STATE HIGHWAY 9 WILDLIFE CROSSINGS MONITORING – YEAR 3 PROGRESS REPORT

December 2015 through April 2018

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Applied Research and Innovation Branch

Prepared by:

Julia Kintsch, Principal Investigator – ECO-resolutions

Patricia Cramer, Principal Investigator – Independent Researcher

Paige Singer, Research Assistant – Rocky Mountain Wild

Michelle Cowardin, Wildlife Biologist – Colorado Parks and Wildlife

Joy Phelan, Research Assistant – Independent Researcher

ECO-resolutions

Cover photos (clockwise from upper left): Mule deer doe and fawn crossing through the BVA Underpass; Silhouette of a mule deer buck atop an escape ramp near the south fence end; Bighorn sheep approaching the CR 1000 wildlife guard; Moose calf following its mother through the North Underpass; Pronghorn at a habitat camera adjacent to a crossing structure; Elk at the south fence end.

Research Study Panel

Bryan Roeder – Study Manager and Study Panel Leader, CDOT Research
Eric Bergman – CPW Wildlife Research
Michelle Cowardin – CPW Wildlife Biology
Cinnamon Levi-Flinn – CDOT Region 3 Environmental
Alison Michael – CDOT/US Fish & Wildlife Service
Jeff Peterson – CDOT Environmental Programs Branch
Francesca Tordonato – CDOT Region 1 Environmental
Catherine Ventling – CDOT Region 3 Environmental

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Executive Summary

The State Highway 9 (SH 9) Colorado River South Wildlife and Safety Improvement Project in Grand County was designed by the Colorado Department of Transportation (CDOT) and partners to improve motorist safety by reducing wildlife-vehicle collisions (WVC) while providing opportunities for wildlife to move beneath and over SH 9 through wildlife crossing structures. Prior to the project, WVC were the most common accident type on this segment of highway, accounting for 60% of all accidents reported to law enforcement. In response to these concerns and with partner support, CDOT installed two wildlife overpass structures, five wildlife underpasses, 10.4 miles of eight-foot-high wildlife exclusion fencing, 61 wildlife escape ramps, and 29 wildlife guards to help reduce WVC while providing safe passages for wildlife. This research study evaluates the effectiveness of the mitigation infrastructure through the use of motion activated cameras and analyses of WVC carcass and accident data. The study maintained a total of 62 motion-triggered cameras at 40 locations in Year 3 to record animal movements and responses to the mitigation. Cameras were placed at crossing structure entrances and in the nearby habitat, at wildlife guards, escape ramps, and the south fence end. This progress report focuses on post-construction monitoring from December 2015 through April 2018.

Mule deer activity and success movements through or over the wildlife crossing structures increased each winter (Fig. E-1) resulting in a total of 45,759 mule deer success movements over the course of the study. From Winter 2016-17 to Winter 2017-18, the overall success rate for mule deer passage increased slightly from 96% to 97%. The total number of mule deer success movements increased by 17%, suggesting that the mitigation is succeeding in improving connectivity for mule deer across SH 9. In each year of the study, mule deer activity was highest during the winter months, corresponding with deer presence on winter range; however, some deer remained in the study area throughout the year. Among each of the crossing structure locations, mule deer activity varied substantially and patterns in crossing structure use also varied relative to the previous winter. Overall, mule deer use of wildlife crossing structures ranged from an average of 5 to 36.9 mule deer success movements per day in Winter 2017-18.

