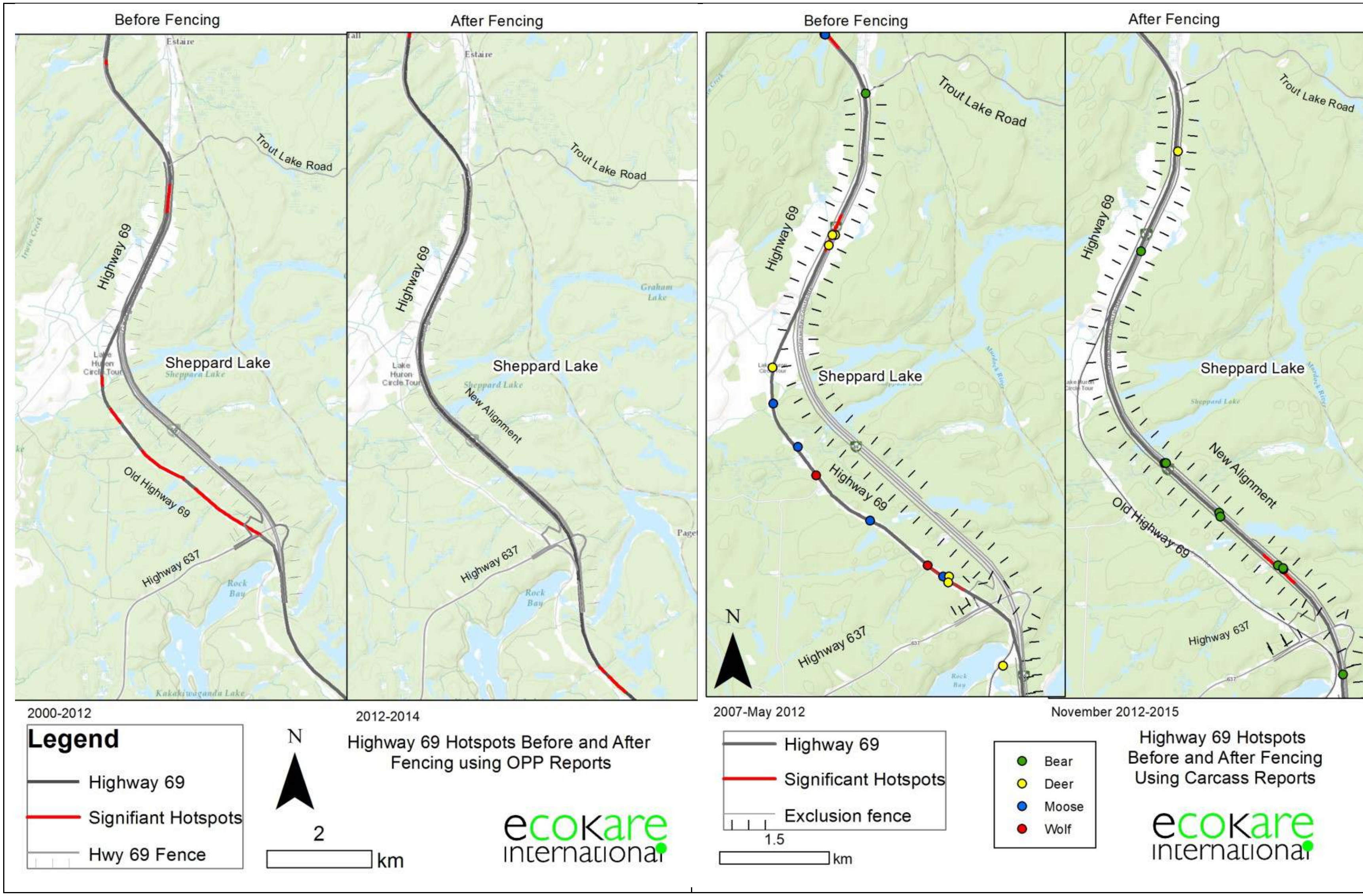


Figure 15: Hotspots on the old Highway 69 and new alignment before and after fencing using WVC reported by OPP (left) and carcass reports (right).

4.2.2.5 Discussions

The four mitigation systems indicated a decrease in large animal WVC when examining all statistical and mapping results. Overall the reduction in WVC was significant on Highway 69 and there were fence end concerns at the three mitigated sections on Highway 11. This trend has been shown by Huijser et al. (2016) where short road sections with wildlife fences (≤3.1 mi (5 km) road length) are on average, less effective (46.59 percent reduction on average) than long road sections (>3.1 mi (5 km) road length) (82.97 percent reduction on average) mainly due to fence-end breaches.

The Highway 69 mitigation (10.5 km) of wildlife fencing is effective at reducing WVC for ungulates but not for Black bears. This is similar to other studies in Banff National Park and in Montana where Black bear WVC did not significantly decrease after fencing (Huijser et al. 2016; Clevenger and Barrueto 2014). Increased road mortality is likely a result of bears navigating the mitigation system at one-way gates, jump-outs (Highway 11), fence-ends and by going under the fence. The high rate of Black bear collisions since 2014 may also be attributed to the spring bear hunting season that was re-initiated in the area in 2014.

The mitigation at Highway 69 is working most effectively at reducing moose-vehicle collisions. There were no moose carcass pick-ups in the fenced section of the new alignment on Highway 69. In addition, no moose were observed road-side of the fence along the entire fenced section of Highway 69 (visual observations and snow-tracking). This was further substantiated in no moose captures on cameras that were located along the fence or presence of moose breaching the fence at section fence-ends. With one exception, one moose was observed road-side of the fence just south of Killarney interchange on Highway 637 on Mar 24th, 2013 (Eco-Kare International 2014).

With the exception of Callander mitigated section, there was only one or two years of OPP reports that occurred after mitigation was installed. The lack of data created an unbalanced design and likely contributed to the nonsignificant results when using all the data in the three mitigated sections. It is recommended to complete this analysis in two years when several years of OPP data is available after fencing is installed at both Sundridge and Wasi sections.

Both the OPP and carcass reports were supplementary and each report type filled in missing gaps of information to conduct a thorough evaluation of mitigated sections of highway. The carcass data provided insight when evaluating species-specific WVC locations and mitigation effectiveness on Highway 69. The OPP data was more useful to determine where significant hotspots occurred before and after fencing at each mitigated section. The carcass data could then be used to evaluate what species was contributing to the hotspot.

More consistency in reporting efforts within the Rutter and Powassan patrol zones would allow the data to be used for fencing evaluations. In addition, using GPS technology available in trucks will greatly improve accuracy in locating hotspots. Many Department of Transportations in the United States have now employed carcass reporting apps that provide more consistent, accurate and complete data collections. Currently, the OPP are collecting species-specific WVC reports that will also improve evaluations.

Fence-end effects were observed at all three of the mitigated sections on Highway 11. Primarily the southern end at Callander, the northern end at Wasi, and the southern end at Sundridge. Fence extensions (approximately 5 km) between Callander and Wasi sections would improve risk of collisions at fence-ends. Texas gates, electro-mats, or fence end treatments can be used at secondary roads. At Sundridge the south-west fence-end should be extended to the Highway 124 and 11 interchange.

5 Effectiveness of mitigation structures

This section evaluates the effectiveness of mitigation measures for large- to mid-sized animals (Red fox and larger) along each of the four mitigated sections on Highway 11 and 69. Each measure is independently analyzed or pooled when relevant. The pooled information from several mitigation design types can provide valuable insight and recommendations for future mitigation implementation.

Individual components of the mitigation systems include: exclusion fencing, fence-end tie-ins, crossing structures, ungulate guards (aka Texas gates), and escape structures: jump-outs and one-way gates. More specifically, the primary mitigation measures include wildlife crossing structures: one overpass, four underpass types (6 structures total), two creek bridge pathways: Murdock River, and Lovering Creek, and jump-outs (two design types of varying heights), one-way gates (three design types), and fence-ends: varying placement and tie-in features (Appendix I) (Table 1).

5.1 Data collection and analyses

At the onset of monitoring all fence-ends, crossing structures, one-way gates, and jump-outs were inventoried with pictures, Geographic Positioning System (GPS) co-ordinates, and assigned a unique identity code to facilitate record keeping and summaries completed at each section of highway and at each type of structure (Table 7, Appendix H). The unique identity codes followed the style of "Structure –Direction Location – Highway Section" (Appendix H).

The mitigation measures were intended for large animals present in the study region and are comprised of White-tailed deer (*Odocoileus virginianus*), moose (*Alces alces*), elk (*Cervus elaphus*), Eastern wolf (*Canis lycaon*), and Black bear (*Ursus americanus*). However, when relevant data for mid-sized mammals such as Lynx (*Lynx Canadensis*), Bobcat (*Lynx rufus*), Coyote (*Canis latrans*), and Red fox (*Vulpes vulpes*) were also included for comparison.

On Highway 69, WVC data was considered post-construction in November 2012 when the wildlife fencing was continuous and complete. Data collected at the crossing structures was considered post-construction as of June 30th 2012, because fencing abutted all the structures, and two lanes of highway were open to motorists on the new alignment. All data on Highway 11 is considered post-construction.

All data collections used non-invasive survey methods to evaluate wildlife behavior, interactions and movements in relation to specific mitigation measures and the road (see methods in Long et al. 2008). The main method for data collection was the use of approximately 60 Reconyx infrared motion detection cameras placed throughout the two study sites (Appendix H). There have been five cameras and five digital camera cards stolen. Additionally, one camera was lost from removal of a tree on the overpass during construction, and another camera was vandalized with spray paint. All theft and vandalism occurred at the Highway 69 site. In addition to Reconyx cameras, 4 Bushnell Trophy HD cameras were purchased in January 2015 and used to monitor the reptile tunnels.

Data were collected approximately one time per month on both highways, 18 times from July 2014 to June 2016 from cameras placed along Highway 11 and 56 times from September 2011 to September 2016 from cameras placed along Highway 69 (See Appendix H for where and when camera monitoring occurred). On each field visit the battery level was checked, the data removed, and the cameras were either realigned or moved to an improved monitoring site.

All picture data was processed using picture processing software and each independent wildlife interaction was entered into an Excel spreadsheet database. Interactions were assigned a unique action code (Table 8) for all fence-ends, one-way gates, jump-outs, crossing structures and ungulate guards. A wildlife interaction was independent if it occurred more than five minutes from the previous interaction in a picture series. Cameras placed at one-way gates and jump-outs were also used to measure presence of wildlife breaches, i.e. on the roadside of the fence. This data was used to supplement interpretation of mitigation effectiveness.

Reconyx digital cameras were installed at 28 monitoring locations from July 2014 and June 2016 on Highway 11 and at 24 to 31 monitoring locations from September 2011 and September 2016 on Highway 69. Monitoring locations varied on both highways as research objectives were refined with information learned from ongoing monitoring. As a general rule, two to six cameras were used at each crossing structure, and additional cameras were placed at a selection of fence-ends, ungulate guards, and escape ramps (Table 7). On Highway 69, cameras were used to monitor animal movements and presence adjacent to the overpass, underpass and Lovering Creek bridge.

Table 7: Overview of camera monitoring and research objectives on Highway 69 and Highway 11 intended for this report and for future summaries.

Mitigation Measure	Duration	Camera Placement	Research Objective
Highway 69			
Overpass, Underpass, Lovering Creek bridge	September 2011 to September 2016	Six, three, and two cameras placed at OP, UP and LCR (respectively). Two additional cameras along OP and UP access roads and one along wildlife movement path at LCR. See Appendix D.	Evaluate large animal species-specific passage rates relative to adjacent abundance surrounding mitigation structures; evaluate sex, age and seasonal use.
Murdock River bridge	January 2015 to September 2016	Four cameras placed. Two at south- and north-east approach, two at south- and north-west approach.	Evaluate large animal species-specific passage rates relative to adjacent population; evaluate sex, age and seasonal use.
Reptile tunnels	February 2014 to September 2016	Four cameras placed at three reptile tunnels, supplementary camera monitoring as part of retainer 5013-E-0028, Assignment 6 from June to Sept 2014 and 2015.	Evaluate large animal species-specific passage rates and compare to other structures.
One-way gates	September 2011-September 2016	Selected one-way gates monitored (12 during study period); placed on fence on road-side. Six gates monitored entire study period.	Evaluate large animal species-specific use and animal presence road-side and safe-side of fence.
Highway 11			
Wasi underpass	July 2014 to July 2016	Three to four cameras placed at entrances and middle of structure.	Evaluate large animal species-specific passage rates and compare to other structures; Seasonal, sex-related use summarized.
Sundridge underpass	July 2014 to July 2016	Two cameras placed at entrance of structure.	Evaluate large animal species-specific passage rates and compare to other structures.
Jump-outs	July 2014 to July 2016	Cameras selectively placed at 8 JO in first year (4 each at Callander and Sundridge), and at 9 JO in second year (5 at Sundridge and 4 at Callander).	Evaluate large animal species-specific use and road-side presence.

Mitigation Measure	Duration	Camera Placement	Research Objective
One-way gates	July 2014 to Oct. 2015	Six cameras were installed at OW gates (four at Sundridge, and two at Callander), all removed in August 2015 except for one at Callander.	Evaluate species use, however gates not working properly at Sundridge and little use at Callander so not monitored in second year.
Highway 11 and 69			
Fence-ends	July 2014 to July 2016 (Hwy 11) and Sept 2011 to Sept 2016 (Hwy 69)	Cameras selectively placed at 8 fence-ends in first year (Hwy 11) focusing on section ends, and at 11 fence-ends in second year, focusing on intersection and section ends; Six cameras at Trout Lake Road, Nelson fence, and Killarney interchange fence-ends for 6 months to 1.5 years.	Evaluated fence-end tie-in placement and design in relation to animal breaches.

Table 8. Definition of interaction terms used to describe wildlife response to mitigation measures using cameras as tools for effectiveness monitoring.

Interaction Type	Definition
Crossing Structures	
Cross	Individual is documented as travelling across (in the middle) of the structure (caught on 2 approach cameras, or caught on a middle camera only) and is not documented turning around.
Approach	Individual is captured on only one approach camera (a camera at one end of the structure or the other) clearly moving onto or off of the crossing structure.
Repel	Individual about to enter/use the structure but abruptly turns around moving away from structure.
Ignore	Individual seen on camera, but no deviation from path or movement behaviour when moving by structure. Often grazing.
Look	Similar to approach but possibly biased because occurs at night and individual changes direction to look at infrared illumination from camera.
One-Way Gate	
Passage	Individual goes through the gate. Usually from the road-side to the safe-side of the fence (as intended), but occasionally the reverse, especially for smaller animals.
Approach	Individual looks at the gate or deviates from path to inspect the structure, but doesn't use it and continues on same path. May approach from either side of the gate.
Repel	Individual looks like it is about to travel through the gate, but turns back quickly and does not go through.
Ignore	Individual seen on camera, but no deviation from path or movement behaviour when moving by gate. Often grazing.
Jump-outs	
Jump	Individual jumps through the jump-out. Usually from the road-side to the safe-side of the fence (as intended), but occasionally the reverse.
Approach	Individual looks at the jump-out or deviates from path to inspect the structure, but doesn't use it and continues on same path. May approach from either side of the jump-out.
Repel	Individual approaches the edge of the jump-out, looks over the edge, then goes back down the ramp and does not use the jump-out.
Ignore	Individual seen on camera, but no deviation from path or movement behaviour when moving by structure. Often grazing.
Fence-ends	
Breach - Toward Hwy	Individual moves past or around the fence end toward the highway; this is also referred to as a breach in the fence.

Interaction Type	Definition
Breach - Away Hwy	Individual moves past or around the fence end away from the Highway; this is also referred to as a breach in the fence.
Approach	Individual looks at the fence or deviates from path to inspect the fence, and continues on same path. May approach from either side of the fence.
Ignore	Individual is moving or gazing in the vicinity of the fence end, but is not interacting with the fence at all. Movement is not directional with respect to the fence.
Repel	Individual approaches the fence end, then abruptly turns away and does not pass the fence.
Jump-out and one-way gates	
Road-side	Fence intrusion, e.g. individual present on the road-side of the wildlife fence.
Safe-side	Individual present on the safe-side of the wildlife fence.

In addition to camera monitoring, any tracks in snow and dirt that were found during routine snow-tracking (see section 4.1) and camera data acquisition surveys were recorded for all large animals that interacted with the mitigation measures. Similar to the camera data, an interaction or wildlife use of a structure from species-specific tracks in sand or snow, pellets and scat, or live wildlife sightings was assessed by assigning an action code (Table 8). In addition, all animal movements from snow surveys were cross referenced with the camera data to avoid duplication of information.

5.2 Wildlife crossing structures

5.2.1 Results

A total of 1,242,400 pictures were processed from cameras on Highway 69. Of these 87,106 or 7.0% were pictures of animals, and 5,080 independent wildlife interactions with mitigation measures were recorded. A total of 501,550 pictures were processed from cameras on Highway 11. Of these 33,319 or 6.6% were pictures of animals, and 1,815 independent large animal interactions with mitigation measures were recorded.

Small animals (139 occurrences) and birds (28 occurrences) were detected most at the reptile tunnels, and large animals were detected most at the overpass (Figure 16). There was almost an equivalent number of small animal occurrences (135) at all three underpass (Highway 11 and 69) as at the reptile tunnels. About half the number of large animals were present at the three underpasses when compared to the overpass (1479).

At the Wasi underpass two Great blue herons were captured. At the overpass and Highway 69 underpass Wild turkeys were observed. A Common Yellow-throat was observed at the overpass. Common birds at the reptile tunnels included Mallard duck, and Canada goose. Other less common species were the American bittern and Wood duck. Common small animals included raccoon, beaver, muskrat, otter, groundhog, rabbits and turtles (Snapping and turtle and Painted turtle). See additional bird and small animal species that were detected at the reptile tunnels during other monitoring assignments (Environmental Retainer 5013-E-0028, Reptile Monitoring Assignments 4 and 6).

Large- and mid-sized animals observed at the overpass included Red fox, coyote, wolf, deer, moose, bear, and a bobcat. Large animals observed at the underpasses on both Highway 69 and 11 and the reptile tunnels on Highway 69 were Red fox, coyote, moose, deer and Black bear.

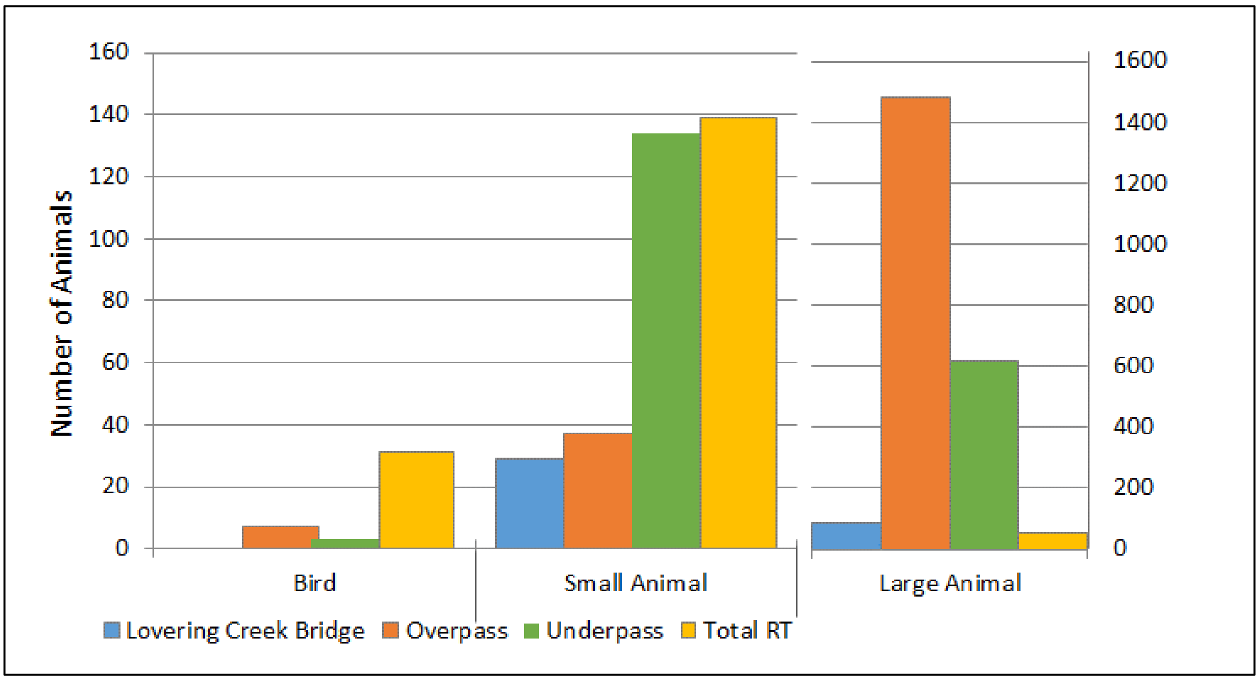


Figure 16: Number of animals grouped by bird, small animal, and large animal observed from camera monitoring at the crossing structures on Highway 69 and Highway 11

All wildlife use (cross + approach) at each of the seven types of wildlife crossings were grouped into one class and compared with repels (Table 9, Figure 17). Approach was grouped with cross and collectively termed 'wildlife use' because in all approach interactions the animal was clearly going onto or exiting the structure and was not seen turning away from the structure (in which case this would be documented as a repel). Note that the three reptile tunnels were grouped together for summary. Only large- and mid-sized animal use (Red fox; coyote; wolf; lynx; bobcat; Black bear, elk; moose; and deer) was summarized. Wildlife use is only summarized for the post-construction period from July 1st, 2012 to September 2016 with both camera and snow-tracking data collectively.

