RESEARCH

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MONITORING PARLEY'S CANYON OVERPASS: WILDLIFE APPROACH AND USE RATES

Prepared For:

Utah Department of Transportation
Research & Innovation Division

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August 2025

DISCLAIMER

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16. Abstract

In 2018, the Utah Department of Transportation installed an overpass that was much longer than it is wide (0.13 width to length ratio, the recommended ratio is 0.8) across a major Interstate. The purpose of our study was to determine if the target species, mule deer (*Odocoileus hemionus*), as well as other animals such as moose (*Alces alces*) and elk (*Cervus canadensis*) would use this crossing structure. Additionally, we sought to determine if there were seasonal or temporal influences on successful crossing rates. We conducted an observational study using trail cameras installed along Parley's Canyon Overpass from May 2020 to September 2024, to record wildlife use of the overpass. We recorded 4335 unique visits to the overpass, involving 5395 animals and at least 34 species. Summer was the time of the greatest visitation and crossing rates of the overpass, with little activity from November - March. The most common animal detected at the overpass were mule deer (>3600), although a wide variety of animals used the overpass in some way over the course of the study. Mule deer and moose successfully used the overpass 97.9% (of 1,973 visits) and 100% (of 65 visits) of total visits, respectively; however, elk only made 3 successful crossings (23.08%). We suggest that, due to high success rates regardless of season or time of day, mule deer feel safe enough to cross Parley's overpass if they encounter it regardless of when they encounter it. Additionally, overpasses with smaller width-to-length ratios like Parley's overpass can be used by mule deer and moose successfully, but not elk.

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UNIT CONVERSION FACTORS

SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
	NOTE: volumes greater than 1000 L shall be shown in m^3			
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
°F	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	°C
		ILLUMINATION		
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
		FORCE and PRESSURE or STRESS		
lbf	poundforce	4.45	newtons	N
lbf/in^2	poundforce per square inch	6.89	kilopascals	kPa

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg (or "t")	megagrams (or "metric ton")	1.103	short tons (2000 lb)	T
		TEMPERATURE (exact degrees)		
°C	Celsius	1.8C+32	Fahrenheit	°F
		ILLUMINATION		
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
		FORCE and PRESSURE or STRESS		
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	poundforce per square inch	lbf/in^2

*SI is the symbol for the International System of Units. (Adapted from FHWA report template, Revised March 2003)

LIST OF ACRONYMS

FHWA	Federal Highway Administration
UDOT	Utah Department of Transportation

EXECUTIVE SUMMARY

Encroachment of human infrastructure fragments wild landscapes and introduces a suite of negative impacts for humans and wildlife. In Utah, roadways threaten migratory ungulates by creating a barrier to movements and preventing access to seasonal migration routes. To mitigate these conflicts, state transportation agencies often install wildlife crossing structures to allow animals to safely cross over or under roadways. Selecting the proper crossing structure requires consideration of the species of interest, landscape, location, and structural dimensions. Often there is a balance between the optimal location, the dimensions of the crossing structures, and what is feasible given the landscape. In 2018, the Utah Department of Transportation installed an overpass that was much longer than it is wide (0.13 width-to-length ratio, the recommended ratio is 0.8) across a major Interstate.

The purpose of our study was to determine if the target species, mule deer (*Odocoileus hemionus*), as well as other animals such as moose (*Alces alces*) and elk (*Cervus canadensis*) would use this crossing structure. Additionally, we sought to determine if there were seasonal or temporal influences on successful crossing rates. We conducted an observational study using trail cameras installed along Parley's Canyon Overpass from May 2020 - September 2024 to record wildlife use of the overpass.

We provide a summary of our data, highlighting visitation and crossing rates. We recorded 4335 unique visits to the overpass, involving 5395 animals and at least 34 species. Summer was the time of the greatest visitation and crossing rates of the overpass, with little activity from November - March. The most common animal detected at the overpass were mule deer (>3600 detections), although a wide variety of animals used the overpass in some way over the course of the study.

We evaluated the proportion of crossings for mule deer, elk, and moose that occurred during different times of the day and among seasons (April 2020 - September 2022). Mule deer and moose successfully used the overpass 97.9% (of 1,973 visits) and 100% (of 65 visits) of total visits, respectively; however, elk only made 3 successful crossings (23.08%). We suggest that, due to high success rates regardless of season or time of day, mule deer feel safe enough to cross Parley's overpass if they encounter it regardless of when they encounter it. Additionally,

overpasses with smaller width-to-length ratios like Parley's overpass can be used by mule deer and moose successfully, but not elk.

We detail an educational program designed to introduce high school students to the scientific method using a subset of the data collected during this study. We piloted this program with high school students at Park City High School in 2023, receiving positive feedback from the students and teachers. We have developed the curriculum for a self-paced online course for use by high school educators as well as home-school programs. In conclusion, the Parley's Canyon Overpass, while unconventional in size, was quickly and successfully used by wildlife. This effort provides a positive forum to teach the public about the importance of wildlife overpasses in wildlife conservation.

A Summary of Wildlife Use of Parley's Canyon Overpass

May 2020 – September 2024

1.0 INTRODUCTION

1.1 Problem Statement

Wild landscapes have become increasingly fragmented through encroachment by anthropogenic factors, such as the development of new roads and buildings, resulting in negative impacts on both wildlife and human populations (Sijtsma et al., 2020). The negative effects of wildlife presence on roadways (e.g., wildlife-vehicle collisions) have raised concerns among wildlife management agencies and transportation agencies. Of primary concern among wildlife biologists are the effects of fragmentation, habitat loss, and "barrier effects" (impedance of animal movement due to roadways or railways) that hinder the migration of many ungulate species; these effects are increasing in conjunction with human development (Koivula et al., 2005; Denneboom et al., 2021). To mitigate the negative effects of human development, wildlife management and transportation agencies aim to increase the permeability of the landscape in the form of wildlife crossing structures (Dodd et al., 2003).

Wildlife crossing structures are built specifically to reconnect landscapes that have been fragmented by the implementation of roads, highways, or railways. These structures allow animals to pass over or under roadways without the risk of being struck by a vehicle while simultaneously reducing drivers' risk of striking an animal, which could potentially end in serious injury or death. Wildlife crossing structures are constructed in various forms such as overpasses (allowing movement over barriers or between gaps [bridges, walkways]) and underpasses (allowing movement under barriers [viaducts, culverts, tunnels]). Variations among types of wildlife overpasses include 'overpasses,' land bridges built for a wide variety of terrestrial species (Gloyne & Clevenger, 2001; Corlatti et al., 2009), 'canopy bridges' built for arboreal animals (Soanes et al., 2013), and 'timber poles' built specifically for flying squirrels (Kelly et al., 2013). Overpasses are much more expensive to build and maintain compared to underpasses (Huijser et al., 2009). In general, overpasses benefit a larger variety of species and have higher effectiveness than underpass structures (Clevenger & Huijser, 2011), but there are exceptions to this (Sawyer et al., 2016) and it is nearly impossible to predict species' preferences across

all structure types. Ultimately, the most effective way to mitigate wildlife-vehicle collisions on a roadway is to combine overpasses with underpasses along a stretch of road to accommodate various species' preferences and provide a variety of options to wildlife (Cramer, 2012).

Factors of Influence

Often, researchers use a species-specific approach to investigate significant variables that attract animals to a wildlife crossing structure and what factors influence successful crossing events such as anthropogenic effects, landscape effects, and design effects (Barrueto et al., 2014; Sawyer et al., 2016; Seidler et al., 2018; Pollock et al., 2019). Additionally, studies may focus on a specific category of influence or scale (Gunson et al., 2011). For example, spatial contiguity such as fragmentation (Sijtsma et al., 2020) focuses on the effects of natural landscapes being broken up by human infrastructure. Another common factor is patchiness or patch-size (Downs and Horner, 2012), which considers the dynamics of ecosystems at different scales and the interacting connectivity between them. Finally, dispersal (Caplat et al., 2016) focuses on the movement of individuals away from their birth population. Researchers may also study landscape features such as terrain (Frank, 2022), which considers the slope and aspect of the surrounding land. Land cover (Mimet et al., 2016) is also considered by studying the composition of soils and vegetation surrounding or directly on a crossing structure to better understand how they influence wildlife crossing behavior or frequency. Anthropogenic elements such as human activity (Ng et al., 2004) and traffic rates (van der Ree et al., 2015) can negatively impact the use of crossing structures. Other abiotic factors such as seasonality (Gloyne and Clevenger, 2001) and time of day (Frank, 2022; Denneboom et al., 2021) have been found to shift patterns of crossing behavior. Lastly, and possibly most studied, are structural elements such as size, length, height, or shape of a structure (Smith et al., 2015), structure type (Sawyer et al., 2016), and structure age (Gagnon et al., 2011). The details of these last elements can be tailored to suit the needs and preferences of the target species to be successful.

In the United States, since collisions with large migratory ungulates are more frequent and costly, they are often the species of concern when considering design characteristics of a crossing structure. While there have been many studies focusing on why species may use certain crossing structures and not others due to landscape and structural influences (Schwender, 2013), there is a remaining gap in knowledge regarding temporal factors of influence and the influence that season and "time of day" have on structure usage. Seasonal patterns in wildlife behavior and movement have long

intrigued scientists; studies have been increasingly centered around seasonal patterns for the last 70 years (Varpe, 2017). These innate responses seen in many species are often drivers of animal movement, behavior, decision making, and various other biological characteristics. This importance also persists in the literature related to wildlife crossing structures (Joly et al., 2021). When considering seasonal patterns in migratory ungulates, we have long understood the general effects season has on them. Migration is essential for ungulates in the American West for a multitude of reasons (e.g., high-quality forage and gene flow). While it is not known exactly why ungulates choose certain routes to reach their seasonal ranges, it is crucial that those migration routes are maintained, and that connectivity within the widest extent of these ranges is kept intact (Simpson et al., 2016). In addition to seasonality, some studies focus on "time of day" analysis, determining which time during the day ungulates display the greatest amount of activity and highest success rates at a crossing structure. Time-of-day evaluation is important because human activity usually peaks during daytime hours and may influence movement of animals (Conover, 2002) and could be the deciding factor between a successful or unsuccessful crossing. These times are typically broken down categorically as the following: crepuscular (dawn and dusk), diurnal (daytime hours after dawn and before dusk), and nocturnal (nighttime hours).