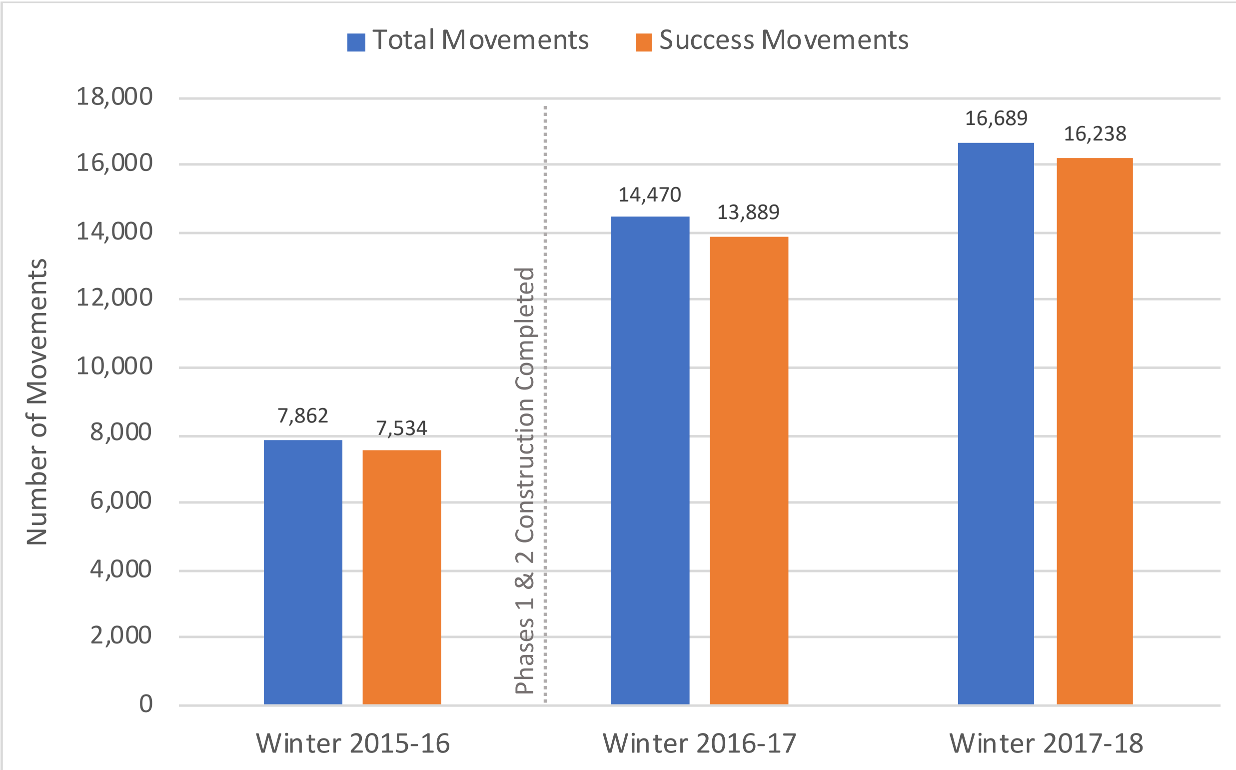

Figure E-1. Total number of mule deer movements and successful movements at crossing structures during each winter of the monitoring research study. In Winter 2015-16, only the north portion (Phase 1) of the project area was constructed and monitored.

Elk, white-tailed deer, moose, pronghorn, and bighorn sheep were also documented successfully using the wildlife crossing structures, although in much lower numbers than mule deer. Success movements by these species remained roughly consistent or increased from Year 2 to Year 3, with success rates ranging from 87% for moose (n=38); 91% for elk (n=76); 92% for white-tailed deer (n=39); 98% for pronghorn (n=52); and 100% for bighorn sheep (n=13). In general, elk were recorded using underpass and overpass structures in the northern portions of the study area (from MP 131.6 – MP 136), with the highest level of elk success movements at the North Overpass (MP 134.3). The majority of elk success movements were by lone individuals or, in some cases, small groups of up to four animals. In addition to ungulates, success movements were made by other large and medium-sized mammals at all of the wildlife crossing structures, including black bear, mountain lion, coyote, red fox, bobcat, badger, hare, skunk and raccoon.

The researchers evaluated two different wildlife guard designs (round bar and flat bar), and found that round bar wildlife guards were, on average, more successful in deterring mule deer from entering the fenced roadway (90% repel rate) than flat bar wildlife guards (78% repel rate). However, much of this difference may be attributed to plowed snow packed in-between the flat bars creating a surface for animals to walk across. In Winter 2017-18, no breaches occurred in this manner, possibly due to the low snow year or changes in plowing practices. From Year 2 to Year 3, the total number times mule deer attempted to breach the wildlife guards decreased by 30% and the number of successful breaches decreased 68% to a total of 23 breaches at all guard types. In Year 3, breach rates were nearly the same at both guard types (9% for round bar guards and 8% for flat bar guards), although the total number of breaches by ungulate species was higher at round bar guards (n=20) than at flat bar guards (n=9). Regardless of guard type, jumping the guard was the most common method of breaching a guard.