Passage rates were defined as use/(use + repel) and were calculated for each crossing structure for each species. Additionally, passage rates were evaluated at the overpass and underpass on Highway 69 for moose and deer for four complete years (September 1st, 2012 to August 31st, 2013…..September 1st, 2015 to Augusts 31st, 2016). These complete years was also used to define seasonal use. Seasons were defined as summer (June, July, August); fall (September, October, November); winter (December, January, February); and spring (March, April, May). Sex for deer and moose was only defined for the fall and summer months when antlers are clearly visible (male), or not (female) in the pictures.

Moose, deer, Black bear, wolves, coyotes, and Red fox all used the crossing structures at the two study sites combined. However, wolves were the least detected species and were not documented at the Highway 11 site. Few Black bears were documented at the Highway 11 site. Deer were detected the most and regularly used the wildlife overpass (Table 9).

Deer used the wildlife overpass 1028 times, comprising 69% of the total wildlife use on the overpass (Table 12, Figure 18). Moose were detected using the overpass 127 times followed by Black bear (114), Red fox (76), coyote (39), and wolves (18). Bobcats have not been documented on the overpass since construction was completed, though prior to construction, a bobcat was observed on the structure on one occasion. Other small mammals were observed using the structure 36 times, most of which were rabbits (23). Elk and lynx have not yet been detected on the structure, though lynx have been observed twice on the overpass access road.

There were very few repels at the overpass for all species (77 or 5.4%) and passage rates were lowest for coyote at 79% and highest for Red fox, moose and deer at approximately 95% (Table 10). Passage rates are highest at the overpass and creek bridge pathways where openness is highest (Table 10).Moose and deer passage rates declined from 100% to 90% over the four years of monitoring at the overpass (Figure 17). This decline is likely because deer were using the overpass more for grazing and entered onto the structure, grazed, then left the structure and this was defined as a repel.

Moose used the Highway 69 wildlife underpass the most (48 times) and also repelled from the structure an almost equivalent number of times (44 repels) (Table 9; Table 10). Deer repelled more times than using the structure, while Red fox and coyote were not documented as repelling from the structure. Of the eight Black bears that used the structure, only one repelled. Overall, the passage rate for all animals at the underpass was 0.57 and this was significantly less than passage on the overpass (Paired t-test; p-value = 0.004). Moose and deer passage rates increased at the underpass from 42% to 58% in the fourth year of monitoring (Figure 17).

Deer used Wasi underpass the most of all the underpasses (97 times), followed by Sundridge underpass (33 times), Highway 69 underpass (34 times), and the three reptile tunnels (2 times) (Figure 18, Figure 19, Table 9). The Wasi and Sundridge underpass were only monitored for approximately two years and deer observations were higher than at the underpass at Highway 69. This is likely indicative of deer abundance on Highway 11 at each study site rather than deer selecting for a particular crossing structure. Furthermore, at Highway 69, deer are selecting to use the overpass as opposed to the other nearby crossing structures.

Noticeably more deer approached the Wasi underpass in the summer months to browse on grasses and then turned around, and this is depicted by the high repel and ignore rates in Figure 19 (bottom). In the fall months both male and female deer used the Wasi underpass more when compared to summer use. Increased male use is likely attributed to the rut and both males and females moving to access resources prior to the winter season (Figure 20, top left, middle). Increased fall and summer movement has also been observed for deer at the overpass on Highway 69 (Eco-Kare International 2014; Eco-Kare International 2017).

Moose used the Highway 69 underpass the most of all the underpasses and again this is likely indicative of abundance of moose at each of the highway mitigation sites. Surprisingly five moose used the Sundridge underpass and of these one was a confirmed crossing. One moose approached and one crossed the Wasi underpass as confirmed by snow-tracking data (Table 9). Moose (male and female) used the overpass noticeably more in the fall than in the summer months (Figure 20, top right) and when all months were compared moose used the overpass more in the spring than other seasons (Figure 21).

Openness ratios (OR) were calculated for the underpass structures on both highways to better interpret passage rates (Table 10). In the case of all open median structures (with the exception of Sundridge underpass), the length of only one structure was used. Deer passage rate was highest at Wasi underpass (63%) followed by the Highway 69 underpass (49%), Sundridge underpass (39%), and the reptile tunnels (25%) (Table 10) and passage rates were somewhat correlated to the OR (Pearsons Coefficient = 0.57). Openness ratios was highest at Highway 69 underpass (1.79), followed by Wasi underpass (1.00) and passage rates were lowest at the reptile tunnels (0.39) and Sundridge (0.20) that both had the lowest OR (Table 10). Moose and deer passage rates increased from 42% to 58% over the four years of monitoring (Figure 17).

Passage rates at all underpass structures combined were highest for wolf (1.00), followed by Red fox (0.89), coyote (0.86), Black bear (0.69), deer (0.53) and moose (0.46, Table 10). Sample size for wolf was small (<5) and is not an accurate representation of passage rate. Overall Black bear and Red fox were the least hesitant to pass through the structures (>90% passage). Deer and coyote showed some hesitation (86% passage) followed by moose (71%). Interestingly, preliminary observations have shown that 12 Black bears that have approached the reptile tunnels, repelled half the time, as opposed to passage rates of 74% at the other structures (Table 10; Figure 18).

Snow-tracking information contributed to an additional 45 individuals using and 10 individuals repelling from the crossing structures (Table 9). Wolf use at the reptile tunnel and moose use at Wasi underpass was only documented with snow-tracking data. Five of six deer repels were confirmed at the reptile tunnels with snow-tracking data (Table 9).

Deer used the Wasi underpass primarily in summer and fall and seldom in the winter or spring (Figure 20, bottom) on Highway 11. Females used the Wasi structure the most and both males and females used the structure the most in the fall (Figure 20, top left). This was in contrast to the wildlife overpass where male and female deer used the overpass almost equally in summer and fall on Highway 69 (Figure 20, top middle). Additionally, females used the overpass more in the summer than the fall and males used the overpass more in the fall than in the summer (Figure 20, top middle).

Both female and male moose used the overpass and underpass on Highway 69 significantly more in the fall season when compared to summer (Figure 20, top right). When all seasons were evaluated, more moose were found on the overpass in the spring than during other seasons (Figure 21) and this was significant in the 2014 monitoring report (Eco-Kare International 2014). There was not a noticeable difference in male and female, or seasonal use at the Highway 69 underpass by deer likely due to low sample size.

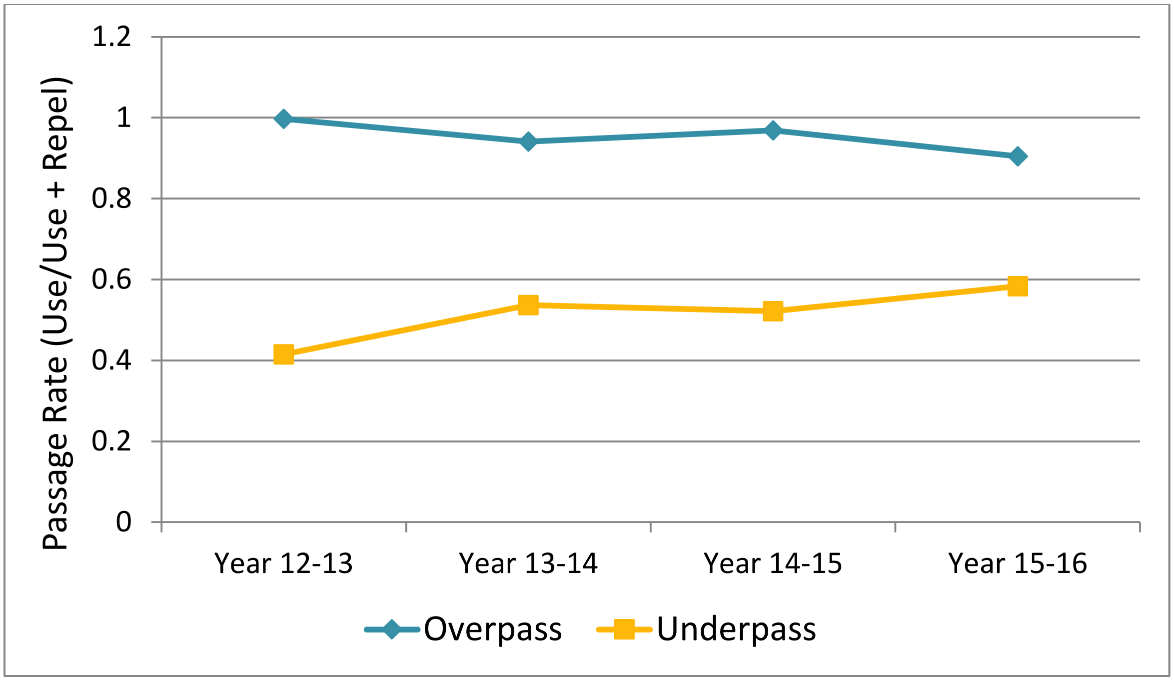


Figure 17: Passage rates for deer and moose over four years of post-construction monitoring at the overpass and large animal underpass on Highway 69. Each year is defined from September 1st to August 31st.

Table 9: A summary of camera and snow-tracking (red text) animal observations that used (cross and approach) the wildlife crossing structures on Highway 69 and 11

	Moose		Deer		Bear		Wolf		Coyote		Fox		Total	
	Use	Rep	Use	Rep	Use	Rep	Use	Rep	Use	Rep	Use	Rep	Use	Rep
Overpass	125+2	7	1025+3	46	114	6+1	13+2	2	39+3	10+1	76+6	4	1392+16	75+2
Underpass	44+4	43+1	30+4	35	8	1	0	0	2+2	0	10+2	0	94+12	79+1
Lovering Creek bridge	2	2	9	5	15	0	3	0	19+4	0	26	2	74+4	9
All Reptile Tunnel	3	3	2	1+5	5+1	6	0+1	0	20+2	6	7+4	0+1	37+8	16+6
Murdock River bridge	2	0	4	0	0	0	0	0	2	0	1	0	9	0
Wasi Underpass	0+2	4	96+1	57	1	0	0	0	21+1	0	0	0	118+4	61
Sundridge UP	5	16	33	51+1	3	1	0	0	1	2	18	4	60	74+1
Total	181+8	75+1	1199+8	195+6	146+1	14+1	16+3	2	104+12	18+1	138+12	10+1	1784+44	314+10

Table 10: A summary of passage rates (use/use + repel) at the wildlife crossing structures on Highway 11 and 69; underpass only includes the reptile tunnels with the large animal underpasses.

Structure	OR (height*width)/length	Moose	Deer	Bear	Wolf	Coyote	Red Fox	Total
Overpass	NA	0.95	0.96	0.94	0.88	0.79	0.95	0.95
Hwy 69 UP	(5 x 5)/14=1.79 (open median)	0.52	0.49	0.89	NA	1.00	1.00	0.57
Lovering Creek bridge	NA	0.50	0.64	1.00	1.00	1.00	0.93	0.90
All Reptile Tunnel	(3.3 x 2.8)/24=0.39 (open median)	0.50	0.25	0.50	1.00	0.79	0.92	0.63
Murdock River	NA	1.00	1.00	NA	NA	1.00	1.00	1.00
Wasi UP	(4 x 4)/16=1.00 (open median)	0.33	0.63	1.00	NA	1.00	NA	0.67
Sundridge UP	(4 x 4)/82=0.20 (closed median)	0.24	0.39	0.75	NA	0.33	0.82	0.44
Total		0.71	0.86	0.91	0.90	0.86	0.93	0.85
Underpass Only		0.46	0.53	0.69	1.00	0.86	0.89	0.58

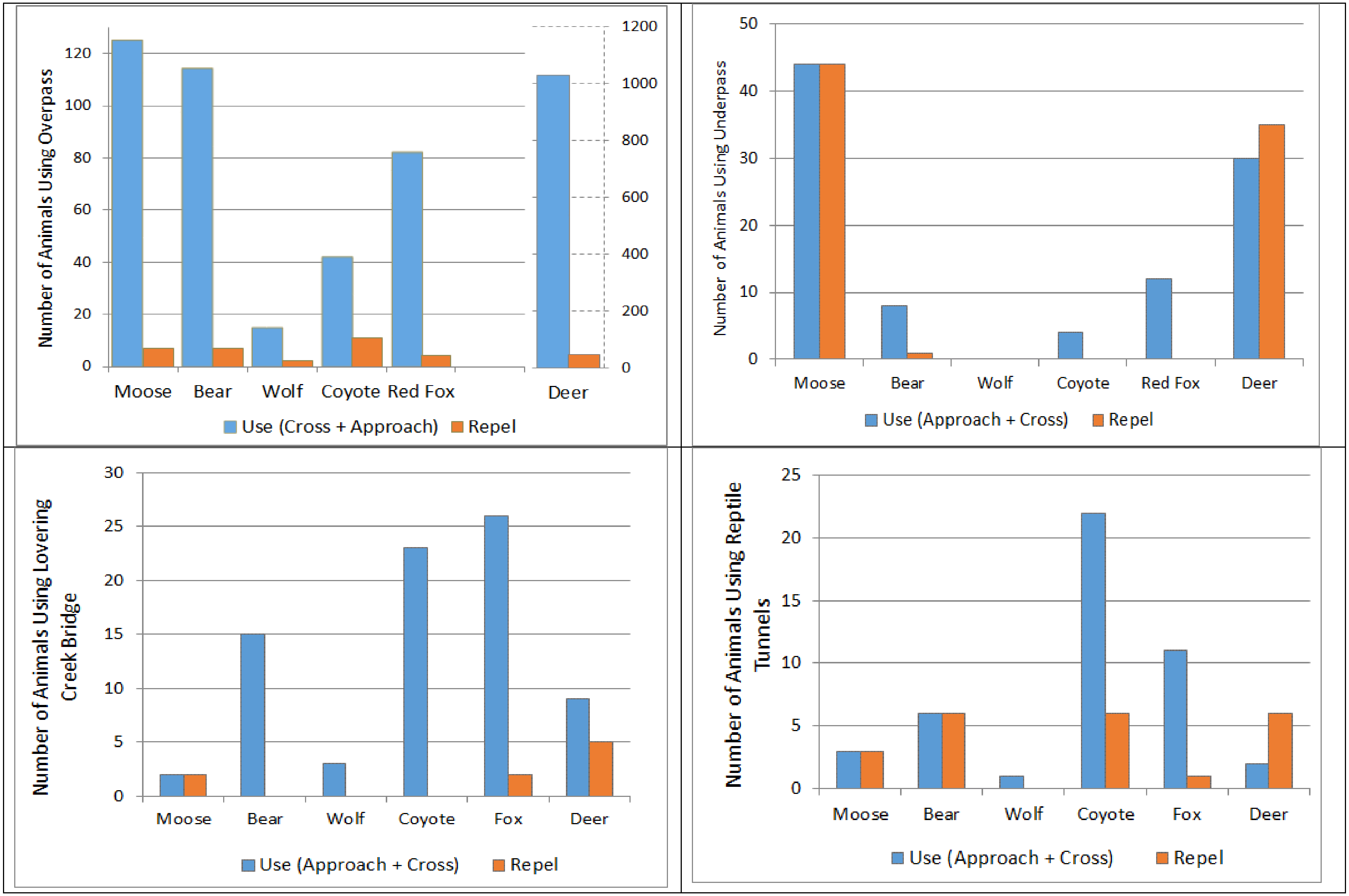


Figure 18: Summaries of the number of animals using and repelling from the crossing structures on Highway 69.

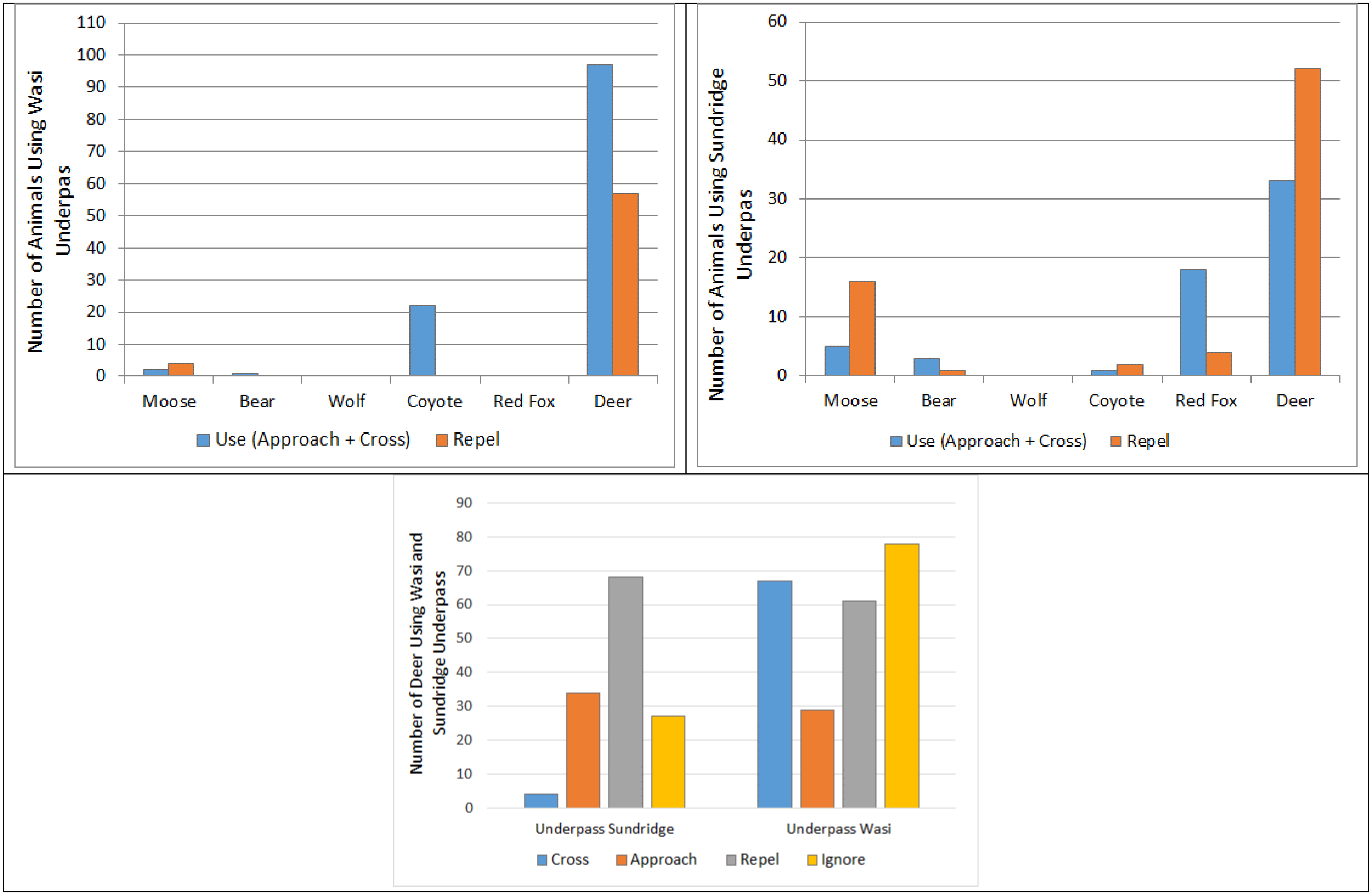


Figure 19: Summaries of the number of animals repelling, ignoring, approaching, and crossing from the crossing structures on Highway 11. Bottom summary only includes Deer and Moose.

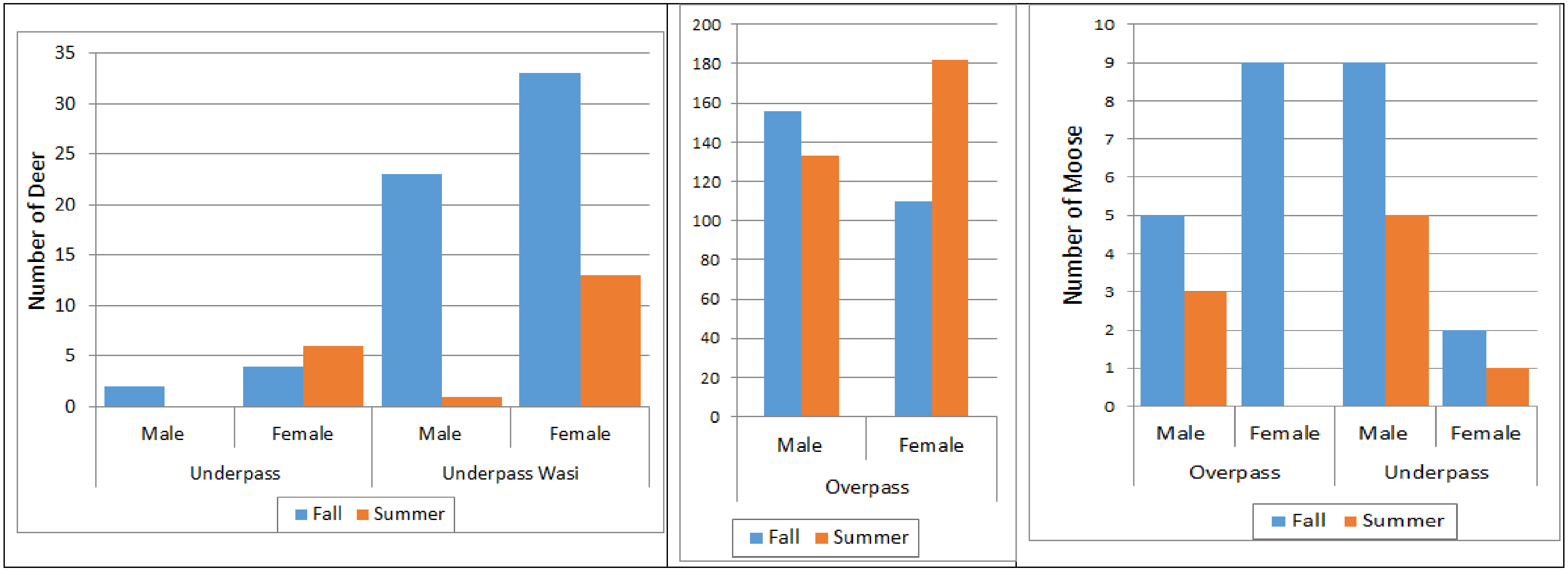


Figure 20: Seasonal use (cross and approach) at the Highway 69 overpass, underpass and Wasi underpass for deer and moose only by sex. Sex determined from photos in fall and winter seasons only.

