Applied Research and Innovation Branch

State Highway 9 Wildlife Crossings Monitoring – Annual Report Year 1

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Report No. CDOT-2017-04
Feb 2017

Technical Report Documentation Page

<table>
<tr><td>1. Report No.
CDOT-2017-04</td><td>2. Government Accession No.</td><td colspan="2">3. Recipient's Catalog No.</td></tr>
<tr><td colspan="2" rowspan="2">4. Title and Subtitle
State Highway 9 Wildlife Crossings Monitoring – Annual Report Year 1</td><td colspan="2">5. Report Date
Feb 2017</td></tr>
<tr><td colspan="2">6. Performing Organization Code
Study 115.01</td></tr>
<tr><td colspan="2">7. Author(s)
Julia Kintsch, Principal Investigator – ECO-resolutions, LLC, Golden, Colorado
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Paige Singer, Research Assistant – Rocky Mountain Wild, Denver, Colorado</td><td colspan="2">8. Performing Organization Report No.
CDOT-2017-04</td></tr>
<tr><td colspan="2" rowspan="2">9. Performing Organization Name and Address
ECO-resolutions, LLC, Golden, Colorado</td><td colspan="2">10. Work Unit No. (TRAIS)</td></tr>
<tr><td colspan="2">11. Contract or Grant No.</td></tr>
<tr><td colspan="2" rowspan="2">12. Sponsoring Agency Name and Address
Colorado Department of Transportation - Research
4201 E. Arkansas Ave.
Denver, CO 80222</td><td colspan="2">13. Type of Report and Period Covered
Annual report Oct 2015 – Oct 2016</td></tr>
<tr><td colspan="2">14. Sponsoring Agency Code</td></tr>
<tr><td colspan="4">15. Supplementary Notes
Prepared in cooperation with the US Department of Transportation, Federal Highway Administration</td></tr>
<tr><td colspan="4">16. Abstract

This research evaluates the effectiveness of the SH 9 Colorado River South Wildlife & Safety Improvement Project, including two wildlife overpasses, and five wildlife underpasses connected with 10.4 miles of wildlife exclusion fencing in Grand County, CO. The project was designed to improve driver safety while allowing for wildlife movement across the road. This study uses motion-activated cameras and WVC crash and carcass data to determine how successful the mitigation measures are. In addition to the crossing structures, deer guards, escape ramps, pedestrian walk-through gates and the fence end are being monitored. WVC carcasses collected in the completed Phase 1 section of the project area decreased from a five-year average of 31, to a total of three in the winter of 2015/16. These preliminary results document the immediate success of this project in decreasing WVC while providing wildlife connectivity. The research study will continue until 2020.

Implementation</td></tr>
<tr><td colspan="2">17. Keywords
Wildlife overpass, wildlife underpass, animal vehicle collisions, safety</td><td colspan="2">18. Distribution Statement
This document is available on CDOT's website
http://www.coloradodot.info/programs/research/pdfs</td></tr>
<tr><td>19. Security Classif. (of this report)
Unclassified</td><td>20. Security Classif. (of this page)
Unclassified</td><td>21. No. of Pages</td><td>22. Price</td></tr>
</table>

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

STATE HIGHWAY 9 WILDLIFE CROSSINGS MONITORING – PROGRESS REPORT

Phase 1 Pre-completion Monitoring

December 2015 through March 2016

Study Number 115.01 February 2017

Report to the Colorado Department of Transportation

Applied Research and Innovation Branch

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Executive Summary

This research study evaluates the effectiveness of the State Highway 9 (SH 9) Colorado River South Wildlife & Safety Improvement Project, including two wildlife overpasses, and five wildlife underpasses connected with 10.4 miles of wildlife exclusion fencing in Grand County, Colorado. Prior to the project, there was an average of 63 large animal carcasses reported along this stretch of road each winter, and an average of 26.6 reported wildlife-vehicle collisions (WVC) accidents. The project was designed to improve driver safety while allowing for wildlife movement across the road. This research study uses motion-activated cameras and WVC crash and carcass data to determine how successful the mitigation measures are in keeping wildlife off the road and moving through the crossing structures. In addition to the crossing structures, deer guards, escape ramps, pedestrian walk-through gates and the fence end are being monitored.

In December 2015, 40 cameras were deployed at 24 monitoring locations in the northern portion of the project area (Phase 1, MP 131-136) where construction was complete, including four wildlife crossing structures (three underpasses and one overpass), deer guards, escape ramps, pedestrian gates and the temporary south fence end. Cameras were programmed to take 3 to 10 consecutive pictures once triggered by motion, with no down time. Photos were collected and batteries changed out of the cameras each month. This progress report presents results of this camera monitoring and carcass data collection during the first winter of monitoring (2015/16).

From December 2015 through March 2016, the cameras recorded 7,013 mule deer movements through all four crossing structures. Mule deer used the overpass structure in the greatest numbers, with an average of 35 successful passages per day, compared to 2.5 to 6.1 successful passages per day for the underpass structures (Fig. E-1). These high numbers reflect regular movements by many of the same individuals throughout the winter season and, at the overpass, may indicate that the location of this structure is correlated with the highest concentration of wintering mule deer. Success rates for mule deer going through and over the structures ranged from 82% at the North Underpass, to 98% at the North Overpass. In addition to mule deer, a variety of other species were documented using the crossing structures, although in much lower numbers. These species include, elk, moose, bobcat, coyote and red fox.

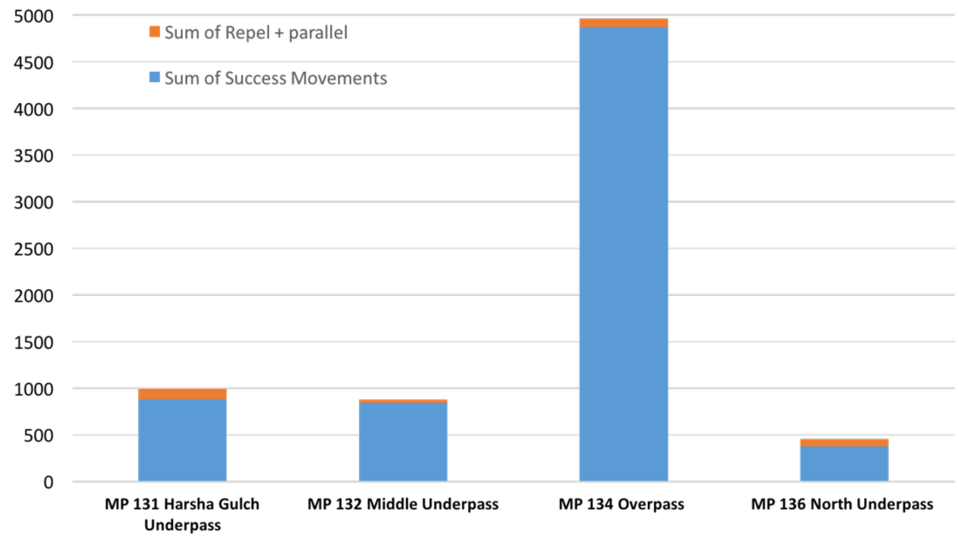

Figure E-1. Comparison of mule deer movements across wildlife crossing structures.

Wildlife-vehicle collision carcasses collected in the completed Phase 1 section of the project area decreased from a five-year average of 31, to a total of three in the winter of 2015/16 (Fig. E-2). This is compared to the Phase 2 segment where no mitigation had been constructed. These preliminary results document the immediate success of this project in decreasing WVC while providing wildlife connectivity. The research study will continue until 2020.

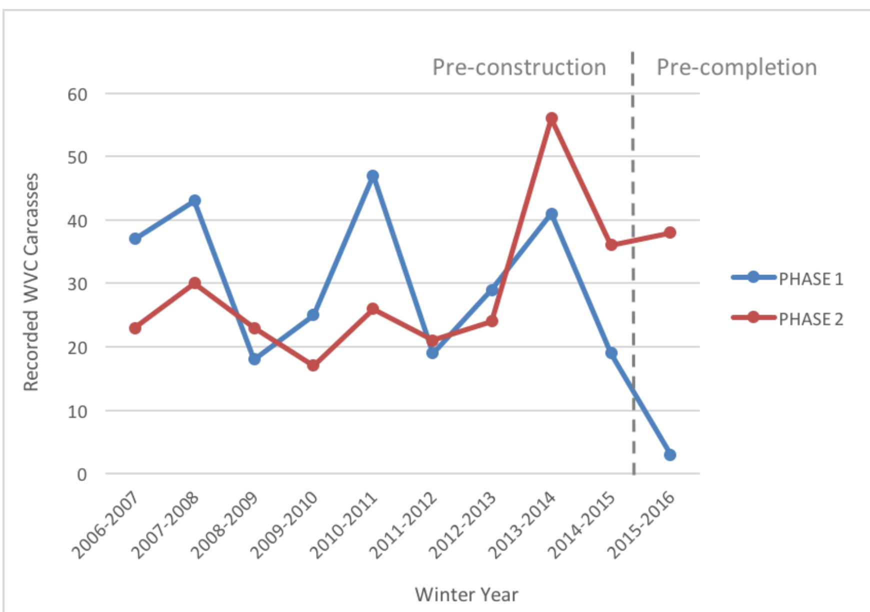

Figure E-2. Reported WVC carcasses compiled by BVR and CPW in Phases 1 and 2 of the project area, nine years pre-construction and one year pre-completion (winter 2015/16).

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Introduction

The State Highway 9 (SH 9) Colorado River South Wildlife & Safety Improvement Project resulted in the installation of seven large wildlife crossing structures between Kremmling and Green Mountain Reservoir in Grand County, Colorado. The project was designed to improve driver safety while providing permeability for wildlife. State Highway 9 runs north-south through the Lower Blue Valley, a broad sagebrush valley between the Gore Range to the west and the Williams Fork Mountains to the east. The Blue River also runs from south to north through the valley, west of the highway, to its confluence with the Colorado River. The Lower Blue Valley supports a high winter concentration of mule deer, as well as other wildlife, such as elk, moose, pronghorn, black bear, bobcat, fox, coyote, and mountain lion throughout the year. These concentrations of wildlife have resulted in numerous wildlife-vehicle collisions (WVC), particularly during the winter months. Reported WVCs accounted for 35% of all reported crash types from 2007-2011, constituting the greatest portion of all crash types on this highway. In this five-year time span, 133 collisions with wildlife were reported to law enforcement, including 17 resulting in injuries and three resulting in human fatalities (CDOT 2012), equating to a rate of 2.4 reported WVC crashes per mile per year. Although these numbers are high, they underestimate the full extent of the conflict between traffic and wildlife on SH 9. More comprehensive winter carcass counts conducted by Blue Valley Ranch from the winter of 2007/8 through winter 2011/12 recorded 274 WVC carcasses, more than double the number of reported accidents.

