A photograph of three deer in a grassy field. In the background, there is a blue highway sign that reads "Lundbreck Falls Provincial Recreation Area" with an arrow pointing right. The sign is mounted on a post. There are several other posts with red lights on top, likely for wildlife crossing. The scene is set in a rural area with trees and a clear sky.

Collision Count: Improving human and wildlife safety on Highway 3

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Photo Credit: Gerry Smith

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Executive Summary

To improve wildlife and human safety along Highway 3, Miistakis Institute and partners developed Collision Count to evaluate the effectiveness of highway mitigation. Alberta Transportation mitigated Crowsnest/Emerald Lake site with fencing and jump-outs in September 2016 and has approved the business case for building an underpass with fencing and jump-outs at the Rock Creek mitigation site.

To support these efforts Collision Count, a citizen science program, was developed with the following goals:

- to undertake pre and post mitigation monitoring to evaluate the effectiveness of highway mitigation for improved wildlife connectivity and wildlife and human safety;
- assess the cost effectiveness of investment in mitigation infrastructure along Highway 3; and
- Establish a correction factor for roadkill pick up and removal, which is the dataset used to determine wildlife vehicle collision hotspots.

We selected three mitigation sites identified in Clevenger et al. (2010) report to include in the assessment, Crowsnest/Emerald Lake, Rock Creek and Iron Ridge (control site). Three parallel 50 meter interval transects were developed adjacent to the highway spanning a distance of 300 meters along the highway. Volunteers walk transects once a week and record roadkill observations using a smart phone app.

In addition to volunteer collected data from the Collision Count Program, Highway 3 maintenance contractors, Volker Stevins survey the highway every weekday in the morning and later afternoon and remove roadkill carcasses found on the highway right of way.

We ran two analyses to assess mitigation impact and advance road ecology research:

- To analyze the effectiveness of mitigation at the Crowsnest/Emerald Lake site a before-after control-impact (BACI) study design was used based on data collected by collision count and highway maintenance contractors.
- To calculate a correction factor between wildlife found beyond the Highway 3 maintenance area, the Highway 3 maintenance dataset was compared to the Collision Count dataset.

Initial results indicate:

- An increasing statistically significant trend in roadkill reports by highway maintenance contractors over the study time period at study sites along Highway 3.
- Mitigation seems to be successful (non-statistical) at the Crowsnest/Emerald Lakes site as collisions have reduced from a mean of 5/year before mitigation to 1/year after mitigation.
- Findings from BACI analysis (statistical) to determine the effectiveness of mitigation at the Crowsnest/Emerald Lakes site indicates at least one more year of data should be collected before forming final conclusions about mitigation effectiveness.
- The ratio of wildlife found by highway maintenance personnel (on right of way) and wildlife reported to Collision Count (off-highway right of way) was 1:1.5. This finding supports applying a correct factor to highway maintenance roadkill data at a minimum of 1.5.

Introduction

In 2010, the Miistakis Institute and partners released a scientific report that provided recommendations to improve wildlife safety and connectivity through identifying nine mitigation sites along Highway 3 in southwestern Alberta (Clevenger et al. 2010). Two sites were prioritized for mitigation, Crowsnest/Emerald Lake and Rock Creek to improve human and wildlife safety (Figure 1). The mitigation of highways through the design and implementation of wildlife crossing structures have been shown to effectively reduce wildlife vehicle collisions (WVCs) and improve landscape permeability for wildlife and to allow sufficient gene flow to prevent genetic isolation (Beckman et al. 2010; Sawaya, Kalinowski, and Clevenger 2014). Wildlife crossing structures also result in improved human safety and economic benefits for people (Clevenger, Chruszcz, and Gunson 2001).

While the benefits of wildlife crossing structures are well established (Huijser and Duffield 2009) it is often the political support of local jurisdictions that wield the decision-making authority to make wildlife crossing structures a reality. Garnering support from local citizens for highway mitigation is a key element in realizing these conservation strategies. In addition, the need for scientific data to accurately determine appropriate locations for wildlife crossings is paramount for the success of these structures. Therefore, to ensure safe passage for wildlife requires dialogue and information sharing between the scientific and local communities and decision makers. We identified a citizen science methodology for addressing the challenge of transportation mitigation as a novel approach for engaging the public, scientists and decision makers around this issue of wildlife connectivity.