Researchers placed monitoring cameras on select escape ramps to evaluate the effects of ramp slope and the presence of perpendicular rail fencing placed to guide animals up a ramp on deer and elk use of escape ramps to exit the fenced right-of-way. Mule deer and elk escape rates off the escape ramps were comparatively low (13% for mule deer, 9% for elk) and results were mixed with respect to the two different slope designs and the presence of perpendicular rail fence. Escape ramps without perpendicular fences had higher intercept rates (61%) than ramps with perpendicular fencing (36%) but perpendicular fence did not have a discernable influence on the likelihood of deer or elk using the ramps to escape the right-of-way. At this point, there are great variations in usage rates at all ramp types and continued monitoring and analyses will help determine the most favorable designs.

Three wildlife-vehicle collision (WVC) datasets described a decreasing trend in WVC carcasses and accidents following the completion of mitigation construction in the SH 9 project area: Blue Valley Ranch/Colorado Parks and Wildlife (CPW) carcass reports; CDOT Maintenance carcass reports; and CDOT Traffic and Safety accident data. In Winter 2017-18, six mule deer and no elk carcasses were recorded in the Blue Valley Ranch/CPW carcass dataset, resulting in a decrease of 89% relative to the pre-construction 5-year average of 56.4 carcasses (Fig. E-2). This decrease was slightly greater than the 86% decrease reported the previous winter. No WVC carcasses were reported in the CDOT Maintenance carcass database in Winter 2017-18. Data from Winter 2017-18 were not available from CDOT Traffic and Safety at the time of this writing but, as of

Winter 2016-17, the number of reported WVC accidents dropped 100% from a pre-construction winter average of 10.2, and just one WVC accident was reported for the entire study period. These results support the assertion that wildlife crossing structures and other mitigation features have been effective in reducing WVC along SH 9, while also providing wildlife connectivity across the highway.