To meet the objective of reduced WVC and allowing for wildlife movement across the highway, two wildlife overpasses and five arch underpasses were constructed and connected with 10.4 miles of 8-foot high wildlife fencing. Other mitigation features include deer guards installed at all road intersections and private driveways; wildlife escape ramps; and pedestrian walk-through gates to provide a pathway for people through the wildlife fence. The project includes drainage culverts, including several medium-sized (8’ box or pipe culverts) that are integrated into the fencing and may provide passage for small or medium-sized fauna. This project is the culmination of a comprehensive and collaborative effort by the Colorado Department of Transportation (CDOT), Colorado Parks and Wildlife (CPW), and the privately-owned Blue

Valley Ranch (BVR), as well as many other public and private partners. The goal of this mitigation project was to reduce vehicle collisions with wildlife while providing permeability for these animals to move safely underneath or above the highway. CDOT and CPW are supporting this research study to evaluate how well the wildlife mitigation achieves these goals.

This research study uses motion-triggered cameras to monitor wildlife activity at wildlife crossing structures, wildlife escape ramps, deer guards (double cattle guards), pedestrian walk-through gates and the south fence end. Cameras were deployed to correspond with the two project construction phases. Phase 1 construction was in the northern portion of the project area (milepost [MP] 131-137) and was completed in November 2015. Mitigation features in this phase included one wildlife overpass, three underpasses, six miles of continuous 8-foot high (2.4 meters) wildlife exclusion fencing on both sides of the highway, 34 escape ramps, 12 deer guards and 2 pedestrian walk-through gates. Phase 2, completed November 2016, was in the southern portion of the project area (MP 126-131), and included a second overpass, two wildlife underpasses, continued wildlife exclusion fencing through the project area, and additional escape ramps, deer guards and pedestrian walk-through gates. Future progress reports will address mitigation in both Phases 1 and 2.

In addition to camera monitoring, this research study analyzes WVC rates in each phase of the project area, using three long-term datasets. Long-term datasets offer a pre-construction baseline to which pre-completion and post-completion WVC rates may be compared (see page 4 for definitions of the monitoring phases). This progress report is focused on the first winter of pre-construction monitoring in the Phase 1 project area (December 2015 through March 2016).

Research Objectives

Seven objectives were established by the Study Panel for the five-year research study:

1. Determine to what extent the wildlife and safety mitigation measures reduce WVC.
2. Determine the level of effectiveness of the wildlife mitigation including, 1) the effectiveness of wildlife overpasses and underpasses in allowing wildlife, primarily ungulates, to move underneath or above the highway, and 2) the ability of animals that breach the fenced right-of-way to use escape ramps to exit the fenced road area.

3. Determine if the fence end, pedestrian walk-through gate and deer guard designs are effective at deterring wildlife (ungulates primarily) from entering the fenced road area.
4. If utilization rates differ among the crossing structures, determine why.
5. Determine if any of the wildlife mitigation features appear to need modification to improve effectiveness.
6. Determine correlation of historic ungulate crossing patterns pre-completion to utilization of post-construction crossing patterns.
7. Compare pre-completion crossing rates to post-construction over/underpass crossing rates.

Methods

Mitigation effectiveness was measured with two general types of measures: the success rate of mule deer, elk and other wildlife through the crossing structures, and the number of times these species moved through the wildlife crossing structures; and the reduction in WVC. The research methods used to evaluate these measures are presented below.

Monitoring Phases

The following monitoring timeframes are defined for this research study:

Pre-construction: Prior to the onset of mitigation construction in April 2015. Pre-construction camera monitoring was conducted by CPW at all crossing structure locations.

Pre-completion: From the onset of this research study (December 2015) until the completion of Phase 2 construction (November 2016)

Post-construction: Following the completion of all construction activities (December 2016) through Winter 2019/20.

Camera Monitoring

In Year 1, 40 motion-triggered Reconyx Professional Series cameras (PC800 and PC900) were deployed at 24 monitoring locations for the pre-construction monitoring effort (Table 1; Fig. 1). Cameras were installed on T-posts using a U-bolt system and Reconyx security boxes. Where cameras were placed in areas with human activity or visible from the roadside, the cameras were mounted inside metal utility boxes to disguise the camera (Fig. 2). All cameras were code-locked and secured with master locks and/or cable locks. The cameras were motion-triggered and took photos day and night with a rapid-fire setting and no down time. Cameras were set to take burst of 10 photos per trigger, and to continue triggering for as long as the moving object is in front of the camera. Exceptions were at deer guards with heavy traffic, where cameras were set to 3 or 5 photos per trigger and, in some cases, were scheduled to trigger only between before dusk to after dawn.

Table 1. Pre-construction monitoring locations. Highlighted gray rows are wildlife crossing structures and habitat adjacent to the structures.

MP	LOCATION NAME	MITIGATION TYPE	SPECIFICATIONS
137.0	Colorado River Bridge	Bridge Underpass	Large existing bridge at north fence end
136.9	County Road 33 Deer Guard	Deer Guard	Flat bar
136.9	Thompson Deer Guard	Deer Guard	Flat bar
136.8	Thompson Escape Ramp	Escape Ramp	2:1 slope with rail fence
136.6	Trough Road Deer Guard	Deer Guard	Flat bar
136.0	North Underpass	Arch Underpass	44'W x 14'H x 66'L
136.0	North Underpass Habitat	Adjacent Habitat	Habitat camera
135.9	SWA Escape Ramp	Escape Ramp	2:1 slope with rail fence
135.6	SWA Pedestrian Gate	Pedestrian Gate	n/a
135.1	Culbreath Deer Guard	Deer Guard	Flat bar
134.5	Rusty Spur Deer Guard	Deer Guard	Flat bar with pedestrian grate
134.3	Overpass Escape Ramp	Escape Ramp	2:1 slope with rail fence
134.3	North Overpass	Overpass	100'W x 66'L
134.3	North Overpass Habitat East	Adjacent Habitat	Habitat camera
134.3	North Overpass Habitat West	Adjacent Habitat	Habitat camera
134.2	BVR Pipe Culvert	Small Culvert	8’ diameter concrete pipe
132.5	Middle Underpass	Arch Structure	44'W x 14'H x 66'L
132.5	Middle Underpass Habitat	Adjacent Habitat	Habitat camera
132.4	BLM Pedestrian Gate	Pedestrian Gate	n/a
131.6	Harsha Gulch Deer Guard	Deer Guard	Flat bar
131.6	Harsha Gulch Underpass	Arch Underpass	44'W x 14'H x 66'L
131.6	Harsha Gulch Underpass Habitat	Adjacent Habitat	Habitat camera
131.2	Harsha Escape Ramp	Escape Ramp	2:1
131.0	Pre-Completion South Fence End	Fence End	20' Clear Zone

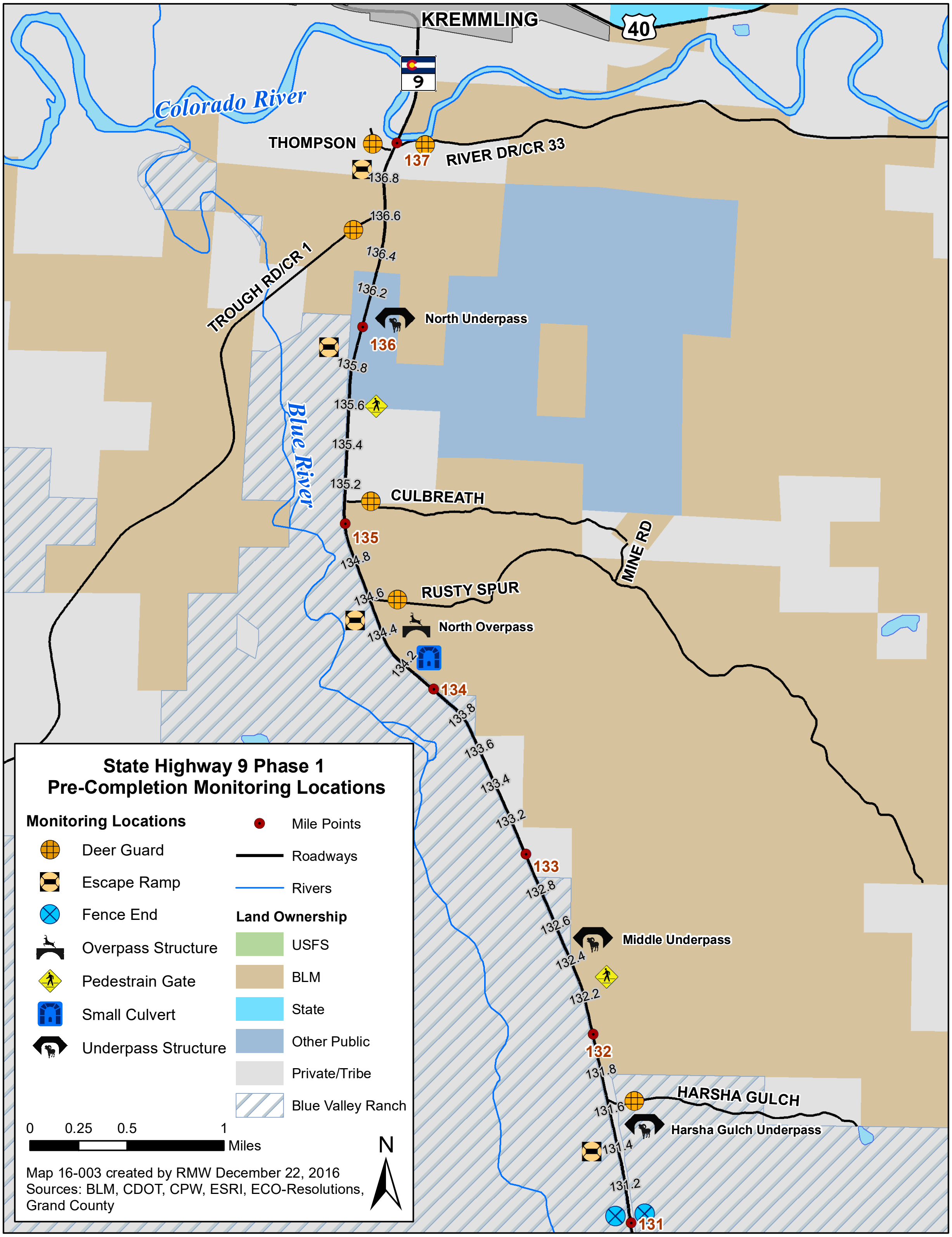

Figure 1. Phase 1 pre-construction monitoring locations.

Figure 2. U-bolt system used to securely mount camera boxes to T-posts (left). Example of a camera installed inside a utility box to hide cameras in high traffic areas, such as this deer guard (right).

At each monitoring location, cameras were set up to maximize capture rates and wildlife responses to the mitigation features. At crossing structures, cameras were placed to capture wildlife behavior at the entrance of the structure to distinguish successful through-passage from repels and parallel movements. Two cameras were placed at each arch underpass, at opposite corners. In addition, a habitat camera was placed on one side of each underpass, 50-100 feet (15-30 meters) from the structure entrance, facing away from the road out into the habitat (Fig. 3). The North Underpass has steep entrance ramps leading to the top of the structure, so in addition to the two cameras on top of the structure, additional cameras were placed at the bottom of the ramps on either side of the structure. These 'entrance' cameras were more likely to capture

Figure 3. Two cameras were positioned at each underpass at opposite corners (left). Habitat camera placed 50-100 feet in front of a structure, facing out into the adjacent habitat (right).

repels and parallel movements, while the structure cameras could be used to confirm through-passage. Habitat cameras were placed on both sides of the overpass to capture wildlife movements in the adjacent habitat.