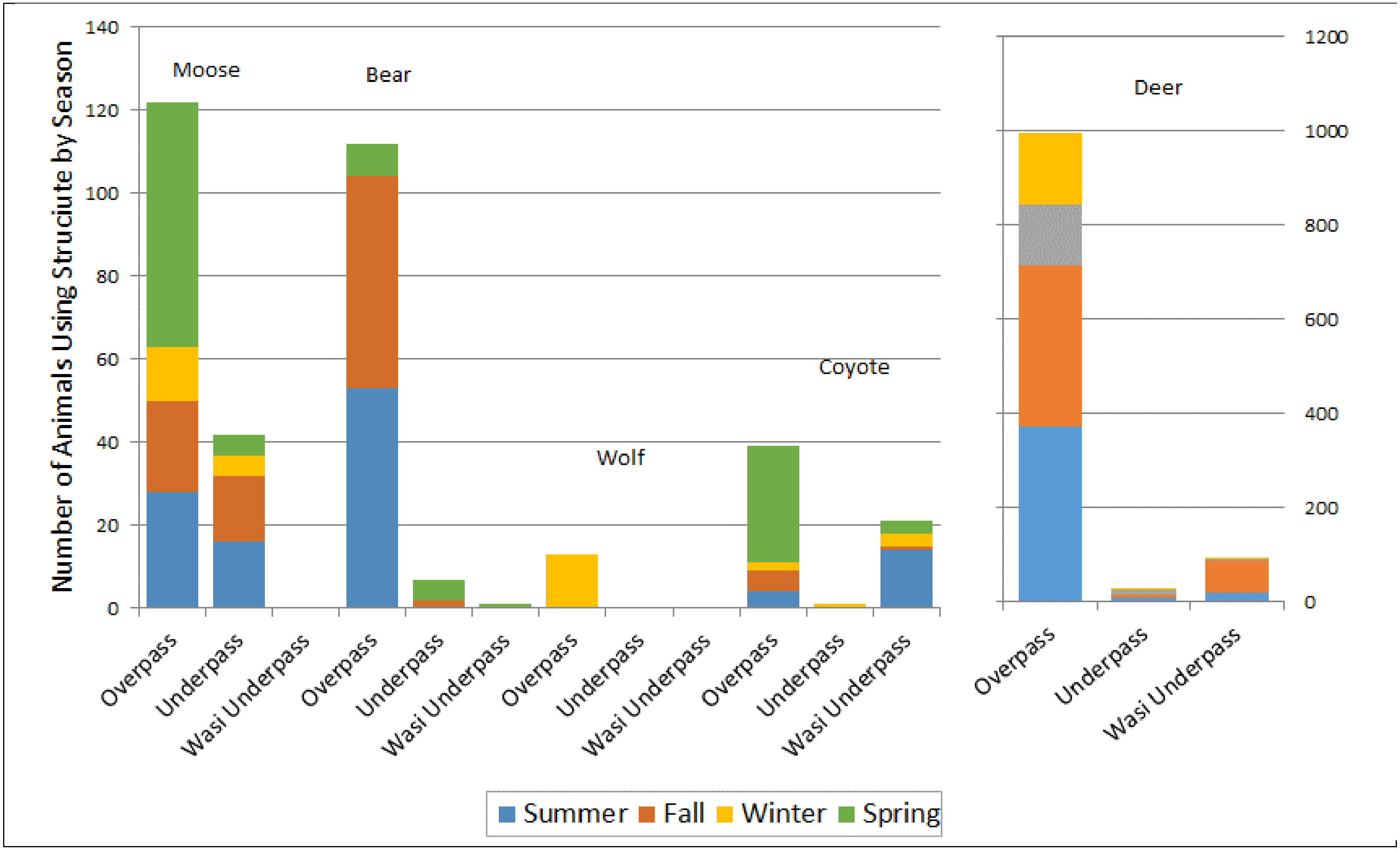


Figure 21: Seasonal use (cross and approach) at the Highway 69 overpass, underpass and Wasi underpass for each species.

5.2.2 Discussion

Combining underpass structures with varying structural characteristics at the two highways and standardizing the willingness of deer to use each structure by calculating passage rates was an informative comparison. Deer passage rate was highest at the Highway 11 Wasi underpass and not the more open Highway 69 underpass. This may because the presence of ground forage (grass and other herbaceous vegetation) for deer at the Wasi underpass may have first attracted deer to the structure and the animals were then more relaxed to continue through the structure.

Deer use was highest at the Highway 11 Wasi underpass even though it was only monitored for two years as opposed to five years at the Highway 69 underpass. This was likely due to higher deer abundance at Highway 11. This is indicated in higher WVC rate per year at the Wasi section of Highway 11 (1.45 WVC per km per year) as compared to a WVC rate of 0.72 along the old Highway section adjacent to the new alignment on Highway 69 (MTO Wildlife Mitigation Program Analysis and Tools Report, 2015). In addition, the presence of forage at the Wasi underpass entrances attract deer to the structures, and fewer deer likely used the Highway 69 underpass because they selected for the nearby overpass that had increased openness and forage.

This study found that White-tailed deer passage rates ranged from 90-100% and 40-60% at the Highway 69 overpass and underpass respectively. Passage rates are similar to that found in Nevada by Simpson et al. (2016). This study found passage rates at two overpasses ranged from 89-98% and from 23-86% at three underpasses that were similar in structure (Cylindrical: 8 m W x 6 m H x 28 m long). Both studies also found that passage rates increased at the underpass with each subsequent year.

Higher frequency of use of Wasi underpass by both males and females in the fall indicate the structure is located in an important movement corridor. However, because this increased use is not seen again in the spring, similar to what was found for Mule deer use of underpass structures in Nevada (Simpson et al. 2016), it is more likely that higher fall use by deer is in search of mates and food resources prior to the onset of winter.

5.3 Jump-outs

Of the larger animals the jump-outs were used by deer (39 times), Black bear (1 time) and Red fox (4 times). Deer primarily (26 times) used the jump-outs at the Callander section compared to the Sundridge section (1 time). Deer also used the jump-outs at Callander to breach the fence 30% of the time. Two deer were found using the jump-outs in Sundridge during snow-tracking surveys (Figure 22 and Table 11). The first deer used the jump-out as intended and another attempted to jump up to the earthern concrete block and got stuck in between the wildlife fence and block structure, where the deer carcass was found (Photo 57). There were many more deer observed road-side of the jump-outs at the Callander section than the Sundridge section and on 33 occasions deer walked to the edge of the jump-out, looked over, but did not use the structure (repel, Table 11).

Recent research in Montana has also shown that use of 1.82-2.13 m high jump-outs by white-tailed deer was very low (about 7 percent use to access the safe side of the wildlife fence) as opposed to Mule deer at 32% (Huijser et al. 2016a). In addition, research in Kootenay National Park has also shown reluctance of use of jump-outs with excavated pits by White-tailed deer (T. Kinley, Parks Canada, email communication, July 28th, 2016).

Likely explanations for lack of deer use at the Sundridge jump-outs that are shorter (1.8 m) than at Callander (2.4 m) are two-fold. First there are fewer deer road-side of the fence at Sundridge mitigation section (13 observations) when compared to the Callander section (91 observations). Second, the jump-outs at Sundridge do not have an earthen ramp that span entirely around the base of the structure (Photo 52**)**. As a result, several deer were documented following the fence line to the structure and turning around because the concrete blocks posed a barrier to movement (Photo 54).

Snow monitoring surveys did not supplement the usage of jump-outs as expected, mainly because there was little wildlife use and movement in the winter months. However, there were several interesting observations during snow-tracking surveys. First, on one occasion deer were tracked using a jump-out to access the ROW to feed on sumac. In addition, during snow surveys a deer carcass was found between the fence and jump-out structure.

Table 11: A summary of Deer interactions with Jump-outs at Callander, and Sundridge mitigated sections on Highway 11 from July 2014 to June 2016. Red counts are generated from snow-tracking data.

Site	Jump-out use		# Repel	# Approach	# Ignore	Total
	Road-side to Safe-side (Right way)	Safe-side to Road-side (Wrong way)	Road-side			
Callander	26	11	33	27	29 + 2	128
Sundridge	1	1	1	1	9 + 2	15
Total	27	12	34	28	42	143

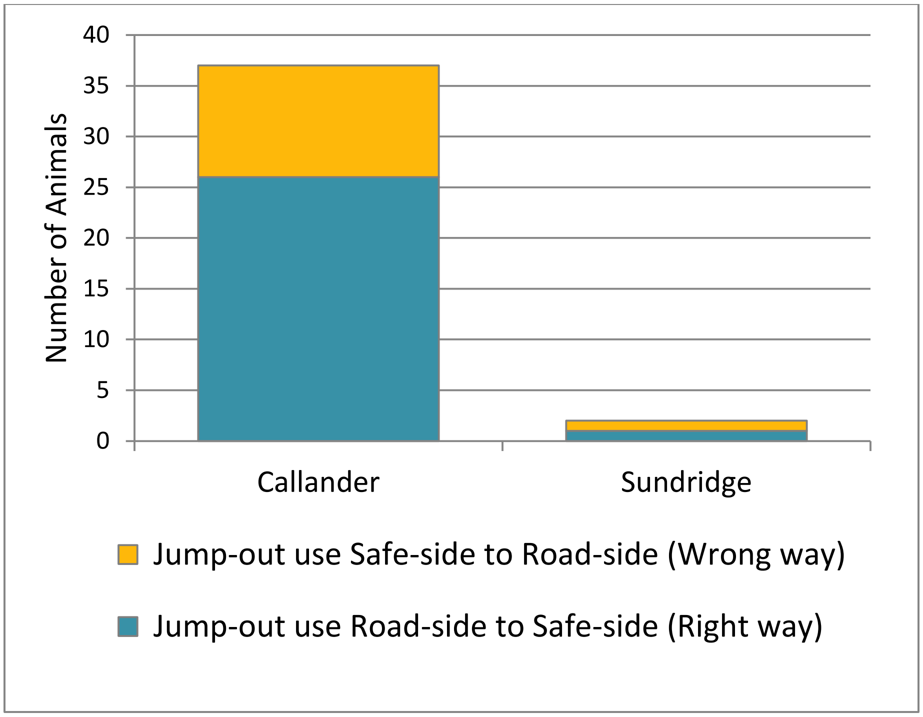


Figure 22: Overview of wildlife use of jump-outs the wrong way (safe-side to road-side) and the right way (road-side to safe-side) at Callander and Sundridge mitigated sections over a two year monitoring period.

5.4 One – way gates

Wildlife use of one-way gates was compiled from September 2011 to September 2016 on Highway 69. One-way gate use was not summarized on Highway 11 because previous monitoring from July 2014 to July 2015 (Environmental Retainer 5013-E-0028, Assignment 1) showed minimal use and inadequate design of gates at the Sundridge section. The prongs are not springing back to position and there are noticeable deer size gaps in the gates that allow deer passage in both directions (Photo 45; Photo 47). It is recommended to fix the gates or close-off the gate so deer cannot access the highway ROW.

On Highway 69, there were 27 passages through the one-way gates road-side to safe-side and Black bear (20 passages) used the gates as intended the most followed by Red fox (9), deer (4), and coyote (3) (Figure 23). All animals (Black bear, lynx, coyote, and Red fox) with the exception of deer, used the gates the wrong way, and Red fox equally traversed through the gates in both directions, while Black bear used the gate as intended more than not as intended. Snow-tracking data supplemented the camera data with nine additional crosses recorded (Table 12).

The number of approaches (74 road-side) and repels (26 road-side) by deer as compared to other animals suggest that deer are interested in using the one-way gates, however are either not accustomed to the five year old structures or are unwilling to use them (Table 12). Design modification are recommended by moving the gates inwards in a v pattern to funnel deer to the opening. Jump-outs show more promise for providing escape measures and design such as that found at Highway 93S in Banff National Park are recommended at new highway mitigation projects (See Section 6.3).

Table 12: A summary of animal interactions (approach, passage and repel) with one-way gates on Highway 69 from July 2015 to June 2016. Red text is additional passages obtained from snow-tracking surveys.

	Approach (Road-side)	Approach (Safe-side)	Passage (Safe-side to Road-side)	Passage (Road-side to Safe-side)	Repel (Road-side)	Repel (Safe-side)	Total
Moose	4	27	0	0	0	3	34
Elk	1	6	0	0	0	0	7
Deer	74	25	0	3+1	26	17	146
Black Bear	8	4	3	10	1	1	27
Lynx	0	0	2	0	0	0	2
Coyote	0	0	1	3	0	0	4
Red Fox	5	2	6+3	8+1	2	0	27
Total	92	64	15	26	29	21	247

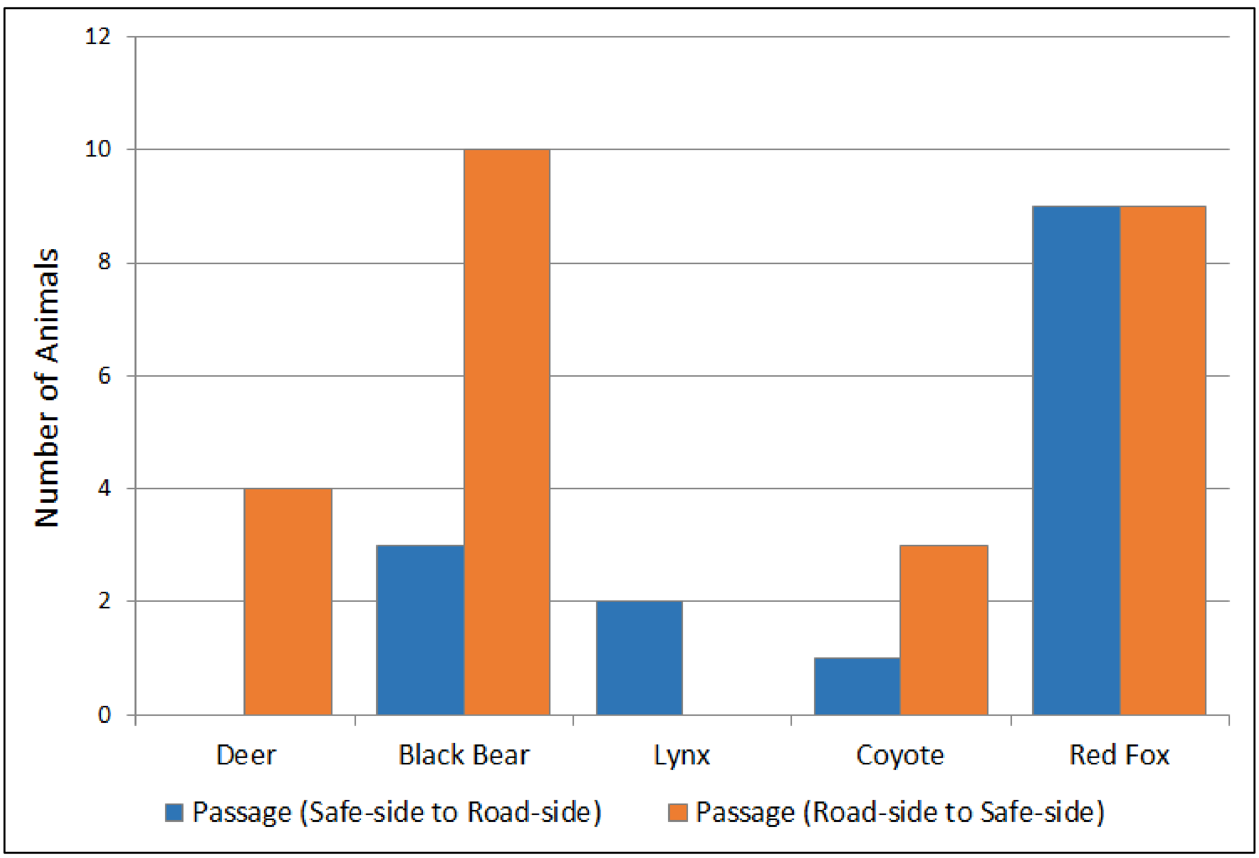


Figure 23: A summary of one-way gate use from the road-side and safe-side on Highway 69 (includes both snow-tacking and cameras data)

5.5 Fence-ends

Fence-ends exist at mitigated section ends and also within mitigated sections at road intersections or intentional fence gaps. A description of the fence-end in relation to the surrounding terrain and its position relative to the highway is collectively termed a fence tie-in (Figure 24).

Generally, the objective of an effective fence tie-in for wildlife is to create a circumstance that discourages an animal from accessing the highway when the animal has followed the fence to a fence-end. Fence-ends were evaluated based on the relationship between the characteristics of the tie-in and deer observations (snow-tracking and camera monitoring). Fence-ends were excluded when the fence tied directly into a structure such as a sheer cliff or structure abutment in such a manner that passage of large mammals was impossible. This is the most effective style of tie-in and should be used whenever possible.

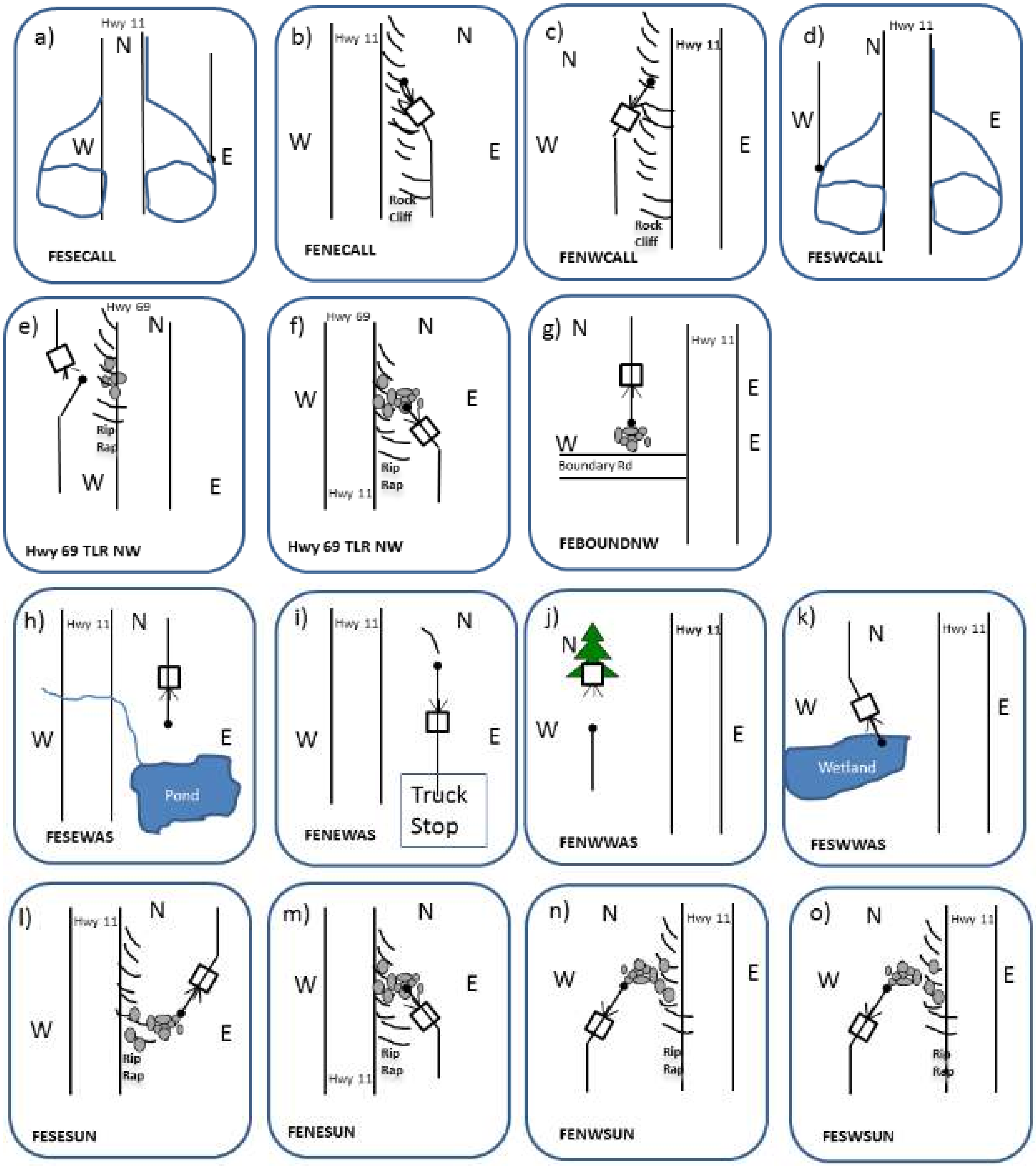


Figure 24. Configuration of fence-ends at the mitigated sections of Wasi, Callander, Sundridge, and Highway 69. Fence-ends at intersections or gaps not included however Boundary Road fence end at NW intersection included as example. Highway 69 southernmost fence-ends were not included because abut Lovering Creek bridge structure.

