Deadly roads for frogs and toads

A spatial study of amphibian road mortalities and culvert location in Elk Island National Park, Alberta, Canada.

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Table of Contents

Table of Figures

Table of Tables

1. Abstract

Road mortalities involving amphibians and reptiles are an unfortunate consequence of linear disturbances across landscapes. With the expansion of populated areas and the need to access remote locations via vehicle, roads are required, but their impact is greater than just their physical footprint. Mitigation efforts, such as the installation of culverts, are one option of reducing road mortalities among amphibian and reptile populations. Amphibians and reptiles are by far the group with the highest mortality rate due to vehicle impacts. Elk Island National Park, located east of Edmonton, Alberta, offers an excellent opportunity to look at the correlation between road mortality incidences and culvert locations. The main parkway receives hundreds of thousands of vehicle visitors annually, and, with culverts already installed throughout the road network, the analysis of the mortality frequency and location of adjacent culverts should be evident. By examining the spatial relationship between road mortality incidences and culvert access we hope to find a workable solution for amphibian populations. We had strong evidence to support that the mortality rate increased as the distance from the nearest culvert decreased; therefore, mortality rates were strongly related to culvert location.

Keywords: culvert, road mortality, wildlife crossings, migration, population biogeography

2. Introduction

2.1 Statement of the Research Problem

Throughout the world, the increase of paved roads has led to biogeographical fracturing across ecological niches (Brunen et al. 2020). As the need for roads and access increases, so does the harm they can cause to certain biological communities. Whether it is from a genetic (Beebee 2013; Cunnington et al. 2014) or physical change in the populations of certain organisms, the impacts of roads and vehicle collisions reaches beyond the road itself.

Roads also have secondary effects on local amphibian populations: the application of road salts and ice melt compounds (Beebee, 2013) can have devastating effects on amphibians due to their permeable skin. Roads attract amphibians and reptiles by providing warmth due to their ectothermic needs (Cunnington et al. 2014). Unfortunately, frogs have been known to freeze on roadways when they sense vehicles approaching (Mazerolle 2004), increasing their chance of collisions. Conservation efforts must be paired with infrastructure needs to harmonize the effect roads have on local populations, especially amphibians and reptiles.

Amphibians, apart from being at significant risk of decline (Beebee 2013), are the most likely to use under-road culverts that are primarily used for watercourse crossings due to their relative size and ability to tolerate aquatic conditions. This study will focus primarily on amphibians, although we acknowledge other animal groups and their negative association with roads.

Elk Island National Park (EINP, the Park) will be used as a study location due to the data collection of road mortalities and its infrastructure of existing culverts.

2.2 Literature Review

It is no secret that roads have an impact on the local environment and create barriers for wildlife (Beebee 2013). Many studies have been conducted on the effects of roads within local populations by focusing on mammals (Brunen et al. 2020; Clevenger et al. 2001), birds, and, perhaps most of all, amphibians and reptiles (Beebee 2013; Cunnington et al. 2014; Markle at al. 2017; Pagnucco et al. 2012; Patrick et al. 2010). Some focus on the effectiveness of culverts as a whole (Cunnington et al. 2014), while other studies have evaluated why roads are so deadly to amphibians and reptiles (Markle et al. 2017). Relationships between road mortality and nearby wetland locations (Patrick 2010) and precipitation (Pagnucco et al. 2012) have also been explored. There is no shortage of studies and research, but what we are attempting is to synthesize the existing literature with the unique needs of EINP.

2.3 Specific Objectives and Hypotheses

This study is not attempting to question the validity of culverts as mitigation tools for fractured landscapes; rather, we are attempting to determine a spatial correlation between the incidences and nearby culvert locations specifically at EINP. If there is indeed evidence that culverts help alleviate road mortalities, then the addition of culverts and other under-road crossings can be considered for ongoing infrastructure projects.

Given the existing research and relevant studies already engaged, we believe that there is a relationship between road mortality incidences and the location of nearby culverts. That is, we posit that road mortality will decrease in frequency with an increase in culverts available as road crossing alternatives. In addition, we believe that the frequency of road mortalities will increase as the distance to the nearest culvert increases and expect a positive correlation between the two.