Collision Count, a citizen science program, was developed with the following scientific goals; to undertake pre and post mitigation monitoring to evaluate the effectiveness of highway mitigation for improved wildlife safety and wildlife connectivity; and improved human safety and cost effectiveness of investment along Highway 3. The program has a conservation goal of building public support for highway mitigation as a means to improve wildlife safety and movement.

The Collision Count program includes volunteers systematically walking a series of transects parallel to Highway 3, extending up to 150m away from the highway, and recording road kill observations using a Collision Count smart phone app. Transects were established at three of the mitigation sites along Highway 3 where Alberta Transportation is considering investing in mitigation infrastructure. The

app enables uploading of a photo to confirm species identification and distinguishes between road kill observed from highway right of way and roadkill observed off of the right of way. Analysis of the data includes a post mitigation assessment in the reduction in WVCs. In addition, an analysis of the difference between road kill observed from highway right of way (usually included in a WVC analysis) and road kill not observed from the right of way (not usually included in WVC analysis), enables the development of a correction factor for WVC data in Alberta, and an important contribution to the road ecology discipline.

Post construction monitoring includes continuation of the Collision Count program to monitor road kill events near emphasis mitigation site, and placement of remote cameras to monitor successful crossings of wildlife.

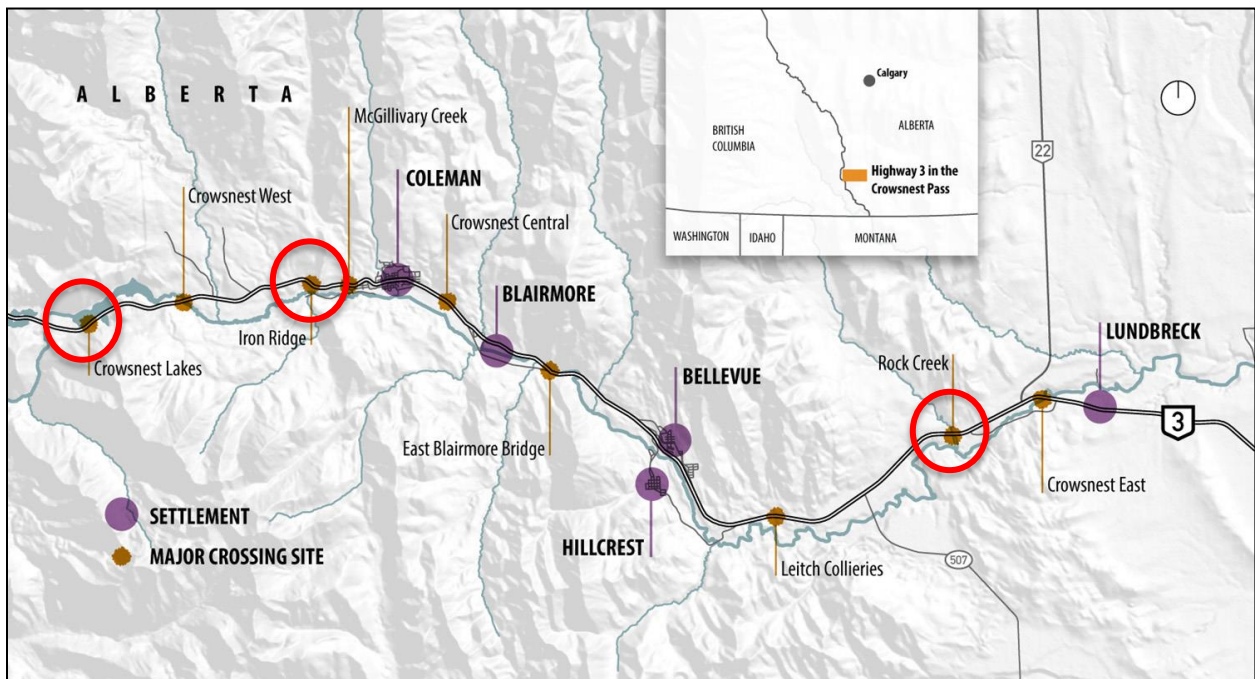


Figure 1: Study Area of Crowsnest Pass and three mitigation emphasis sites (included in study)

Methods

Data were collected from two sources, the Highway 3 maintenance contractor carcass reporting and the Collision Count program for three emphasis mitigation sites; Rock Creek (rc), Iron Ridge (ir) and Crowsnest Lakes (cl) (Figure 1). Two of these sites, rc and cl have been identified as priority for mitigation to reduce WVCs

and ensure safe wildlife passage. Iron Ridge was used as a control site as there are no immediate efforts to mitigate this section for wildlife. These data were analyzed with two goals, to assess the effectiveness of mitigation efforts at the Crowsnest/Emerald Lakes site and calculate a correction factor to account for underreporting of wildlife vehicle collisions (WVC).