Cameras at other monitoring locations were positioned to capture specific wildlife behaviors. At deer guards and pedestrian walk-through gates, cameras were placed to capture wildlife behavior in front of the guard or walk through gate (e.g., approaches, repels and breaches). Two cameras were set up at each monitored escape ramp, one at the base of the ramp to capture wildlife approaching the ramp or walking around the ramp; and one on the habitat side to capture wildlife at the top of the ramp, including successful jump downs as well as jump up attempts from the habitat side onto the ramp. At the south fence end, cameras were positioned to capture both wildlife movements into and out of the fenced right-of way, as well as movements that occurred beyond the fence end.

Cameras were visited every 4-5 weeks to exchange memory cards and batteries. Photo data were systematically processed to identify events every time a camera is triggered. Events are defined by the movements of individuals or groups at crossing structures, deer guards, escape ramps, pedestrian gates, and the fence end. Events were defined as 15-minute time periods based on the methodology developed by Cramer (2012) because animals typically leave the camera area within 15 minutes. For each 15-minute timeframe, if an animal approached a structure multiple times without crossing, this was considered a single event until the animal crossed, repelled, or the 15-minute period ended, in which case a new event would be recorded. Events at all monitoring locations were recorded in a SQL database created for this research.

All events were categorized by time of day according to three time periods: day, night, and dawn/dusk. To account for the changes in the timing of dawn and dusk throughout the year, time of day was determined by the images themselves – color photos are taken during the day; black and white photos are taken at night; and black and white photos taken at dawn and dusk appear with a lighter background.

For each event at a crossing structure, the researchers identified, by species, the number of individuals and the gender of each individual, the direction of the movement, and their response to the crossing structure: through passage (success), repel or parallel movement. These were defined as follows:

Success – Movement all the way through the crossing structure.

Repel – Initial movements near the entrance to the crossing structure that resulted in the animal turning away from the structure rather than passing through.

Parallel – Animals moved near the structure, but were headed in a direction beyond the structure entrance, or were either grazing on vegetation, with behaviors that were not indicative of attempts to use the structure.

Total Movements were calculated for each wildlife crossing structure as,

Total Movements = Success Movements + Repel Movements + Parallel Movements

Unique movements by individual deer were tallied only once, even when two cameras recorded the movement. Individual repel and parallel movements were tallied only once when the same deer moved in front of a camera multiple times in a 15-minute event period.

Species numbers were tallied at the habitat cameras that face away from the road out into the habitat. Tallying species presence at habitat cameras allows comparisons of species composition and abundance in the habitat near a crossing structure with the species successfully using the crossing structure. Since these cameras are meant to document species presence and abundance, the photos are analyzed without a categorization of animal behavior.

At deer guards, animal movements were categorized as a breach, repel or parallel movement. A breach movement occurred when an animal jumped or walked over the guard or, by another method, was able to move into the highway right-of-way. At escape ramps, movements inside the fenced right-of-way were categorized as walk around the base of the ramp, or ascend the ramp and either turn around or jump down. Additional tallies were made to document jump up attempts from the habitat side of the ramp. At the fence end, individual movements were categorized as movements into the fenced right-of-way, movements from the fenced-right-of way out to the adjacent habitat, or movements that occurred beyond the fence end.

The following indices were calculated for each monitoring location, as applicable. These indices were then used to evaluate performance as described below under *Performance Measures*.

- **Successful passage rate** – For each species at a given crossing structure location, the total number of individual movements of the species that were recorded moving through the structure divided by the total movements by that species.
- **Repel rate** – For each species at a given crossing structure location, the total number of number of individual movements of the species that were recorded being repelled at a structure divided by the total movements by that species. Repel rate was also calculated for deer and elk at deer guards, pedestrian walk-through gates and fence ends. In these cases, a repel movement is the desired wildlife behavior response to the mitigation features, i.e., the total number of times deer/elk were repelled divided by the total number of times deer/elk approached the mitigation feature.
- **Parallel rate** – For each species at a given monitoring location, the total number of individual movements of the species that were recorded moving parallel to the mitigation feature divided by the total movements by that species. This metric is calculated for crossing structures, escape ramps, and pedestrian walk-through gates.
- **Successful jump-down rate** – This metric is calculated for deer and elk at escape ramps. It is the total number of times deer/elk were recorded successfully jumping down from an escape ramp divided by the number of times cameras captured deer/elk walking up the escape ramp.
- **Breach rate** – This metric is calculated for deer and elk at deer guards, escape ramps, pedestrian walk-through gates, and fence ends. It is the total number of times individual deer/elk breached the mitigation divided by the total number of times deer/elk approached that mitigation feature. For example, at a deer guard, breaches occur when animals cross over the guard; at escape ramps, breaches occur when animals jump up onto an escape ramp from the habitat side of the wildlife exclusion fencing; at a pedestrian walk-through gate, breaches occur when animals pass through the gate; at the fence end, breaches occur when animals enter into the fenced right-of way from beyond the fence end.

- **Average deer per day** – the total number of unique deer movements observed at the structure divided by the sampling effort. Sampling effort is calculated as the number of days a camera was in operation (or the average number of days for locations with two cameras) and is useful for standardizing the number mule deer photographed when there is variation in the number of days that cameras were in operation at different monitoring locations. Deer per day may also be calculated for deer guards.
- **Average successful deer passages per day** – The total number of times deer successfully used a structure divided by sampling effort.

Wildlife-Vehicle Collision Data Analysis

Wildlife-vehicle collision rates were analyzed using three independent datasets – WVC carcass data compiled by BVR and CPW; WVC carcass data recorded by CDOT maintenance units; and WVC accident reports compiled from law enforcement by CDOT Traffic and Safety. Blue Valley Ranch staff have recorded WVC carcass data north of Spring Creek Road (MP 128.5) to the town of Kremmling (MP 138) since 2005 and will continue to report these data through the duration of this research study. However, the 2005 data do not include month or day, and these data were excluded from further analysis. Since 2013, CPW has also been collecting carcass data south of Spring Creek Road to the southern end of the project area (MP 126). Carcass data are collected daily from November through April, when WVC are most common, with incidental reports compiled through the remainder of the year. Data collection includes all species, with a focus on ungulates and large and medium-sized animals.

CDOT maintenance units have been recording carcasses due to WVC since 2005. Carcass reporting by maintenance personnel is voluntary. It is likely that reporting effort in the first years of the program was inconsistent. As the program has become more established, reporting effort is believed to be more consistent. WVC carcass pickups are reported year-round for all species, although the majority of carcass reports are deer and elk. To compare WVC carcass reports from CDOT with those collected by BVR and CPW, the researchers examined the data only for the months of November through April.

The study will also examine ten-year WVC accident reports compiled by CDOT Traffic and Safety. Wildlife-vehicle collision crashes, while underreported, are reported consistently statewide and offer a useful standard for comparing WVC crash rates inside the project area with those outside of the project area. However, 2016 data were not available at the writing of this report, precluding an analysis of these data.

Each of the WVC carcass datasets were analyzed with respect to the date and location of WVC, and the species involved in these collisions. For this progress report, the researchers compared the five-year pre-construction averages (winter 2010/11 – 2014/15) for each dataset with the pre-completions WVC carcass rates (winter 2015/16). Two segments are identified in the project area relative to this analysis: The Phase 1 pre-completion segment (MP 131-137), and the Phase 2 pre-construction segment (MP 126-137).

Since CDOT maintenance units report WVC carcass pickups statewide, it was possible to also make a comparison of WVC rates beyond the project area, including SH 9 south of the project boundary, and on US Highway 40 (US 40) east of Kremmling. Comparing WVC carcass rates inside the project area with those outside of the project area, but within habitat used by the same ungulate herds and affected by the same weather patterns helps researchers to generalize reasons for changes in WVC, and the extent to which these changes may be due to the mitigation or other factors. In addition, an increase in WVC from an annual baseline outside of the project area with a corresponding decrease in the mitigated area may suggest a shift in wildlife movement around the mitigated segment.

Performance Measures

Performance measures allow an evaluation of how well the wildlife mitigation accomplishes stated objectives of a highway improvement project. These measures help agencies take adaptive management actions to increase the effectiveness of the mitigation, or to inform future mitigation projects in other locations. It is essential to define measurable performance measures at the outset of a project to objectively evaluate project success. The performance measures may be re-gauged in light of future research results and information from forthcoming comparable studies.

The wildlife mitigation system on SH 9 is evaluated with respect to wildlife connectivity and traffic safety. Specifically, how well the crossing structures allow wildlife populations to access habitat on both sides of the highway, the wildlife connectivity measures; and how well the mitigation reduced WVC, the traffic safety measures. The following performance measures were generated by the researchers in conjunction with the research Study Panel.

Wildlife Connectivity Performance Measures

Wildlife connectivity is assessed for large and meso mammal species. To evaluate how well the wildlife crossing structures facilitate species' use, performance measures are based two rates: 1) success rates, and 2) the number of movements recorded through or over structures per year for each species (movements/year).

Success Rates

1. Mule deer success rate at each structure will be a minimum of 60%, and have a goal of 80% success during the final year of the study (based on Montana - Cramer and Hamlin 2016; Utah - Cramer 2014, 2016; Wyoming - Sawyer et al. 2012).

2. Elk success rate at each structure will be a minimum of 60%, and have a goal of 75% success during the final year of the study (based on Arizona - Gagnon et al. 2011).

3. Success rate for all meso to large mammal species detected near each structure will be a minimum of 60%, and have a goal of 80% success for each structure during the final year of the study (based on Montana – Purdum 2013).

Movements per Year

4. By the end of the study, male and female mule deer movements through all crossing structures will be in the same male:female proportions as are estimated for the local population (based on population estimates as determined by CPW).

5. By the end of the study, male and female elk movements through all crossing structures will be in the same male:female proportions as estimated for the local population (based on population estimates as determined by CPW).

6. By the end of the study, the number of elk success movements at all structures annually, will be at least 50% of the number of elk movements captured at associated habitat cameras (i.e., documenting animals in the vicinity of the structures, but not necessarily using structures), irrespective of season (based on Arizona – Gagnon et al. 2011).

7. Each year there will be an increase in the number of mule deer movements at wildlife crossing structures annually until an overall equilibrium/plateau is reached (based on Arizona- Gagnon et al. 2011; Dodd et al. 2012; Utah - Cramer 2016; Montana - Cramer and Hamlin 2016).

8. Each year there will be an increase in the number of elk movements at wildlife crossing structures annually until an overall equilibrium/plateau is reached (based on Arizona- Gagnon et al. 2011; Dodd et al. 2012; Utah - Cramer 2016; Montana - Cramer and Hamlin 2016).

9. Each year, there will be at least one to several successful movements through or over crossing structures for every one of the less common species of large ungulates and carnivores in the study area that are documented by the habitat cameras. This may include pronghorn, moose, white-tailed deer, mountain lion, black bear, bobcat, and other species (Utah - Cramer 2016; Montana - Cramer and Hamlin 2016).

10. By the end of the study, at least 80% of the individual mule deer and elk approaches to each deer guard will be deterred from entering the road right-of-way (based on Utah – Cramer and Flower 2016; Flower 2016).