Specific objectives of this study include:

1. To conduct an analysis of road mortalities within EINP.
2. To determine if there is a significant correlation between road mortality frequency of amphibians and location of culverts.

2.4 Significance and Importance of the Study

Conservation efforts must be tailored to the specific landscape and ecosystem that requires protection. In this instance, a busy road connecting guests to feature throughout the Park is not only present but necessary. By looking at possible mitigation efforts of road mortalities, we can determine whether the implementation of additional culverts would be beneficial to local amphibian populations.

Animal-vehicle collisions (AVC) are the leading cause of non-natural vertebrate mortalities in protected areas such as parks (Pagnucco et al. 2012). While AVCs can harm the vehicle occupants, this is usually only the case with meso- to megafauna such as deer (*Odocoileus spp.*) moose (*Alces alces*), elk/wapiti (*Cervus canadensis*), and, unique to EINP, bison (*Bison bison spp.*). By contrast, road incidents involving amphibians rarely damage or impact vehicles.

3. Materials and Methodology

3.1 Location of Study

Elk Island National Park, Alberta, Canada, is located 50 km east of MacEwan University. A national park, it is situated within the Beaverhills Biosphere and consists of a mixed parkland ecosystem. Bogs, fens, marshes, ponds, and lakes are all waterbody types found within the Park. The main parkway (Elk Island Parkway) is a 20 km paved roadway running north/south through the Park between Highway 16 and Township Road 550. Administration Road is a 4.5 km paved roadway that connects the main parkway to the west gate located at Range Road 203 and Township Road 544. The Park is home to a number of amphibian and reptile species, including the boreal chorus frogs (*Pseudacris maculata*), western toads (*Anaxyrus boreas*), tiger salamanders (*Ambystoma mavortium*), and plains garter snakes (*Thamnophis radix*). Several of the species found within the Park are listed as sensitive species by the Government of Alberta (2022).

3.2 Research Design and Sampling Strategy

Two sets of data were required for the analysis of this study:

1. Road mortality incident information (E.g., species type, GPS location, date of discovery, etc.).
2. Existing culvert locations within the Park.

The data for the road mortality information was provided to us by EINP for the purposes of this study via convenience sampling and observational collection methods. The existing culvert locations were mapped on foot by the researcher and compared with existing EINP infrastructure records.

By mapping both the coordinates of the road mortalities and the culvert locations into a mapping software program (QGIS® 3.23.3), both a visual and analytical spatial relationship was determined.

3.3 Procedures and Techniques

Road mortality incidence information was collected by patrolling park employees on both an incidental and targeted sweep basis. We found that there was value in combining the two acquisition types for data analysis; therefore, there will be no distinction made between road mortality collection sources. Incidents were recorded using Survey123®, a GPS software application available on tablets, or a GPS unit (Garmin GPSMAP® 64x series). Information including the location of the incident (Lat/Long decimal coordinates), genera and species type (if identifiable), and other relevant data were collected during the sweeps. For the purposes of this project, we used data with a range from May 24, 2023 to September 14, 2023 inclusive in order to capture the time that sweeps protocols were enacted with the most consistency.

Culvert information and location was conducted on foot by the researcher using the GPS phone application Avenza (Avenza Maps® 5.1.1 (232.9)) and GPS coordinates (Lat/Long decimal) of the culverts were captured. As culverts extend beneath road surfaces and are not one single point, the researcher used the outflow (i.e. downstream) of the culvert where it emerges from the bank as the culvert location. A total of 56 culverts were mapped along Elk Island Parkway and Administration Road.

3.4 Data Collection and Analysis

To determine the nearest culvert to the road mortality points, a measuring tool within QGIS was used. Counts were then grouped into corresponding blocks and analyzed. Buffers of 10m aided in the visual capture of the mortality-to-culvert distance (Table 1).

Table 1. Block number and corresponding distance (m) of diameter from culvert to a maximum of 250m (n=25).

Block no.	Distance (m)
01	0-10
02	10-20
03	20-30
04	30-40
05	40-50
//	//
25	240-250

An example of the data integration within QGIS is shown in Figure 1.