Ungulate Preferences

Seasonal patterns in wildlife behavior and movement have long intrigued scientists; studies have been increasingly centered around seasonal patterns for the last 70 years (Mohammadi and Kaboli, 2016; Varpe, 2017). Seasonal migration, which is seen in many different species, is often a significant driver of animal movement, behavior, and decision making (Joly et al., 2021). Most native ungulates in the American west migrate throughout the year to gain access to food, shelter, and breeding grounds. These movements are also critical to maintain gene flow and thus species' vigor (Sawyer et al., 2016). Wildlife species with larger spatial requirements or that seasonally migrate are often more susceptible to the effects of roadways (Gloyne and Clevenger, 2001). Migratory ungulates, such as mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and moose (*Alces alces*), are among the most negatively affected species in Utah (Cramer, 2013). A vast majority of wildlife-vehicle collisions afflict mule deer annually due to the high number of migrating individuals encountering major highways and interstates along their migration routes (Sawyer et al., 2012; Cramer et al., 2019).

Ungulates generally prefer viaducts over any other crossing structure (Young et al., 2023). When comparing overpasses to underpasses, ungulates tend to have higher success rates on overpass structures

(Simpson et al., 2016). Research has determined that ungulates show highest success rates at viaducts that are relatively long, have surrounding vegetative cover at both entrances, and no water present in the crossing structure (Denneboom et al., 2021). In terms of overpass success, ungulates exhibit preference for overpass structures that are relatively long compared to how wide they are (>0.8 width to length ratio; Brennan et al., 2022). They prefer to have open entrances that are not covered in vegetation. Ungulates, as a group, cross underpasses most successfully when the underpass is designed to be relatively wide and long with no vegetative cover at the entrances (Denneboom et al., 2021). In general, wildlife crossing structures are more successful for all species of ungulates when paired with at least 2.5-meter-high fencing that guide animals into the crossing structure (Mysłajek, 2020; Borowik, 2021; Baker, 2022). It should be noted that, although these characteristics are considered preferences for ungulates, they should not be used in a project prescription based on these statistics alone as the specific preferences of the target species could be different from the generalities of the ungulate group.

Mule Deer

When focusing on migratory ungulates in North America, seasonal effects are almost always a significant factor affecting attempted crossing and successful crossing rates of individuals (Clevenger and Waltho, 2006). Mule deer migration occurs in response to severe cold weather events and snowpack (Monteith et al., 2011). Nutritional condition, age, and summer residency of individual mule deer may also affect migratory responses and could cause individuals to delay migration, putting them at higher risk of mortality to natural causes (Monteith et al., 2011). Past studies have determined that mule deer are most active and most successful at using wildlife crossing structures during the autumn months, followed by the spring (Sawyer et al., 2012; Simpson, 2012; Starr, 2013; Dodd et al., 2012). However, Kintsch et al. (2020) noted an exception; in their study, mule deer were most active and were successful 96-97% of the time at wildlife crossing structures during the winter months. Schwender (2013) also found that mule deer were most active and successful during the autumn, but the second most active season was the summer (41.46% and 28.57% success rate, respectively). Starr (2013) found that mule deer were more active during the summer at 3 underpasses while 2 other underpasses had the highest activity in autumn. Additionally, mule deer are most active and more successful at using crossing structures during the crepuscular hours of the day (Starr, 2013). Perhaps the most influential driver of deer-crossing success rates is structure age; several studies determined that success rates rapidly increased annually after a structure installation, and by the third year, mule deer were roughly 80-98% successful and accustomed to using the wildlife crossing structures (Sawyer and LeBeau, 2011; Sawyer

et al., 2012; Simpson, 2012; Schwender, 2013; Starr, 2013; Frank, 2022). It should also be mentioned that most studies determined that mule deer had higher success rates (percentage of successful crossings out of total number of attempted crossings) at overpasses compared to underpasses or jump-outs (dirt ramp allowing animals out but not back in; Simpson, 2012; Starr, 2013; Frank, 2022).

Elk

Elk migration occurs at similar seasonal periods to mule deer but typically does not extend as far as mule deer migration does. Compared to mule deer, elk are more active and successful at using crossing structures in the spring (Gagnon et al., 2007; Dodd et al., 2012) and autumn (Gagnon et al., 2017). These two studies both noted that seasonal influence had the greatest effect when determining successful underpass use. Multiple studies reported that elk are more active at crossing structures during crepuscular hours of the day (Gagnon et al., 2007; Dodd et al., 2012; Barrueto et al., 2014; Kintsch et al., 2020); however, Starr (2013) found the opposite to be true. Dodd et al. (2012) noted that elk success rates were highest during nocturnal hours and lowest during diurnal hours, while Gagnon et al. (2007) recorded the highest success rates from dusk into the nighttime hours. Elk seem to have better success rates at underpasses rather than overpasses in each study, which is the inverse effect we see with mule deer (Gagnon et al., 2007; Kintsch et al., 2020; Dodd et al., 2012).

Elk success on overpasses where studies reported width and length of structures are limited in the literature. However, elk success in summer and winter was positively correlated to the width of a structure (both overpasses and underpasses), and the length of the structure is negatively associated with elk crossing success in summer (Clevenger and Waltho, 2005).

Moose

The timing of moose migration varies more than both elk and deer. Moose migration in the American West typically occurs between April and June as they move from winter to non-winter ranges; they then return to wintering ranges typically between December and January. Migration is largely considered to be a response to snowfall or snowpack during these periods (Demarchi, 2003). Moose also exhibit slightly different seasonal behaviors and patterns related to wildlife crossing activity and success rates (Demarchi, 2003). Seasonally, moose appeared to be more active and have higher successful crossing rates during summer months (Starr, 2013) and were virtually absent during spring months

(Starr, 2013; Noordeloos, 2016). Additionally, moose were most active and had higher successful crossing rates during nocturnal periods (Starr, 2013; Noordeloos, 2016).

Utah Wildlife Crossings

As of April 2024, there were 119 wildlife crossing structures in Utah, only two of which were overpasses; some of these crossings are opportunistic and were not constructed intentionally to assist wildlife. The two overpasses were the I-15 overpass located in Beaver County, Utah, and Parley's overpass, on Interstate 80 (I-80 henceforth) on the border of Salt Lake and Summit Counties, Utah. The other 117 crossing structures were underpasses of distinct types (arches, bridge underpasses, culverts, or viaducts; Utah Wildlife Migration Initiative, 2022). Most were built specifically to assist migratory ungulates, specifically mule deer, because of the high amount of wildlife-vehicle collisions involving them and the threat they pose to human safety (Huijser et al., 2009). Since mule deer are crepuscular animals (more active during dawn and dusk) and migrate seasonally, it is paramount that wildlife crossing structures are effective enough to be used by mule deer, and other ungulates, during periods of high human travel frequency.

There is a high volume of traffic on I-80 (57,000 vehicles per day and rising) and much of this traffic occurs during daytime hours (Cramer et al., 2019). The main goal of this study was to observe how migratory ungulates used Parley's overpass and to separate crossing events (behavior exhibited by animals at a structure) by season and time of day to better understand how these factors affect overpass visitation rates, and subsequent crossing success.

1.2 Objectives

The first objective was to determine if a structure with the dimensions of Parley's overpass would be effective for ungulates throughout the year. The second objective was to determine if there were seasonal or temporal factors that affected visitation rates and the frequency of use. Understanding the patterns of use and limitations of Parley's overpass will allow wildlife and transportation agencies to consider whether to install future crossing structures with similar characteristics to Parley's overpass. This study will add to the body of literature regarding wildlife overpass use by migratory ungulates during seasonal and temporal variations

1.3 Scope

To monitor wildlife use of the overpass, Utah State University (USU) and UDOT placed video and photo cameras along the Parley's Canyon Overpass (Figure 1). In 2019, UDOT installed three motion-triggered stationary remote video cameras. In May 2020, USU installed six motion-triggered Bushnell (Bushnell Corporation, Overland Park, Kansas, USA) trail cameras (Bushnell 20 MP trail camera, 720p HD color video, Passive Infrared Sensor). Data was collected for 5 years and analyzed to determine successful crossings of the overpass.

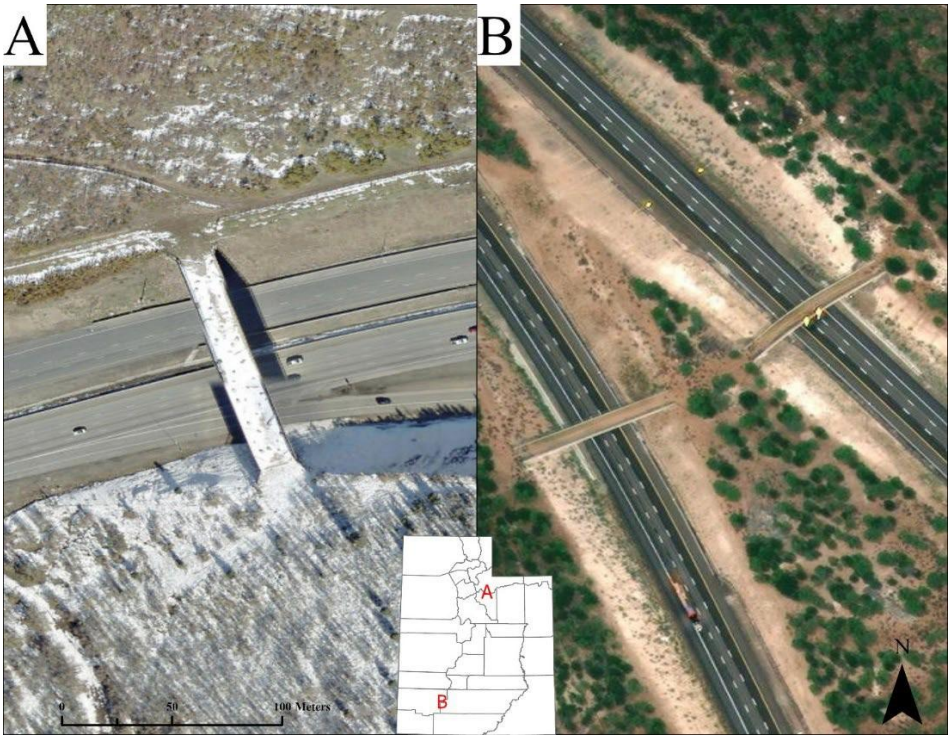


Figure 1. An aerial view of Parley's Canyon Overpass (A), Summit County, Utah, and I-15 overpass (B), Beaver County, Utah, 2024.

2.0 RESEARCH METHODS



Figure 2. The location and orientation of motion-triggered cameras deployed on Parley's Canyon Overpass, Summit County, Utah, 2021-2023. One photo camera was located in the center of the overpass and all the other cameras recorded video.