Collision Count Data

At each mitigation site, a series of three parallel 50 meter interval transects were established parallel to Highway 3. The transects span a distance of 300 meters away from the highway centered around the emphasis mitigation site (Figure 2-6). Volunteers walk transects once a week and record roadkill observations and the date of their survey using a smart phone app (Figure 7). For each roadkill observation observers report species, if it was located on the highway right of way or off of the highway right of way, and included a photo of the carcass. A local project coordinator trained each volunteer on data collection protocols, safety guidelines and use of the smartphone application. The coordinator assigned transects to the volunteers weekly (most transects are walked in pairs). Since program inception, twenty volunteers have contributed to the program.



Figure 2: Rock Creek North Transects



Figure 3: Rock Creek South Transects



Figure 4: Iron Ridge South Transect



Figure 5: Iron Ridge North Transects



Figure 6: Emerald Lake East and West Transect

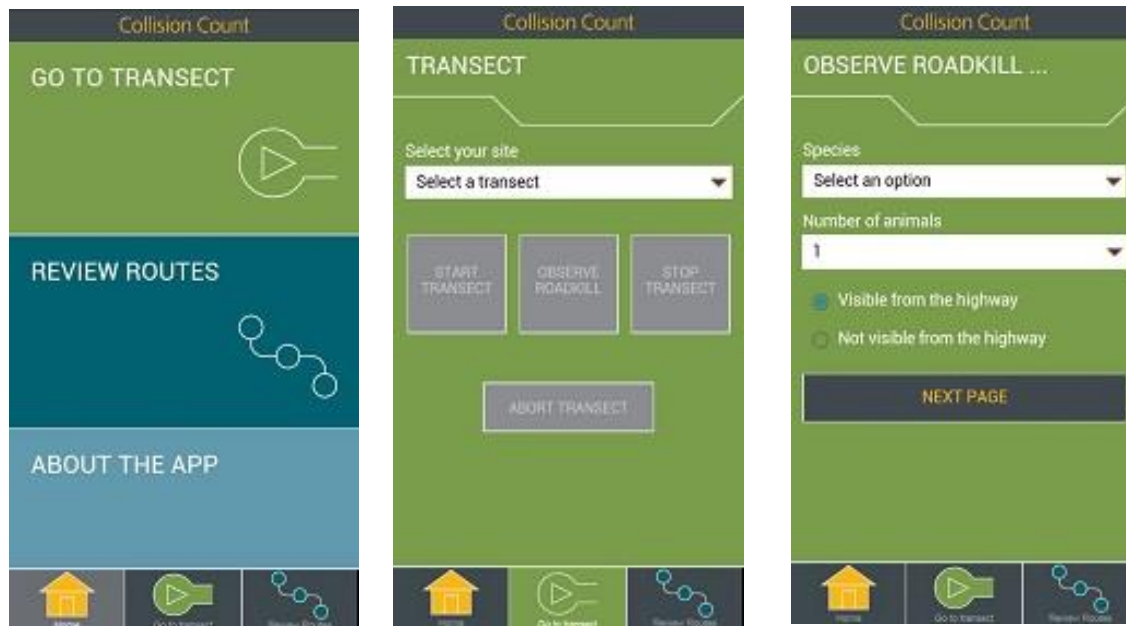


Figure 7: Collision Count smartphone application

Data collection started in 2014 and has been on-going weekly with the exception of periods when snow fall prevented volunteers from parking safely, or fire hazard resulted in a ban on walking the transects in the autumn of 2017 and winter of 2018. For this assessment we used data from April 2014 to December 2017.

Highway Maintenance Contractor Data

Highway 3 maintenance contractors, Volker Stevins survey the highway every weekday in the morning and later afternoon and remove roadkill carcasses found on the highway right of way. From 1997 to December 2017, data was recorded on to hard copy forms and then transcribed using local landmarks used by highway maintenance contractors by Miistakis Institute into a GIS layer. The roadkill data associated with Collision Count transects, 150 m on either side of the three mitigation sites was extracted from the dataset.