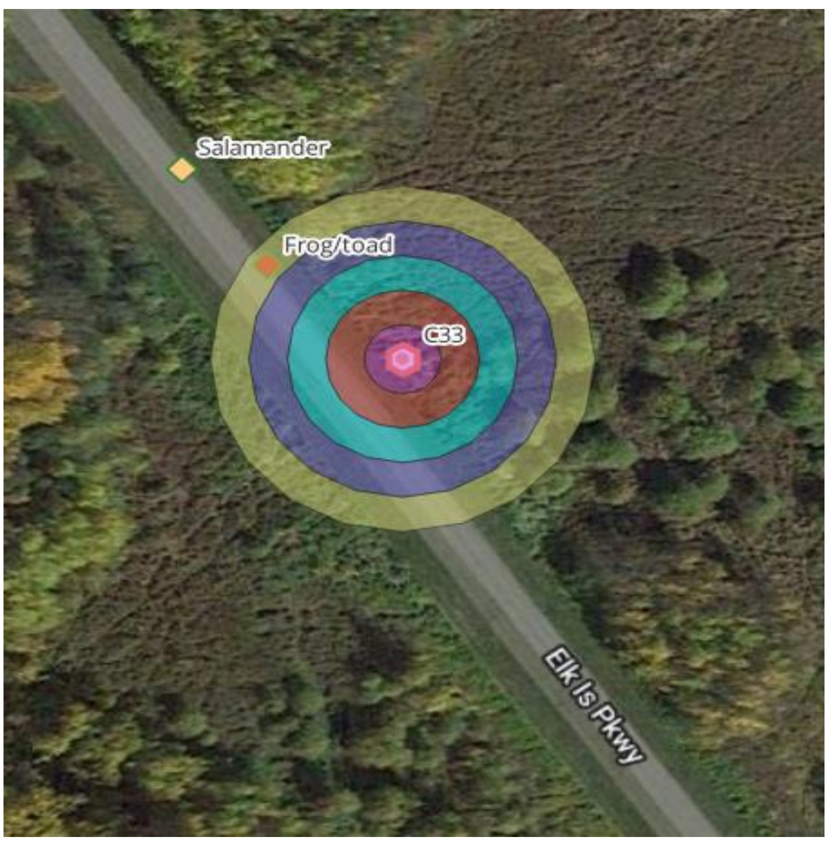

Figure 1. Example of road mortality and culvert location mapping within QGIS® software. The concentric circles display increasing buffers of 10m intervals (0-10m to 40-50m).

The data were analyzed using IBM® SPSS® Statistics to produce a simple linear regression model. The mortality counts were used for frequency counts and the block sections of 10m intervals were used for the culvert distance.

4. Results

4.1 Data Analysis

Data collected from EINP were categorized by date then by species. Species were identified and then further sub-categorized for this study into FROG/TOAD (n=149) or SALAMANDER (n=6) due to the high number of unidentified carcasses (Table 2).

Table 2. Species of road mortalities and corresponding count (n=155).

Species	Number	
Frog species	**3**	
Boreal Chorus Frog (*Pseudacris maculata*)		2
Wood frog (*Lithobates sylvaticus*)		1
Toad species	**10**	
Western toad (*Anaxyrus boreas*)		10
Unknown frog/toad species	**136**	
Salamander	**6**	
(Western) Tiger salamander (*Ambystoma mavortium*)		6
Total:	**155**	

A simple linear regression model resulted in a negative correlation (y=-0.4346x+11.85, R^2=0.855); there is a significant correlation between the number of count frequencies and the distance to the nearest culvert (Figure 2).