5.5.1 Statistical analysis:

Fence-ends were classified based on the presence or absence of five characteristics (independent variables): artificial rock pile (*rock pile*), rip-rap at fence-end (*rip rap*), fence-end at top of rock cliff (*cliff top)*, an additional section of fencing that extended towards the highway (*fence extension*), and rock or grass substrate at fence-end (*substrate*). Next fence-ends were classified into low (Photo 35), moderate (Photo 31) and steep slope (Photo 40) relative to the highway (*slope*; Appendix I).

Independent estimates of deer presence or absence (dependent variable) at the fence-ends were based on the observation of deer through the use of the camera and snow-tracking monitoring. As the two monitoring methods represent different sampling periods with snow-tracking limited to the winter months, and camera monitoring taking at varying times of the year, the two estimates of deer presence were analysed separately. In order to account for varying sampling intensity, deer presence was standardized by monitoring days. Sampling effort was equal using snow-tracking data.

A logistic regression test was used to evaluate the relationship between the probability of a deer being present at a fence-end and the characteristics of the fence-end tie-in for both snow-tracking and camera observations. The odds ratio was used to determine the change in probability of deer presence with each independent fence-end characteristic while all other characteristics were held constant. For example, this would be used to evaluate the probability of deer presence at a fence-end if a rock pile was added when all other characteristics were unchanged. Finally, a likelihood ratio test was used to test how well the model fit the data. The full model was as follows:

Deer presence ~ rock pile + rip rap + cliff top + fence extension + slope + substrate

5.5.2 Results

Based on the camera monitoring, deer were present at 19 of 26 fence-ends (73.1%) (Appendix I). A full model was not possible using camera monitoring to evaluate all fence tie-in characteristics with deer presence due to quasi-complete separation of the dependent variable (deer presence or absence). Separation occurs when a single independent variable is influencing the dependent variable. Excluding slope from the model removed this issue: however, there were still concerns with extremely large standard errors for both cliff top and fence extensions.

When the relationship between deer presence (camera data) and the individual fence-end characteristics were tested, only cliff-top performed well (Likelihood Ratio Test, $\chi^2 = 5.585042$, df = 1, $p = 0.018$). Deer were 94.1% more likely to be present when a fence-end was not on-top of a cliff (deer present at 17 of 20 fence-ends not on cliff) than when the fence-end was on a cliff (present at 1 of 4 cliff top fence-ends).

Snow-tracking detected deer at 12 of 33 fence-ends (Appendix I). There were no statistical concerns but the full model was not significant ($\chi^2 = 10.3046$, df = 7, $p = 0.172$). Of the individual fence-end characteristics, substrate influenced deer presence the most (Likelihood Ratio Test, $\chi^2 = 5.25896$, df = 1, $p = 0.022$). Deer were 83.2% more likely to be present at a fence end when the substrate is grass (present at 7 of 11 grass fence-ends) than when the substrate is rock (present at 5 of 22 rock fence-ends).

6 Overall Discussion and Recommendations

6.1 Crossing structures and fencing

At the Callander mitigated section, the adjacent terrain is rugged with rocky slopes, and road intersections are below grade. This configuration facilitates placement of fence-end tie-ins below Highway 11 or at a sheer or rugged rock interface that impose a barrier for deer access to the ROW. This opportunity is not the case at the southernmost fence-end at Lake Nobonsing Road and a fence-end modification is required to improve effectiveness of the mitigated section. A 50-100 m fence extension into the forest at Lake Nobonsing Road, may reduce deer access to the ROW. However, a better solution would be a fence extension to Watson Road at the Wasi mitigated section with a fence extension away from the highway. Ungulate guards, improved fence tie-ins and or electrro-mats need to be integrated at the road interchanges.

Overall, the Highway 69 mitigated section is most effective at reducing both deer- and moose-vehicle collisions. Improvements to reduce bear collisions include the use of a buried apron especially where there is a gap between the bottom of the fence and the ground. One-way gates should be closed off because the existing design has minimal value for deer use, and bear and other animals are travelling the wrong way onto the highway. Future modifications to one-way gate design are warranted that entail an inward offset of gates from the fence line so animals are funneled to the opening. Closure of the gap just south of the Killarney interchange, and improved tie-ins at fence ends at the Killarney interchange, and at the north-west tie-in at Trout Lake Road will also reduce breaches by bears and other animals.

Overpasses should be considered as the most optimal multi-species structure for large and small animals on MTO highways. However, when placed properly, more open wildlife underpasses are important complementary structures for providing connectivity for ungulates, namely moose and deer in this study. Specifications at tunnel entrances is recommended to be at least 4 m x 4 m with open median based on this research and a literature review (Retainer Assignment 5015-E-0017, Assignment 7). The reptile tunnels showed little connectivity for ungulates, however these structures are adjacent to wetland habitat and varying water levels and ice are likely influencing ungulate passage more than a lack of openness. A multi-variate analysis that evaluates wildlife use of crossing structures of varying landscape and structural features is recommended when monitoring is concluded.

6.2 Fence ends

It was clear in the fence-end monitoring that deer did not navigate the fence-ends and hence access the ROW, where they abutted steep rocky highway slopes, with rock pile treatments.

This was apparent when comparing the few fence breaches at the Sundridge section fence-ends with Wasi where the fence-ends were at grade with the highway and placed at natural landscape conditions. Fence-ends at vegetated habitat on both sides of the fence attract deer to this location and encourage deer to breach the system and access the highway ROW. Further, fence-ends within forest cover, e.g. the north-west fence end at Wasi, should be avoided because they buffer highway noise and provide deer with a secure location where they can access the ROW and cross the highway.

6.3 Escape structures

Little monitoring is available for one-way gates in other road mitigation projects and research conducted has shown gates have limited wildlife use. Bissonnette and Hammer (2000) found that Mule deer were 8-11 x more likely to use jump-outs than one-way gates. One-way gates can easily be navigated by mid-sized animals such as lynx and agile animals such as Black bears allowing access to the ROW not as intended (Eco-Kare International 2014).

If one-way gates are considered in future projects than design modifications may improve successful passages at future mitigated sections. These include constructing an outrigger fence extension perpendicular to the fence that will funnel animals into the gate (Photo 78). Similar to this idea is to construct gates in a V design so that animals moving along the fence are funneled into the gate (Photo 79). To deter Black bear wrong-way use, prongs could be spaced closer together.

Design modifications include creating a ramp that is accessible for wildlife as they approach the jump-out from along the fenced ROW, similar to the Callander Jump-outs. Another design that has worked well on Highway 93S in Kootenay National Park, entails excavating the earth on the safe-side of the fence so animals will jump down from the road-side (Photo 58). Unpublished results have shown that initially White-tailed deer do not use the jump-outs the wrong way to access the highway, and deer used the structures as well as one moose and a Grizzly bear (T. Kinley, Parks Canada, email communication, July 28th, 2016).

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Appendix A Acronyms

AADTV	Annual Average Daily Traffic Volume
JO	Jump-out
LHRS	Linear Highway Referencing System
MTO	Ministry of Transportation
NER	Northeastern Region
OPP	Ontario Provincial Police
OR	Openness Ratio
OW gate	One-way Gate
ROW	Right-of-Way
UP	Underpass
WDS	Wildlife Detection System
WVC	Wildlife-Vehicle Collision(s)

Appendix B Photo library

A picture inventory of structures, and wildlife interactions was compiled for highway 11 and 69 and are organized by mitigation section.

Appendix B.1 Callander

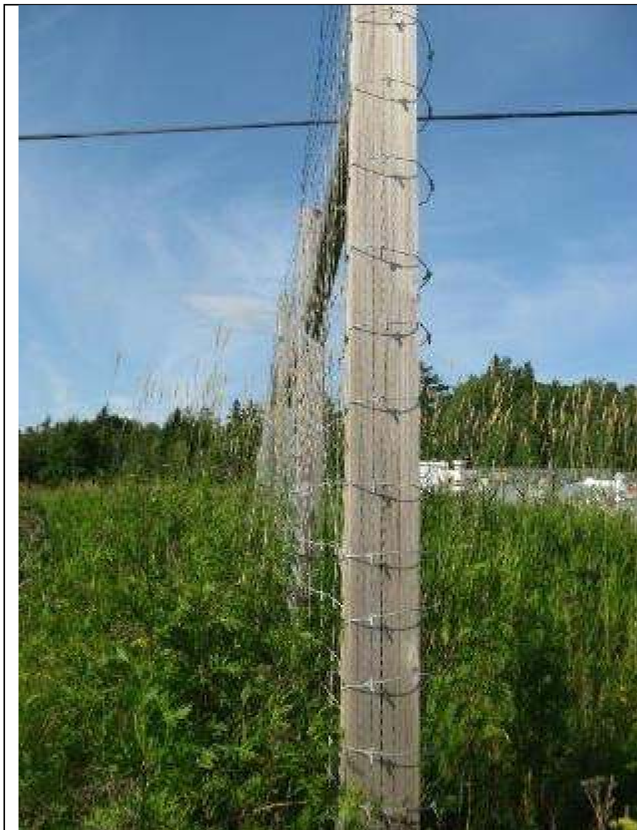


Photo 1:SE fence end at Callander

Photo 2:Fence at Callander with three top wires

Photo 3: Single one-way gate at Callander (first generation), 17 July 2014

Photo 4: Paired one-way gate at Callander (second generation), 17 July 2014

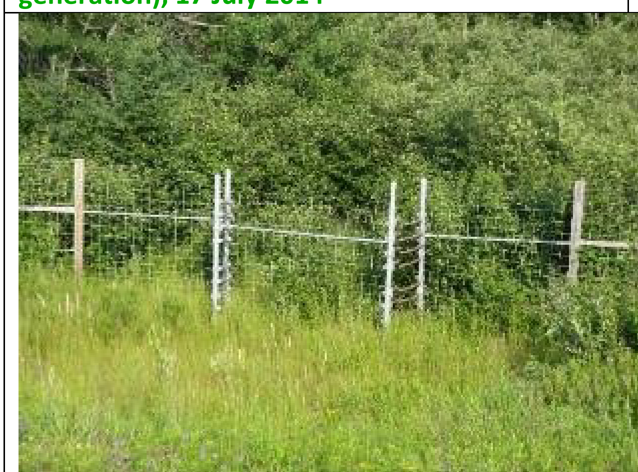


Photo 5: Paired one-way gates at Callander (OWE1CALL), 17 July 2014

Photo 6: One-way gate camera placement (OWW2CALL), 18 July 2014

Photo 7: Road-side view of jump-out at Callander, note sloped ramp at all angles (JOW7CALL), 17 July 2014

Photo 8: Road-side view of jump-out at Callander with overgrown vegetation (JOE1CALL), 17 July 2014

Photo 9: Deer using jump-out safe-side to road-side (JOE5CALL), 20 November 2014

Photo 10: Deer using jump-out road-side to safe-side (JOE1CALL), 8 August 2014

Photo 11: Deer using jump-out (JOW2CALL), 9 April 2014

Photo 12: Deer using jump-out (JOW2CALL), 9 April 2014

	
Photo 13: First Deer using JO (JOW2CALL), 14 March 2014	**Photo 14: Second Deer using JO (JOW2CALL), 14 March 2014**
	
Photo 15: Deer approach jump out from safe-side at(JOW2CALL), 13 March 2016	**Photo 16: Deer breech-toward (FESWMOUNT2), 30 April 2016**
	
Photo 17: Deer repel or jump (JOW2CALL), 15 March 2016	**Photo 18: Deer breech-away (FESWMOUNT2), 5 May 2016**

	
Photo 19: Fawn deer breech away (FESWMOUNT2), 23 May 2016	

Appendix B.2 Wasi

	
Photo 20: Picture of camera on tree pointing at fence end (FENWWAS)	**Photo 21:** View from behind camera showing creek and vegetated cover at fence end (FENWWAS)
	
Photo 22: Deer tracks on road-side of exclusion fencing	**Photo 23:** View of the middle of the underpass at Wasi

Photo 24: Moose and calf enter Wasi underpass but eventually repel, 23 June 2014

Photo 25: Deer turning around at east entrance of Wasi Underpass, 8 June 2014

Photo 26: Camera view of the middle of the Wasi underpass

Photo 27: Camera mounted on the north side in the middle of the Wasi underpass (UPMNWAS)

Photo 28: Moose entering and turning around at Wasi Underpass, 2 August 2014

Photo 29:Deer walking towards middle of Wasi underpass; and repelled (UPMSWAS), 25 July 2014

Photo 30: Deer walking through middle of Wasi underpass (UPMNWAS), 12 October 2014

Appendix B.3 Sundridge

Photo 31: Rock pile treatment and steep slope at Sundridge (FENWSUN)

Photo 32: Rock pile treatment and steep slope at Sundridge (FENWSUN)

Photo 33: Highway view of rock pile treatment and steep slope at Sundridge (FENESUN)

Photo 34: Camera view of rock pile treatment and steep slope in snow at Sundridge (FENESUN)

Photo 35: Highway view of rock pile treatment and moderate slope at Sundridge (FEBOUND1)

Photo 36: Camera view of rock pile treatment and moderate slope at Sundridge (FEBOUND1)

Photo 37: Highway view of rock pile treatment and moderate slope (FEBOUND1)

Photo 38: Deer and fawn going around FEBOUND1, 7 October 2014

Photo 39: Rock pile and steep slope at fence end in snow (FESESUN)

Photo 40: Highway view of rock pile and steep slope at Sundridge (FESESUN)

Photo 41: Deer going over rock pile at FESESUN. 31 March 2014

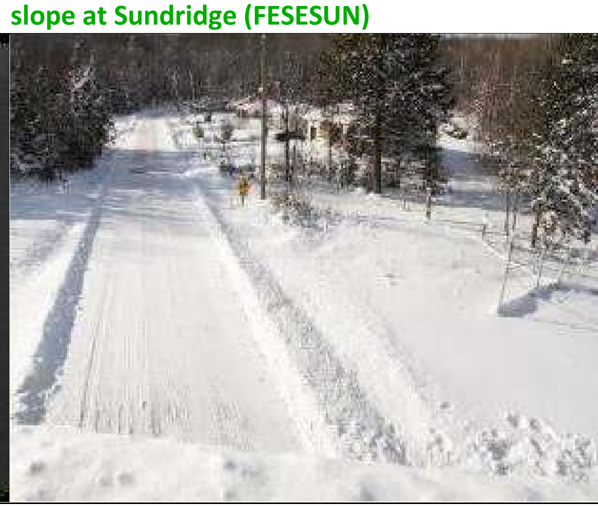


Photo 42: Below grade Adams Road fence end; 21 November 2014

	
Photo 43:Above-grade Hill Valley Road fence end, 21 November 2014	
	
Photo 44: One-way gate with bottom apron	**Photo 45: Zoom in of one-way gate at Sundridge with prongs open (OWW18SUN)**

Photo 46: Paired one-way gate and jump-out (OWW4SUN)

Photo 47: Deer using one-way gate safe-side to road-side (OWW18SUN), 30 Oct-2014

Photo 48: Deer using one-way gate road-side to safe-side (OWW22SUN), 29 August 2014

Photo 49: Deer moving through one-way gate back to safe-side (OWW12SUN) ,21 Nov-14

Photo 50. Jump-out top view (JOW22SUN)

Photo 51. Zoom-in of Jump-out top view (JOW19SUN)

Photo 52. Jump-out side view at Sundridge with no ramp for Deer to access along fence

Photo 53. Gap between fence and concrete blocks

Photo 54. Deer approaching jump-out and turning around (JOW18SUN), 9 September 2014

Photo 55. Safe-side of Jump-out at Sundridge

Photo 56. Turkey using jump-out (JO22WSUN), 18 July 2014

Photo 57. Deer carcass found during snow-tracking at JOE16SUN, 14 January 2015

Photo 58: Jump-out along Highway 93S in Kootenay National Park, 7 Aug 15.

Photo 59. Deer exiting joint use underpass 8 minutes later, 25 June 2014 (UPESUN)

Photo 60. Fisher at the east entrance of the joint use underpass, 1 April 2014

Photo 61. Young moose entering underpass (UPESUN), 25 May 2016

Photo 62. Young moose turning around at underpass (UPESUN), 25 May 2016

Photo 63. large canid breach toward(FENWSUN), 13 March 2016

Photo 64:Bull Moose Walking around fence end (FENWSUN), 29 May 2015

Photo 65: Deer jumping rock pile at fence end (FEBOUNDSE), 29 April 2016

Photo 66:Deer walking around fence end (FESWADAM), 01 May 2016

Photo 67: Deer walking around Fence (FEBOUNDNE), 04 July 2015

Appendix B.4 Highway 69

Photo 68:Overpass

Photo 69:Overpass west approach

Photo 70: Underpass with access road approach, 22 April 2012

Photo 71: Underpass with open middle in winter

Photo 72: Lovering Creek bridge showing wildlife path

Photo 73: Top view of the east approach to the wildlife path

Photo 74: Wildlife path along Murdock SE entrance

Photo 75: Top view of the east approach to the wildlife path

Photo 76: Wildlife path along Murdock Crossing north side

Photo 77: Murdock River Crossing NE approach

Photo 78: One-way gate with perpendicular deflection extension to funnel animals to one-way gate, 17 May 2015.

Photo 79: One-way gate installed in a V design on Highway 69

Photo 80: Two Sandhill cranes at UP access road, 20 Aug 2016

Photo 81: Black bear at underpass access road, 4 Sept 2016

Photo 82: Moose travelling on access road, 3 May 2016

Photo 83: Female adult deer and fawn on underpass access road, 6 Jun 2016

Photo 84: Bull Moose, UP access road, 2 Jul-16

Photo 85: Moose crossing (MRNE), 26 Mar-16

Photo 86: Deer entering MRNE,14 Jun 2016

Photo 87: Moose exiting MRNW, 26 Mar 2016

Photo 88: Camera view at MRNW,22 Feb 2016

Photo 89: Black bear on ledge at east approach at Lovering Creek bridge, 10 Aug 16

Photo 90: Deer walking inside of fence at one-way gate, 31 May 2016

Photo 91: Bears using one-way gate wrong way on 17 Aug 2016

Photo 92: Black bear breech toward Kill South fence end, 12 May 2016

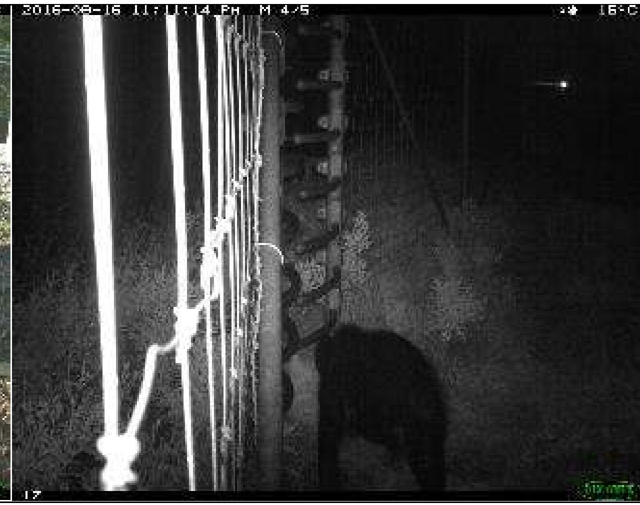


Photo 93: Black Bear uses o-way gate at one-way gate east 11, 16 Aug 2016

Photo 94: Bear wrong way at OWG, 28 Jul 16

Photo 95: Moose approach OWE2 from inside

Photo 96: Doe with fawn in UP median, 03 Sep-16

Photo 97: Doe with fawn turning around at underpass, 09 Jul-16

Photo 98: Moose hesitating at UP but eventually crossing the underpass, 01 Jun 2016

Photo 99: Doe deer repelling at underpass, 19 Jul 2016

Photo 100: Adult and Fawn enter UP, 27 Jul 16

Photo 101: Adult & fawn repel at UP, 27 Jul 16

Photo 102: Three coyotes on access road at tree at overpass, 05 May 2016

Photo 103: Fox exiting overpass, 25 May 2016

Photo 104: Bull Moose entering overpass, 29 May 2016

Photo 105: Doe with fawn exiting overpass, 07 Aug 2016

Photo 106: Bear approaching OP, 13 Jun 16

Photo 107: Moose using overpass, 24 April 16

Photo 108: Cow Moose exiting overpass, 29 May 2016

Photo 109: Cow moose exiting OP, 19 May 2016

Photo 110: Bear and cubs at E OP,12 Sep 16

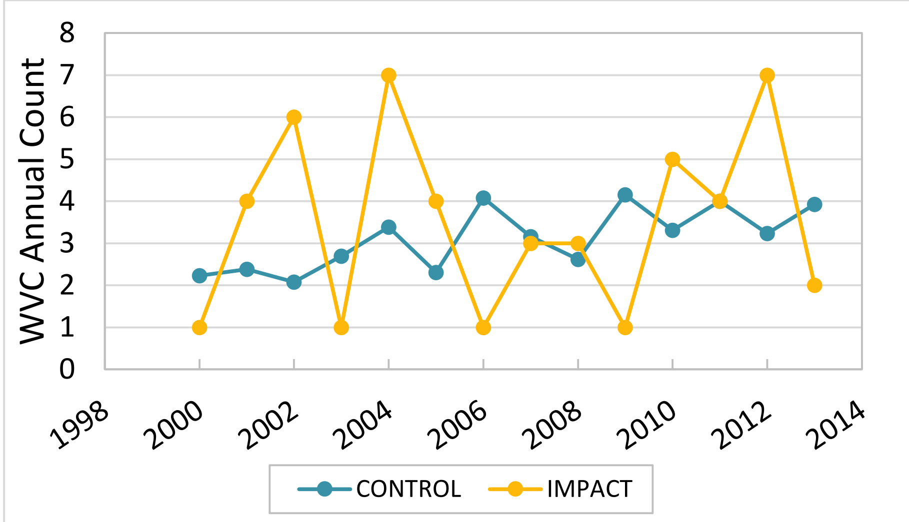
Photo 111: Two fawns & adult at OP, 21 Aug-16