Data Analysis

Wildlife fencing and jump-out installations were completed at Crowsnest/Emerald Lake mitigation site in September 16, 2016. No mitigation has occurred at Rock Creek or Iron Ridge and these were used as controls. The Collision Count data and highway maintenance contractor data were summarized by year.

To analyze the effectiveness of mitigation at the Crowsnest/Emerald Lake site a before-after control-impact (BACI) study design was used. The Highway 3 maintenance data from 2014-2017 was combined with the Collision Count data for this analysis. BACI is appropriate when there are data prior to a potential impact and the expected impact is permanent. The interaction term between before/after and control/impact is the variable of interest in BACI models and a significant interaction term tells us there is a BACI effect.

To calculate a correction factor between wildlife found beyond the Highway 3 maintenance area, the Highway 3 maintenance dataset was compared to the Collision Count dataset.

Results

To determine the trend in wildlife vehicle collisions, roadkill data was plotted from 1997 to 2017 within 300m from the three mitigation sites (150 m east and west). Figure 2 shows an increasing trend in roadkill reports by highway maintenance contractors over this time period. Linear regression was significant ($p=0.011$). The outlier in 2013 is due to 12 Bighorn Sheep being reported in a short period of time, suggesting many might have happened at once. Mitigation at Crowsnest/Emerald Lakes was completed September 16, 2016. There were no wildlife-vehicle collisions reported from September 16 to the end of the year in 2016 at Crowsnest/Emerald Lakes.