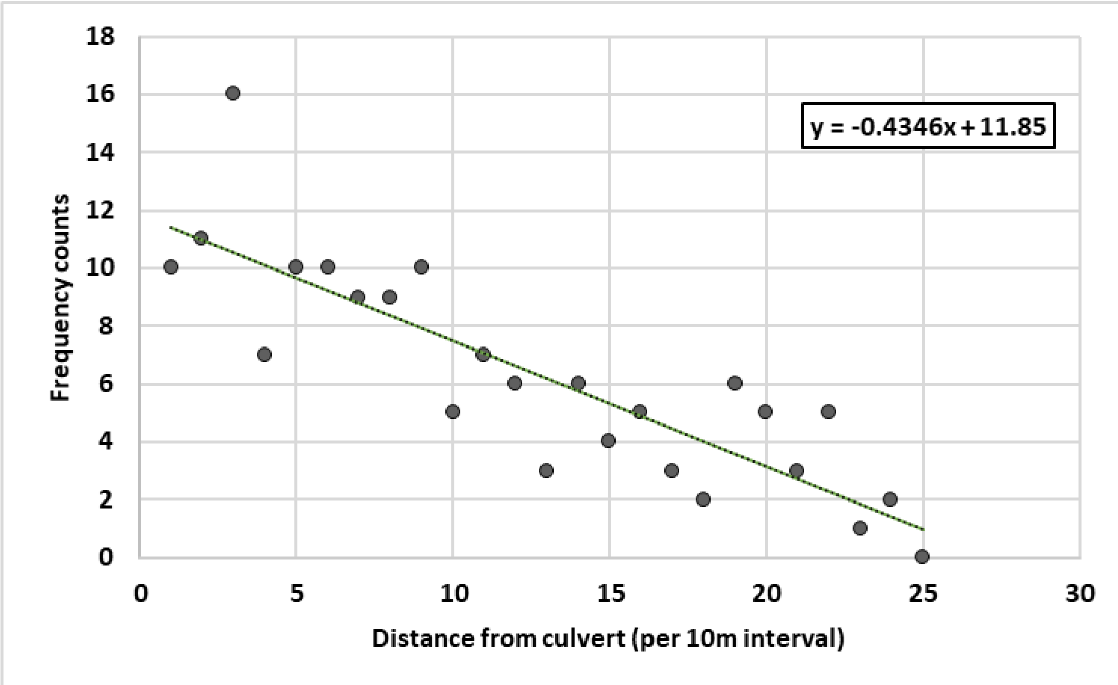

Figure 2. Relationship between the frequency of road mortalities and the distance from the nearest culvert in 10 m intervals (p-value<0.01; y=-0.436x + 11.85; R^2=0.855; n=155; α=0.05).

4.2 Assumptions

By using a linear regression model, we ensured that all related assumptions were not, or mildly, violated. Our Shapiro-Wilk test p-value was 0.296 (d.f.=25; s.d. of 0.979). Additionally, our residuals resulted in weak violations by observing the data on a Normal P-P Plot of Regression with the frequency counts as the dependent variable. We had no clear indication of violations for equal variances and our linearity displayed an obviously strong linear association.

5. Discussion

We expected to find a positive linear relationship between the frequency of counts and distance from culverts; however, with the result of a negative correlation, we must look at many factors that may influence the use of culverts by the amphibians in hopes of explaining the data.

As the distance from the culvert increased, the frequency counts decreased. The block with the highest mortality frequency count was 20-30m (n=16) and the block with the lowest mortality frequency count was 240-250m (n=0), which was the terminal block analyzed in this study. All remaining blocks were clustered along the line of best-fit aligning with the negative correlation result.

5.1 Culvert usage

Our results do not align with a study conducted by Delgado et al. (2018) that found no difference in distance of casualties to the nearest available wildlife crossing (i.e. culvert); however, they were sampling across vertebrate classes and categorized amphibians and reptiles together, whereas we excluded reptiles (snakes) from our study.

In response to the negative correlation, the lack of culvert usage may be explained by not only the condition of the culvert (E.g. free-flowing, jammed/blocked, collapsed, etc.) but also the material of the culvert (E.g. corrugated stainless steel, concrete, metal, etc.), the size of the culvert (length and diameter), as well as the substrate of the culvert (E.g. bare earth, water, concrete/steel/metal, foliage, rocks, etc.). The details of the culverts were not recorded or analyzed, therefore an appropriate usage comparison between culvert types within EINP cannot be determined at this time.

Another possible reason for the negative correlation could be, as Cunnington et al. (2014) proposed, that culverts alone are not enough to reduce fatalities. Location to the nearest wetland may impact the use of culverts by amphibians and reptiles (Patrick et al. 2010). Small vertebrates and amphibians and reptiles have been shown to favour flat-bottomed drainage culverts compared to round metal culverts (Cunnington et al. 2014).