Photo 112: Calf moose entering overpass, 26 Jun 2016

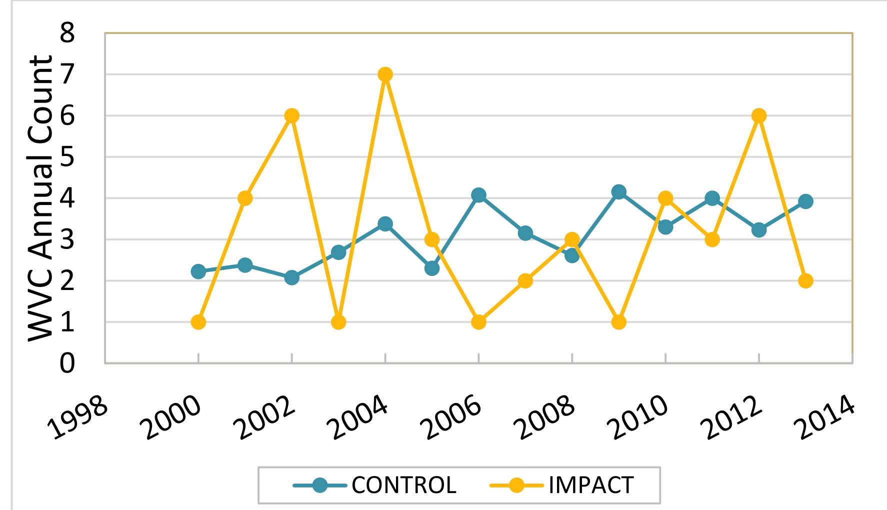
Photo 113: Adult bear with cub entering overpass, 20 Aug 16

Photo 114: Common Yellow throat on Overpass, 15 July 2016

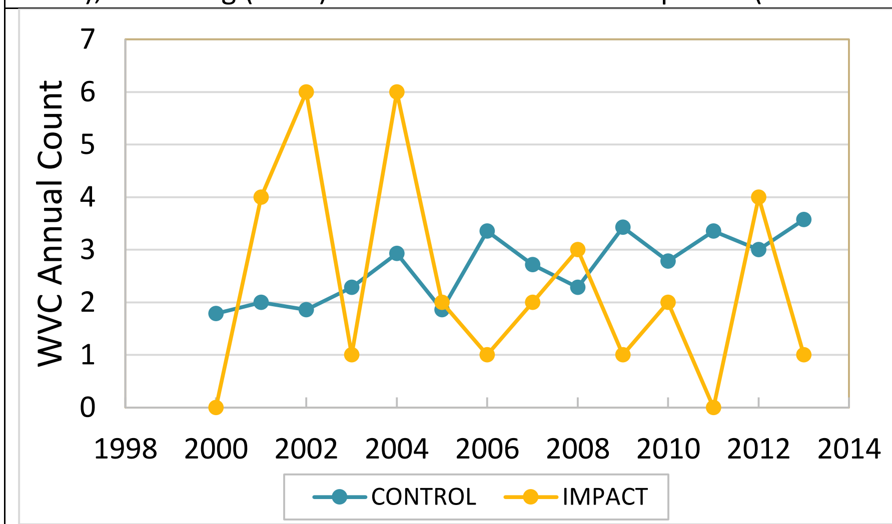
Appendix C Summary of WVC counts by year in each mitigated section



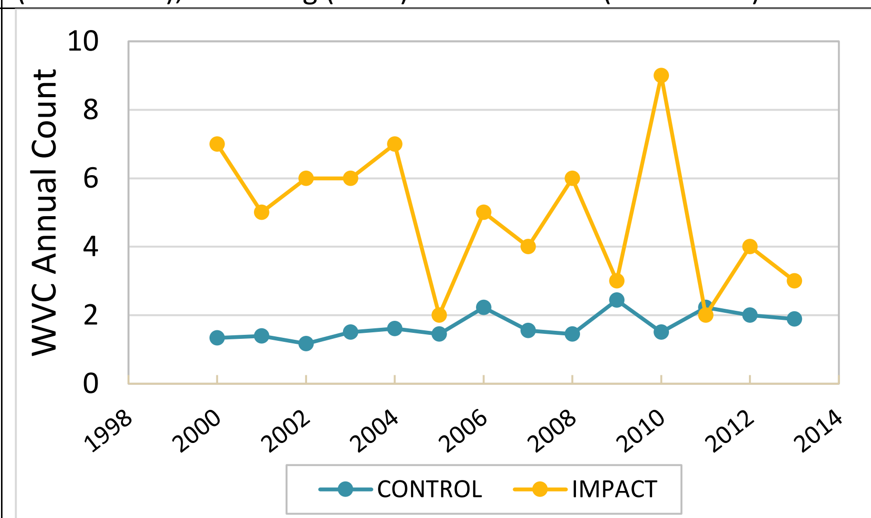
CALLANDER OPP: 615 WVC (2000 to 2013); 219 Before period (2000-2005); 54 During (2006) and 342 within the After period (2007-2013).



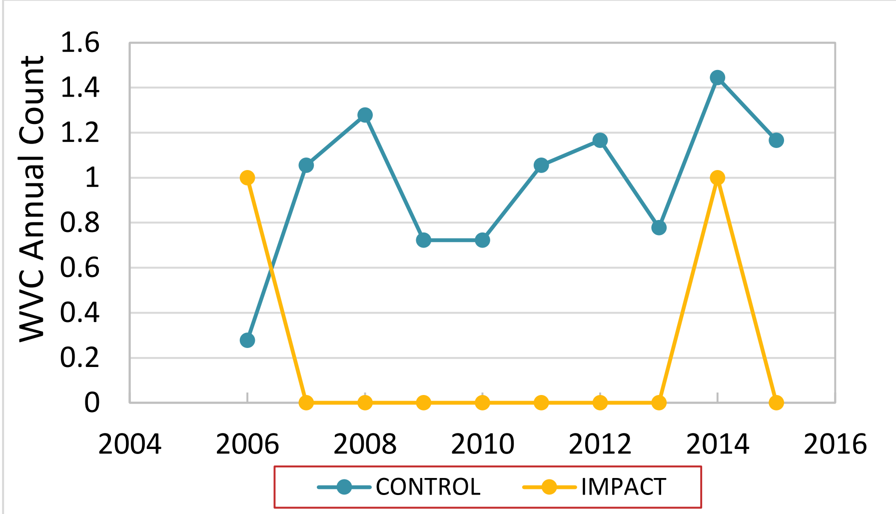
CALLANDER No Intersection OPP: 609 (2000 to 2013), 218 Before (2000-2005); 54 During (2006) and 337 After (2007-2013).



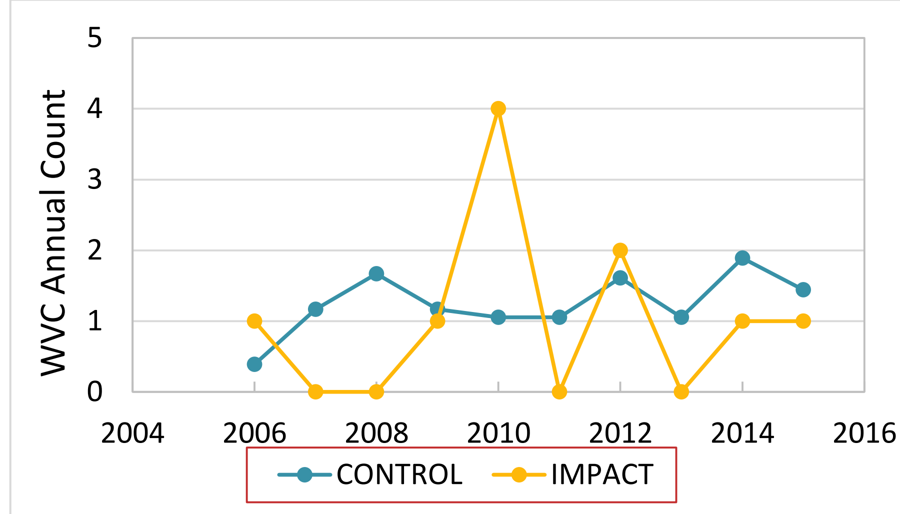
CALLANDER Truncated OPP: 554 (2000 to 2013); 197 Before (2000-2005); 48 During (2006) and 309 during the After period (2007-2013)



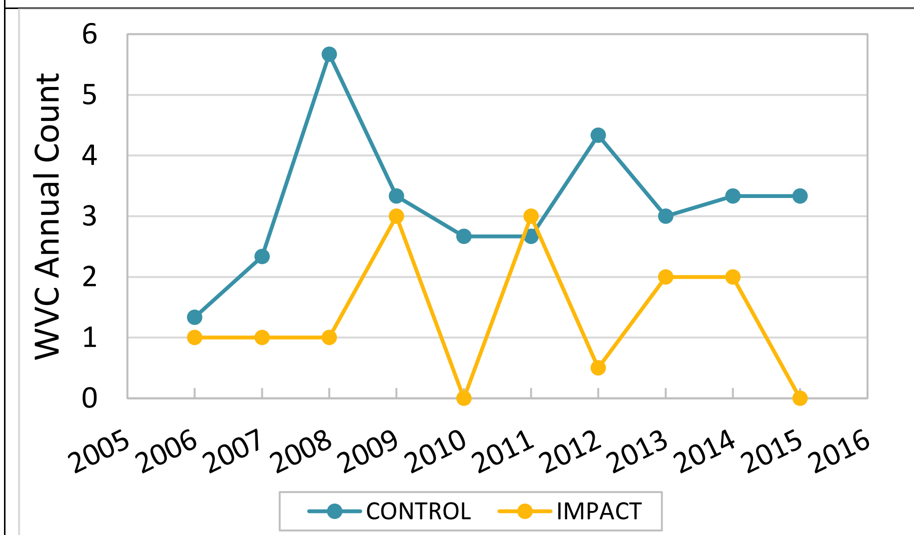
WASI OPP ALL: 496 (2000 to 2013); 377 Before period (2000-2010), 42 During (2011) and 77 After period (2012-2013).



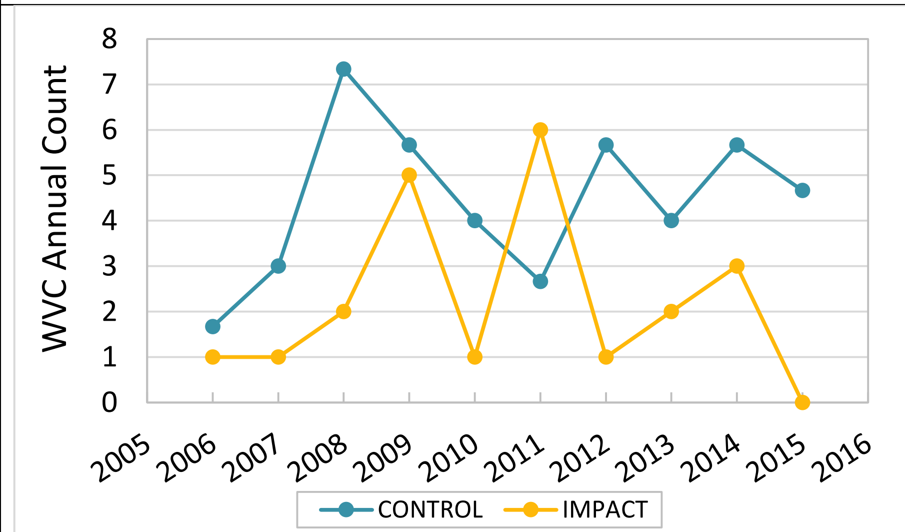
WASI Deer Carcass: 74 Before (2006-2010), 19 During (2011) and 83 After period (2012-2015).



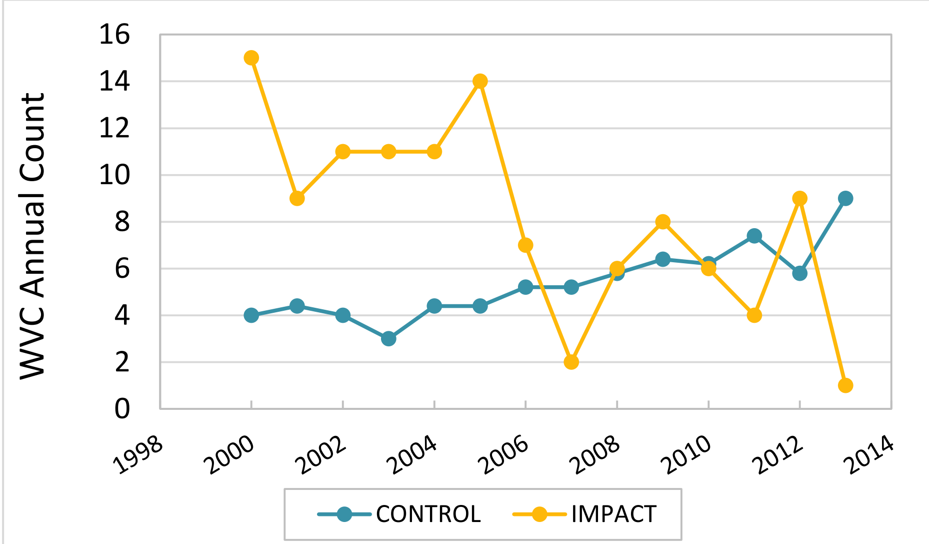
WASI Large Animal Carcass: 20 moose Before, 24 After, 0 During; 10 bear Before, 5 After, 0 During; 104 large mammal Before, 19 During, and 112 After.



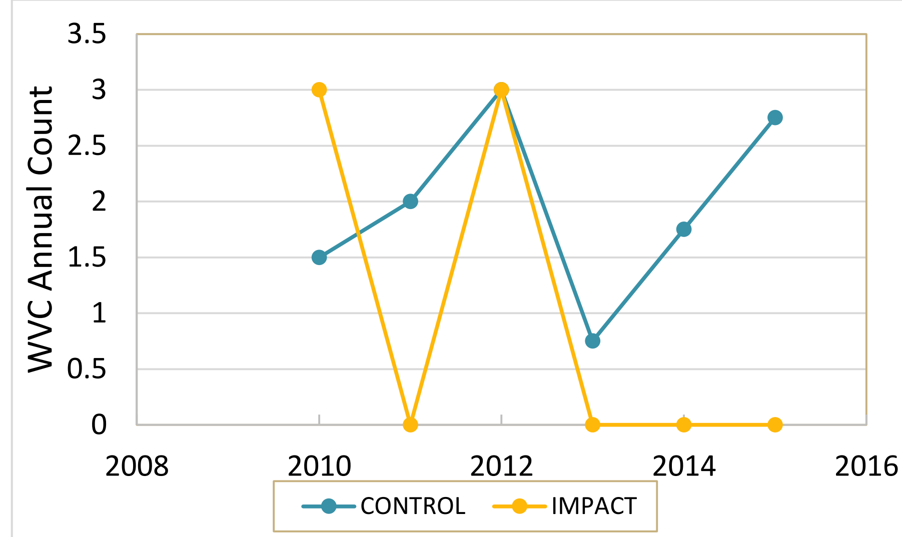
SUNDRIDGE Deer Carcass: 63 Before period (2006-2011), 14 During (2012-2013) and 35 After (2014-2015).



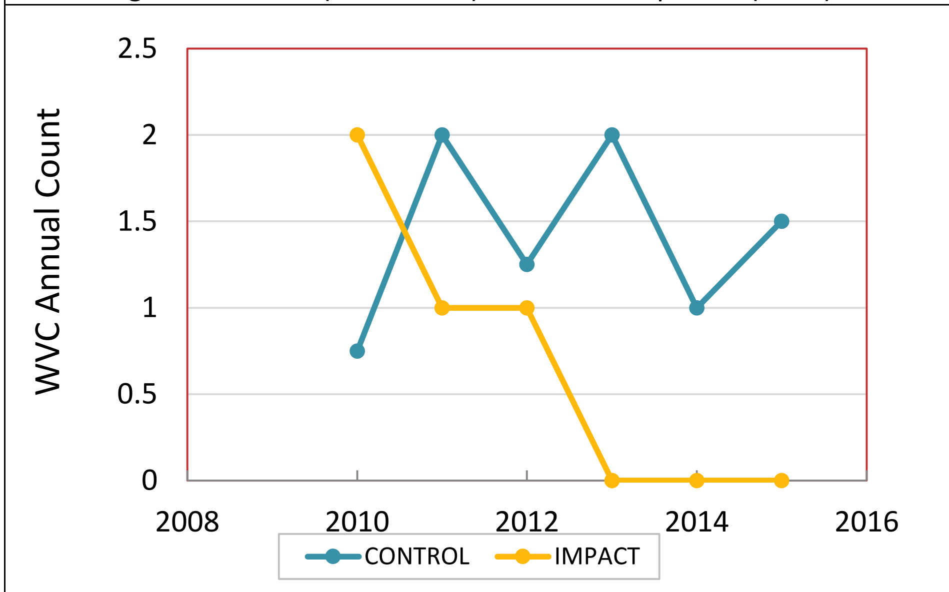
SUNDRIDGE Large Animal Carcass: 18, 5 and 11 moose and 8, 0 and 4 bear in the Before, During and After, respectively; 89 Before (2006-2011), 19 During (2012-2013) and 50 After (2014-2015).



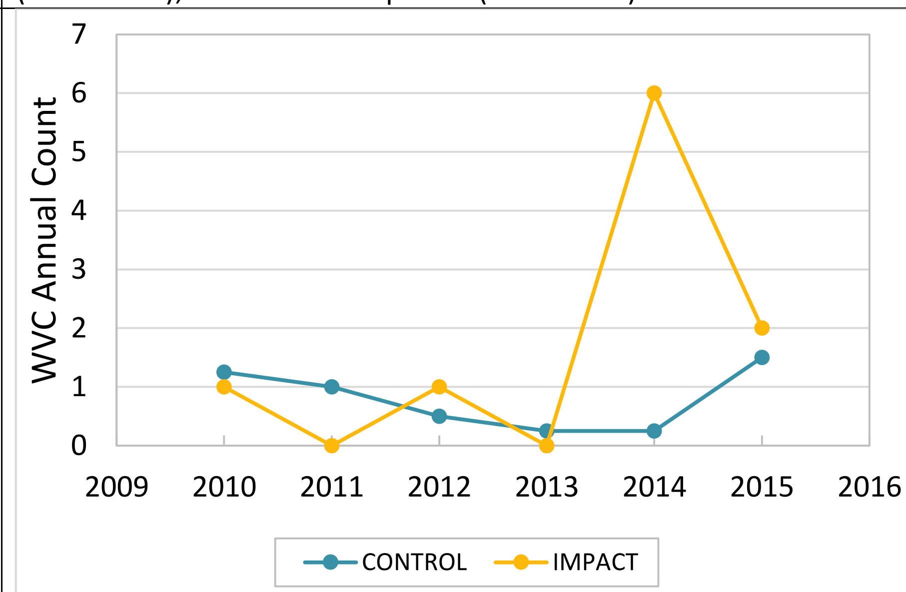
HWY 69 OPP: 490 from 2000 to 2013; 365 Before period (2000-2010); 79 during construction (2011-2012) and 46 After period (2013).



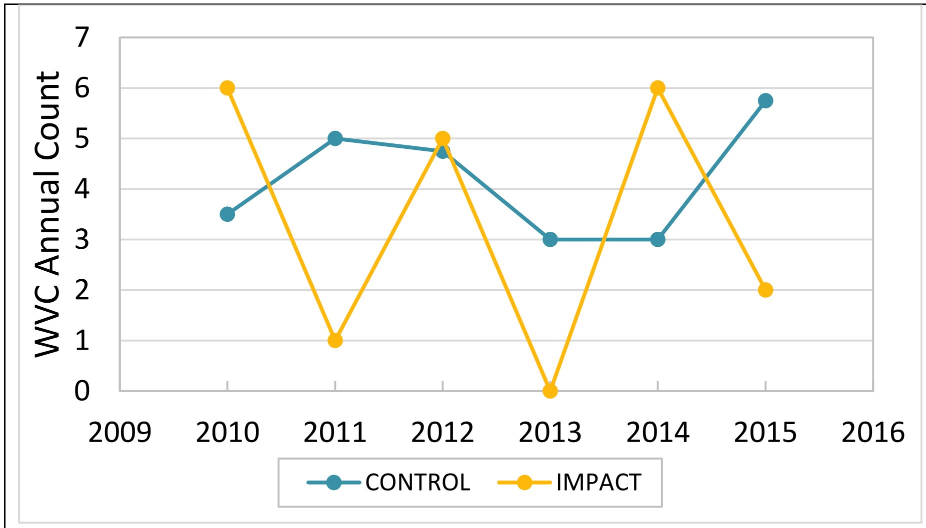
HWY 69 Deer Carcass: 9 Before period (2010); 23 during construction (2011-2012); 21 in the After period (2013-2015).



HWY 69 Moose Carcass: 5 Before period (2010), 15 During (2011-2012) and 18 in the After period (2013-2015).