2.1 Overview

To monitor wildlife use of the overpass, Utah State University (USU) and UDOT placed video and photo cameras along the structure. In 2019, UDOT installed three motion-triggered stationary remote video cameras. In May 2020, USU installed six motion-triggered Bushnell (Bushnell Corporation, Overland Park, Kansas, USA) trail cameras (Bushnell 20 MP trail camera, 720p HD color video, Passive Infrared Sensor); 5 were set to record 1 one-minute video when triggered, with a 0.7-second lag between subsequent detections (i.e., animal movements); the sixth camera was placed in the center of the overpass and set to record a burst of 3 photos when triggered, with a 5-second lag between subsequent detections (Figure 2) to ensure capture of any animal in the middle of the structure.

Cameras were able to capture events at up to 24 m in the direction they were oriented, which covers the entire width of the overpass. Cameras were situated ~1.5m off the ground oriented in a way where they could capture crossing events on the overpass and capture parallel events (events where animals walk past the entrance of a crossing structure, but do not enter it) near the overpass (Figure 2). Having the cameras oriented this way allowed the researchers to capture events across the entirety of the structure and detect if an animal crossed from one side to the other, attempted to cross but returned to the entrance, or was only near the overpass.

USU researchers set cameras to the highest sensitivity levels to increase the ability to detect any animal activity; we were able to use this setting with minimal false triggers due to the lack of vegetation or moving non-target objects on the structure. We placed each camera inside a steel box that was locked with a coded combination lock. We visited the overpass every 2-6 weeks to retrieve SD cards and maintain the cameras. We monitored these cameras through September 2024.

2.2 Detection Categorization

Wildlife activity at the Parley's Canyon Overpass was first categorized as a detection, and then detections were examined to determine overpass use (hereafter 'crossing event'). A detection was simply an animal photo on one or more cameras. For each detection, we recorded the following information: camera number, file name, date of detection, time of detection (military time), general weather at time of detection, length of video, species in detection, size of group in detection, age/sex class of individuals in detection, and the nature of the crossing event. If an animal was detected on additional cameras within 10 minutes, we considered this part of the initial detection. If this was a >10-minute gap between video captures we considered the subsequent capture an independent event.

We looked at a cluster of detections recorded at subsequent times among cameras to determine a wildlife crossing event. For analysis, a group of animals (often a female and her young) were considered as one crossing event. We created 5 categories of possible types of crossing events: 1) if an animal was detected entering, then exiting from the same side of the crossing, within the same video, we considered this an 'approach;' 2) if an animal was detected only entering the structure we considered this as "entered;" 3) if an animal was detected only exiting the structure, we categorized this as "exited;" 4) if an animal was detected on one of the cameras situated in the center of the crossing, but nowhere else, we denoted which direction they were heading and categorized the detection as "other;" 5) If an animal was detected walking past the crossing (parallel event), we categorized this as "parallel." Each photo was given one of these 5 designations.

By examining the series of designations for a particular animal, or group of animals, we could determine if the animal or group successfully crossed the overpass. For example, if an

animal was detected entering the overpass on one side and detected exiting the overpass on the other side, we considered this a successful crossing. We limited the allowable time for a successful crossing to 10 minutes, to ensure that we were evaluating one event. If an animal was detected entering and exiting on the same side, we considered this an attempted crossing. If an animal entered the crossing but was never detected exiting, then the detection was marked as inconclusive.

We conducted summary statistics to determine total numbers of individual detections, crossing attempts, and successful crossings by species, by time of day, and season. Detections and crossing attempts were converted to a rate of # of detections/100 camera nights and #crossing attempts/100 camera nights. This rate allowed for a constant comparison when considering the variability of days per month, the number of cameras in operation at any one time, and how many years we collected data in a given month. For example, for any given month the calculation was ((# detections during that month)/(# days during that month))*100. We did not include an additional calculation for the number of cameras, because this factor was taken into account when calculating the number of detections.

2.3 Regression Analysis for Seasonal and Circadian Differences

We conducted statistical analyses in R (v4.2.1; R Core Team, 2022) To determine if there were any differences in daily use or seasonal use. We focused analyses on ungulates as a group (all ungulate species collectively) and separately (mule deer, elk, and moose). We conducted a generalized linear model (GLM) analysis in R with “time of day” and “season” as factors of influence and plotted the outcomes to ensure the lines fit the model properly. We ran a binomial regression model to get a prediction of success rates for our seasonal and time-of-day measurements for mule deer and moose; elk were excluded from the analysis due to a small sample size. Lastly, to determine the successful crossing rate of specific species and all crossing events we distributed success and repel events dichotomously and calculated success rate as a simple binomial proportion (Equation 1).

Equation 1:

$$\text{Success Rate} = \frac{\text{Species Unsuccessful Events}}{\text{Species Successful Events}} \times 100$$

2.4 Dimension of Wildlife Crossings

We compare usage from April 2020 to July 2022 by mule deer (*Odocoileus hemionus*) at the Parley's Canyon overpass to that of 20 underpasses, 1 overpass, and 4 viaduct crossing structures in the state of Utah. Due to the compatibility of data we collected at Parley's overpass and the data that have been collected from other crossing structures, we compared success rates of crossing events only for mule deer.

Each mule-deer crossing event, excepting parallel events and inconclusive detections, was deemed either "successful" or "unsuccessful." A total of 41,819 successful/unsuccessful crossing events were analyzed across 26 different wildlife crossing structures. Using observations at the event level, such that the response was binary (either successful or unsuccessful), we estimated the probability of successful passage at each structure using a generalized linear model with a binomial distribution and logit link. Crossing structure was the fixed factor, and we assumed that all events at a crossing structure were independent events and that the events at each crossing structure represented the same sampling scenario (day of year, time of day, etc.).

The statistical model was fit using the glmmTMB function in the glmmTMB package (Brooks et al., 2017) in R software (v4.2.1; R Core Team, 2022). We used the emmeans package (v1.8.5; Lent, 2023) to estimate probability of successful passage at each crossing structure.

3.0 DATA EVALUATION

3.1 Overview

In this section, we provide the summary analyses of all mammalian visitors and users of the overpass for the duration of the study May 2020 - September 2024. Because the scale of use differs greatly among species, we chose to separate our results into 'common' and 'uncommon' species for the ease of interpretation. We also conducted a statistical analysis of seasonal and temporal factors affecting successful crossing rates for the three common ungulates, elk, moose and mule deer from 2020-2022. Finally, we consider the crossing rates observed at Parley's Canyon in context by comparing the length of width of this structure to those of other crossing structures, and their successful crossing rates.

3.2 Overpass Visitations (Detections)

Parley's Canyon Overpass was used by a variety of animals either simply as habitat, used during their daily activities, or as a way to get from one side of Interstate 80 to the other side. If we detected an animal on either side of the overpass, we considered this a visit to the overpass, regardless of the subsequent use of the overpass. We recorded 4335 unique visits to the overpass, involving 5395 animals. The most common animal detected at the overpass were mule deer (>3600), although a wide variety of animals used the overpass in some way over the course of the study.

The following animals were detected <5 times during the course of the study: American mink (*Neogale vision*), unknown bat species, domestic chicken (*Gallus domesticus*), dark-eyed junco (*Junco hyemalis*), deer mouse species (*Peromyscus sp*.), domestic dog (*Canis familiaris*), green-tailed towhee (*Pipilo chlorurus*), unknown hawk species (*Buteo spp.*), jackrabbit (*Lepus sp.*), mourning dove (*Zenaida macroura)*, red squirrel (*Tamiasciurus hudsonicus*), domestic sheep (*Ovis aries*), wild turkey (*Meleagris gallopavo*), unknown woodrat species (*Neotoma sp.*), and yellow-bellied marmot (*Marmota flaviventris*). Uncommon animals were detected between five and 50 times during the course of the study (Figure 3). Uncommon species that were

detected at the overpass ranged from small mammals (mice, squirrels, etc.) to black bears (*Ursus americanus*).

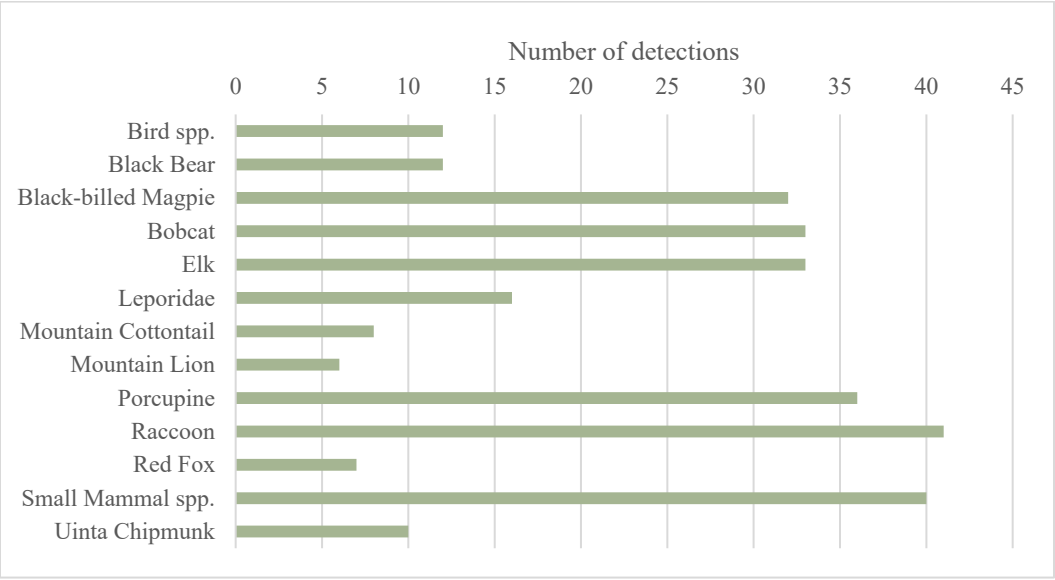


Figure 3: The number of detections of uncommon wildlife species at the Parley's Canyon Overpass, Utah. May 2020 - September 2024.

Common users (>100 detections) of the overpass area included coyotes (*Canis latrans*), moose (*Alces alces*), mule deer (*Cervus elaphus*), and rock squirrels (*Otospermophilus beecheyi*; Figure 4). These five species commonly used the area near the overpass as well as the overpass itself. There were 105 detections of unknown species, often smaller mammals that moved so quickly that they were a blur in the video.