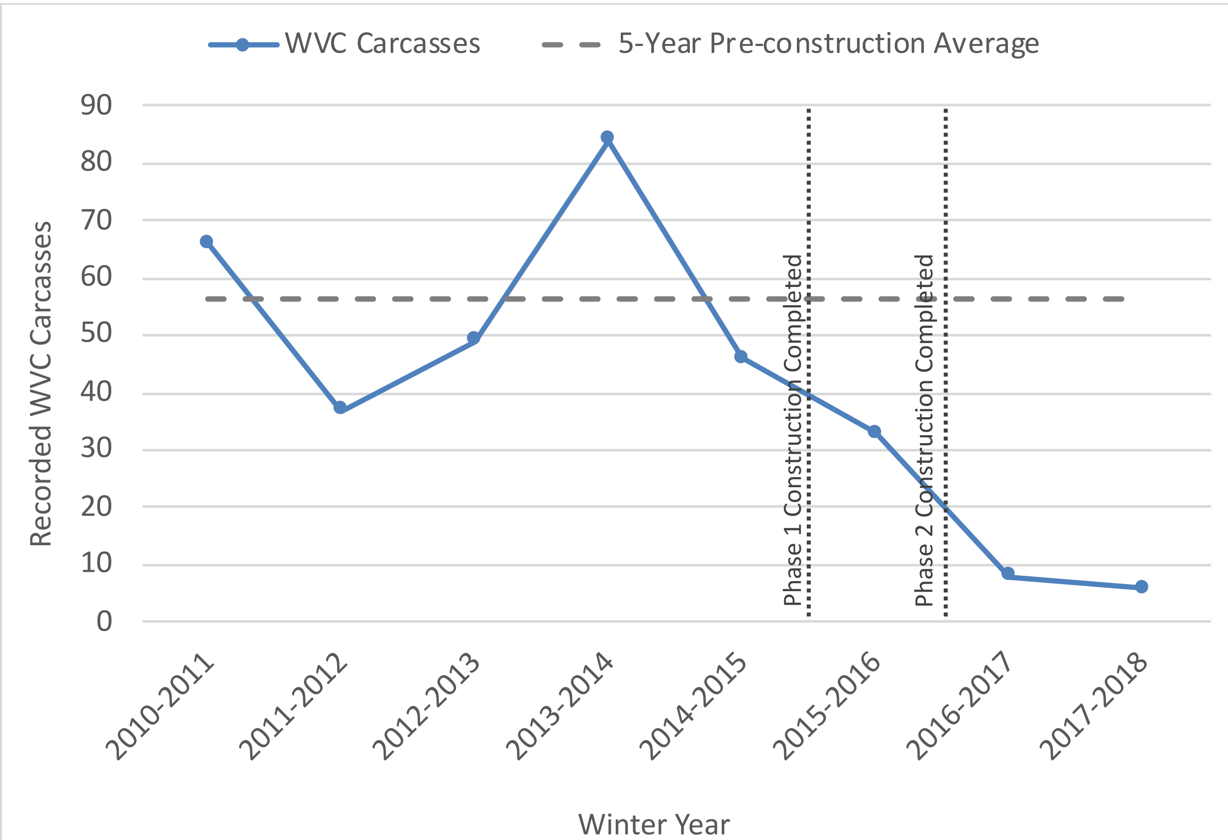

Figure E-2. Mule deer and elk carcass counts recorded by BVR and CPW compared to the five-year pre-construction average of 56.4 carcasses per year.

The results from the first three years of monitoring on SH 9 are promising and several performance measures for the mitigation project regarding mule deer use of crossing structures have already been achieved. Other objectives, for example, regarding elk use of crossing structures or ungulate use of escape ramps, have not yet been achieved, but will continue to be monitored and evaluated. The study will continue to evaluate and report on all of these features through Winter 2019-20, and the researchers will continue to work with CDOT and CPW to adaptively manage the structures, fencing, wildlife guards and escape ramps and to use these results to inform future wildlife-highway mitigation projects.

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Introduction

The State Highway 9 (SH 9) Colorado River South Wildlife & Safety Improvement Project installed seven large wildlife crossing structures and 10.4 miles of wildlife exclusion fence between Kremmling and Green Mountain Reservoir in Grand County, Colorado. The project was designed to improve driver safety while providing permeability for wildlife. The highway runs north-south through the lower Blue valley, a broad sagebrush ecosystem 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 River valley supports a high concentration of mule deer (*Odocoileus hemionus*) and American elk (*Cervus canadensis*) during the winter months as wildlife settle onto their winter range. Resident mule deer and elk herds also inhabit the valley throughout the year. Other species include moose (*Alces alces*), pronghorn (*Antilocapra americana*), bighorn sheep (*Ovis canadensis*) American black bear (*Ursus americanus*), bobcat (*Lynx rufus*), red fox (*Vulpes vulpes*), coyote (*Canis latrans*), and mountain lion (*Puma concolor*). Some animals make daily movements across SH 9, where the highway bisects an individual's range, while other animals may make more infrequent movements. These concentrations of wildlife have resulted in numerous wildlife-vehicle collisions (WVC), particularly during the winter months.

During the five winters (December through April) prior to the onset of project construction in 2015, reported WVC crashes were the most common accident type on this segment of highway, accounting for 60% of all accidents reported to law enforcement personnel. During this timeframe, 50 WVC accidents with mule deer or elk were reported, 4% of which resulted in injuries to humans. However, accident reports underestimated the full extent of the conflict between traffic and wildlife on SH 9. More comprehensive winter carcass counts conducted by Blue Valley Ranch during this same timespan recorded 282 WVC mule deer and elk carcasses, more than triple the number of reported accidents.

The goal of this mitigation project was to reduce vehicle conflicts with wildlife while providing permeability for animals to move safely through passages below or over the highway. To meet these objectives, two wildlife overpasses and five arch underpasses and 10.4 miles of 8-foot high wildlife fencing on both sides of the highway were constructed in two construction phases. Other mitigation features include wildlife 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 culverts (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. 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, wildlife guards, pedestrian walk-through gates and the southern terminus of the wildlife exclusion fence to evaluate the wildlife mitigation with several performance measures. 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 wildlife exclusion fencing on both sides of the highway, 34 escape ramps, 12 wildlife 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 an additional 27 escape ramps, 17 wildlife guards and 5 pedestrian walk-through gates.

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 post-construction WVC rates may be compared.

This progress report focuses on post-construction monitoring from its onset at the completion of the Phase 1 segment (December 2015) through April 2018.

Research Objectives

The following research 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 wildlife overpasses and underpasses in allowing wildlife, primarily ungulates, to move underneath or above the highway.
3. Determine the ability of animals that breach the fenced right-of-way to use escape ramps to exit the fenced road area.
4. Determine if the fence end, pedestrian walk-through gate and wildlife guard designs are effective at deterring wildlife (ungulates primarily) from entering the fenced road area.
5. If utilization rates differ among the crossing structures, determine why.
6. Determine if any of the wildlife mitigation features appear to need modification to improve effectiveness.
7. Determine correlation of historic ungulate crossing patterns pre-completion to utilization of post-construction crossing patterns.
8. Compare pre-completion crossing rates to post-construction over/underpass crossing rates.