HWY 69 Black Bear Carcass: 6 Before, 7 During and 16 After.

	
HWY 69 Large Animal Carcass: 20 Before period (2010), 45 During (2011-2012) and 55 After (2013-2015).	

Appendix D Summary of WVC collected by research team

Forty-eight large animals were found on Highway 69 from September 2011 to June 2016. Four large animals were found on Highway 11 from June 2014 to April 2016. The majority of the animals found on Highway 69 were Black bear (11) followed by deer (9) and moose (8). Three deer and one moose were found on Highway 11 (Table 13).

On Highway 11, two of the deer-vehicle collisions were associated with a fence end, one at Lake Nosbonsing Road in the Callander section and the other at Hill Valley Road in the Sundridge section. The moose was found between the Sundridge and Wasi Sections (Figure 25).

Three elk-, four moose- and one deer- vehicle collision occurred in the entire study period in the unmitigated section between Nelson Road Interchange and Trout Lake Road fence-end. Two deer and one moose occurred on Highway 69 and old Highway 69 prior to the exclusion fence being completed. Two deer- and five Black bear-vehicle collisions occurred in the mitigated fence section on the new alignment after the fence was completed in October 2012. The two deer collisions were likely associated with the Killarney fence-end at the Highway 69 and 637 interchange (Figure 26).

Table 13: A summary of wildlife carcasses found on each highway by species during the monitoring period.

Species	11	17	69	522	637	654	Old 69	Grand Total
Bear	0	0	11	0	0	0	0	11
Moose	1	0	8	0	0	0	2	11
Elk	0	0	7	0	0	0	1	8
Deer	3	1	9	1	1	1	0	16
Ungulate	0	0	4	0	0	0	0	4
Wolf	0	0	4	0	0	0	0	4
Coyote	0	0	1	0	0	0	0	1
Red Fox	0	0	3	0	0	0	0	3
Unknown large mammal	0	0	1	0	0	0	0	1
Grand Total	**4**	**1**	**48**	**1**	**1**	**1**	**3**	**59**

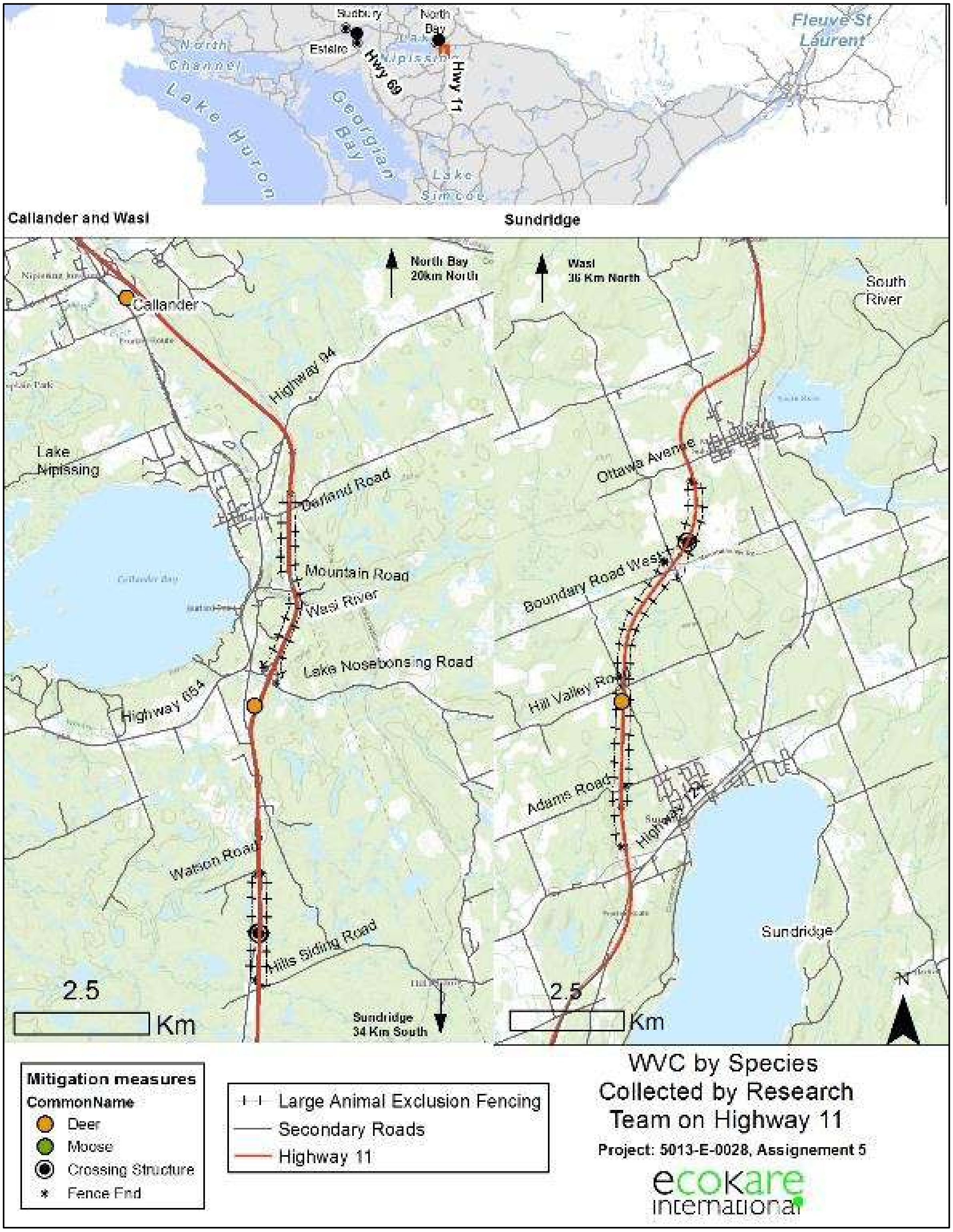


Figure 25: Wildlife-vehicle carcasses found opportunistically by research team on Highway 11.

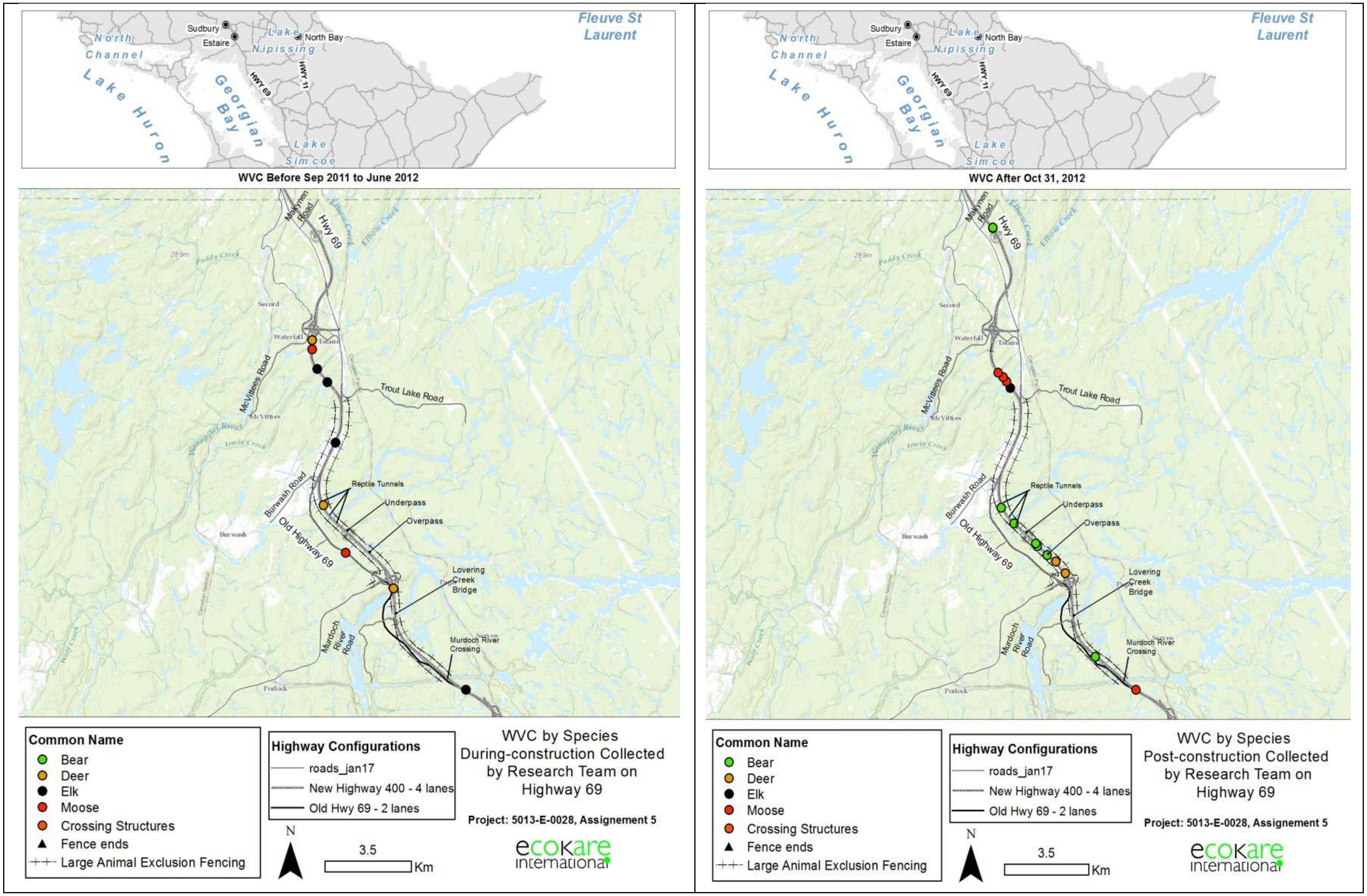
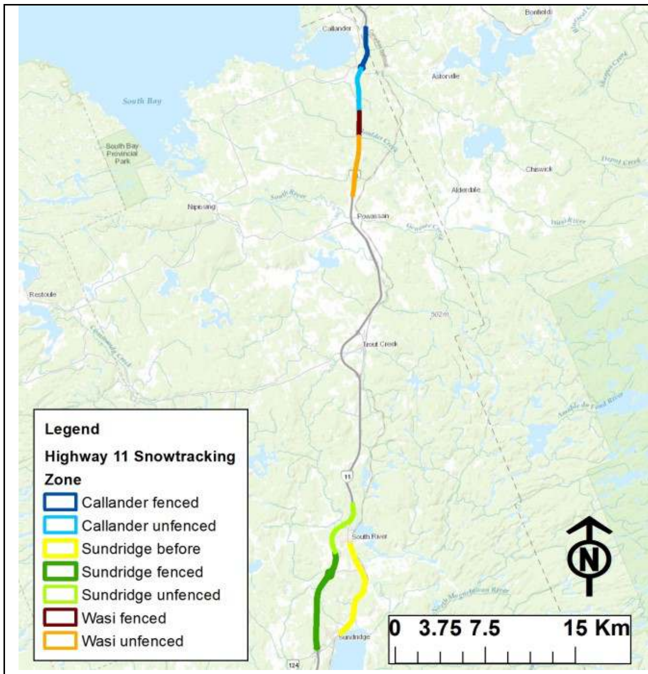


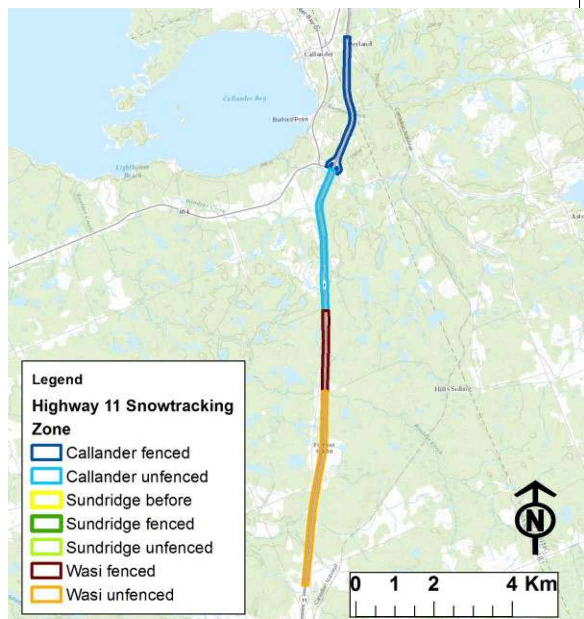
Figure 26: Wildlife carcasses found by research team at the Highway 69 study site during and after mitigation construction during the monitoring period.

Appendix E Treatment Sections

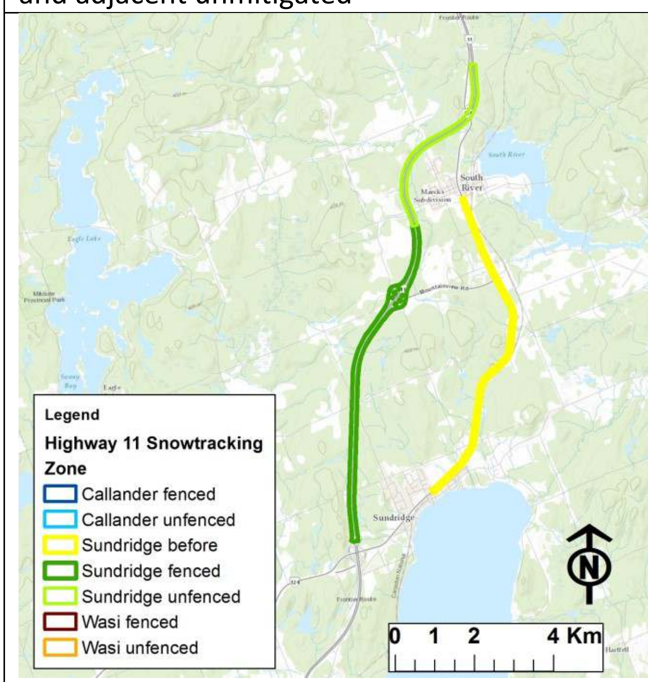
Snow-tracking Evaluation Treatments



Snow-tracking Zones on Highway 11 mitigated and adjacent unmitigated

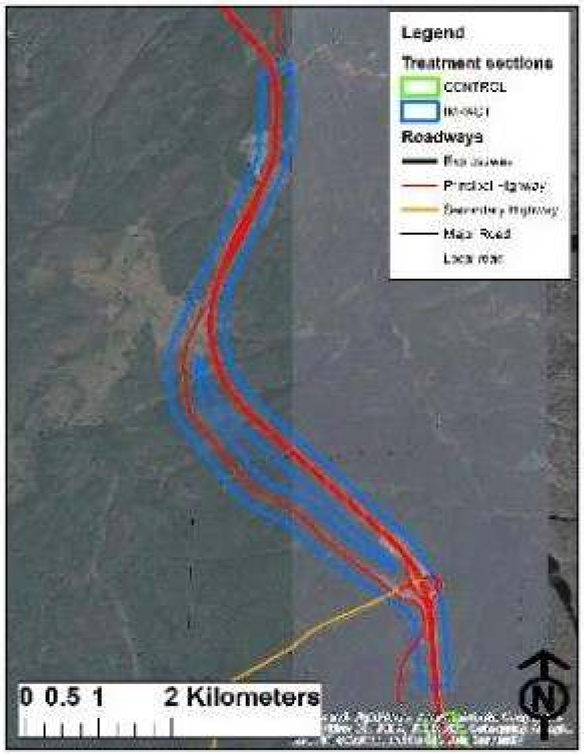


Zoom in of Callander and Wasi zones

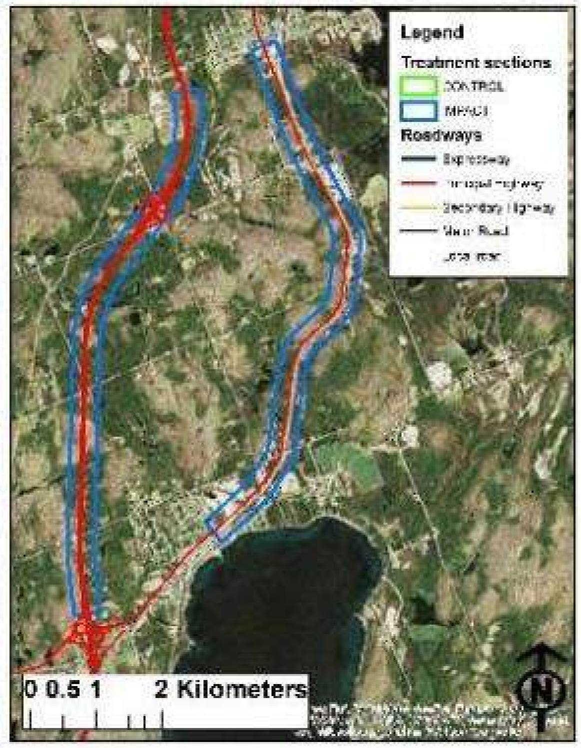


Zoom in of Sundridge zone with old highway and new alignment

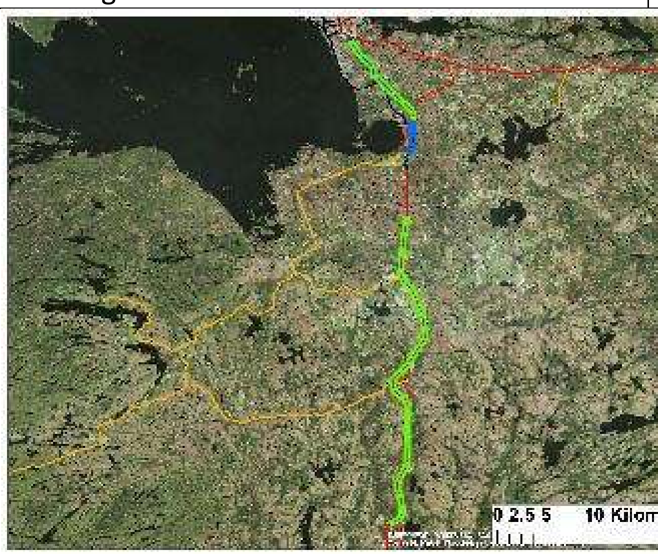
WVC Evaluation Treatments



Impact Section Hwy 69: Old Highway 69 and New Alignment

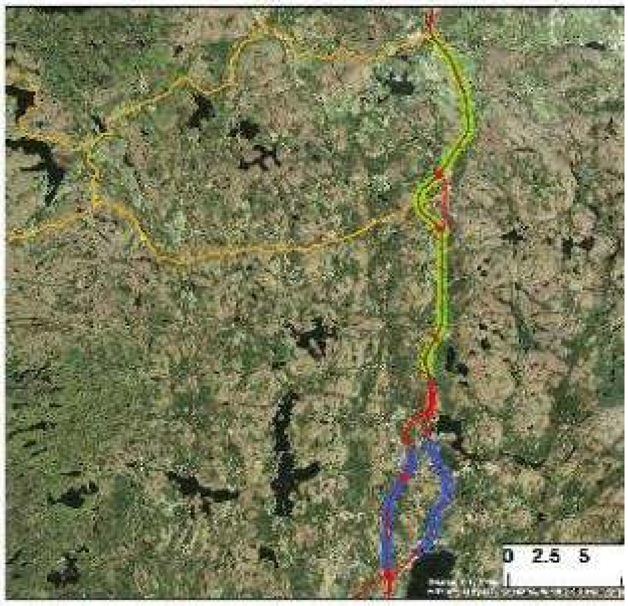
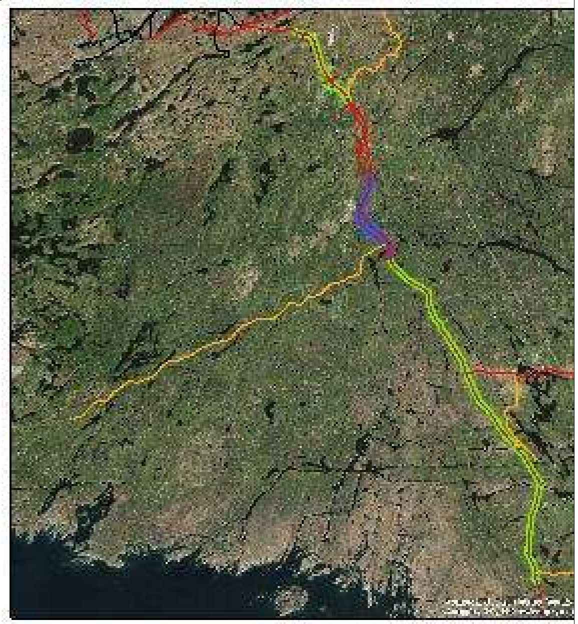


Impact Section Sundridge Hwy 11: Old highway 11 and New Alignment



Impact and Control Sections (13) within Powassan Patrol Zone Hwy 11: Callander

Impact and Control (18) Sections within Powassan Patrol Zone Hwy 11: Wasi

	
Impact and Control sections (3) within Powassan Patrol Zone Hwy 11: Sundridge	Impact and Control sections (5) within Rutter Patrol Zone Hwy 69

Appendix F Camera locations

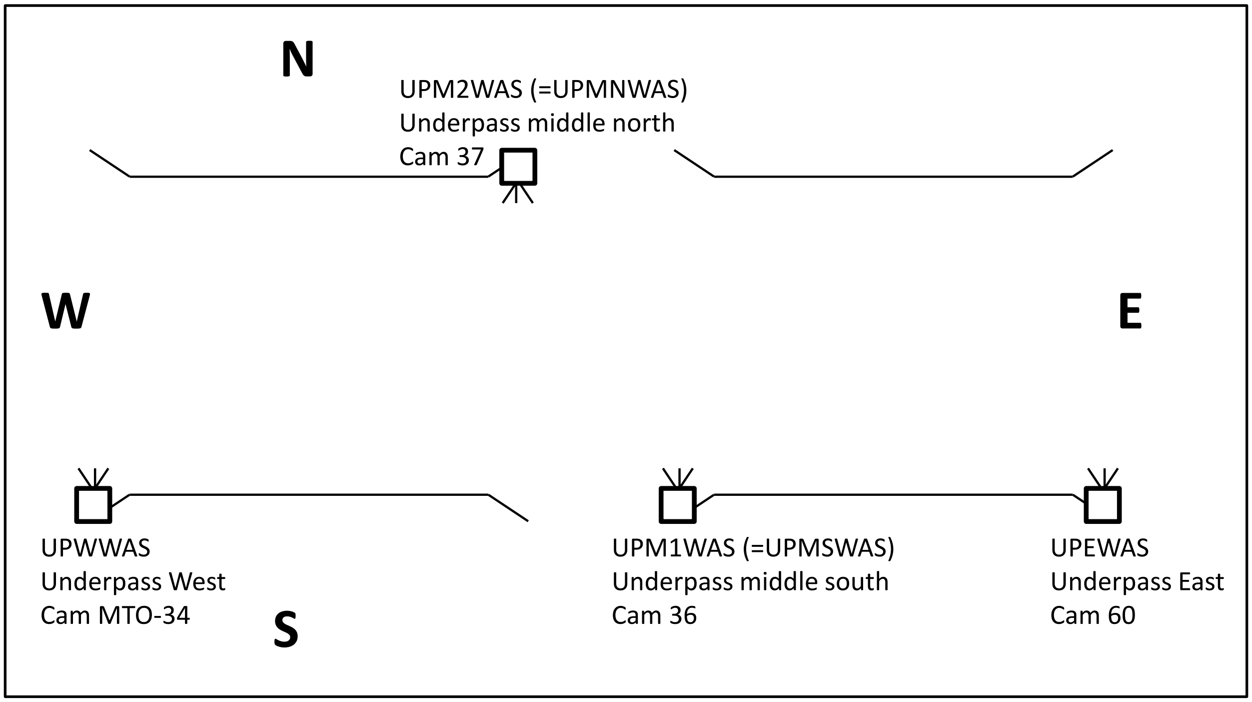


Figure 27: Locations of cameras on the 4m x 4m wildlife culvert at Wasi.