11. By the end of the study, 50% of the individual mule deer and elk that ascend an escape ramp will jump down to the habitat side, and no animals will jump up onto the ramp from the habitat side. This threshold will be reevaluated in Year 2 of the study (based on Arizona – Arizona Game and Fish Department, unpublished data; Colorado – Siemers et al. 2015).

12. By the end of the study, 100% of the individual mule deer and elk approaches to each pedestrian walk-through gate will be deterred from entering the road right-of-way. This threshold will be reevaluated in Year 2 of the study.

13. By the end of the study, the proportion of ungulate movements at the south fence end that enter into the fenced right-of-way will decrease to 20% or less (based on Utah – Cramer unpublished data, 2016).

Traffic Safety Performance Measures

Traffic safety performance measures evaluate how well the wildlife mitigation reduced wildlife-vehicle collisions. This is measured with reported crashes and carcasses.

14. The annual average number of WVC reported crashes (CDOT Traffic and Safety data) within the mitigated area of the study will decrease by at least 80% during the final two years of the study when compared to the five-year pre-construction average (based on Alberta, Canada - Clevenger and Barrueto 2014; Wyoming - Sawyer et al. 2012; compiled study – Huijser et al. 2009).

15. The annual average number of wildlife carcasses reported by Blue Valley Ranch and Colorado Parks and Wildlife within the mitigated area of the study will decrease by at least 80% during the final two years of the study when compared to the five-year pre-construction average (based on Alberta, Canada - Clevenger and Barrueto 2014; Arizona – Gagnon et al. 2015; Washington – McAllister et al. 2013).

16. By the last year of the study, the average annual number of WVC reported crashes within one mile south of the south fence end will not increase over the five-year average annual pre-construction crash rate for this section of road (based on Arizona – Gagnon et al. 2015; Wyoming – Sawyer et al. 2012).

Results: Winter 2015/16 Pre-Completion Monitoring

During the first winter of pre-completion monitoring (December 7, 2015 through March 31, 2016), the majority of movements were made by mule deer. Cameras also documented elk, moose, bobcat, coyote, red fox and hare. Complete results of pre-construction winter monitoring are presented in the following sections.

Mule Deer Use of Wildlife Crossing Structures

Mule deer successfully moved through all the crossing structures on multiple occasions during this first winter of pre-completion monitoring. Mule deer were recorded using the structures 7,013 times during this period. Deer were recorded at all structures nearly every week during this period, with most movements resulting in successful through-passage. The highest number of movements were captured at the North Overpass, and surpassed the number of successful movements at each of the underpass structures by a factor of five. The number of movements at the Middle Underpass and Harsha Gulch Underpass were similar, while the lowest numbers were reported at the North Underpass (Figure 4). Table 2 summarizes the success rates, repel rates and parallel rates at each crossing structure. Success rates were greater than 80% at each of the crossing structures. The highest success rate (98%) was observed at the North Overpass, while the lowest success rate was at the North Underpass (82%).

Table 2. Mule deer movements at wildlife crossing structures.

Monitoring Location	Total Movements	Success Movements	Average Deer per day	Average Success per Day	Success Rate (%)	Repel Rate (%)	Parallel Rate (%)
MP 136 – North Underpass	457	377	3.0	2.5	82	13	5
MP 134 – North Overpass	4,964	4,875	35.7	35	98	0.5	1.5
MP 132 – Middle Underpass	920	877	6.2	5.9	95	3	1.5
MP 131 – Harsha Gulch Underpass	992	884	6.8	6.1	89	6	5
Totals	**7,333**	**7,013**	**-**	**-**	**-**	**-**	**-**

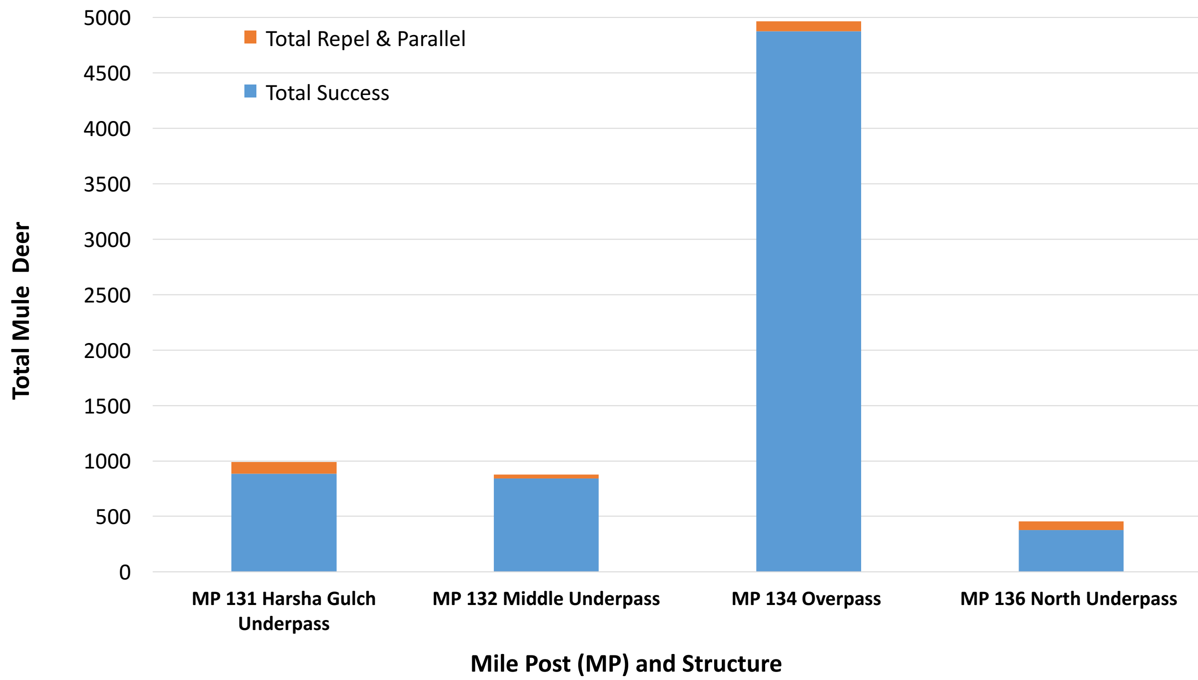

Figure 4. Comparison of mule deer movements across wildlife crossing structures. Total successful through-passages (success) and total repels and parallel movements at each crossing structure.

In general, mule deer movements at crossing structures were lowest around the beginning of the study period (December 7, 2015) when Phase 1 construction shut down for the winter. This timeframe also corresponded with deer arrival on winter range, which was later than average due to mild weather and snowfall during the month of November. The number of mule deer movements increased towards the middle or end of the study period covered in this report (March 31, 2016). A 52-week scale was used to compare movements across structures and, in future reports, across years. Peak mule deer activity was generally between weeks 10 and 13 at the North Underpass, the North Overpass and the Middle Underpass, which corresponds with the month of March. At Harsha Gulch Underpass peak activity occurred during week 5 (late January) with a smaller peak in week 8 (mid-February). Figures 5-8 depict, for each crossing structure, the total number of mule deer movements detected relative to total success movements by week of the year. For a given week, the closer the paired green and blue bars are in height, the greater the success rate for that week.

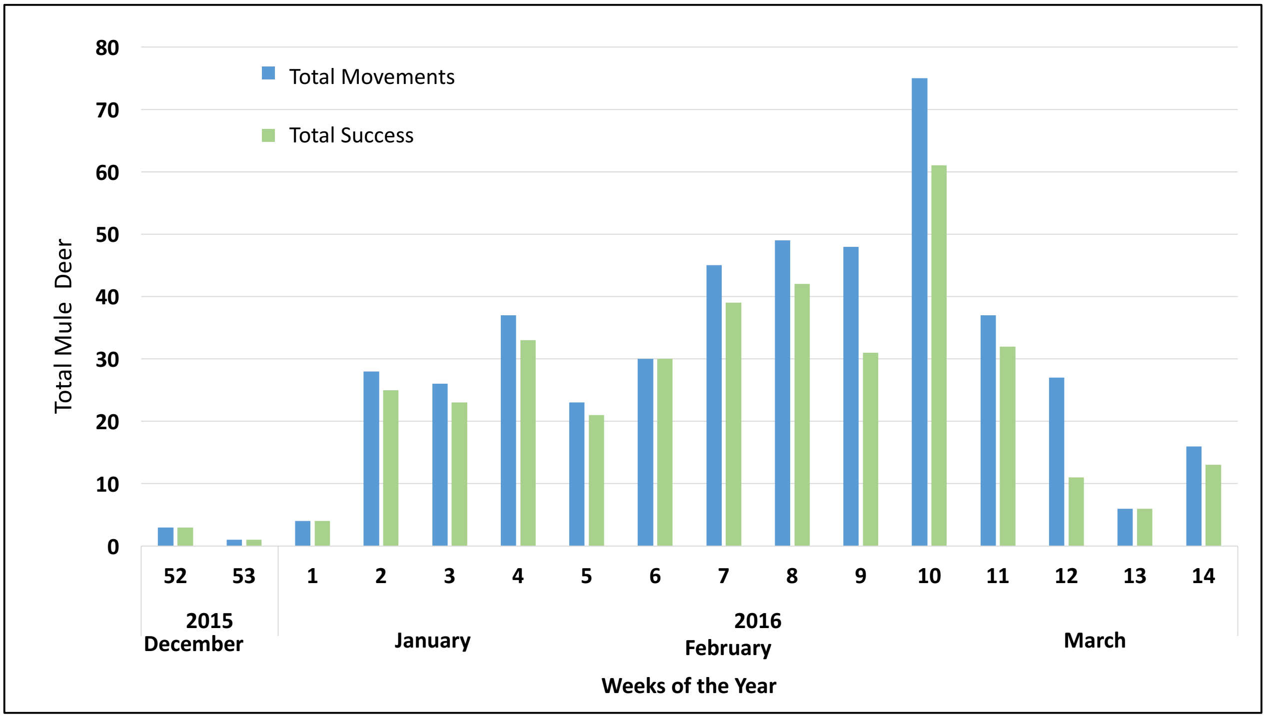

Figure 6. Mule deer total movements and success movements by week of the year at the North Underpass (MP 136.0). Note y-axis scale is 0-80.