Methods

Mitigation effectiveness was measured with two general types of measures: the number of movements made by mule deer, elk and other wildlife through the crossing structures and success vs. repel rates for each species; and the reduction in WVC. Complete camera monitoring, photo analysis and WVC data analysis methods and performance measures are presented in Appendix A.

Pre-construction monitoring was conducted using motion triggered cameras at all crossing structure locations from November 2014 to the onset of mitigation construction in March 2015 by CPW. At each planned structure location, a camera was set up in the natural areas on either side of the highway to document wildlife presence. Additional pre-construction monitoring was conducted by the research team in the Phase 2 segment through Winter 2015-16. The results of pre-construction camera monitoring were presented in the Year 2 Progress Report and are available in Appendix B. Post-construction monitoring commenced in December 2015 in the Phase 1 segment and in December 2016 in the Phase 2 segment and will continue through Winter 2019-20. Post-construction monitoring involved the deployment of 62 cameras at 49 locations, including 40 locations that were monitored in Year 3.

Definitions of the indices calculated for each monitoring location are defined as follows:

- **Total movements** – the sum of all success movements, repel movements, and parallel movements by a species at a given location.
- **Success 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 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 small culverts, wildlife guards and fence ends.
- **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 small culverts and escape ramps.

- **Intercept rate** –This metric is calculated for deer and elk at escape ramps. It is the total number of times deer/elk were recorded ascending an escape ramp divided by the number of times deer/elk approached an escape ramp.
- **Escape 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 ascending the escape ramp.
- **Breach rate** – This metric is calculated for deer and elk at wildlife guards, escape ramps, pedestrian walk-through gates, and fence ends. It is the total number of times individual deer/elk breached the mitigation feature divided by the total number of times deer/elk approached that mitigation feature. For example, at a wildlife 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 (not individuals) 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 of 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 wildlife guards.
- **Average mule deer success movements per day** – The total number of times deer successfully used a structure divided by sampling effort.

Monitoring locations are listed in Table 1; Figures 1 & 2 depict the locations of all monitoring sites across the study area. At various points during this research, monitoring cameras were moved to new locations to capture different mitigation features using a limited number of cameras.

Table 1. Monitoring Locations. Monitoring periods are defined as: Year 1 (December 2015 – April 2016); Year 2 (May 2016 – April 2017); Year 3 (May 2017 – April 2018). Highlighted gray rows were not monitored in Year 3.

MP	LOCATION NAME	MITIGATION TYPE	SPECIFICATIONS	MONITORING PERIODS	NOTES
PHASE 1 SEGMENT – CONSTRUCTED SUMMER/FALL 2015					
137.0	Colorado River Bridge	Bridge Underpass	Existing bridge	Year 3	-
136.9	County Road 33 Wildlife Guard	Wildlife Guard	Flat bar	Years 1-3	-
136.9	Thompson Wildlife Guard	Wildlife Guard	Round bar	Years 1-3	Replaced with round bar July 2016
136.8	Thompson Escape Ramp	Escape Ramp	2:1 slope with rail fence	Year 1	-
136.6	Trough Road Wildlife Guard	Wildlife Guard	Flat bar	Years 1-3	-
136.6	Trough Road 3:1 Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2 & 3	Constructed Summer 2016
136.6	Trough Road 2:1 Escape Ramp	Escape Ramp	2:1 slope with rail fence	Years 2 & 3	-
136.0	North Underpass	Arch Underpass	44'W x 14'H x 66'L	Years 1-3	-
136.0	North Underpass Habitat	Adjacent Habitat	Habitat camera	Years 1-3	-
135.9	SWA Escape Ramp	Escape Ramp	2:1 slope with rail fence	Year 1	-
135.6	SWA Pedestrian Gate	Pedestrian Gate	n/a	Years 1 & 2	Gated Fall 2017
135.1	Culbreath 2:1 Escape Ramp	Escape Ramp	2:1 slope with rail fence	Years 2 & 3	-
135.1	Culbreath 3:1 Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2 & 3	Constructed Summer 2016
135.1	Culbreath Concrete Box Culvert	Small Culvert	8’W x 8’H x 100’L	Years 2 & 3	-
135.1	Culbreath Wildlife Guard	Wildlife Guard	Round bar	Years 2 & 3	Replaced with round bar July 2016
134.5	Rusty Spur Wildlife Guard	Wildlife Guard	Flat bar	Year 1	Location gated Summer 2016
134.3	Overpass Escape Ramp	Escape Ramp	2:1 slope without fence	Years 1-3	-
134.3	North Overpass	Overpass	100'W x 66'L	Years 1-3	70’ wide fence opening
134.3	North Overpass Habitat East	Adjacent Habitat	Habitat camera	Years 1-3	-
134.3	North Overpass Habitat West	Adjacent Habitat	Habitat camera	Years 1-3	-
134.2	BVR Concrete Pipe Culvert	Small Culvert	8’ diameter x 193’L	Year 1	Plus 23’L concrete trough
133.8	BVR Concrete Box Culvert	Small Culvert	8’W x 6’H X 130’L	Years 2 & 3	Plus 30’L concrete trough
132.5	Middle Underpass	Arch Structure	44'W x 14'H x 66'L	Years 1-3	-