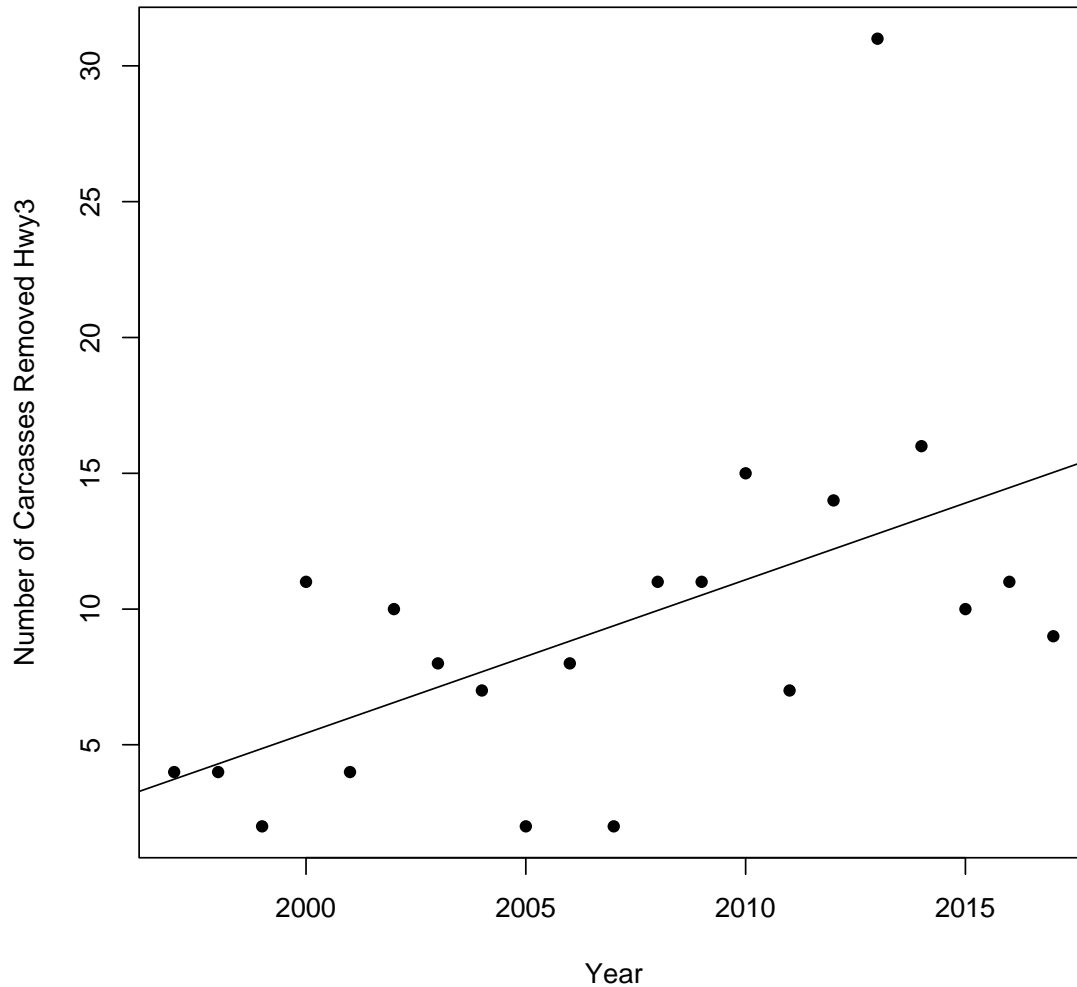


Figure 8: Highway maintenance data from 1997-2017 for the three sites of interest, Crowsnest/Emerald Lakes, Iron Ridge and Rock Creek.

Effectiveness of Mitigation at Emerald/Crowsnest Lakes

To determine if there has been a decrease in wildlife vehicle collision before and after mitigation a Before-After Control Impact (BACI) was run in R. Table 1 highlights the data from two mitigation sites and one control site, transects for each site are separated north (n) and south (s) of highway at Rock Creek (rc), and Iron Ridge (ir) or east (e) or west (w) at Crowsnest Lake/Emerald Lake (el) based on presence of

existing underpass. Highway Maintenance Contractor roadkill data collected by Volker Stevin staff (V) for the site is also displayed for each year.

Table 1: Summary of the number of total wildlife found per species, each year for each site

Year 2014

	ele	elw	eV	irn	irs	irV	rcn	rsc	rcV
Bighorn Sheep	0	1	3	0	0	0	0	0	0
Bird	0	0	0	0	0	0	1	0	0
Cat	2	0	0	0	0	0	0	1	0
Cougar	0	0	0	0	0	0	0	0	0
Deer	0	0	1	4	1	0	6	4	12
Elk	0	0	0	0	1	0	0	0	0
Skunk	0	0	0	0	0	0	0	0	0
Unknown	1	0	0	1	4	0	0	1	0
TOTAL	3	1	4	5	6	0	7	6	12
TOTAL Transects	29	34	daily	37	30	daily	33	37	daily

Year 2015

	ele	elw	eV	irn	irs	irV	rcn	rsc	rcV
Bighorn Sheep	0	0	1	0	0	0	0	0	0
Bird	0	0	0	0	0	0	0	0	0
Cat	0	0	0	0	0	0	0	0	0
Cougar	0	0	0	0	0	0	0	0	0
Deer	4	0	2	0	0	2	3	1	5
Elk	0	0	0	0	1	0	0	0	0
Skunk	0	0	0	0	0	0	0	0	0
Unknown	0	0	0	2	1	0	0	0	0
TOTAL	4	0	3	2	2	2	3	1	5
TOTAL Transects	47	48	daily	54	45	daily	50	52	daily

Year 2016

	ele	elw	eV	irn	irs	irV	rcn	rsc	rcV
Bighorn Sheep	1	0	1	0	0	0	0	0	0
Bird	0	0	0	0	0	0	0	0	0
Cat	0	0	0	0	0	0	0	0	0
Cougar	0	0	0	0	0	0	0	0	0
Deer	0	0	0	0	1	2	1	2	8
Elk	0	0	0	0	0	0	0	0	0

Skunk	0	0	0	0	0	0	0	1	0
Unknown	0	0	0	0	0	0	2	0	0
TOTAL	1	0	1	0	1	2	3	3	8
TOTAL Transects	45	42	daily	49	49	daily	60	55	daily

Year 2017

	ele	elw	eIV	irn	irs	irV	rcn	rCs	rcV
Bighorn Sheep	0	0	1	0	0	0	0	0	0
Bird	0	0	1	0	0	0	0	0	0
Cat	0	0	0	0	0	0	0	0	0
Cougar	0	0	0	0	0	0	1	0	0
Deer	0	0	0	0	0	0	6	5	7
Elk	0	0	0	0	0	0	0	0	0
Skunk	0	0	0	0	0	0	0	0	0
Unknown	0	0	0	0	0	0	0	0	0
TOTAL	0	0	2	0	0	0	7	5	7
TOTAL Transects	42	42	daily	35	41	daily	49	45	daily

ele = Emerald Lake East, elw = Emerald Lake West, eIV = Emerald Lake Volkers
 irn = Iron Ridge North, irs = Iron Ridge South, irV = Iron Ridge Volkers
 rcn = Rock Creek North, rCs = Rock Creek South, rcV= Rock Creek Volkers