In addition, culverts will only aid in the problem if the animals adapt to and choose to use them (Woltz et al. 2008). Behavioural adaptation by the amphibians is required, and by including such mitigation structures like culverts and fencing within their habitat, the amphibians may become more likely to use them (Pagnucco et al. 2012).

One proposed method to increase culvert usage is the deployment of exclusion fencing that would effectively funnel the animals into the culvert (Markle et al. 2017) and away from the road surface, or to keep them from gaining access to the roads completely. This is not without challenges, as the logistics of installing and maintaining appropriate exclusion fencing is costly and time-consuming (Markle et al. 2017). Also, if the amphibians have no access to the roads, genetic bottlenecks may occur due to the lack of access to suitable mating and hibernation habitats.

5.2 Assumptions, Limitations, and Possible Sources of Error

Due to the dynamic nature of this study, it is important to recognize assumptions and limitations associated with this research. Road mortality incidence sweeps are not performed daily throughout the year and are carried out on foot, bicycle, or vehicle. As discussed, we are grouping the incidental and sweep finds together. Not every part of the roadways was swept at a consistent time interval, and we must assume that not all road mortalities are accounted for. Animal remains may be swept away due to rain, be carried elsewhere, or removed by scavengers (Beebee 2013).

There may be fluctuations in migration and hibernation movement of amphibians (Markle et al. 2017) throughout the year. We were only able to analyze the findings of one May thru September season; however, early spring migration and late fall hibernations may not have been captured within this time period. Vehicle traffic was not quantified and analyzed, so it is difficult to draw any conclusions about mortalities per vehicle/visitor.

Human error in identifying the remains correctly must also be considered. Given the large number of carcasses that were not identified at the species level it is difficult to provide recommendations about the types of mitigation structures to use, as the usage may vary between boreal and wetland frogs and toads.

Also, as the culvert mapping took place on foot by a non-Parks Canada staff member. There is the possibility that not all culverts were found or accounted for. For the culverts that were located, detailed information and states of operation were not captured.

6. Conclusions

While the statistical analysis yielded results opposite to what we expected, the results are no less critical in determining mitigation efforts for amphibian wildlife crossings. Going forward, the use of this study can be applied to the parkway infrastructure of EINP. A further study of the various states of culverts would also be beneficial to Park employees in terms of repair and maintenance needs to ensure that the culverts are available for use by various vertebrates.

Paired with the numerous other studies on the use of wildlife crossings for various vertebrate classes, we believe that this study can aid in developing strategies going forward for animal welfare where road usage results in road mortalities.

7. Recommendations

Several recommendations can be made to ensure that studies similar to this are completed effectively and efficiently:

7.1 Data Collection Methodology

Improved standards on road mortality sweeps would definitely ensure that the data analyzed is as complete as possible. Using the same time of day and the same method (on foot, bicycle, vehicle) paired with better identification efforts would provide more precise data that can be extrapolated to greater populations and allow for more accurate recommendations of mitigation efforts.

Employing an intensive culvert location and investigation would provide for a comparison model of preference of culvert usage by the organisms. Detailed data collection of the culverts would increase the recommendations based on existing vs. ideal conditions.

Other improvements to the methodology would be the inclusion of pitfall traps and/or implementation of trail cameras at the entrances or exits of the culverts. This would allow for, not only correct species identification of what is using the culverts but would also quantify the usage efforts overall. In turn, this would remove the assumption that animals are using culverts even in their ideal condition.

7.2 Further Studies

We would like to propose that further studies, if using the recommendations mentioned above, look at the usage of various culvert types and conditions. In addition, the spatial relation of the culverts, nearest wetland or waterbody type, and hot spots of road mortality counts should be investigated. Do amphibians have a preference between existing culverts within EINP? Does the location of the nearest wetland factor into road mortalities? Are there obvious seasonality correlations with increased counts?

While these are intensive and laborious efforts, we believe that the quantifiable outcomes could greatly benefit the disturbance and danger that roads have on local animal populations.

8. Acknowledgements

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Appendix I – Elk Island National Park map

Legend

Elk Island Parkway – teal

Administration Road – orange