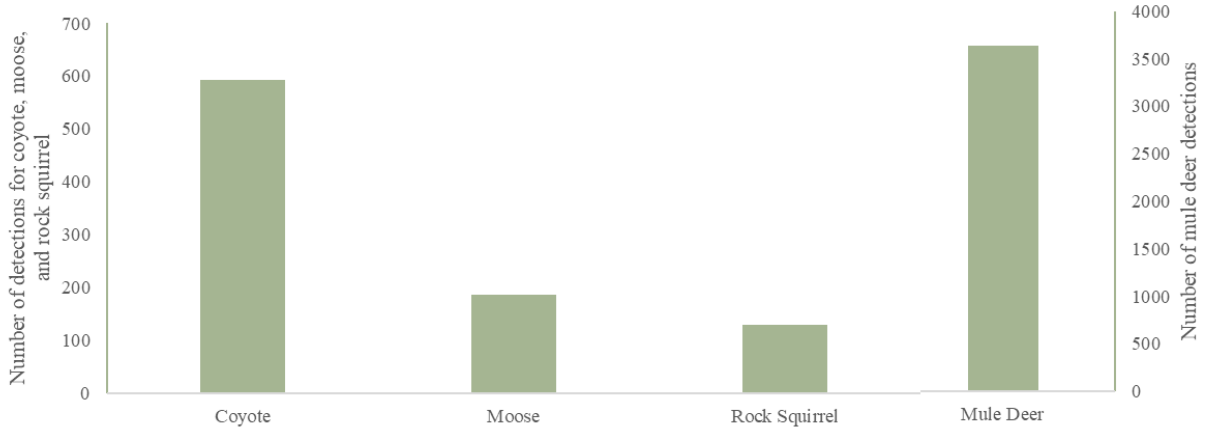


Figure 4: The number of detections of common wildlife and humans at the Parley's Canyon Overpass, Utah. May 2020 - September 2024.

3.3 Crossing Attempts by Wildlife

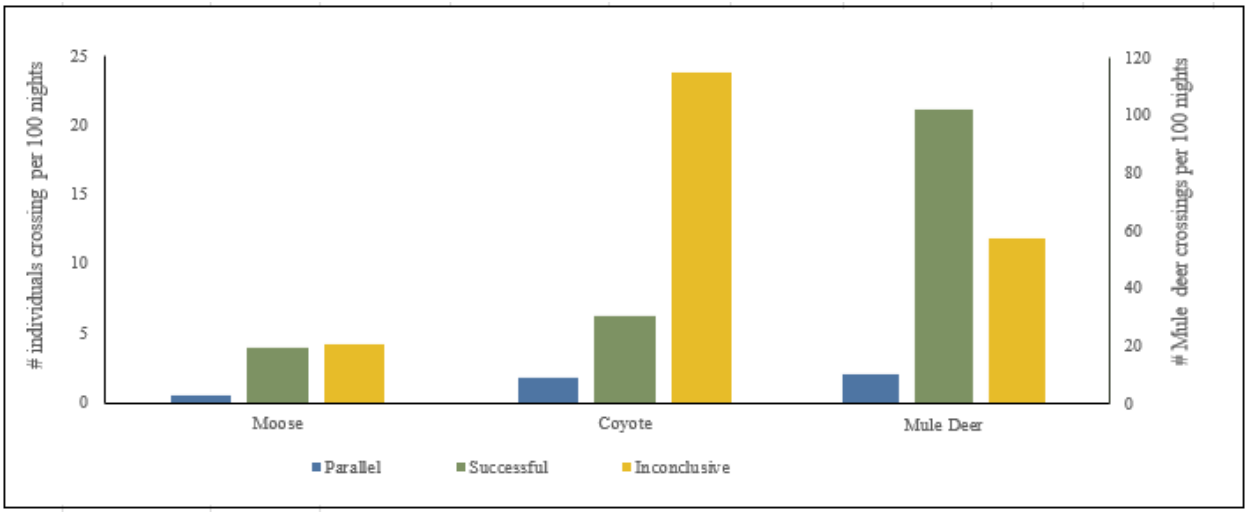


Figure 5: Number of individual coyote, moose, and mule deer crossing events per 100 nights at Parley's Canyon Overpass May 2020 - September 2024.

Detections among the five trail cameras were analyzed to determine an approach to or adjacent use near the overpass, an unsuccessful crossing (the animal entered the overpass, passed the apron, and then returned), and a successful crossing (the animal entered the overpass and continued to exit out the other side). When we documented an animal entering but not exiting, or we documented an animal only exiting, we considered this an 'undetermined' crossing. We

detected 1867 crossing attempts, involving 2563 individuals. Often, these individuals were a mother mule deer and her offspring and therefore decisions were made as a group, rather than at the individual level. In this situation, the family group was considered as one event (Ledbetter, 2025). However, it is interesting to note just how many individuals were involved in crossing attempts during the study. Crossing attempts varied greatly among species, and also among years.

Coyote, moose, and mule deer had the highest rates of crossing events during the study (Figure 5). Mule deer had the highest rates of successfully crossing the overpass; however, coyotes use the area along the overpass regularly. This documented activity among coyotes was most likely due to the fact that there appeared to be a den of coyotes immediately adjacent to the south entrance of the overpass. The individuals associated with this den were frequently detected along the apron of the south side of the crossing. Most of the time, however, we could not determine whether or not they were crossing the overpass. It appeared that it was more likely that they were just using the apron of the overpass as part of their home range and daily activities. If we look at just the crossing rates of our 4 most common species, one can see that the rates of successful crossing varied across the years; for this figure we present the number of crossing attempts, rather than the number of individuals involved (Figure 6).

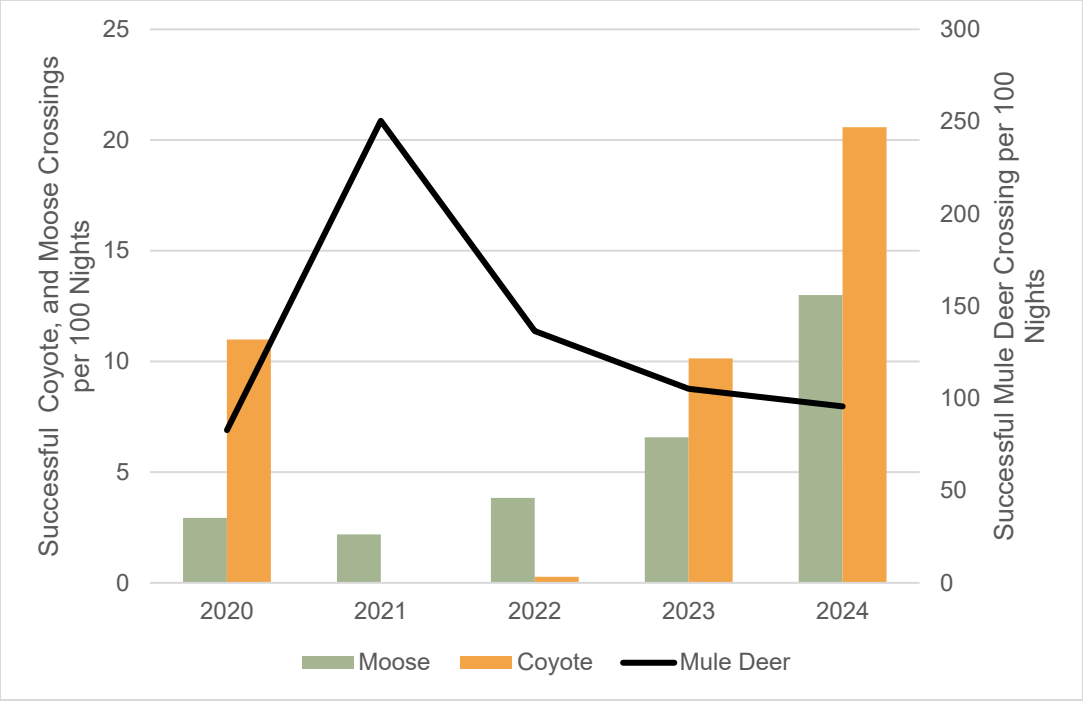


Figure 6: The number of successful crossings per 100 nights of coyote, moose, and mule deer, illustrated by year, at Parley's Canyon Overpass, Utah, May 2020 - September 2024. Mule deer are plotted on a different axis due to difference in scale.

While not as common, black bear, elk, porcupine, raccoon, and rock squirrel were also detected successfully crossing Parley's Canyon overpass (Figure 7). With the exception of elk, these animals were seen alone on most detections. Elk were seen traveling perpendicular to the overpass on the north side more often than they were seen crossing the overpass. Interestingly, black bears had slightly higher rates of successful crossings than elk.

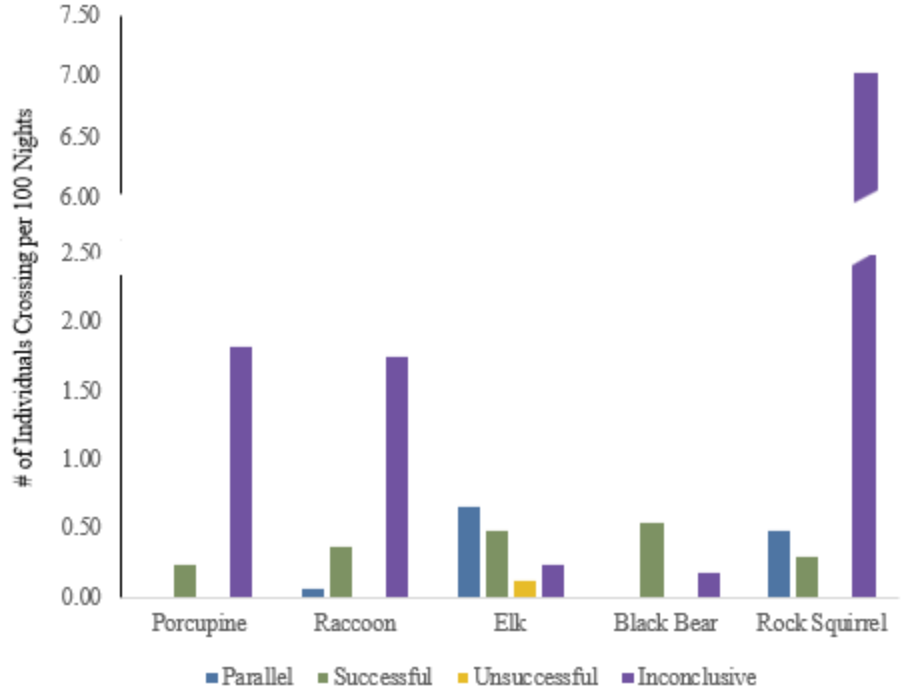


Figure 7: The number of individual animals crossing events per 100 nights by uncommon mammals detected at Parley's Canyon Overpass, Utah. May 2020 - September 2024.