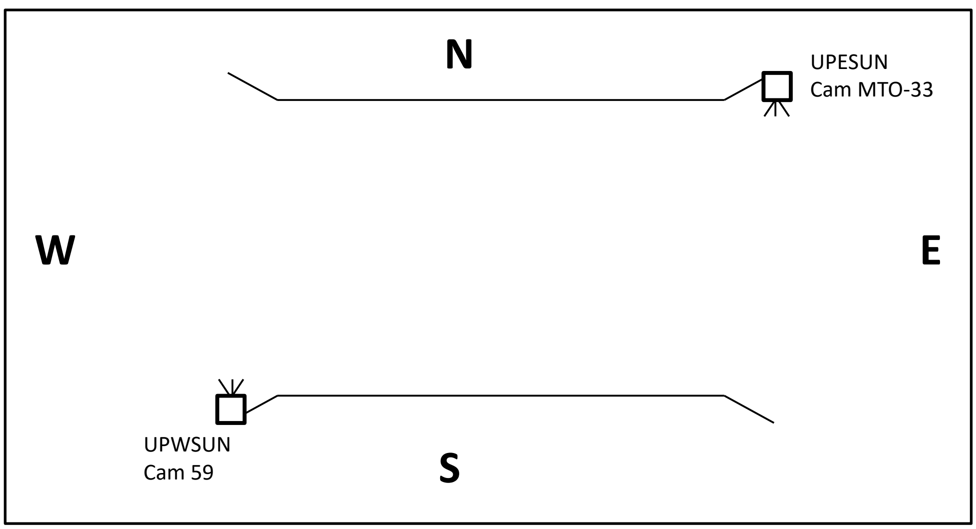


Figure 28: Locations of cameras on the 4m x 4m joint snowmobile-wildlife culvert at Sundridge.

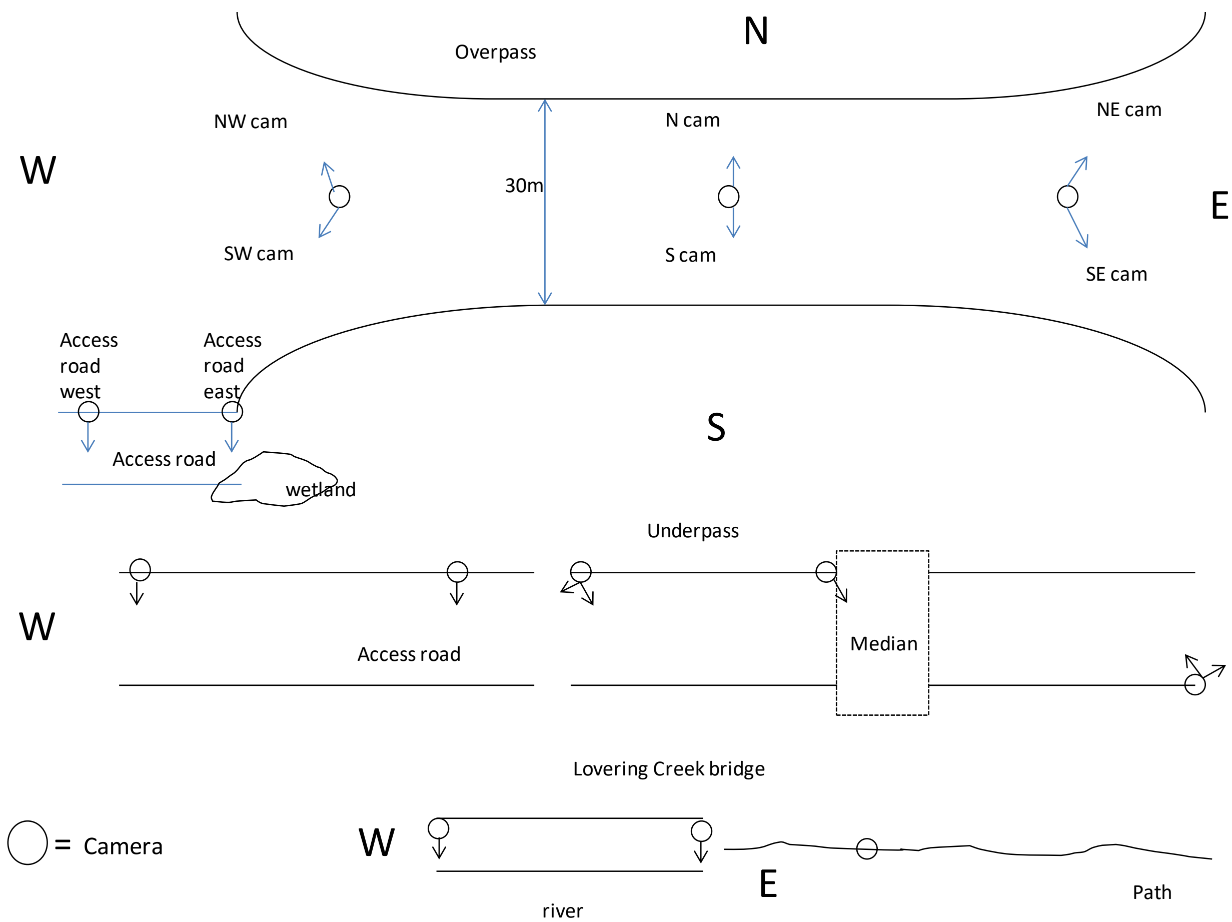


Figure 29: Location of cameras at Overpass, Underpass and Lovering Creek

Appendix G Zoom in of mitigation measures per section

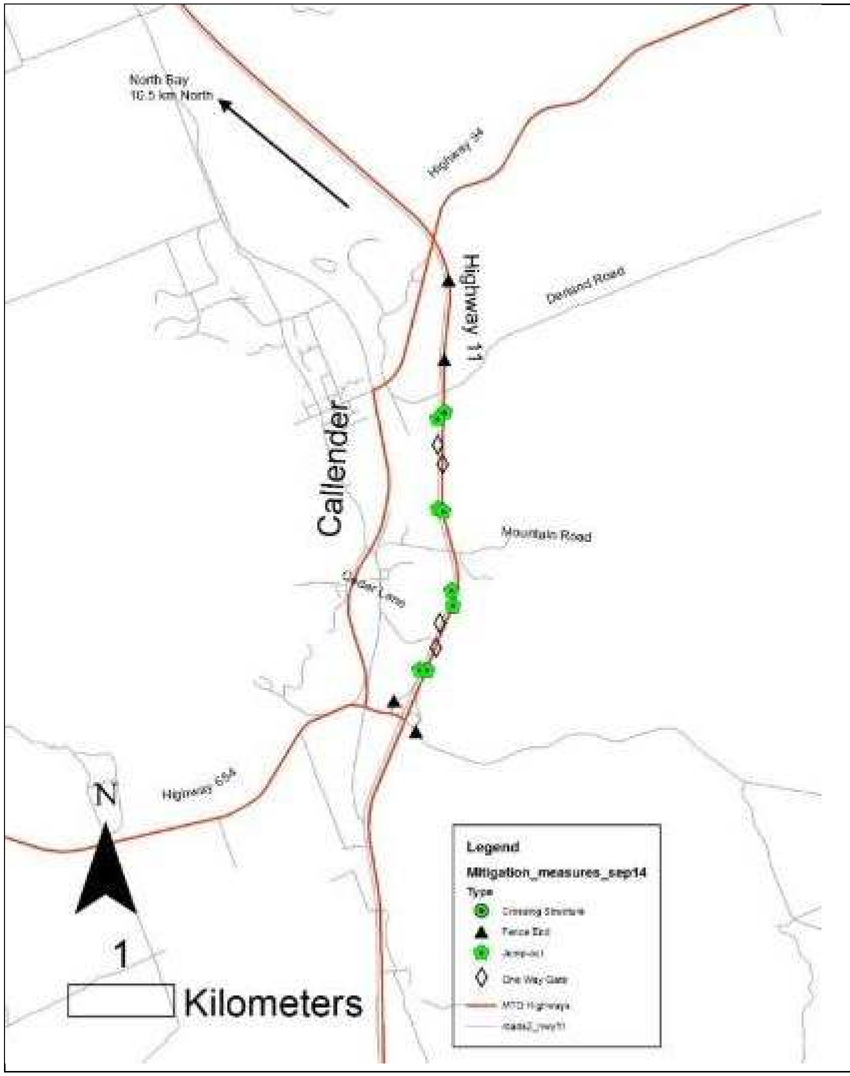


Figure 30: Mitigation measures near Callander, Ontario

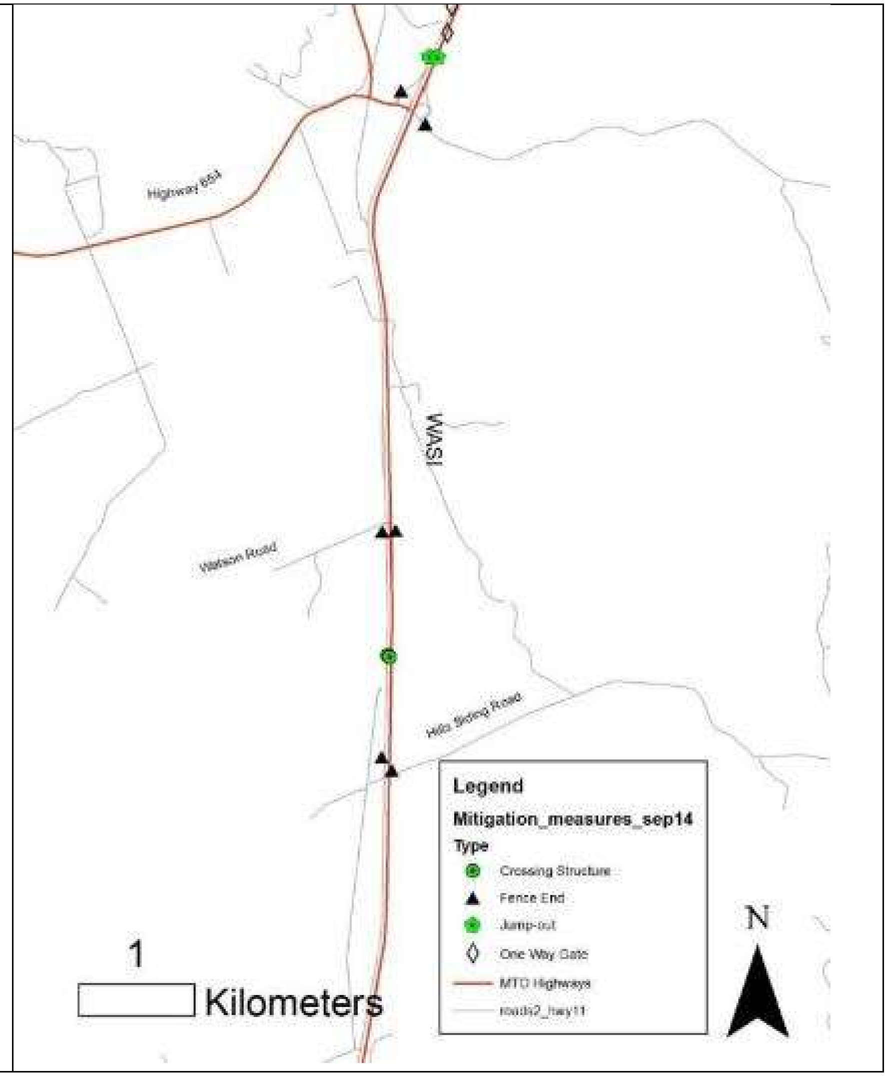


Figure 31: Mitigation measures at and south of the Wasi River crossing at Hwy 654

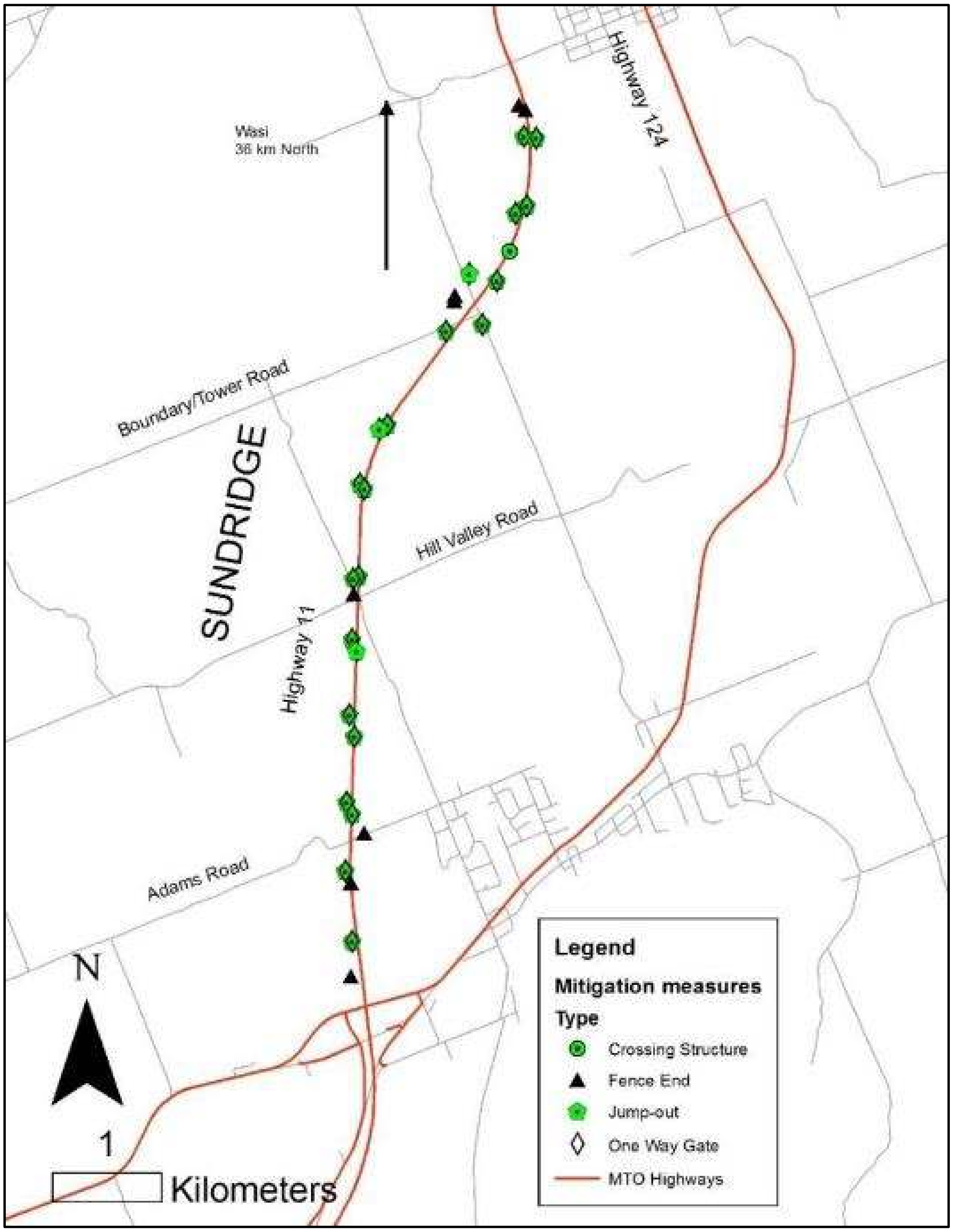


Figure 32: Mitigation measures near Sundridge, Ontario

Appendix H Inventory

The unique identity code for each mitigation measure follows the standard code of "Structure type – Location direction relative to highway–Highway section. In the case of JOs and OW gates where there are many, a number is assigned to each starting at one in each section.

Code	Structure type
UP	Underpass
OP	Overpass
FE	Fence-end
JO	Jump-out
OW	One-way gate
UG	Ungulate guard

Code	Location
NW	Northwest
NE	Northeast
SW	Southwest
SE	Southeast

Code	Highway section
CALL	Callander (Hwy 11)
WAS	Wasi (Hwy 11)
SUN	Sundridge (Hwy 11)
Hwy 69	Highway 69
NA	New Alignment

Highway	Highway Section	Location	Code	Camera Number	Sampling Effort (month)	Structure Type	Easting	Northing
Hwy 11	Sundridge	Boundary/Tower Rd FE	FEBOUNDNE	51	20.1	FE	624454	5074970
Hwy 11	Sundridge	Boundary/Tower Rd FE	FEBOUNDNW	55	21.2	FE	624079	5075039
Hwy 11	Sundridge	Boundary/Tower Rd FE	FEBOUNDSE	35	22.0	FE	624454	5074970
Hwy 11	Sundridge	Boundary/Tower Rd FE	FEBOUNDSW			FE	624075	5074992
Hwy 11	Sundridge	Hill Valley Rd FE	FEHILLNE	37	22.1	FE	623190	5072211
Hwy 11	Sundridge	Hill Valley Rd FE	FEHILLNW			FE	623122	5072247
Hwy 11	Sundridge	Hill Valley Rd FE	FEHILLSE	47	22.7	FE	623189	5072287
Hwy 11	Sundridge	Hill Valley Rd FE	FEHILLSW	49	22.7	FE	623115	5072235
Hwy 11	Sundridge	Adams Rd FE	FENEADAM			FE	623140	5070107
Hwy 11	Callender	NE FE	FENECALL			FE	627310	5121329
Hwy 11	Sundridge	NE FE	FENESUN	45	22.5	FE	624725	5076739
Hwy 11	Wasi	NE FE, Watson Rd	FENEWAS	38	21.3	FE	626747	5113572
Hwy 11	Sundridge	Adams Rd FE	FENWADAM			FE	623054	5070031
Hwy 11	Callender	NW FE	FENWCALL	39	2.2	FE	627269	5120577
Hwy 11	Sundridge	NW FE	FENWSUN	54	21.1	FE	624663	5076785
Hwy 11	Wasi	NW FE, Watson Rd	FENWWAS	39	21.3	FE	626632	5113565
Hwy 11	Sundridge	Adams Rd FE	FESEADAM	36	7.6	FE	623138	5070020
Hwy 11	Callender	SE FE	FESECALL			FE	627000	5117076
Hwy 11	Sundridge	SE FE	FESESUN	26	18.8	FE	623125	5069658
Hwy 11	Wasi	SE FE, Hills siding Rd	FESEWAS	35	10.5	FE	626717	5111508
Hwy 11	Sundridge	Adams Rd FE	FESWADAM	58	7.6	FE	623057	5070015
Hwy 11	Callender	SW FE	FESWCALL			FE	626793	5117364
Hwy 11	Sundridge	SW FE	FESWSUN	44	7.6	FE	623125	5068800