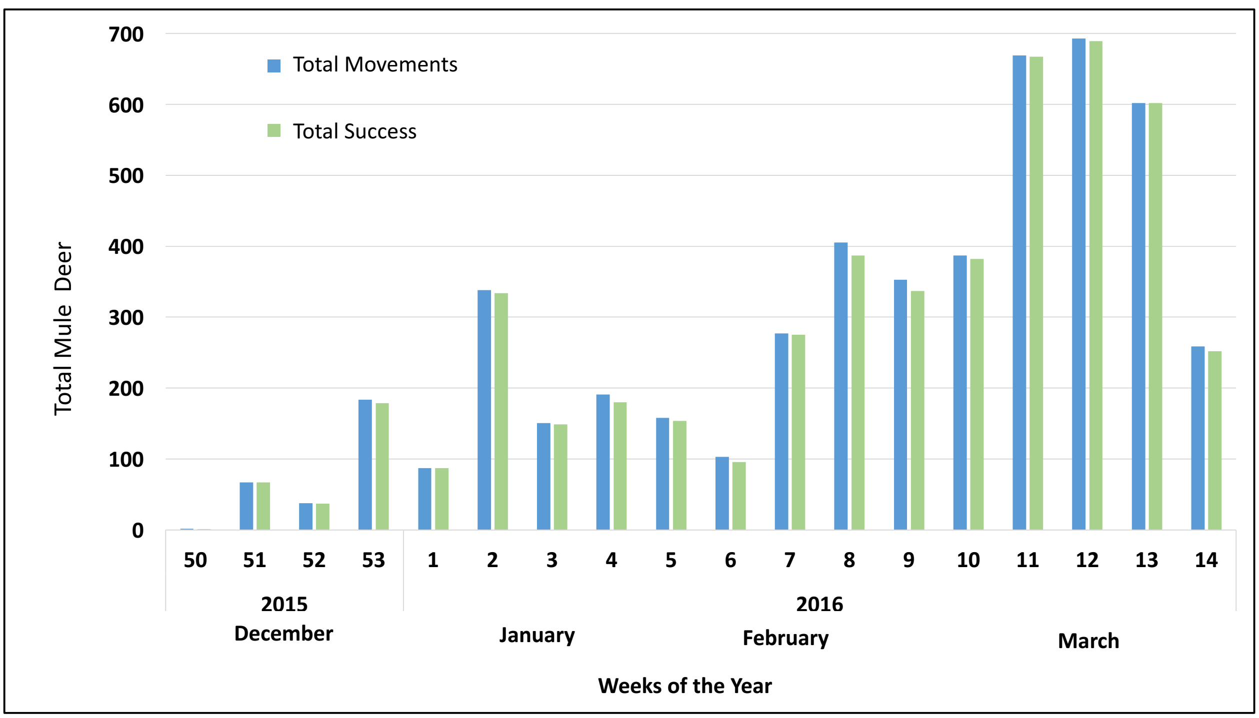

Figure 5. Mule deer total movements and success movements by week of the year at the North Overpass (MP 134.3). Note y-axis scale is 0-700.

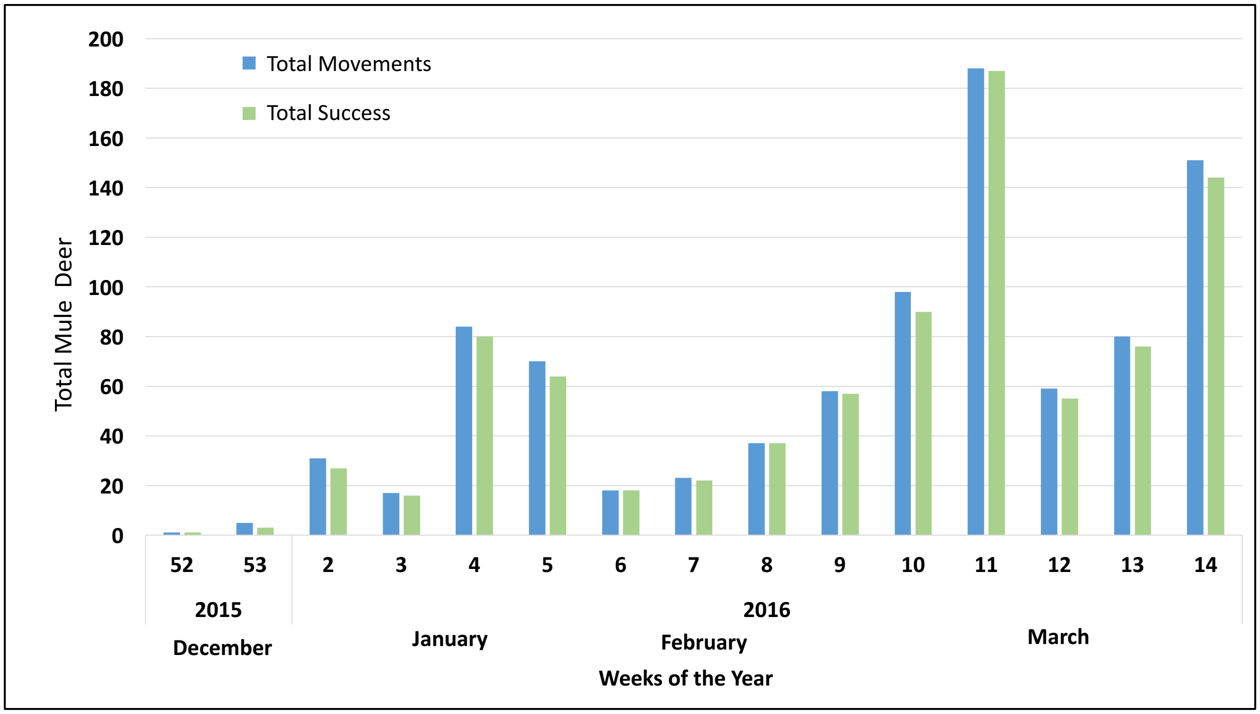

Figure 8. Mule deer total movements and success movements by week of the year at the Middle Underpass (132.5). Note y-axis scale is 0-200.

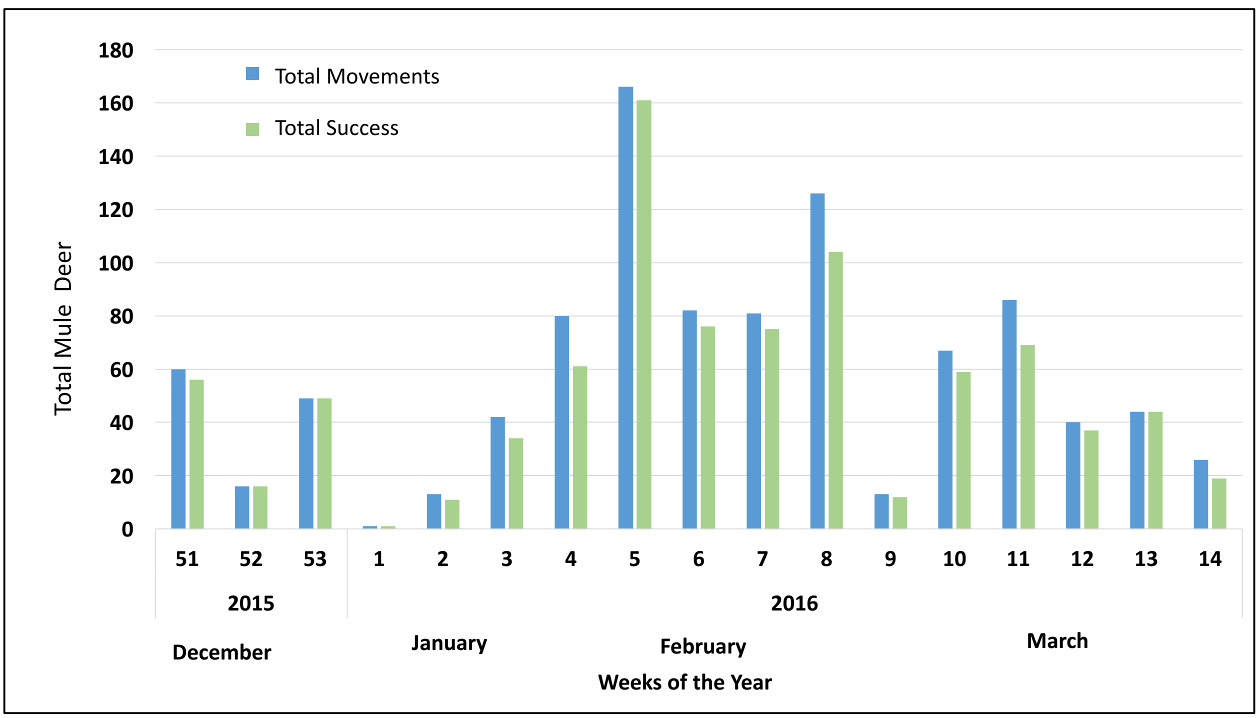

Figure 7. Mule deer total movements and success movements by week of the year at the Harsha Gulch Underpass (MP 131.6). Note y-axis scale is 0-180.

Camera monitoring documented movements by male and female deer, although, in many cases, gender is undetermined, for example, in immature animals or males who have shed their antlers. Numbers and percentages for each gender of individual mule deer whose movements were detected are presented in Table 3.

Table 3. Gender of mule deer whose movements were detected at wildlife crossing structures.

Monitoring Location	Males	Females	Unknown	% Male	% Female
MP 136 – North Underpass	54	201	201	12%	28%
MP 134 – North Overpass	391	1,397	3,182	8%	28%
MP 132 – Middle Underpass	127	167	609	14%	19%
MP 131 – Harsha Gulch Underpass	173	211	554	18%	23%
Total	**745**	**1,976**	**4,546**	**10%**	**27%**

Movements through or over the crossing structures occurred in both directions, originating from the east and moving west, or originating from the west and moving east. At the North Overpass east-to-west movements were nearly equal with west-to-east movements. There were more east-to-west movements at both the North Underpass and the Middle Underpass, while Harsha Gulch Underpass saw a greater number of west-to-east movements. As the project area is located within winter range, many of the same animals are making regular movements through the structures to access the habitat and resources on either side.

On several occasions mule deer were documented crossing over the North Overpass outside of the wildlife exclusion fence, along the structure edge. A gap in the wildlife fence between the fence and the edge of the structure was blocked with four-strand barbed wire fencing; however, camera monitoring documented that deer trapped in the right-of-way breached the barbed wire and crossed the overpass outside of the fence (Fig. 9).

Figure 9. Mule deer crossing over the North Overpass outside of the wildlife exclusion fence.

Elk and Other Species Use of Wildlife Crossing Structures

In addition to mule deer, a variety of other species were documented using the wildlife crossing structures. Table 3 lists, for each structure, species total movements at a crossing structure, successful through passage movement and repels, and offers a comparison with the species' presence at the habitat cameras.

Table 4. Movements by other species at wildlife crossing structures. Movements is the number of movements that species made at a crossing structure. Success, repel and success rate are tallied by species at each structure. Habitat presence is the total number of times the species was captured at the habitat cameras, in the habitat adjacent to the structure.