3.4 Time of Day and Seasonality of Crossing Attempts

3.4.1 Initial Analysis of Time of Day and Seasonality (2020-2022)

Mule deer: We determined 2,580 total crossing events, 1,973 (76.47%) of which involved mule deer. There were 343 (17.38%) detections from mule deer events that did not include enough information to conclude whether the crossing event was successful; therefore, we labeled these data as inconclusive and did not include them in the analysis. There were 111 parallel crossing events (5.63%) that were also excluded from the analysis. After removing inconclusive and parallel crossing events there were 1,519 mule deer crossing events for analysis. Of those crossing events, 1,486 (97.83%) crossings were "successful" while 35 (2.17%) were "unsuccessful" events. On average, mule deer visited the overpass 2.4 times a day. We examined the 1,973 mule deer detections by considering season and times of day to better understand when mule deer are most frequently visiting. Mule deer were most active at Parley's overpass in summer where they visited the overpass 1,269 times (64.32% of total). They were least active during autumn months at only 145 visits (7.35% of total). In winter, mule deer were slightly more active than autumn with 152 total visits (7.70% of total). In spring, mule deer visited the overpass a total of 407 times (20.63% of total).

Visitation on the overpass varied by time of the day (Figure 8). We detected mule deer mostly during the nighttime with 1,124 visits (56.97% of total). Mule deer visited the overpass the least during crepuscular hours, with only 149 visits (7.55% of total). Lastly, mule deer visited 700 times during daytime hours (35.48% of all crossing events).

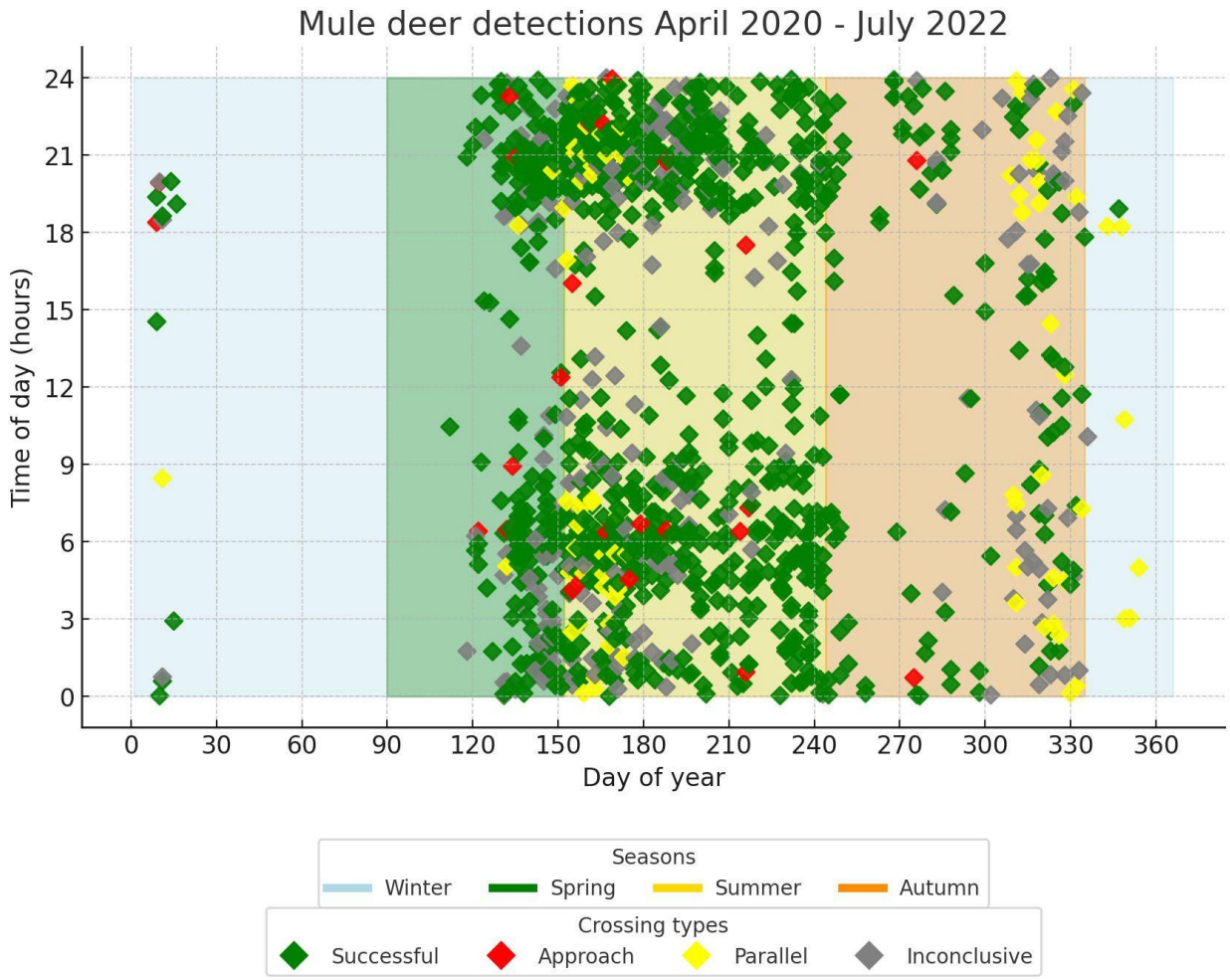


Figure 8: Seasonal and temporal variation of mule deer detections and crossing events at Parley's Canyon Overpass, Utah, 2020-2022.

Elk: There were 13 (0.50% of total crossing events) elk crossing events with only 3 (23.08% of all elk crossing events) successful crossings. Eleven of these crossing events occurred in winter, the other two were in spring and summer. Elk were most active in the daytime (7 detections), followed by nighttime (6 detections). Because of the relatively low level of detections for elk, we did not conduct a binomial regression on these data.

Moose: We detected fewer moose crossing events than mule deer (65 crossing events; 2.52% of all events) but moose exhibited a 100% crossing success rate for those that entered the overpass. Out of 65 moose detections, 7 were parallel, and 17 were inconclusive. Moose crossing events occurred similarly in summer (22 events; 33.85% of total) and winter (20 events; 30.77% of

total), then declined in spring (16 events; 24.62% of total) and autumn (7 events; 10.77% of total). Temporally, moose visited Parley's overpass in the daytime the most often (29 events; 44.6% of total), followed by nighttime (25 events; 38.46% of total), with fewer visits during crepuscular hours (11 events; 16.92% of total).

We conducted a binomial regression model with season as an explanatory variable to predict which season mule deer have the highest and lowest probabilities of crossing success at Parley's overpass. The results of this model determined proportional probabilities for success rates within each season. The model expressed that the highest probability of mule deer crossing successfully was in the summer months (June to September; 98.0%) and lowest probability for success would be during spring months (April to May) at 96.20% (Table 1). However, these differences were subtle and only varied slightly from one another.

Similar to the test for seasonal variation, we conducted a binomial regression to determine the influence of time of day on success rates for mule deer crossing events. The results of the model predicted that mule deer had similar crossing event rates throughout the 24-hour day, although there was a slightly higher probability (97.60%) of a nocturnal crossing event (Table 2).

Table 1. Binomial regression test resulting in percent probabilities of mule deer crossing success with seasonal variation conducted on Parley's Canyon Overpass, Summit County, Utah, USA, 2020-2022. Percent probability represents the proportion at which the model predicted mule deer would cross given each season. LCL is the lower confidence level and UCL is the upper confidence level.

Season	% Probability	LCL	UCL
Autumn	97.1% ± 0.02	89.3%	99.3%
Spring	96.2% ± 0.01	92.3%	98.2%
Summer	97.9% ± 0.01	96.5%	98.7%
Winter	96.4% ± 0.03	86.6%	99.1%

Table 2. Binomial regression test resulting in percent probabilities of mule deer crossing success with time of day variation conducted on Parley's Canyon Overpass, Summit County, Utah, USA, 2020-2022. LCL is the lower confidence level and UCL is the upper confidence level.

Time of Day	% Probability	LCL	UCL
Crepuscular	97.5% ± 0.03	82.1%	98.7%
Daytime	97.2% ± 0.008	95.0%	98.4%
Nighttime	97.6% ± 0.006	95.9%	98.6%

3.4.2 Summary of Crossing Attempts 2020-2025

We also present a summary analysis of activities for the entire study period (2020-2025; Figure 9). Deer and moose had a >95% successful crossing rate; while the number of mule deer using the overpass was nearly 27 times greater than that of moose. Mule deer used the overpass more often in the summer months, with use tapering off during the fall to comparatively little use over the winter and early spring. No such pattern existed with moose; use of the overpass was similar between January and June, for example. Decreased crossing attempts from November to April were also detected in the uncommon species (those that were 1-2 times per 100 nights): bear, porcupine, raccoon, and rock squirrels (Figure 10).

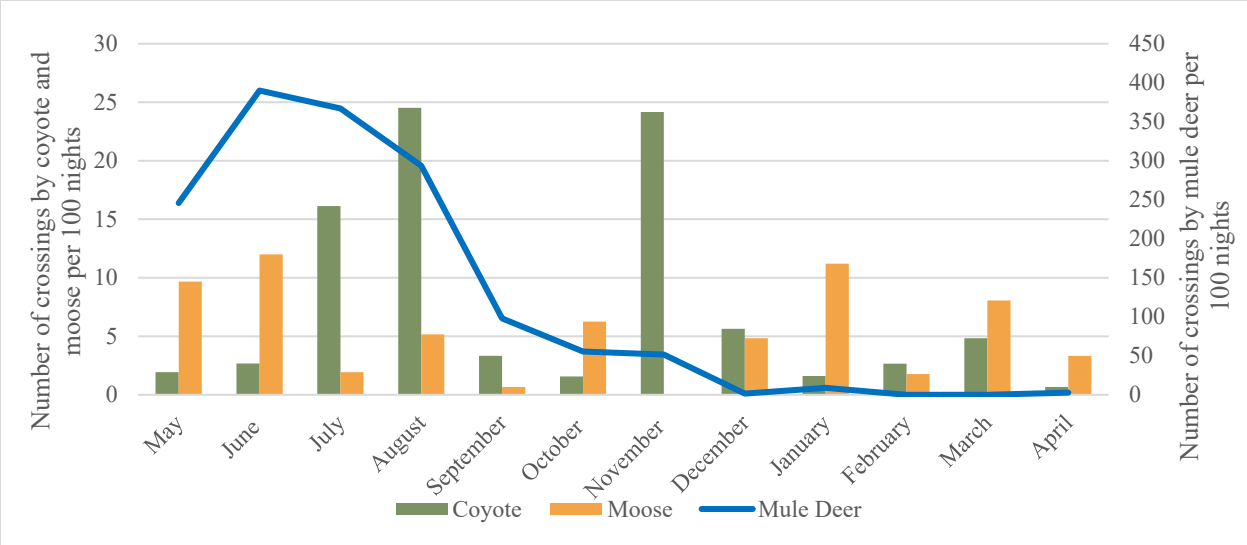


Figure 9: The rate of successful crossing attempts by month for coyotes, moose, and mule deer at Parley's Canyon Overpass, Utah, May 2020 - September 2024. Mule deer are plotted on a separate axis due to difference in scale.