Highway	Highway Section	Location	Code	Camera Number	Sampling Effort (month)	Structure Type	Easting	Northing
Hwy 11	Wasi	SW FE, Hills siding Rd	FESWWAS	51	10.5	FE	626629	5111617
Hwy 11	Sundridge	West side	JO22WSUN	46	22.5	JO	624708	5076495
Hwy 11	Sundridge	East side	JOE10SUN			JO	623196	5072461
Hwy 11	Sundridge	East side	JOE11SUN			JO	623247	5073262
Hwy 11	Sundridge	East side	JOE14SUN			JO	623460	5073855
Hwy 11	Sundridge	East side	JOE16SUN			JO	624325	5074772
Hwy 11	Sundridge	East side	JOE17SUN			JO	624457	5075172
Hwy 11	Callender	East side	JOE1CALL	50	22.5	JO	627106	5117654
Hwy 11	Sundridge	East side	JOE20SUN	48	22.5	JO	624734	5075857
Hwy 11	Sundridge	East side	JOE21SUN			JO	624818	5076481
Hwy 11	Sundridge	East side	JOE3SUN			JO	623132	5070284
Hwy 11	Callender	East side	JOE5CALL	56	19.9	JO	627261	5119155
Hwy 11	Sundridge	East side	JOE5SUN			JO	623152	5070997
Hwy 11	Sundridge	East side	JOE7SUN			JO	623176	5071782
Hwy 11	Callender	East side	JOE8CALL			JO	627272	5120086
Hwy 11	Sundridge	West side	JOW12SUN			JO	623204	5073311
Hwy 11	Sundridge	West side	JOW13SUN			JO	623381	5073810
Hwy 11	Sundridge	West side	JOW15SUN			JO	623995	5074711
Hwy 11	Sundridge	West side	JOW19SUN			JO	624630	5075789
Hwy 11	Sundridge	West side	JOW1SUN			JO	623135	5069119
Hwy 11	Callender	West side	JOW2CALL	41	22.5	JO	627040	5117658
Hwy 11	Sundridge	West side	JOW2SUN	43	7.6	JO	623073	5069762
Hwy 11	Sundridge	West side	JOW4SUN			JO	623081	5070396
Hwy 11	Callender	West side	JOW6CALL	53	21.1	JO	627209	5119174
Hwy 11	Sundridge	West side	JOW6SUN			JO	623110	5071194
Hwy 11	Callender	West side	JOW7CALL			JO	627207	5120024
Hwy 11	Sundridge	West side	JOW8SUN			JO	623132	5071886
Hwy 11	Callender	new Jump-out	JOW9CALL			JO	627337.6	5118396
Hwy 11	Sundridge	West side	JOW9SUN			JO	623146	5072442
Hwy 11	Sundridge	West side	JUW18SUN	44	14.0	JO	624208	5075241
Hwy 11	Callender	Derland Rd NEFE	NEFEDERLAND			FE	627290	5120299
Hwy 11	Callender	Mountain Rd NEFE	NEFEMOUNT			FE	627345	5118807
Hwy 11	Callender	Derland Rd NWFE	NWFEDERLAND			FE	627208	5120369
Hwy 11	Callender	Mountain Rd NWFE	NWFEMOUNT			FE	627233	5118935
Hwy 11	Sundridge	West side	OW11SUN			OW	623247	5073262
Hwy 11	Sundridge	West side	OW22WSUN	47	13.1	OW	624708	5076495
Hwy 11	Sundridge	East side	OWE10SUN			OW	623196	5072461
Hwy 11	Sundridge	East side	OWE14SUN			OW	623460	5073855
Hwy 11	Sundridge	West side	OWE16SUN			OW	624325	5074772

Highway	Highway Section	Location	Code	Camera Number	Sampling Effort (month)	Structure Type	Easting	Northing
Hwy 11	Sundridge	East side	OWE17SUN			OW	624457	5075172
Hwy 11	Sundridge	East side	OWE20SUN	49	13.1	OW	624734	5075857
Hwy 11	Sundridge	East side	OWE21SUN			OW	624818	5076481
Hwy 11	Callender	East side	OWE3CALL			OW	627253	5119595
Hwy 11	Sundridge	East side	OWE3SUN			OW	623132	5070284
Hwy 11	Sundridge	East side	OWE5SUN			OW	623152	5070997
Hwy 11	Sundridge	East side	OWE7SUN			OW	623176	5071782
Hwy 11	Sundridge	West side	OWW12SUN			OW	623204	5073311
Hwy 11	Sundridge	West side	OWW13SUN			OW	623381	5073810
Hwy 11	Sundridge	West side	OWW15SUN			OW	623995	5074711
Hwy 11	Sundridge	West side on off ramp	OWW18SUN	43	14.0	OW	624208	5075241
Hwy 11	Sundridge	West side	OWW19SUN	58	14.0	OW	624630	5075789
Hwy 11	Callender	West side	OWW1CALL			OW	627188	5117862
Hwy 11	Sundridge	West side	OWW1SUN			OW	623135	5069119
Hwy 11	Callender	West side	OWW2CALL	40	13.1	OW	627225	5118095
Hwy 11	Sundridge	West side	OWW2SUN			OW	623073	5069762
Hwy 11	Callender	West side	OWW4CALL			OW	627205	5119775
Hwy 11	Sundridge	West side	OWW4SUN			OW	623081	5070396
Hwy 11	Sundridge	West side	OWW6SUN			OW	623110	5071194
Hwy 11	Sundridge	West side	OWW8SUN			OW	623132	5071886
Hwy 11	Sundridge	West side	OWW9SUN			OW	623146	5072442
Hwy 11	Callender	Derland Rd SEFE	SEFEDERLAND			FE	627277	5120174
Hwy 11	Callender	Mountain Rd SEFE	SEFEMOUNT			FE	627388	5118705
Hwy 11	Callender	Derland Rd SWFE	SWFEDERLAND			FE	627193	5120229
Hwy 11	Callender	Mountain Rd SWFE	SWFEMOUNT			FE	627320	5118698
Hwy 11	Sundridge	Underpass	UPESUN	33 (MT0)	22.5	CS	624574	5075441
Hwy 11	Wasi	East tunnel approach	UPEWAS	60	22.5	CS	626696	5112481
Hwy 11	Wasi	South side middle facing north	UPMNWAS			CS	626678	5112494
Hwy 11	Wasi	North side, facing S	UPMSWAS			CS	626696	5112481
Hwy 11	Sundridge	Underpass	UPWSUN	59-11 (34MTO)	22.5	CS	624574	5075441
Hwy 11	Wasi	West tunnel approach	UPWWAS	34-MTO	25.1	CS	626678	5112494
Hwy 11	Callender	Cedar Lane	Road			FE	627179	5117972
Hwy 11	Callender	East side	JOE3CALL			JO	627351	5118262
Hwy 637	Hwy 637	FE Kill N	FEKN	10	20.3	FE	516789	5119115
Hwy 637	Hwy 637	FE Kill S	FEKS	18	20.3	FE	516805	5119067
Hwy 637	Hwy 637	OW-Killarney North	OWKILLN	26	6.9	OW	517066	5119275
Hwy 637	Hwy 637	OW-Killarney South	OWKILLS	28	19.8	OW	516993	5119160

Highway	Highway Section	Location	Code	Camera Number	Sampling Effort (month)	Structure Type	Easting	Northing
Hwy 637	Hwy 637	Ungulate Guard North	TGN	26,28	13.9	Texas Gate	516980	5119533
Hwy 637	Hwy 637	Interchange Hwy 69	UGS	14,UWAY	22.6	UG	517190	5119289
Hwy 69	NA	Fence gap East N	FEGapEN2			FE	516367	5120769
Hwy 69	NA	Fence gap East S	FEGapES2			FE	516517	5120633
Hwy 69	NA	FE gap N	FEGapWN1			FE	517668	5118851
Hwy 69	NA	FE gap S	FEGapWS1			FE	517683	5118657
Hwy 69	NA	FE Lovering Creek East	FELCE			FE	517746	5118040
Hwy 69	NA	FE Lovering Creek West	FELCW			FE	517720	5118071
Hwy 69	NA	FE Nelson Interchange North	FENIN	28	4.8	FE	514373	5128719
Hwy 69	NA	FE Nelson Interchange South	FENIS	10	17.2	FE	514331	5128405
Hwy 69	NA	FE TLR E	FETLRE	19	4.9	FE	515501	5126596
Hwy 69	NA	FE TLR W	FETLRW	26	4.1	FE	515511	5126442
Hwy 69	NA	Lovering Creek Bridge NE	LCBrNE	11	47.1	CS	517754	5118037
Hwy 69	NA	Lovering Creek Bridge NW	LCBrNW	22,21	56.4	CS	517721	5118068
Hwy 69	NA	Lovering Creek East tree	LCE2	11	47.1	Trail	517835	5118005
Hwy 69	NA	Murdock River Bridge NE	MRBrNE	3	21.0	CS	519720	5115616
Hwy 69	NA	Murdock River Bridge NW	MRBrNW	MRNW	21.0	CS	519763	5115560
Hwy 69	NA	Murdock River Bridge SE	MRBrSE	28	21.0	CS	519957	5115504
Hwy 69	NA	Murdock River Bridge SW	MRBrSW	MRNW	21.0	CS	519899	5115483
Hwy 69	NA	Overpass access Rd East	OPAE	9	62.0	Access Rd	516696	5120328
Hwy 69	NA	Overpass access Rd West	OPAW	15, 27, 11,52	26.1	Access Rd	516212	5120161
Hwy 69	NA	Overpass middle north	OPMN	5	60.3	CS	516770	5120397
Hwy 69	NA	Overpass middle south	OPMS	4, 50	60.2	CS	516770	5120397
Hwy 69	NA	Overpass north-East pole	OPNE	13	56.9	CS	516729	5120464
Hwy 69	NA	Overpass north-West pole	OPNW	17,20,33	54.2	CS	516686	5120356
Hwy 69	NA	Overpass south-East pole	OPSE	12, 55	59.8	CS	516729	5120464
Hwy 69	NA	Overpass south-West pole	OPSW	16, 32	56.9	CS	516686	5120356
Hwy 69	NA	OW-East 1	OWE1	19	48.6	OW	517193	5120053
Hwy 69	NA	OW-East10	OWE10	21, 20	18.0	OW	515472	5125069

Highway	Highway Section	Location	Code	Camera Number	Sampling Effort (month)	Structure Type	Easting	Northing
Hwy 69	NA	OW-East 11	OWE11	17	48.6	OW	515593	5125911
Hwy 69	NA	OW-East 2	OWE2	24	45.6	OW	516593	5120601
Hwy 69	NA	OW-East 3	OWE3	21	39.8	OW	516326	5120800
Hwy 69	NA	OW-East4	OWE4			OW	516148	5120953
Hwy 69	NA	OW-East 5	OWE5			OW	515679	5121382
Hwy 69	NA	OW-East5a	OWE5a			OW	515323	5121695
Hwy 69	NA	OW-East6	OWE6			OW	514960	5122100
Hwy 69	NA	OW-East7	OWE7			OW	514699	5122812
Hwy 69	NA	OW-East8	OWE8			OW	514752	5123472
Hwy 69	NA	OW-East9	OWE9	27	15.1	OW	515122	5124239
Hwy 69	NA	OW-East9a	OWE9a			OW	515299	5124673
Hwy 69	NA	OW-Killarney exit ramp	OWKILL			OW	517733	5119147
Hwy 69	NA	OW-West 1	OWW1	14,28,30	58.9	OW	515536	5125686
Hwy 69	NA	OW-West 2	OWW2	13,29	62.8	OW	515158	5124501
Hwy 69	NA	OW-West3	OWW3			OW	514652	5123427
Hwy 69	NA	OW-West4	OWW4			OW	514638	5122931
Hwy 69	NA	OW-West5	OWW5			OW	514820	5122231
Hwy 69	NA	OW-West6	OWW6			OW	515317	5121635
Hwy 69	NA	OW-West7	OWW7			OW	515904	5121105
Hwy 69	NA	OW-West8	OWW8			OW	516270	5120774
Hwy 69	NA	OW-West9	OWW9			OW	516520	5120553
Hwy 69	NA	Reptile Tunnel 1 East	RT1E	41,65	11.8	CS	514775.1	5122425
Hwy 69	NA	Reptile Tunnel 1 West	RT1W	63,55	9.4	CS	514775.1	5122425
Hwy 69	NA	Reptile Tunnel 2 East	RT2E	64,39,29	18.0	CS	515061.1	5121934
Hwy 69	NA	Reptile Tunnel 2 West	RT2W	62	20.2	CS	515061.1	5121934
Hwy 69	NA	Reptile Tunnel 3 East	RT3E	50	12.5	CS	515402.6	5121600
Hwy 69	NA	Reptile Tunnel 3 West	RT3W	34,65	13.5	CS	515402.6	5121600
Hwy 69	NA	Underpass access Rd East	UPAE	1, 25	54.1	Access Rd	515703	5121226
Hwy 69	NA	Underpass access Rd West	UPAW	6,18,14	46.0	Access Rd	515043	5121053
Hwy 69	NA	Underpass East approach	UPE	3	60.2	CS	515779	5121297
Hwy 69	NA	Underpass centre	UPM	23	50.9	CS	515779	5121297
Hwy 69	NA	Underpass West approach	UPW	2	60.2	CS	515739	5121262

Appendix I Fence end Inventory

Hwy	Structure	Date monitored w cam	Cam	Fence end tie in relative to hwy 11 or 69	Hwy / Road	Secondary Rd over or under hwy (int)	Rock Pile	Tie into rock (rip rap) hwy slope (y/n)	Tie into cliff wall (y/n)	Tie into rock face or bridge wall (y/n)	Tie into cliff above hwy (y/n)	Ext from main fence towards hwy (Y/N)	Ext sections at fence end	Toward or away from hwy	Slope (moderate steep or none)	Substrate Type	Comments	Type	Cam	Snow	deer pres/abs
11	FESWSUN	18/09/15 to 31/05/16	**44**	at grade	11	na	y	y	n	n	n	n	5	toward	moderate	rock		section end	none	none	n
11	FESESUN	11/11/14 to 31/05/16	**26**	below grade	11	na	y	y	n	n	n	n	3	toward	steep	rock		section end	1 deer	none	y
11	FESWADAM	18/09/15 to 31/05/16	**58**	below	Adams Rd	under	y	n	n	n	n	n	4	toward	steep	rock		Int end	1 deer	none	y
11	FESEADAM	18/09/15 to 31/05/16	**36**	below	Adams Rd	under	y	n	n	n	n	n	4	toward	steep	rock		Int end	none	none	n
11	FENWADAM	18-Sep-15		below	Adams Rd	under	n	n	n	n	n	n	1	toward	none	grass	Some houses end	Int end	na	none	n
11	FENEADAM	18-Sep-15		below	Adams Rd	under	y	n	n	n	n	n	3	toward	steep	rock		Int end	na	none	n
11	FEHILLNE	18/09/15 to 31/05/16	**37**	at grade	HV Rd	over	y	y	n	n	n	n	0	na	moderate	rock	ties half way up slope	Int end	1 deer, 1 bear	none	y
11	FEHILLSW	18/09/15 to 31/05/16	**49**	above	HV Rd	over	y	n	n	n	n	n	2	toward	none or na	rock		Int end	1 deer	none	y
11	FEHILLNW	12-Mar-15		above	HV Rd	over	y	n	n	n	n	n	1	toward	none or na	rock		Int end	na	5 deer	y

11	FEHILLSE	18/09/15 to 31/05/16	**47**	at grade	HV Rd	over	y	y	n	n	n	n	0	na	modera te	rock		Int end	1 bear, 3 deer	none	y
11	FEBOUND NE	28/06/15 to 14/04/16	**51**	at grade	Boun dary Rd	over	y	n	n	n	n	n	0	na	steep	rock		Int end	1 bear, 1 deer	10 deer (same tracki ng sessio n)	y
11	FEBOUND SE	22/07/15 to 31/05/16	**35**	at grade	Boun dary Rd	over	y	n	n	n	n	n	0	na	steep	rock	animals can walk around FE, rip rap not at FE	Int end	3 deer	5 deer	y
11	FEBOUND SW	18-Jul-14		at grade	Boun dary Rd	over	y	n	n	n	n	n	0	na	modera te	grass		Int end	na	none	
11	FEBOUND NW	25/08/2014 to 22/07/15	**55**	at grade	Boun dary Rd	over	y	n	n	n	n	n	0	na	modera te	grass		Int end	29 deer	20 deer (10 each durin g 2 tracki ng sessio n)	y
11	FENESUN	18/07/14 to 31/05/16	**45**	at grade	11	na	y	y	n	n	n	n	3	towar d	modera te	rock		secti on end	6 deer	none	y
11	FENWSUN	25/08/2014 to 31/05/16	**54**	at grade	11	na	y	y	n	n	n	n	3	towar d	modera te	rock	fence end half way up	secti on end	2 deer, 1 moos e	none	y

11	FESEWAS	17/07/2014 to 06/06/2015	**35**	at grade	HS Road	na	n	n	n	n	n	n	0	na	none	grass	wetland	section end	40 deer	none	y
11	FESWWAS	17/07/2014 to 06/06/2015	**51**	at grade	HS Road	na	n	n	n	n	n	n	3	toward	none	grass	wetland	section end	22 deer	none	y
11	FENWWAS	17/07/2014 to 25/04/2016	**39**	at grade	Watson Rd	na	n	n	n	n	n	n	0	na	none	grass	forest	section end	230 deer	11 deer	y
11	FENEWAS	17/07/2014 to 25/04/2016	**38**	at grade	Watson Rd	na	n	n	n	n	n	n	0	na	none	grass	truckstop	section end	66 deer, 1 moose	10 deer	y
11	FESECALL	none		below	Nosbonsing	under	n	n	n	n	n	n	0		none	grass		section end	na	2 deer	y
11	FESWCALL	none		below	Nosbonsing	under	n	n	n	n	n	n	0		none	grass		section end	na	1 deer	y
69	FELCE	22-Oct-15		below	69	na	n	y	n	y	n	n	3	toward	steep	rock	fence ends at LC bridge,	section end	na	na	na
69	FELCW	22-Oct-15		below	69	na	n	y	n	y	n	n	7	toward	na	rock	fence ends at LC bridge,	section end	na	na	na
11	FEGAPCALLSW	none		at grade	11	none	n										Gap in fence at slope with 4 foot paige wire	gap end	na	na	na

11	FEGAPCALLNW	none		at grade	11	none	n										Gap in fence at slope with 4 foot paige wire	gap end	na	na	na
69	FEGapWS1	22-Oct-15		below	69	na	y	y	n	n	n	n	2	toward	steep slope	rock	fence abut rip rap rock slope, inwards	gap end	na	na	na
11	FESWMOUN	18/09/2015 to 25/04/2016	**55**	at grade	Mountain Rd	under	n	n	n	n	n	y	4	toward	na	rock	tie into high vertical rock cliff above hwy	int end	3 deer	none	
11	FESEMOUN	none		below	Mountain Rd	under	n	n	n	y	n	y	6	toward	na	boulders	fence tied into steep rock face at hwy 11	int end	na	none	n
11	FENEMOUN	18/09/2015 to 25/04/2016	**40**	below	69	under	n	n	n	n	n	y	6	toward	na	bush	inward ext	int end	16 deer	none	y
69	FEGapWN1	22-Oct-15		at grade	HWY 69	na	n	y	n	n	n	n	6	toward	at grade but deer need to climb slope	rock	fence is at grade with hwy 69 shoulder	Gap end			

11	FESWMOUN2	15/04/2016 to 31/05/2016	**55**	above	None	none	n	n	n	n	y	n	0		na	grass	fence end at rocky cliff, Apr 25, 2016	int end	67 deer	1 deer	y
11	FENWMOUN	25/04/2016 to 31/05/2016	**40**	at grade	Mountain Rd	under	n	n	n	n	y	n	0		na	bush		int end	none	none	n
69	FE Kill S	08/01/2015 to 03/08/2016	**18**	at grade	637	over	n	n	n	n	n	n	2	toward	none	grass		int end	2 deer, 1 wolf	1 wolf	y
69	FE Kill N	08/01/2015 to 03/08/2016	**10**	at grade	637	over	n	n	n	n	n	n	3	toward	none	grass		int end	1 wolf	2 deer	y
11	FESEDER	none		at grade	Derland Rd	under	n	n	n	y	n	n	0	na		rock/ grass/ bush	fence tied into rock face	int end	na	none	n
11	FESWDER	none		below	Derland Rd	under	n	y	n	n	n	y	na	toward	steep	rock	houses near FE	int end	na	none	n
11	FENEDER	none		below	Derland Rd	under	n	y	n	n	n	y	na	toward	steep	rock	houses near fence end	int end	na	none	n
11	FENWDER	none		below	Derland Rd	under	n	y	n	n	n	y	2	toward	steep	Boulder	ties into steep rock face at hwy	int end	na	none	n
11	FENWCALL	25/04/2016 to 31/05/2016	**39**	at grade	11	none	n	n	n	n	y	n	5	toward	na	rock cliff	tie into vertcal rock cliff	section end	0 deer	none	n

69	FEGapES2	24-Nov-15		below	69	na	n						2		steep	rock	between OP and UP, fence abuts rip rap slope	gap end			
11	FENECALL	25/04/2016 to 31/05/2016	**38**	at grade	11	none	n	n	n	n	y	n	5	toward	na	rock cliff	tie into vertical rock cliff, cam stolen	section end	na	2 deer	y
69	FETLRW	15/02/12 to 17/06/12	**26**	below	69	na	n	y	n	n	n	n	5		steep	rock	tie into rip rap of hwy slope	section end	4 deer	3 deer	y
69	FETLRE	21/01/12 to 17/06/12	**19**	below	69	na	y	y	n	n	n	n	6	toward	steep	rock	tie in rip rap hwy slope - pre-construction monitoring	section end	na	1 elk	n
69	FENIS	05/07/12 to 03/12/13	**10**	above	69	na	n	n	n	n	y	n	0		na	rock cliff	tie into rock cliff	section end	none	none	n
69	FENIN	21/04/12 to 12/09/12	**28**	above	69	na	n	n	n	n	y	n	0		na	rock cliff	tie into rock cliff	section end	1 wolf	none	n