BACI Dataset

To run BACI analysis a dataset was created (Table 2) by adding the wildlife counts from each route in Table 1, but wildlife that are not affected by mitigation were excluded, such as birds/cats/skunks (Figure 9). As noted ir and rc were control sites as no mitigation has occurred on these sites while el is the impact site where mitigation occurred. Mitigation at el occurred September 2016 so years 2014 to 2016 were before and 2017 data is after.

Table 2: BACI dataset from R

```
> BACIdata
```

	year	site	BA	CI	wildlife.count
1	2014	el	before	impact	6
2	2014	ir	before	control	11
3	2014	rc	before	control	23
4	2015	el	before	impact	7
5	2015	ir	before	control	6
6	2015	rc	before	control	9
7	2016	el	before	impact	2
8	2016	ir	before	control	3
9	2016	rc	before	control	13
10	2017	el	after	impact	1
11	2017	ir	after	control	0
12	2017	rc	after	control	19

A mixed effects model was used with site as the random variable. A mixed effects model was chosen because there were multiple control sites.

```
> result.lme<-lme(wildlife.count~CI+BA+BA*CI, random= ~1|site, data=BACIdata)
```

Table 3 represents the model summary for the mixed effects model wildlife~CI+BA+BA:CI, random=site where C=control, I=impact, B=before, A=after. The control/impact, before/after interaction

Table 3: BACI model summary from R

```
Fixed effects: wildlife.count ~ CI + BA + BA * CI
```

	Value	Std.Error	DF	t-value	p-value
(Intercept)	9.500000	6.372373	7	1.4908103	0.1796
CIimpact	-8.500000	11.037274	1	-0.7701177	0.5822
BAbefore	1.333333	4.291002	7	0.3107277	0.7651
CIimpact:BAbefore	2.666667	7.432234	7	0.3587975	0.7303

The model summary interaction term is not significant (p=0.7303), indicating there is not a statistically significant trend in wildlife vehicle collisions before and after mitigation.