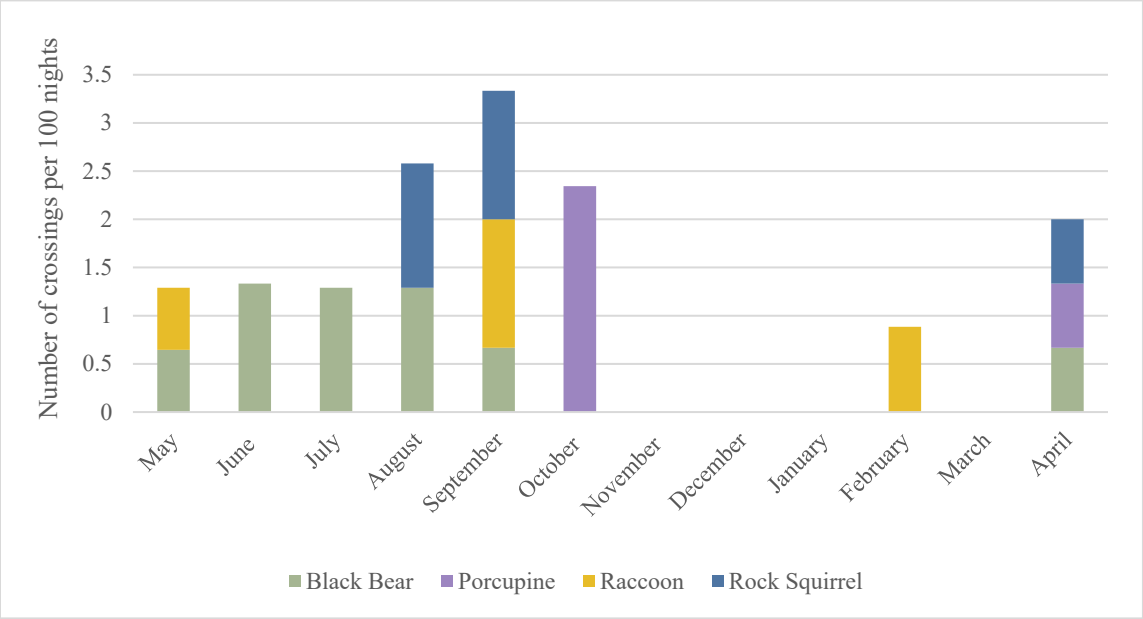


Figure 10: The rate of successful crossing attempts by month for black bear, porcupine, raccoon, and rock squirrel at Parley's Canyon Overpass, Utah, May 2020 - September 2024.

3.5 Dimension of Wildlife Crossings

This comparative analysis (Figure 11) gives us some insight into what preferences mule deer in Utah have for different types and dimensions of crossing structures. Different trends among successful crossing use reveal which crossing structures are effective for passing mule deer. Parley's Canyon Overpass, for example, has a very high passage success rate (97.8%) which highlights its effectiveness as a crossing structure. The high success rates of these crossing structures can be attributed to multiple factors such as likely design, location, fencing presence, and total length of fencing.

When comparing Parley's Canyon Overpass (Parley's overpass) to other crossing structures in Utah, there is a clear distinction in efficacy. For instance, the only structure that out-performed Parley's overpass was US 6 RxR (railroad) bridge viaduct by a very small margin (0.2%). Interstate 80, over which Parley's overpass was constructed, has a much higher AADT (57,000 vehicles/day) than US 6 RxR bridge (9,350 vehicles/day) which may explain the larger

difference between visitation by mule deer. Although these are two different structure types, they had similar crossing success rates by mule deer. Other research has indicated that dimensions (specifically width) have a large effect on crossing success, especially by ungulates (Denneboom et al., 2021). We constructed a table of the reported crossing rates of Utah wildlife crossings based on length and width ratios (Table 3).

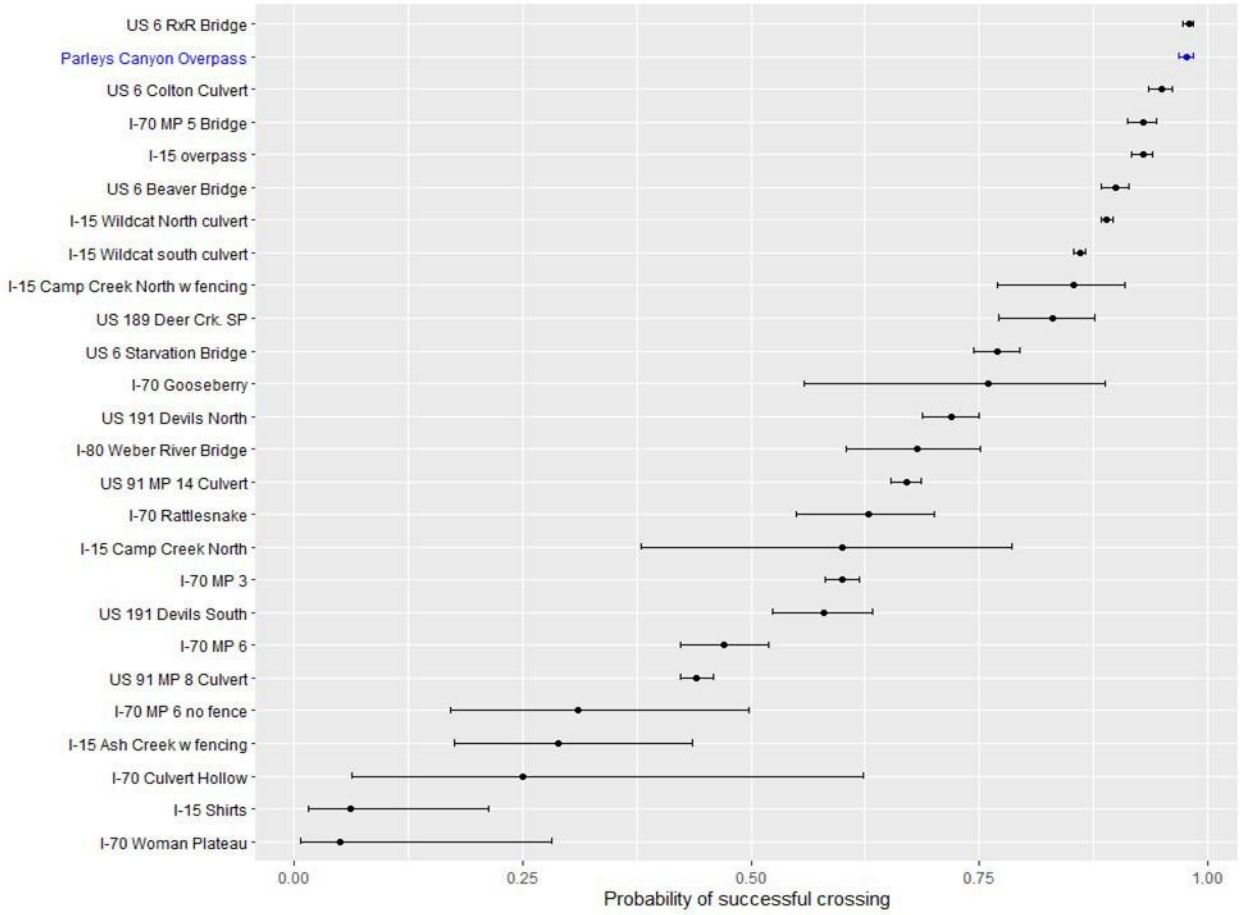


Figure 11. A point plot with confidence intervals displays 26 Utah wildlife crossing structures and their respective probabilities of successful crossings for mule deer. Lines represent the upper and lower confidence levels in the regression analysis.

There were 6 highly effective (>90% success rate) crossing structures evaluated. Three of the six crossing structures were located on US Highway 6 which may indicate that mule deer densities in that area may be higher or that mule deer populations may have a stronger drive to migrate than others due to resource availabilities. Comparing these six crossing structures seems to indicate that pairing crossing structures with high fencing is necessary to facilitate high crossing success by mule deer and other wildlife.

This analysis also reveals which crossing structures have the lowest predicted probability of successful crossing, such as US 91 MP 8 culvert (44%) and I-70 MP 3 underpass (60%). These crossing structures were monitored for over two years, have exclusionary fencing present, and have an adequate amount of total crossing by mule Despite the low crossing success, there was frequent visitation by mule deer; US 91 MP 8 culvert was visited by 2.4 mule deer per day and I-70 MP 3 underpass was visited by 3.3 mule deer per day. Some crossing structures had a very limited number of crossing events with one crossing structure having no variability in success. The lack of crossing events on a crossing structure limits the accuracy of the model in predicting successful crossing events and hinders the confidence level of the probability for those events.

Individual animals were not marked for this study which renders our data unable to estimate density or determine how many individuals had multiple crossing events. Therefore, we treated all crossing events by one or multiple species at a time as uniquely independent events. Future studies of use on a crossing structure may implement a method for identifying individuals to determine which events are unique. Furthermore, comparison data would be more accurate if the deer density had been estimated before the study took place in your area of concern. Data are inevitably biased because areas with higher densities may be subject to higher visitation rates from a certain species.

Table 3. A table showing all wildlife crossing structures analyzed in Utah displaying width/length ratio, crossing success rates, and visitations per day. Data for Parley's Canyon Overpass was collected May 2020 - July 2022, Summit County, Utah. All other days were reported in Cramer (2013). Duplicate crossing IDs are separate wildlife crossing structures on the same road where one is fenced, and the other is not. All data reflect mule deer crossings only.