Monitoring Location	Movements*	Elk	Moose	Bobcat	Coyote	Red Fox	Human
MP 136 – North Underpass	Movements	2	0	1	2	1	3
	Success	2	0	0	2	1	n/a
	Repel	0	0	1	0	0	n/a
	Success Rate	100%	0	0%	100%	100%	n/a
	Habitat Presence	5	0	0	1	1	0
MP 134 – North Overpass	Movements	0	1	0	2	5	0
	Success	0	1	0	1	4	n/a
	Repel	0	0	0	1	0	n/a
	Success Rate	0	100%	0	50%	80%	n/a
	Habitat Presence	9	0	0	13	4	0
MP 132 – Middle Underpass	Movements	4	0	7	6	3	2
	Success	4	0	7	5	3	n/a
	Repel	0	0	0	1	0	n/a
	Success Rate	100%	0	100%	83%	100%	n/a
	Habitat Presence	2	0	8	2	1	0
MP 131 – Harsha Gulch Underpass	Movements	1	0	8	1	6	6
	Success	1	0	8	1	4	n/a
	Repel	0	0	0	0	0	n/a
	Success Rate	100%	0	100%	100%	67%	n/a
	Habitat Presence	1	0	0	0	0	0
Total Movements Detected at Structures		**7**	**1**	**16**	**11**	**15**	**11**
Total Presence Detected at Habitat Cameras		**17**	**0**	**8**	**16**	**6**	**0**

**At a given location, where the sum of success and repels for a species does not equal the total number of movements indicates that parallel movements also occurred.*

Other species captured include jackrabbit, ground squirrel, raccoon, birds, and domestic cat, dog and cow. Vehicles/snowmobiles were documented passing through Harsha Gulch Underpass on three occasions – most likely the landowner accessing their property on both sides of the road. At the North Overpass, elk were photographed, but only at the west side habitat camera. The habitat camera at the North Underpass is on the east side, while the habitat cameras at the Middle Underpass and at Harsha Gulch Underpass are on the west side. Elk were documented at all of these habitat cameras. Overall, elk presence was captured at habitat cameras 17 times and 7 elk movements were captured at structures. Of the elk that approached crossing structures, each of these movements resulted in successful through-passage.

Only 11 humans were recorded at the crossing structures; this does not include researchers conducting camera checks. While construction was ongoing (between Phases 1 & 2), construction activities ceased during the winter months covered by this report.

Wildlife Movements at Other Mitigation Features

Deer Guards

Cameras were deployed at 6 deer guard locations in Phase 1 of the project area during pre-completion monitoring. The guards are just under 16' (4.9-m) long with flat bars spaced 4" (2.5-cm) apart, and of varying widths, corresponding to the width of the road or driveway. Some guards have a 2.5' (0.7-m) wide pedestrian grate across the bars per landowner requests (Fig. 10). The fence gate over the Rusty Spur deer guard was closed on January 21, 2016, and that camera re-deployed to the Thompson driveway for the remainder of the reporting period. All other deer guards had cameras deployed for the duration of this reporting period. Wildlife movements, including breaches and repels for each species are presented in Table 4. Based on these results, breach and repel rates were calculated for each species at each monitoring location.

Figure 10. Example of a pedestrian grate across a deer guard.

Table 5. Wildlife movements at deer guards. Movements is the total number of times that species visited the deer guard. Breach and repel movements were used to calculate breach and repel rates for each species at each structure.

Deer Guard	Movements*	Mule Deer	Elk	Bobcat	Coyote	Red Fox
County Rd 33 Deer Guard (MP 136.9)	Movements	12	0	0	4	17
	Breach	8	0	0	4	15
	Repel	4	0	0	0	2
	Breach Rate	67%	n/a	n/a	100%	88%
	Repel Rate	33%	n/a	n/a	0%	12%
Thompson Deer Guard (MP 136.9)	Movements	7	1	0	0	0
	Breach	0	0	0	0	0
	Repel	7	1	0	0	0
	Breach Rate	0%	0%	n/a	n/a	n/a
	Repel Rate	100%	100%	n/a	n/a	n/a
Trough Rd Deer Guard (MP 136.6)	Movements	14	0	0	4	1
	Breach	7	0	0	4	1
	Repel	7	0	0	0	0
	Breach Rate	50%	n/a	n/a	100%	100%
	Repel Rate	50%	n/a	n/a	0%	0%
Culbreath Deer Guard** (MP 135.1)	Movements	24	0	0	0	1
	Breach	11	0	0	0	1
	Repel	13	0	0	0	0
	Breach Rate	46%	n/a	n/a	n/a	100%
	Repel Rate	54%	n/a	n/a	n/a	0%
Rusty Spur Deer Guard** (MP 134.5)	Movements	5	0	1	0	3
	Breach	4	0	1	0	3
	Repel	1	0	0	0	0
	Breach Rate	80%	n/a	100%	n/a	100%
	Repel Rate	20%	n/a	0%	n/a	0%
Harsha Gulch Deer Guard (MP 131.6)	Movements	11	0	3	2	11
	Breach	0	0	3	1	11
	Repel	11	0	0	1	0
	Breach Rate	0%	n/a	100%	50%	100%
	Repel Rate	100%	n/a	0%	50%	0%

**At a given location, where the sum of breach and repels for a species does not equal the total number of movements indicates that parallel movements also occurred.*
***Deer guard location with pedestrian grate.*

The primary objective of the deer guards is to prevent ungulate incursions into the fenced right-of-way, particularly mule deer and elk. One-hundred and nine deer movements were recorded at the deer guards in Phase 1. Of these, 68 movements resulted in repels, while 38 times deer were recorded breaching the guard. Most breach movements were made by deer moving from the habitat side of the fence into the fenced right-of-way; however, breach movements were also documented of deer returning to the habitat side from the fenced right-of-way. Five such mule deer movements were captured at the County Road 33 deer guard; one at the Culbreath deer guard, and six at the Trough Road deer guard. Two guards had deer breach rates over 60% (County Rd 33 and Rusty Spur). Only one elk movement was recorded at the Thompson Deer Guard during this timeframe, and that movement resulted in a repel from the guard. Other species documented at the deer guards include badger, domestic cat, hare, raccoon and unknown. Most breach movements by all species were made by walking on top of the bars. On six occasions deer were recorded jumping across the guards. At Trough Road, deer breached the guards on seven occasions by walking across snow that was packed into the guard.

Escape Ramps

Two escape ramp locations were monitored during the timeframe of this report. The Overpass Escape Ramp (MP 134.3) has a 2:1 slope and no perpendicular rail fence. The SWA Escape Ramp (MP 135.9) has a 2:1 slope with perpendicular rail fence. Table 5 summarizes mule deer movements and responses at each ramp location. Of the deer that approached the Overpass Escape Ramp, 12% of approaches resulted in deer successfully jumping down to the habitat side of the fence. No deer were recorded ascending or jumping down the SWA Escape Ramp.

Table 6. Mule deer movements at escape ramps in the Phase 1 portion of the project area.

Escape Ramp	Walk Around Ramp	Walk up Ramp and Turn Around	Walk up Ramp and Jump down
Overpass Escape Ramp (MP 134.3)	9	36	6
SWA Escape Ramp (MP 135.9)	2	0	0

Pedestrian Walk-Through Gates

Pedestrian walk-through gates for the SH 9 project are derived from the V-shape design used by the Montana Department of Transportation. Because the wildlife fence follows the CDOT right-of-way, the V-shape would have infringed on the adjacent lands. To preclude issues with landowners, CDOT created a modified design (Fig. 11). Two pedestrian walk-through gates are present in the Phase 1 project area, both of which had cameras deployed during pre-completion monitoring.

No mule deer breaches were documented through the pedestrian walk-through gates into the fenced right-of-way during this time period. Cameras recorded a total of seven repels and twenty-nine parallel movements in front of the gates.

Figure 11. CDOT pedestrian walk-through gate design.

South Temporary Fence End

The temporary end for the wildlife exclusion fence was at the southern terminus of the Phase 1 project area (MP 131.0). On both sides of the highway, the wildlife fence is constructed along the right-of-way line. At the temporary fence end, the fence line angles in toward the pavement, ending 20’ from the pavement edge so that it is not inside the clear zone.

A total of 35 wildlife movements were recorded at the fence end, including 27 movements by mule deer and eight movements by red fox. The majority of mule deer movements occurred beyond the fence end (n=13), but 11 deer movements were documented moving from the habitat side of the fence into the fenced right-of-way (Fig. 12). Movements into the fenced right-of-way occurred when deer moved from the habitat side of the fence and either walked around the fence into the right-of-way or crossed the road and entered the right-of-way on the opposite side. Movements out of the fenced right-of way occurred when animals already inside the wildlife fence moved out to the habitat side of the fence. Movements beyond the fence includes movements where animals crossed the road beyond the fence end as well as those where the animal did not cross the road, but repelled from the road and remained beyond the fence end.

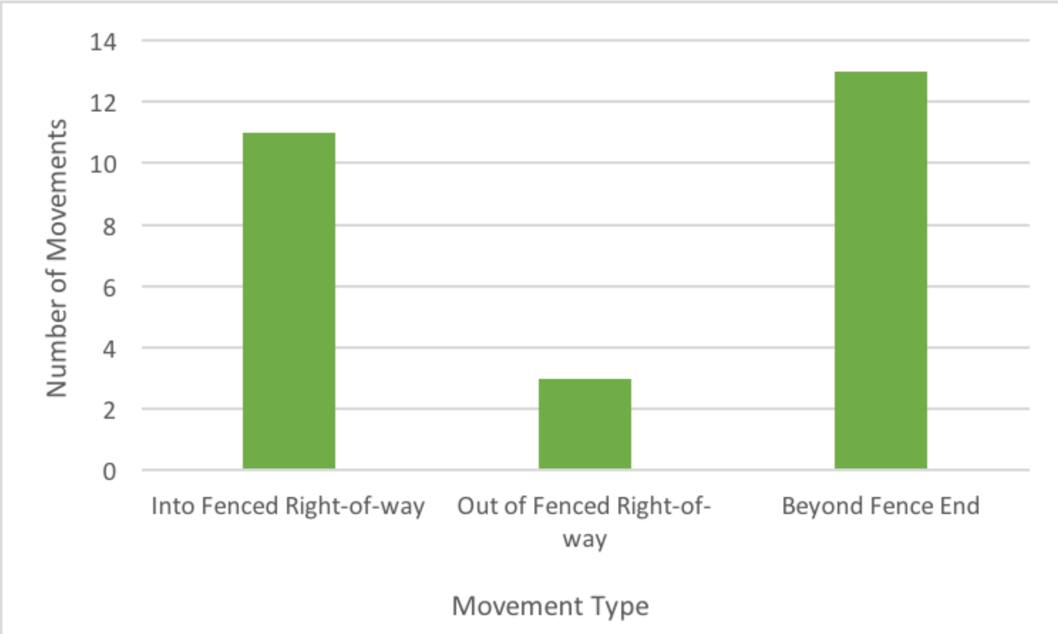

Figure 12. Mule deer movements at the temporary south fence end.

Pre-construction and Pre-completion Wildlife-Vehicle Collision Rates

Results from analyses of BVR/CPW WVC carcass dataset and the CDOT maintenance WVC carcass dataset are presented below.

BVR/CPW Carcass Data

Blue Valley Ranch and CPW recorded a total of 575 WVC carcasses within the project area from the winter of 2006/07 through the winter of 2015/16. Ninety-eight percent of recorded carcasses were mule deer. One percent were elk, and the remainder are coyote, fox, mountain lion and turkey. Across the project area, there is considerable annual variation in the number of carcass reports. Pre-construction carcass reports in the six-mile long Phase 1 vary from a low of 18 WVC in the winter of 2008/09 to a high of 47 in 2010/11. The Phase 1 segment averaged 31 carcasses per winter from 2010/11 through 2014/15. In the Phase 2 segment (five miles long), pre-construction WVC range from 17 in the winter of 2009/2010 to 56 in 2013/14. The Phase 2 segment averaged 32.6 carcasses per winter over the last five winters pre-construction. In the winter of 2015/16, Phase 1 had just three carcasses reported, and Phase 2 had 38 carcasses reported (Fig. 13).