MP	LOCATION NAME	MITIGATION TYPE	SPECIFICATIONS	MONITORING PERIODS	NOTES
132.5	Middle Underpass Habitat	Adjacent Habitat	Habitat camera	Years 1-3	-
132.4	BLM Pedestrian Gate	Pedestrian Gate	n/a	Years 1 & 2	Gated Fall 2017
131.6	Harsha Gulch Wildlife Guard	Wildlife Guard	Flat bar	Year 1	-
131.6	Harsha Gulch Underpass	Arch Underpass	44'W x 14'H x 66'L	Years 1-3	-
131.6	Harsha Gulch Habitat	Adjacent Habitat	Habitat camera	Years 1-3	-
131.6	Harsha Jumpdown Escape Ramp	Escape Ramp	Jumpdown w/o fence	Year 3	Ramp graded into natural downslope
131.2	Harsha Escape Ramp	Escape Ramp	2:1 slope with fence	Year 1	-
131.0	Phase 1 Temporary Fence End	Fence End	20' clear zone	Year 1	Temporary location
PHASE 2 SEGMENT – CONSTRUCTED SUMMER/FALL 2016					
130.8	BVA Underpass	Arch Underpass	44'W x 14'H x 66'L	Years 2-3	-
130.8	BVA Habitat	Adjacent Habitat	Habitat camera	Years 2-3	-
130.8	CR 1002 Wildlife Guard	Wildlife Guard	Round bar	Year 3	-
129.7	CR 1000 Wildlife Guard	Wildlife Guard	Flat bar	Year 3	-
129.5	South Overpass	Overpass	100'W x 66'L	Years 2-3	68.5’ wide fence opening
129.5	South Overpass Habitat	Adjacent Habitat	Habitat camera	Years 2-3	-
129.1	Badger Road Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2 & 3	-
129.0	Badger Road Wildlife Guard	Wildlife Guard	Round bar	Year 3	Half guard length fenced
128.5	Triangle Road Wildlife Guard	Wildlife Guard	Round bar	Years 2-3	-
128.5	Spring Creek Wildlife Guard	Wildlife Guard	Flat bar	Years 2-3	-
128.5	Spring Creek Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-3	-
128.4	South Spring Creek Escape Ramp	Escape Ramp	3:1 slope with rail fence	Years 2-3	-
128.0	Summit County Pedestrian Gate	Pedestrian Gate	n/a	Year 2	Gated Fall 2017
127.7	Williams Peak Underpass	Arch Underpass	44'W x 14'H x 66'L	Years 2-3	-
127.7	Williams Peak Habitat	Adjacent Habitat	Habitat camera	Years 2-3	-
126.7	East Fence End Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-3	-
126.6	West Fence End Escape Ramp	Escape Ramp	3:1 slope with rail fence	Years 2-3	-
126.6	South Fence End	Fence End	30’ clear zone	Years 2-3	-