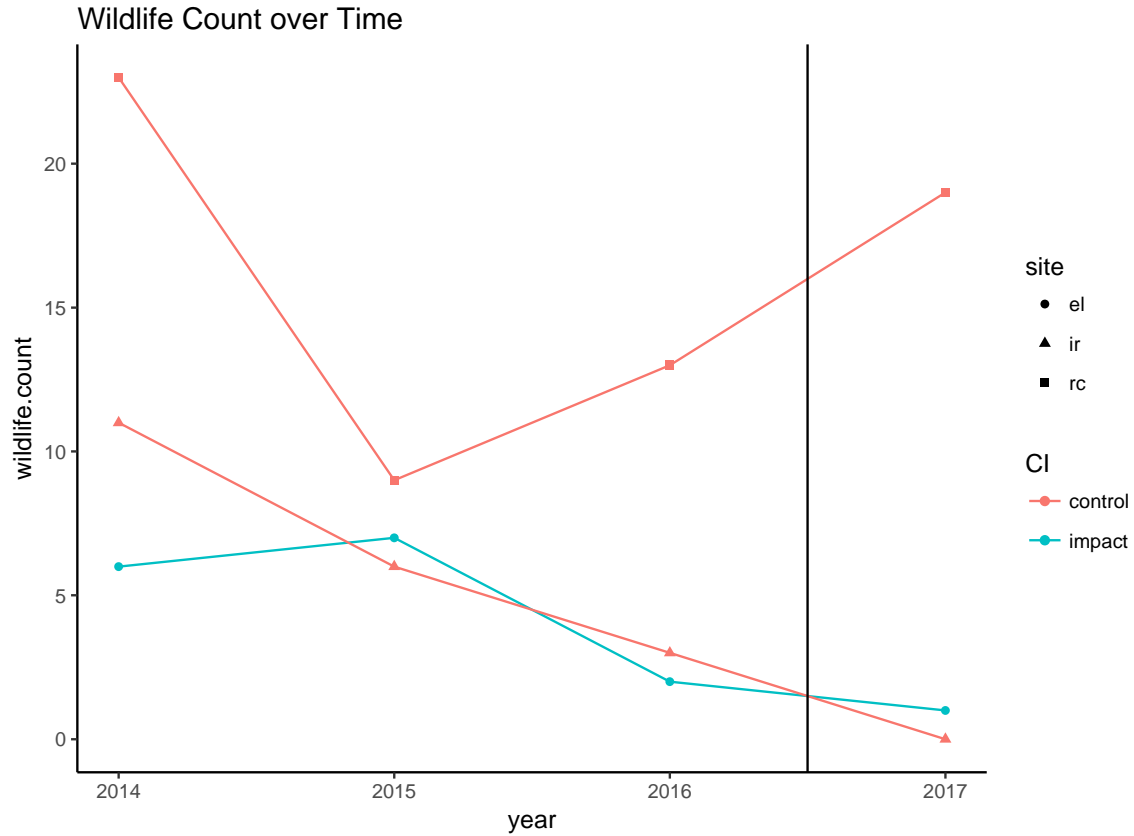


Figure 9: Plot of the number of wildlife for each year at the three sites of interest: Crowsnest/Emerald Lakes (el), Iron Ridge (ir) and Rock Creek (rc). The black vertical line is the completion date for mitigation at Crowsnest/Emerald Lakes (September 16, 2016).

BACI Analysis Re-Run excluding Bones

The BACI analysis was also run excluding the presence of bones to account for the higher number found at the inception of the Collision Count program which could have been from years prior to the study (Figure 10).

Table 4 presents the model summary (excluding bone records from Collision Count dataset) for mixed effects model wildlife~CI+BA+BA:CI, random=site where C=control, I=impact, B=before, A=after.

Table 4: Model Summary (excluding bones) for the mixed effects model

```
Fixed effects: wildlife.count ~ CI + BA + BA * CI
              Value Std.Error DF   t-value p-value
(Intercept)   9.500000  6.737422  7   1.4100348  0.2014
CIimpact      -8.500000 11.669557  1  -0.7283909  0.5992
BAbefore      -0.500000  3.742188  7  -0.1336117  0.8975
CIimpact:BAbefore  4.166667  6.481659  7   0.6428395  0.5408
```

The control/impact, before/after interaction term is not significant (p=0.5408).