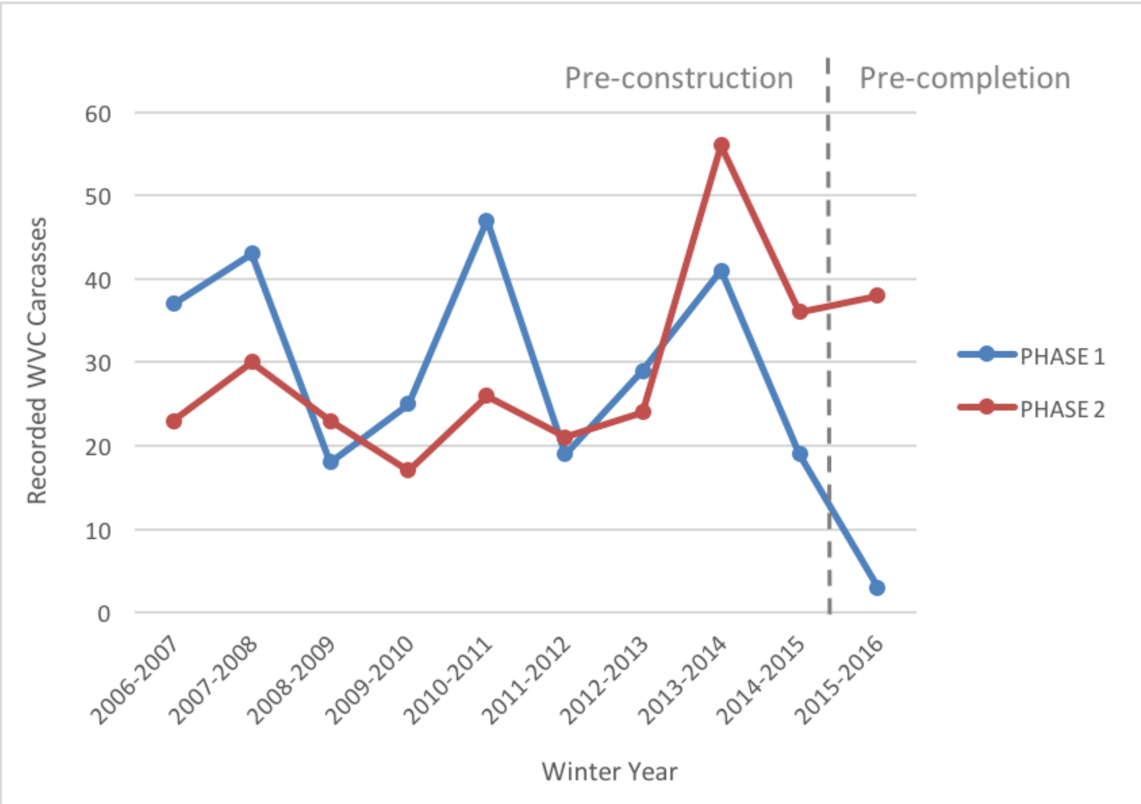

Figure 13. Reported WVC carcasses compiled by BVR and CPW in Phases 1 and 2 of the project area, nine years pre-construction (from winter 2006/07 through winter 2014/15) and one year pre-completion (winter 2015/16).

CDOT Maintenance Carcass Data, SH 9

CDOT maintenance units reported a total of 309 WVC carcass pickups in the project area from the winter of 2006/07 through the winter of 2015/16. Ninety-five percent of recorded carcasses were mule deer. Two percent were elk, and the remainder were fox, rabbit and unknown. As with the BVR/CPW carcass dataset, there was considerable annual variation in the number of carcass reports due to population fluctuations, weather factors and other impacts. Excluding the first three winters in the dataset (due to presumed inconsistencies in reporting effort in the early years of the CDOT carcass reporting program), pre-construction carcass reports in the Phase 1 segment varied from a low of 2 WVC in the winter of 2009/10 to a high of 31 in 2013/14. The five-year pre-construction average for the Phase 1 segment was 18.8. In the Phase 2 segment, pre-construction WVC range from 9 in the winter of 2006/2007 to 30 in 2013/14. The five-year average for the Phase 2 segment was 23. One carcass was collected in Phase 1 during the first winter of pre-completion monitoring (2015/16). In Phase 2, there were 31 recorded carcass pickups in winter 2015/16 (Fig. 14).

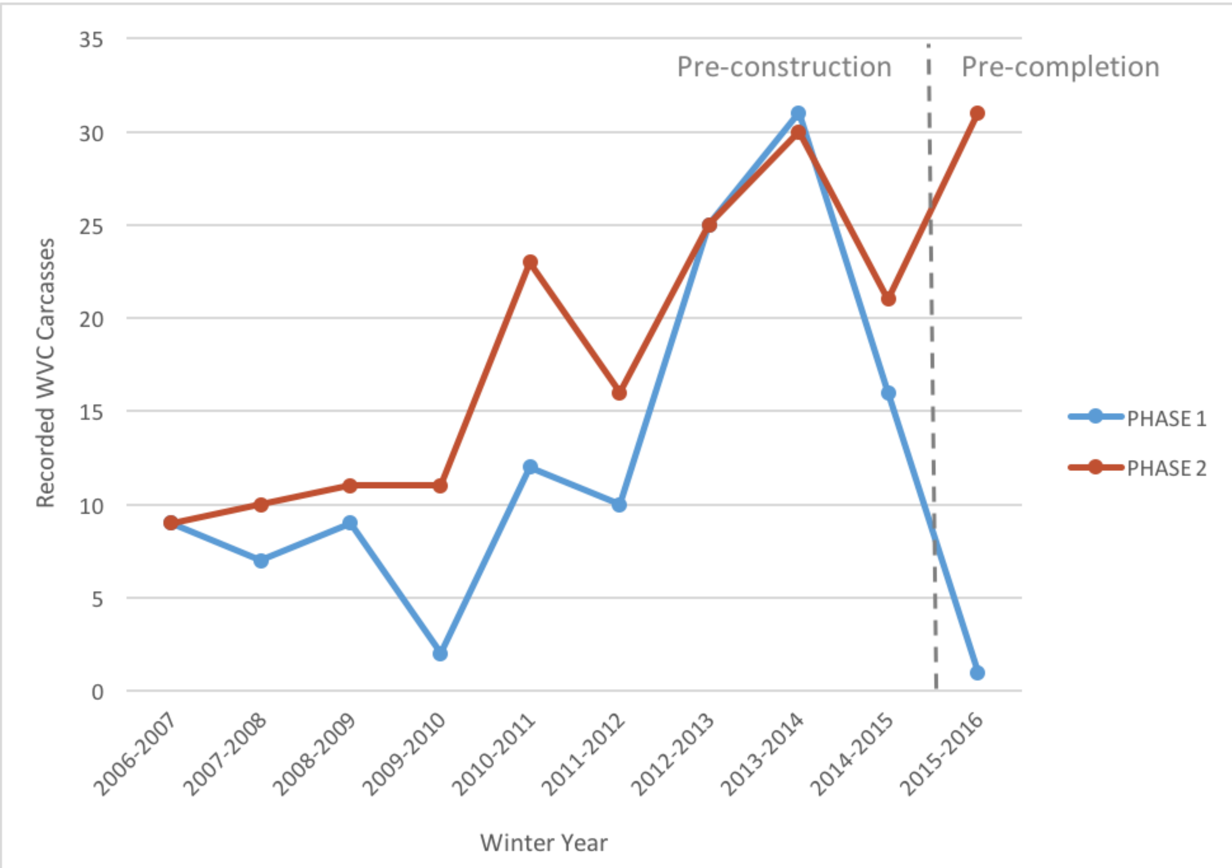

Figure 14. Reported WVC carcasses reported by CDOT Maintenance in Phases 1 and 2 of the project area, ten years pre-construction (from winter 2006/07 through winter 2014/15) and one year pre-completion (winter 2015/16).

The CDOT WVC carcass dataset was also examined with respect to mileposts, including one mile south of the project area and two miles north, to the town of Kremmling (Fig. 15). Pre-construction, the highest WVC carcass rates occurred inside the project area. Pre-completion, high WVC rates continued to occur in Phase 2, where mitigation construction had not yet commenced, and WVC decreased in Phase 1, where mitigation construction was completed. Few WVC carcasses were reported north of the project area pre-construction or pre-completion.

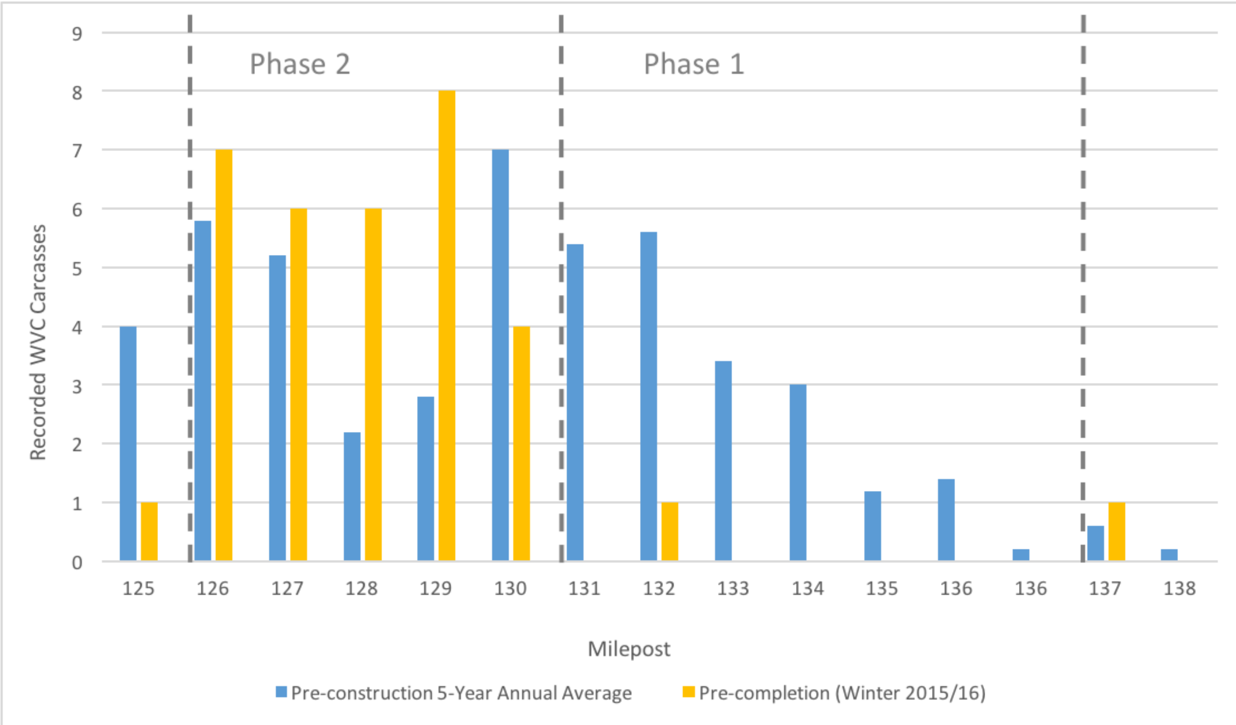

Figure 15. Comparison of the pre-construction annual average (blue bars) and pre-completion total (yellow bars) reported WVC carcasses reported by CDOT maintenance by milepost.