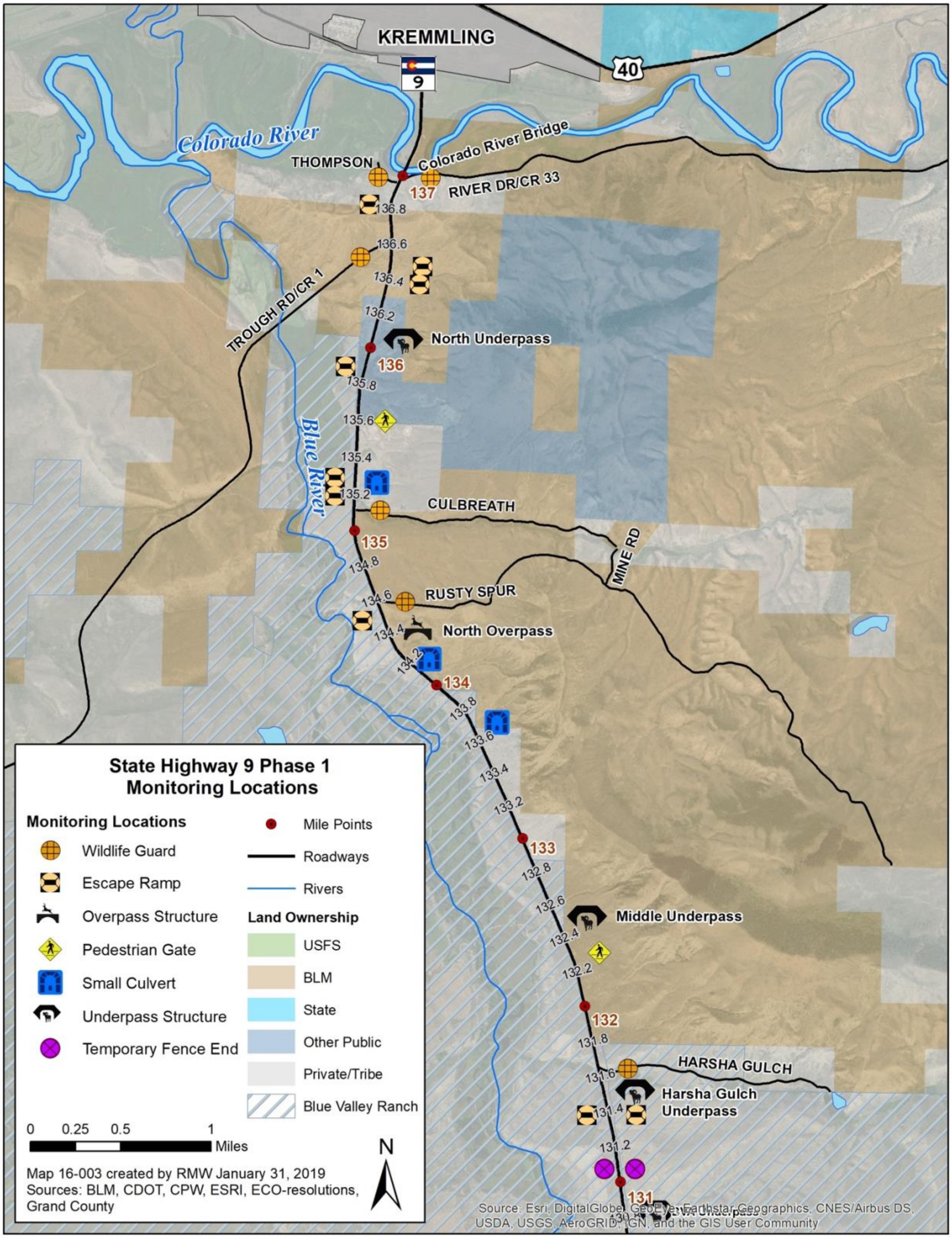

Figure 1. Phase 1 (north segment, MP 131 – 137) monitoring locations through April 2018.