Crossing ID	Type	length	width	WL Ratio	Success Rate	Total Crossings	Mule Deer/Day
I-15 Ash Creek	underpass	41.0	7.9	0.19	0.29	45	0.13
I-15 Camp Creek North	underpass	53.0	3.5	0.07	0.85	102	0.28
I-15 Camp Creek North (no fence)	underpass	53.0	3.5	0.07	0.61	20	0.05
I-15 Shirts	underpass	62.9	4.0	0.06	0.06	33	0.09
I-15 Wildcat North Culvert	underpass	19.9	11.1	0.56	0.89	8460	8.06
I-15 Wildcat South Culvert	underpass	21.2	8.0	0.38	0.86	11700	10.68

I-70 Gooseberry	underpass	29.8	3.6	0.12	0.76	25	0.04
I-70 Culvert Hollow	underpass	66.9	3.3	0.05	0.25	8	0.02
I-70 MP 3	underpass	54.7	5.0	0.09	0.60	2712	3.28
I-70 MP 5 Bridge	underpass	23.1	14.6	0.63	0.93	962	1.24
I-70 MP 6	underpass	70.2	5.2	0.07	0.47	406	0.45
I-70 MP 6 (no fence)	underpass	70.2	5.2	0.07	0.31	29	0.04
I-70 Rattlesnake	underpass	60.8	3.6	0.06	0.63	156	0.23
I-70 Woman Plateau	underpass	63.8	3.6	0.06	0.05	20	0.06
US 189 Deer Crk SP	underpass	62.0	5.0	0.08	0.83	200	1.63
US 191 Devil's N	underpass	43.4	4.3	0.10	0.72	788	1.17
US 191 Devil's S	underpass	47.1	4.8	0.10	0.58	309	0.42
US 6 Colton Culvert	underpass	29.8	8.1	0.27	0.95	1194	1.37
US 91 MP 14 Culvert	underpass	50.2	5.2	0.10	0.67	3097	3.38
US 91 MP 8 Culvert Bridge	underpass	47.8	4.8	0.10	0.44	2918	2.39
I-80 Weber River Bridge	viaduct	31.0	39.5	1.27	0.68	151	1.36
US 6 Beaver Bridge	viaduct	29.8	32.9	1.10	0.90	1541	1.62
US 6 RxR Bridge	viaduct	26.1	28.3	1.08	0.98	2455	2.42
US 6 Starvation Bridge	viaduct	24.9	32.9	1.32	0.77	1062	1.00
Parley's Canyon	overpass	97.0	15.0	0.16	0.98	1574	1.91
I-15 overpass	overpass	63.8	6.7	0.11	0.93	1852	1.68

4.0 CONCLUSIONS

4.1 Summary

From 2013 to 2018 there were 36,741 reported vehicle collisions with mule deer in Utah; and an additional 888 collisions with moose. Annually, wildlife-vehicle collisions cost the Utah public over $138 million (Cramer et al., 2019). During this time, the approximately 11-mile section of I-80 between Parley's Summit and I-40 experienced an average of 2.6 wildlife-vehicle crashes/mile/year, or 28.6 crashes annually (Cramer et al., 2019). A concurrent study of collision rates after the construction of the overpass determined that the Parley's Canyon Overpass reduced wildlife-vehicle collisions by 66% - 77% almost immediately (Siu, 2023). Our data supports this immediate effect of the overpass; both moose and mule deer were crossing the overpass an annual average of 6 times per 100 days as early as 2020. During summer months, we detected 2- 4 successful mule deer crossings a day, annually. We were unable to differentiate among individual deer and thus do not know how many deer were crossing the overpass; nor do we know if these animals would have attempted to cross I-80. However, the inferred reduction in risk of deer-vehicle collisions supports the conclusions of Siu (2023).

4.2 Wildlife Crossings of the Parley's Overpass

In addition to the target species of mule deer and moose, we detected a wide variety of species visiting the overpass during our study. Coyotes commonly crossed the overpass, while black bear, elk, porcupines, raccoons, and rock squirrels were infrequent users of the overpass. Many more species visited, and possibly crossed, the overpass. Thus, it appears that the overpass may be accepted into the environment of these local species. For example, rock squirrels were commonly detected foraging around the apron of the overpass.

4.2.1 Seasonality and Annual Use

We observed a seasonal pattern of usage in our large mammal species that visited and crossed Parley's Canyon overpass. These seasonal patterns of usage most likely reflect the precipitation patterns found in the Canyon. During December - April, Park City, a town close to

the overpass, experiences 388.4 cm (152.9 in) of snow annually. As snowpack increases in the area, ungulates and large mammal species usually move to other areas of the mountain where snow is less or minimize their movements during this time period to conserve energy. As the snow melts, and ungulate species begin their migrations in the area, we see an increase in Parley's Canyon overpass visitation and crossing rates.

We also found a fluctuation in animal crossing detections from year to year. Moose, human, and coyote detections were near zero in 2021 and 2022, with an increasing trend detected in 2023 and 2024. We suggest that these fluctuations were a result of differences in moose and coyote densities in the immediate area, rather than a direct response to Parley's Overpass. A study of mammal densities or direct movement patterns should be conducted to confirm this hypothesis.

Mule deer frequently used Parley's Canyon overpass to cross Interstate 80. It would have been useful to be able to evaluate the daily and seasonal use patterns in relation to the relative density of deer on either side of Interstate 80. It is possible that the increased usage could have been an effect of emigration from areas of high density to areas of low density. Another hypothesis is that deer are using this overpass to facilitate migration including seasonal elevation transitions. Unfortunately, there were no mule deer with GPS collars detected on Parley's Canyon overpass from which we could gather movement data. Therefore, we usually could not determine if an individual deer was using this overpass repeatedly as part of their migration corridor. However, we did detect frequent usage by family groups, which were uniquely identifiable, traveling in either direction across the overpass. This suggests that mule deer were incorporating this travel route as part of their daily home range patterns of use.

4.2.2 Mule Deer

Seasonal fluctuations in visitation (i.e., not crossing attempts) in my study reveal that mule deer used the overpass far more often during summer months. The seasonal variation in visits use could be attributed to the seasonal change in behavior exhibited by migratory animals, such as mule deer, where movement is influenced by weather conditions, specifically snowfall (Garrott et al., 1987; Monteith et al., 2011). Parley's overpass exists at what is considered a high altitude (2,132 meters) with annual snowfall averages of 678.2 cm (NOAA NCEI, 2024) which

means snowpack typically persists through May and green-up of vegetation occurs in June (Utah Climate Center, 2024). As snow melts in spring, mule deer start to migrate to higher quality forage and rearing habitat which leads to elevational movements to their summer ranges (Pierce et al., 2004) which may be the reason behind the heightened activity and subsequent crossing success during summer months. Our results regarding seasonal crossing success by mule deer are similar to what Simpson et al. (2016) found in northeast Nevada, where 2 overpasses were monitored with no significant seasonal effect found on mule-deer crossing success. In Washington State, Starr and McAllister (2014) observed an abundance of mule deer detections during summer months (June to September) at 2 different underpass crossing structures, which is similar to what we found in northern Utah on Parley's overpass.

Hunting activity in the area may also explain differences between summer and autumn activity. In late summer through the autumn, hunting seasons for migratory ungulates begin, which introduces the presence of humans in typically uninhabited areas which may help explain why activity is much lower in the autumn. The smallest proportion of visitation occurred in autumn, which is the initiation of the hunting season in this area. Possibly, the deer have small movements, and stay in sheltered areas, during this time, to avoid hunting pressure (Sergeyev et al., 2022).

Additionally, predator avoidance and parturition/rearing fawns have been noted as reasons for mule deer movement which suggests that individuals will move away from open areas to more densely covered areas under the influence of these pressures (Pierce et al., 2004). Since the south side of the interstate is much more densely covered in vegetation, thus providing more cover for mule deer, deer may move at higher frequencies during summer (after snow melts and before these pressures initiate) and not move as frequently during the autumn when hunting pressure peaks. These findings support what Sergeyev et al. (2022) found in Utah when they determined that migratory ungulates would travel from public lands to private lands before hunting pressure begins. The reduced activity in autumn persists through winter and spring until snowmelt resumes the pattern of increased summer activity.

Mule deer are considered crepuscular animals, thus we expected to see high visitation to the overpass during dawn and dusk; however, we detected the highest proportion of visitation occurred at night. Conversely, Starr and McAllister (2014) observed peaked activity during crepuscular times of day, in their study of mule deer crossings in Utah. Similarly, Simpson et al.

(2016), found that mule deer preferred crepuscular crossing times at overpasses, but the dawn peak was short (0500-0800). Although activity varied among the seasons and times of day, the probability of crossing successfully did not. This could indicate that mule deer feel safe enough to cross Parley's overpass if they encounter it regardless of timing of when they encounter it.

The differences in temporal activity patterns across many studies may largely be due to varied methods of analysis and differences in categorizing seasons and times of day. However, temporal (time of day) analyses would benefit from using a standardized method across projects as comparisons would be much clearer this way. Additionally, the heightened nighttime activity may be attributed to the high amount of human activity during crepuscular and daytime hours of the day at Parley's overpass. Interstate 80, which Parley's overpass spans, has an average annual daily traffic rate of 57,000 vehicles per day which produces a lot of noise and could make approaching Parley's overpass intimidating to wildlife during periods of high human activity. As people travel to and from Park City from Salt Lake City in the mornings and evenings, it may deter animals from using the overpass during those periods.

Although there was variation between seasonal and time-of-day crossing success results, the predicted rates of crossing success for season or time of day were only slightly different. Confidence level ranges for each variation were small which indicates an accurate estimation of success probability. This further suggests that the amount and proportion of successful crossings by mule deer was enough to explain any significant seasonal or temporal differences, had any been present. This further indicates that mule deer are consistently incorporating Parley's overpass as a part of their daily home range, rather than migratory routes. For example, we observed an individual mule deer doe with 3 fawns successfully using the overpass multiple times (over 20 occasions in one summer season) which indicates a level of comfort with the overpass, essentially incorporating the overpass as part of their home range

4.2.3. Moose

For moose crossing events, we evaluated results from 7 wildlife crossing structures and only one had a WL ratio above 0.8 (1.24; Dunne and Quinn, 2009; Gunson and Healey, 2015). Moose had a successful crossing rate of 97% at the overpass studied by Gunson and Healy (2015); the other 6 crossing structures passed moose successfully with an average rate of 81%

(Dunne and Quinn, 2009). In their study, Dunne and Quinn (2009) saw a 71% success rate by moose on the overpass with the smallest WL ratio (0.48).

Parley's overpass had the highest moose success rate with 100% success from overpasses ranging from WL ratios of 0.13 (Parley's overpass) to 1.24 (Dunne and Quinn, 2009; Gunson and Healey, 2015). Similar to mule deer, these results suggest that overpasses can still be highly effective for moose regardless of width or WL ratio. This may also suggest that there may be different factors of influence that drive successful passage by migratory ungulates other than overpass width. According to Utah's State Geographic Information Database (AGRC, 2021), the area where Parley's overpass is located is a crucial wintering habitat for moose. Moose success and seasonal occurrence on Parley's overpass may be explained by the large area of available habitat moose have there. This explanation is consistent with Dunne and Quinn (2009), where they found high moose success on overpasses in areas closer to preferred moose habitat.