CDOT Maintenance Carcass Data, SH 40

In addition to WVC rates on SH 9, the researchers also analyzed the CDOT WVC carcass dataset from MP 184 to MP 199 on US 40, an east-west highway that runs through the town of Kremmling. Comparisons were made between the five-year pre-construction average number of mule deer and elk carcasses, and those reported during the winter of 2015/16, following mitigation construction in Phase 1. This comparison was made to determine whether the mitigation on SH 9 may have shifted wildlife movements, particularly elk, from SH 9 to US 40, with a resulting increase in WVC on US 40 (Fig. 16).

All reported elk carcass pickups in this segment were reported between MP 188-190, east of the town of Kremmling, with the most pre-construction elk carcass pickups in 2010/11 (n=5). Reported deer WVC carcasses were highest at MP 189. The most deer pickups were reported in Winter 2015/16, following the construction of Phase 1 on SH 9. One elk carcass was reported at MP 189.9 following the construction of Phase 1 on SH 9, in Winter 2015/16. Overall, WVC carcass pickups in winter 2015/16 (n=25) were higher than the five-year pre-construction annual average of 16 WVC/year for this segment, but within the five-year range.

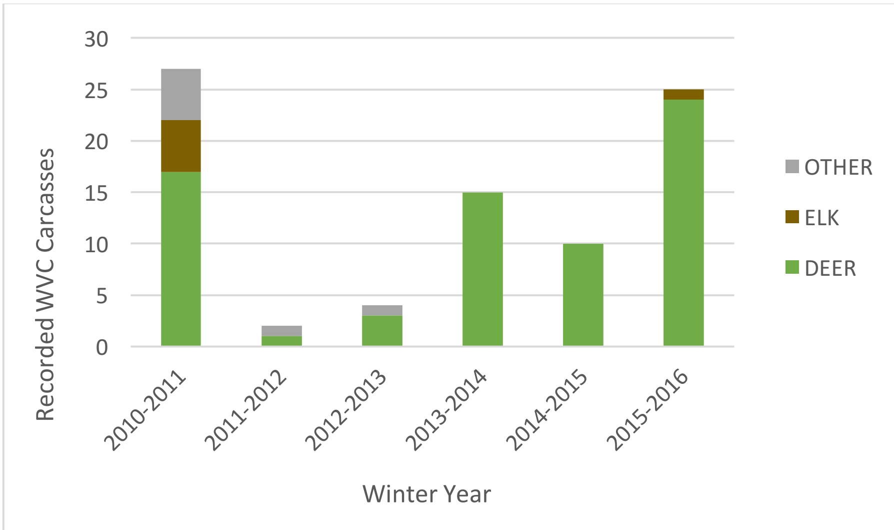

Figure 16. Deer and elk WVC carcass pickups by CDOT maintenance units on US 40 from MP 184, west of Kremmling, to MP 194 east of Kremmling.

Discussion

Mule Deer and Other Species Use of Wildlife Crossing Structures, Deer Guards, and Escape Ramps

The number of times mule deer used crossing structures (7,013), the success rates for mule deer at those four structures (ranging from 82% to 98%), and the overall results with other species of wildlife indicated highly successful results for the initial months at the four wildlife crossing structures. These success rates and use rates for the first winter following construction in Phase 1 were higher than the researchers anticipated. These high movement numbers reflect regular movements being made by many of the same individuals throughout the winter season. The most extraordinary results were the number of times mule deer used the overpass to cross SH 9 (4,875) compared to the number of times they used all of the other three structures combined (2,138). The high numbers of deer movements at the overpass may have partially been a result of the location of the overpass in relation to where the mule deer wintered.

Other species of wildlife were detected, but in much lower numbers than mule deer. While few elk were photographed at habitat cameras (n=17) or at the crossing structures (n=7), none of the seven elk at crossing structures were repelled and all crossed through successfully. Five of these passages were made by cow elk at the underpass structures, which was uncommon in other studies in Utah and Montana (Cramer 2016, Cramer and Hamlin 2016). No elk were documented using the overpass, although elk were photographed at the overpass habitat cameras. The low numbers of elk documented may result from several factors: 1) the number of elk in the northern portion of the study area (Phase 1) is lower than in the southern portion (Phase 2); 3) mild winter conditions may have resulted in fewer elk in the study area this year; and 3) elk may take longer to adapt to new mitigation features than mule deer. The research study will continue to explore these factors over time. Moose were only detected on one occasion at the North Overpass, where a successful crossing was made by a bull moose.

The percentages of male mule deer at the different structures suggests a potential preference for underpass structures. While buck mule deer movements comprised 12% to 18 % of total mule deer movements at the three underpass structures, they were only 8% of total movements on the overpass. Notably, the majority of movements at all structures are by deer of unknown gender, and male deer movements may be underestimated, particularly after antlers have been shed. As the results presented here assess only the first winter of activity during pre-completion monitoring, any species or gender preferences for different crossing structure types will be evaluated in future reports.

The more uncommon species of ungulates such as bighorn sheep, white-tailed deer, and pronghorn were not photographed during the initial months of the research study. Coyote (n=11), bobcat (n=16), and fox (n=15) were all detected at the structures and readily used them, although not all animals detected moved through the structures.

Overall, the deer guards that were monitored were 59% effective in repelling deer and elk from entering into the fenced right-of-way. The Thompson and Harsha Gulch Deer Guards both had 100% repel rates. Notably, the Harsha Deer Guard is adjacent to the Harsha Gulch Underpass, which may contribute to the high repel rate at this location (see Allen et al. 2013). Similarly, the Thompson Deer Guard is located next to the Colorado River Bridge, although the County Road 33 deer guard is located on the other side of the highway and had a much lower repel rate (33%). Repel rates at the other monitored guards ranged from 20% at Rusty Spur to 50% at Trough Road. The Culbreath and Trough Road deer guards are located the furthest from a crossing structure, and both had had high breach rates (46% and 50%, respectively). These observed high breach rates led to an adaptive management change in the deer guard design at several locations during Phase 2 construction (summer 2016). It is expected that over time the number of deer attempting to and actually breaching the guards will decrease, and the parallel rate will increase as more mule deer learn to use the crossing structures.

The number of times mule deer used the monitored escape ramps to jump down to the habitat side of the wildlife exclusion fence, (n=6), was a small fraction of the total number of times they were photographed at the ramps in the right-of-way (n=51). Although this is a small percentage of the total times mule deer were photographed at the ramps, it is also typical of other study results (Cramer, unpublished data; Arizona Game and Fish Department, unpublished data). As time goes on, the mule deer may adapt to the ramps and use them more often, but the best result is a lowered number of deer in the right of way that would be approaching those ramps.

Traffic Safety

The Phase 1 segment saw a notable decrease in WVC carcasses during the winter of 2015/16 in relation to previous years and in comparison to the Phase 2 segment. The number of carcasses collected in Phase 1 pre-completion (BVR-CPW data, n=3) represented a 90 percent reduction from the previous five-year winter average. Alternatively, in the Phase 2 segment where mitigation was not yet constructed, the carcasses reported (BVR-CPW data, n=38) represented a 17 percent increase above the five-year average. These pre-completion results support the assertion that the wildlife overpass and three wildlife underpasses, along with the wildlife fencing, escape ramps and deer guards in Phase 1 were effective in reducing the WVC along SH 9, while also providing wildlife connectivity.

Phased Construction and Adaptive Management Recommendations

The commencement of monitoring activities between Phases 1 and 2 of construction (Summer 2015 and Summer 2016, respectively) created a unique opportunity for the research team and CPW to recommend adaptations to the mitigation designs based on the preliminary results and observations from the first winter of monitoring (2015/16). Pre-completion monitoring documented initial wildlife responses to the Phase 1 mitigation features. The camera data provided a basis for the researchers to work with CDOT project engineers to integrate modifications into the Phase 2 project designs with regards to the deer guards and escape ramps in an effort to improve the performance of these mitigation features. Specifically, the recommended alterations included:

- **Deer guards.** Deer breaches observed in Phase 1 were hypothesized to be the result of 1) deer being able to easily walk on the flat bards, and 2) snow getting trapped between the flat bars and creating a packed surface for deer to walk across. As a result of these observations, CDOT developed a round-bar guard design that was installed at three locations in Phase 2 and was used to replace the flat-bar guards at two locations in Phase 1. This will enable the research team to study the relative effectiveness of the two designs in preventing incursions into the fenced right-of-way by deer and other wildlife

- **Escape ramps**. Based on observations in Phase 1, the research team made several suggestions regarding escape ramp design and placement: 1) the 2:1 slope of the escape ramps may inhibit wildlife from ascending the ramps, 2) ramps placed at low points relative to the roadway, where deer trapped in the fenced right-of-way tend to congregate may be more effective than ramps at high points relative to the roadway, and 3) that the perpendicular rail fence on the ramps may not be functioning as intended and, instead, may obscure wildlife visibility at the top of the ramps. As a result of these recommendations, all escape ramps in Phase 2 were constructed with a 3:1 slope instead of a 2:1 slope, and two new 3:1 slope ramps were constructed in Phase 1 to provide a comparison to the existing 2:1 slope ramps. In addition, six of the new ramps were constructed without guide rail fence. These modifications will allow the research team to evaluate these design modifications during post-construction monitoring, though it is recognized that small sample sizes and confounding variables may make it difficult to draw clear conclusions.
- **Small culverts.** Several small 8'x8' (2.4-m) box culverts in Phase 1 were not tied into the wildlife fencing and instead are 'fenced out'. These culverts were not identified as wildlife culverts and were not deemed valuable for wildlife passage in the original design plans. However, small culverts may provide passage for a number of small- and medium-sized wildlife in the project area. The researchers recommend that small culverts in Phase 2 be tied into the wildlife fencing and that the fencing around select culverts in Phase 1 be reconstructed to tie into the culverts.
- **Fence gap on North Overpass.** To prevent mule deer from crossing the overpass outside of the wildlife fence, as documented by camera monitoring, the researchers recommended that the gap between the fence and the structure edge be closed with wildlife fencing. These fence gaps was closed during Phase 2 construction.
- **Fence gaps.** Multiple fence gaps where the fencing did not come all the way down to the ground were observed in Phase 1. The researchers recommended that fence gaps be minimized to less than 8" (15-cm) throughout the project to prevent wildlife incursions into the right-of-way.

Next Steps

Several objectives for the mitigation project regarding mule deer use of the crossing structures have already been achieved during the first months of pre-completion monitoring. This report documents only the first four months of what will be a five-year research study, and as such these preliminary results are encouraging.

Phase 2 construction was completed in 2016, and camera traps were placed on the remaining structures by December 2016. Post-construction monitoring will continue using 62 camera traps at 44 monitoring locations through 2020, including all structures, the southern terminus of the wildlife fencing, and at select escape ramps, pedestrian walk-through gates, and double cattle guards. In Year 2 of the research study, the researchers will address pre-construction and pre-completion photo cataloguing and data analysis (Task 5); post-construction monitoring (Task 4); and prepare a draft literature review (Task 2).

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