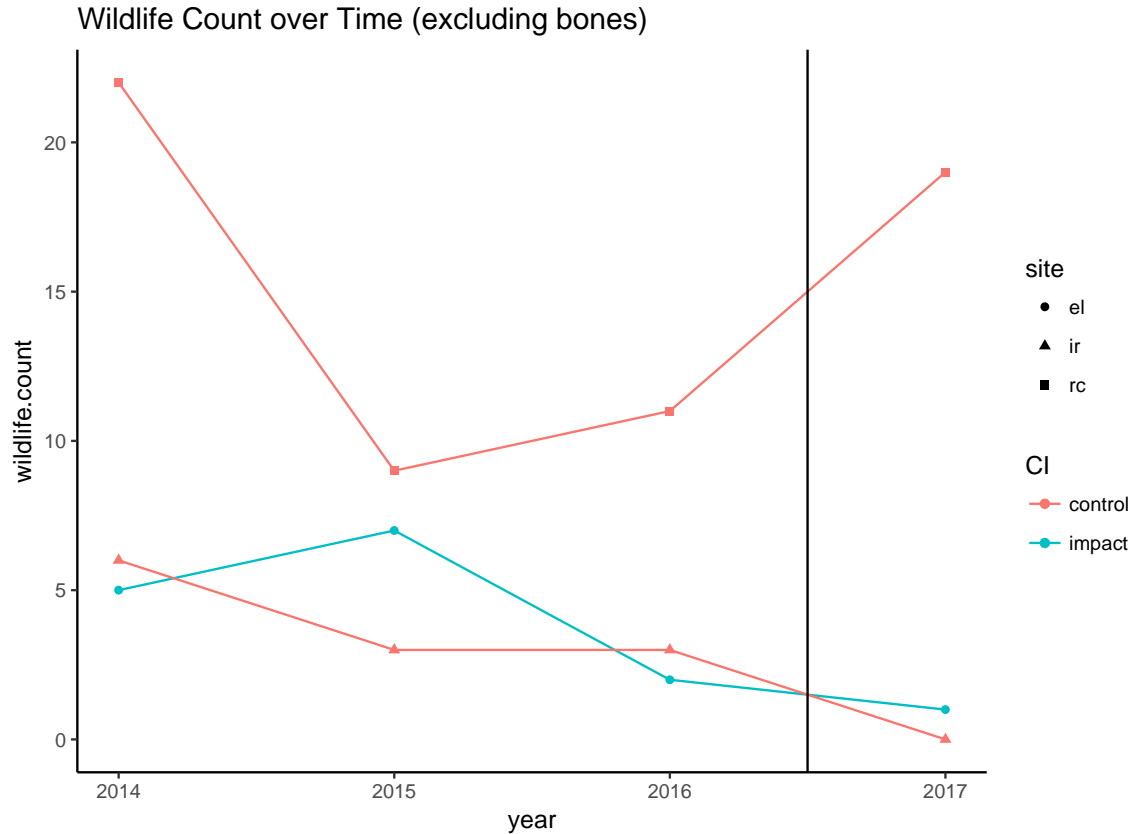


Figure 10: Plot of the number of wildlife, excluding bone sightings for each year at the three sites of interest: Crowsnest/Emerald Lakes, Iron Ridge and Rock Creek. The black vertical line is the completion date for mitigation at Crowsnest/Emerald Lakes (September 16, 2016).

Correction factor for Wildlife-Vehicle Collisions

The overall ratio of roadkill found on the highway right of way and off the highway right of way within 150m of the mitigation site (Table 4) was **1:1.5** over the four year period (Table 5).

Table 5: Number of wildlife reported by Highway Maintenance Contractors and Collision Count from 2014-2017.

	Highway Maintenance				Collision Count			
	2014	2015	2016	2017	2014	2015	2016	2017
Bighorn Sheep	3	1	1	1	1	0	1	0
Bird	0	0	0	1	1	0	0	0
Cat	0	0	0	0	3	0	0	0
Cougar	0	0	0	0	0	0	0	1

Deer	13	9	10	7	15	8	4	11
Elk	0	0	0	0	1	1	0	0
Skunk	0	0	0	0	0	0	1	0
Unknown	0	0	0	0	7	3	2	0
TOTAL Wildlife	16	5	11	9	28	12	8	12
TOTAL Transects	daily	daily	daily	daily	201	296	300	256

Table 6: Roadkill found on right of way and off right of way per year ratio

Year Ratio

2014: 1:1.75

2015: 1:2.4

2016: 1:0.7

2017: 1:1.33

This ratio helps confirm a correction factor should be applied to large mammal carcass data collected by Highway Maintenance Contractors. In most years more carcasses were found off the right of way (not typically reported by Highway Maintenance Contractors) than on the right of way.

Discussion

Highway maintenance contractor data indicates wildlife vehicle collisions are increasing over time at the three emphasis mitigation sites.

The findings from the BACI analysis to determine the effectiveness of mitigation at the Crowsnest/Emerald Lakes site indicates at least one more year of data should be collected before forming conclusions about mitigation effectiveness. There is high variability between years and thus trends will become more apparent by collecting additional years of data. However, mitigation seems to be successful at the Crowsnest/Emerald Lakes site as collisions have reduced from a mean of 5/year before mitigation to 1 WVC after mitigation.

Our control sites highlight the variability between years. Iron Ridge WVC also decreased after mitigation at Crowsnest/Emerald Lakes from a mean of 6.7 prior to mitigation to 0 after mitigation whereas Rock Creek increased from a mean of 15 prior to mitigation to 19 after mitigation. In the absence of a common crossing

point or link between Crowsnest/Emerald Lakes and Iron Ridge, this decrease in WVC could indicate high variability between years.

The ratio of wildlife found by highway maintenance personnel and wildlife reported to Collision Count was 1:1.5. The highest number of WVC found in Collision Count vs Highway Maintenance data was in 2015 (1:2.4) and the lowest was in 2016 (1:0.7). It is likely that 1.5 is a conservative correction factor to apply to highway maintenance contractor data as we only accounted for distance 150m north and south of the highway, representing an area of 45,000m². It is assumed that wildlife wander farther than this and succumb to injuries from collisions with vehicles. In addition, transects were only walked once a week, and we are not able to account for possibility of scavenging by carnivores on roadkill.

Regardless this is a conservative metric that can be applied to the annual Alberta Wildlife Watch dataset of roadkill observations to enable more accurate account of costs from wildlife vehicle collisions.

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