4.2.4 Elk

Very few elk visited the overpass, and still fewer crossed it. It may be that the land south of the overpass was not attractive to elk in this region. For example, every elk detection in this study occurred on the north side of the overpass where there is much more undeveloped private land and forage availability. The south end of the overpass is located next to a residential area. Sergeyev et al. (2022) found that elk prefer to inhabit private lands, especially when hunting season draws near in Utah. Also, Interstate 80 acts as a divide between two different hunting units where regulations are subject to change and hunting pressure typically begins in August.

Past studies have noted that elk show higher amounts of activity on underpasses compared to other crossing structures (Gagnon et al., 2007; Dodd et al., 2012; Barrueto et al., 2014; Gagnon et al., 2017; Kintsch et al., 2020). However, there are exceptions to this, and elk have had success on overpass structures. For example, the only other overpass in Utah is situated along a major migration route for elk near Beaver, Utah on Interstate 15, and Cramer (2013) concluded that elk passed over this structure successfully 28 times which was more than any other crossing structure in her study (Cramer, 2013). That overpass is essentially a series of 2 overpass structures and is similar to Parley's overpass (WL ratio = 0.11) in that it is narrow and long. Parley's overpass is at 2132m elevation, and the I-15 overpass is 805m; perhaps this

difference in elevation and associated habitat contributed to the differences in observations. The lack of visits and crossing success by elk may also suggest either this WL ratio is too small or there are habitat and population constraints limiting their use of Parley's overpass. This difference in elk crossing frequency and success may be due to natural vegetative cover present on the I-15 overpass where Parley's overpass has very minimal vegetative cover and is mostly rock substrate with scattered logs throughout. Further, Cramer notes that I-15 overpass is located along a major elk migratory route (Cramer, 2013) and there isn't evidence of Parley's overpass being located along a major elk migratory route. This explanation would be consistent with the findings by Clevenger et al. (2001) where, although elk crossing success and occurrence wasn't specified, it was noted that elk use of two overpasses in Alberta, Canada reduced wildlife-vehicle collisions on the Trans-Canada Highway by 96%. Those overpasses have natural vegetative cover throughout.

4.3 Dimensions of Wildlife Crossing Structures

The length-width ratio of overpasses is one factor that may influence wildlife visitation and ultimately crossing the structure (Brennan et al., 2022). Although each species has its own preference, Clevenger and Huijser (2011) suggest that overpasses in North America should have a width between 50 to 70 meters for large mammals to successfully cross structures that cover four lanes of roadway (Clevenger and Huijser, 2011; Barrueto and Clevenger, 2017). Additionally, Iuell et al. (2003) recommended the width-length ratio for an overpass crossing structure is to be at least 0.8 or greater for large mammals. The location for Parley's overpass was selected based on wildlife-vehicle collision occurrences; however, this location did not allow for a structure with these recommended widths.

We evaluated mule deer success rates from 10 different overpasses in North America and compared those to the WL ratio of the crossing structures they used (Dunne and Quinn, 2009; Cramer, 2013; Gunson and Healey, 2015; Simpson et al., 2016; Kintsch et al., 2017). Of these crossing structures, only 3 adhered to the WL ratio recommendation of 0.8 or higher and averaged an 82% mule deer success rate. The other 7 crossing structures were below 0.8 WL ratio and averaged a success rate of 82%. However, one of these structures had a small sample size of only 22 crossing attempts with a 55% success rate. The overpasses in Utah (Parley's

overpass and I-15 overpass), had the lowest WL ratios (0.1). Interestingly, mule deer had a 97.9% success rate at Parley's overpass and 93.0% success rate at the I-15 overpass. If one were to plot success rate to overpass WL ratio as reported in past studies (Dunne and Quinn, 2009; Gunson and Healey, 2015), we can see that there is no relationship between ratio and success rate. Therefore, there must be some other factors at play, such as habitat or density.

The results of this study suggest that overpasses with smaller WL ratio can be effective structures for mule deer and moose. Although the overpass has a smaller WL ratio than most overpasses built for ungulates, we recorded a variety of animals visiting and crossing the overpass. Success rates for mule deer on Parley's overpass were often similar to or greater than that of structures that were wider and had larger WL ratios (Simpson et al., 2016; Kintsch et al., 2017). The I-15 overpass in Utah studied in Cramer (2013) also had a very low WL ratio (0.11) and an even smaller width (6.7 meters) than that of Parley's overpass, and still, mule deer crossed successfully 93% of the time. The reason behind this success could be due to the location of the overpasses. Placed along major migration routes, it seems mule deer quickly incorporate overpasses into their home ranges and cross with higher rates of success. Although ungulates prefer wider overpasses in general, it seems that narrow overpasses can still successfully pass mule deer under the right circumstances.

In most instances overpasses are installed over highways to reduce the rate of wildlife-vehicle collisions. Interstate 80 was designated as one of the top 25 hotspots for wildlife-vehicle collisions in Utah (Cramer et al., 2019). From 2008 to 2017 there was a total of 2.36 wildlife-vehicle collisions recorded per mile on an 11.1-mile stretch on Interstate 80 from Parley's Summit to US 40 (Cramer et al., 2019). The high visitation and crossing rates measured during this study suggest that wildlife are using the overpass rather than trying to cross the highway. Using data from Utah Department of Transportation and Utah Department of Natural Resources, Siu (2023) found that immediately following the completion of Parley's overpass, there was a 66-77% reduction in wildlife-vehicle collisions within the span of the structure itself (i.e., 3.5 miles east and west from the overpass). Siu also noted the potential spillover effects that may occur at the end of the 3.5-mile fence line of Parley's overpass indicating an increase in wildlife-vehicle collisions in those spots where the fence line ends and animals may decide to cross the road.

5.0 RECOMMENDATIONS AND IMPLEMENTATION

5.1 Recommendations

The Parley's Canyon Overpass was created with the objective of reducing vehicle collisions involving moose and mule deer, as well as the related objective of facilitating their movements across I-80. We monitored the direct use of wildlife at the overpass and found that moose and mule deer used the overpass regularly, with annual fluctuations. However, it would be valuable to evaluate this use in relation to the population density and migration patterns of mule deer and moose.

Utah Department of Natural Resources monitors the landscape movement patterns of thousands of individual ungulates annually. In collaboration with the Utah Department of Transportation, these agencies are using movement data to inform future wildlife crossing locations and the effectiveness of current crossing structures. To date, Parley's Canyon Overpass is not located within a mapped migration corridor (https://wildlifemigration.utah.gov/land-animals/corridors/) created by monitoring animals via GPS transmitting collars. However, this does not mean that species do not migrate through the area. We suggest the importance of implementing a GPS monitoring study within the area of Parley's Overpass to determine individual use of the structure.

5.2 Implementations

While this study was informative in creating visitation and successful crossing rates, it would have been insightful to be able to track individual animals. In several instances, such as when we detected a female with her young, we were able to determine individuals, and thus detect repeated use, but these were a small fraction of the sample. Information at an individual level would provide us with behavioral knowledge regarding an animal's tendency to incorporate the overpass into their home range and daily movement patterns.

Parley's overpass is a long and narrow overpass crossing structure that has high visitation and high success rates of moose and mule deer. It is important to note that Parley's overpass was built with a small WL ratio due to the landscape characteristics of where it was built. Options

were limited for placement which led to the unique design of Parley's overpass. This narrow design is less costly than that of wider overpasses, especially when one needs to cover more than 4 lanes of traffic and still maintain a width of 50 meters or greater and a WL ratio of 0.8. Only 29% of overpasses in North America adhered to a greater than 50-meter width recommendation and 21% of overpasses in Europe adhered to the 0.8 WL ratio recommendation (Brennan et al., 2022). Using data from Utah Department of Transportation and Utah Department of Natural Resources, Siu (2023) found that immediately following the completion of Parley's overpass, there was a 66-77% reduction in wildlife-vehicle collisions within the span of the structure itself (i.e., 3.5 miles east and west from the overpass). Despite Parley's overpass being well below the 0.8 WL ratio recommendation, Siu's results suggest that there will be an estimated $15 million cost benefit over the overpass's lifetime, which is a 2:1 cost-effectiveness ratio (Siu 2023). If you consider the benefits of reduced negative impacts to wildlife, the cost benefit would be even greater (i.e., non-tangible benefits).

Despite the results of this study, managers should still attempt to build wildlife crossing structures to the recommended dimensions for their target species. Only in situations where those recommendations cannot be met should managers consider altering dimensions since wider overpasses have historically been more successful in the literature (Denneboom et al., 2021). As research progresses, alterations to historically successful structure design should be minimal and still adhere as closely as possible to the preferences of their target species regarding not only dimensions, but other characteristics (crossing type, substrate, surrounding vegetation, etc.) to maximize effectiveness given success of previous research. However, this study provides insight into how widths for overpasses can be narrower if the target species are mule deer or moose.

The purpose behind studying temporal drivers was to better understand if season or time of day have any effect on success or visitation rates. Because mule deer, elk, and moose are migratory, seasonal differences might imply that the overpass is an important migration corridor. Conversely, summer movements might indicate the necessity of this overpass not only for autumn migration in moose and mule deer, but also for rearing young and reconnecting home ranges of local herds. Therefore, it may be beneficial to limit human activity on the north side of the overpass, especially during summer months, as most visitation occurred during those months. Since there was a high amount of mule deer activity during nighttime hours, the risk for wildlife-vehicle collisions is decreased during those hours. However, it is important to warn drivers of

potential ungulates on the roadway ahead of each end of the fence line where ungulate activity is expected to be higher.

Management objectives (reducing wildlife-vehicle collisions, restoring connectivity, etc.) should be clearly defined before implementing a plan for structure construction. For example, landscape types and structure dimensions similar to Parley's overpass can offer crossings to mule deer and moose effectively but not elk. Because moose and deer were the primary targets in the construction of this overpass (Howard personal comm.), the lack of elk visitation is not a concern for Parley's overpass. However, this could be deemed a failure if elk were the target species of concern. Continued research on why elk may be passing over one overpass in Utah and not another should be considered if elk become a target species for a future crossing structure. Future research regarding wildlife crossings in Utah, and Parley's overpass specifically, should continue monitoring efforts to better understand usage patterns regarding large migratory ungulates and how those patterns trend over time.

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