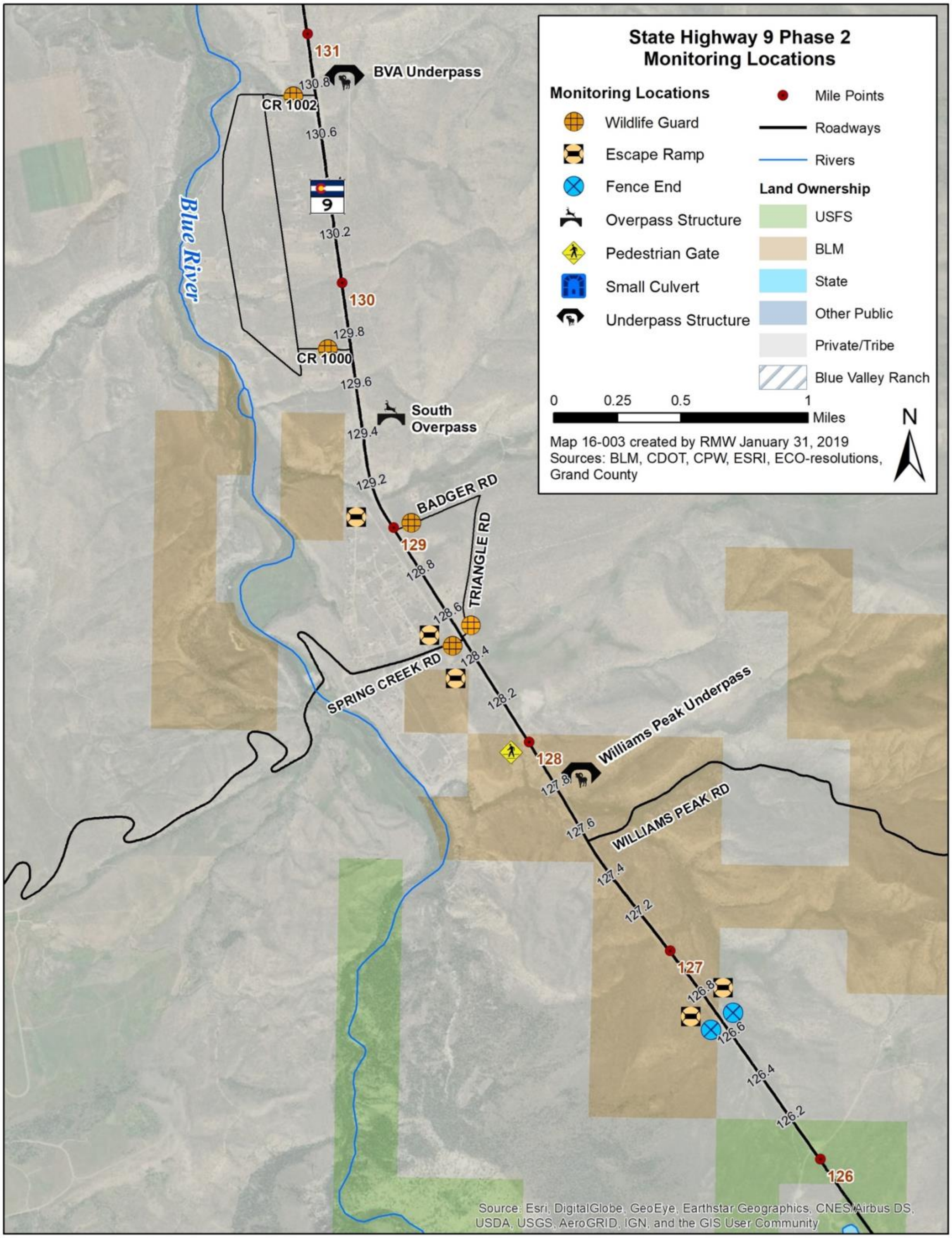

Figure 2. Phase 2 (south segment, MP 126 – 131) monitoring locations through April 2018.

Results

Post-Construction Monitoring

In Year 3, cameras were in operation for 226 days during the non-winter months of 2017 (April 19 – November 30) and 140 days during Winter 2017-18 (December 1 – April 19). Cameras were in operation for varying lengths of time depending on location. Battery depletions and equipment malfunctions also decreased the number of monitoring days at certain locations.

Since the start of this study in December 2015, monitoring cameras have recorded a total of 45,759 success movements by mule deer through or over the designated crossing structures. For the Year 3 reporting period, large and medium-bodied wildlife were recorded at crossing structures 24,707 times, including 23,808 success movements for an overall success rate of 96% for all structures combined. Mule deer account for the bulk of this activity, having made 23,691 individual movements at crossing structures, resulting in 22,863 success movements. From Winter 2016-17 to Winter 2017-28, the overall success rate for mule deer passage increased slightly from 96% to 97%, and the total number of mule deer success movements increased by 17%.

Mule deer activity was highest during the winter months, corresponding with deer arrival on winter range; however, some deer remained in the study area throughout the year. These resident deer made 6,441 success movements during the non-winter months of 2017 with an overall success rate of 95%. For this reporting period, elk were detected only during the non-winter months. Species such as black bear, moose, white-tailed deer, red fox and pronghorn were most commonly observed during non-winter months. Others, such as bighorn sheep, bobcat, coyote and moose were observed throughout the year. Mountain lions were most common during the winter months.

Mule Deer Use of Wildlife Crossing Structures During Winter 2017-18

Mule deer activity and success movements through or over the crossing structures has increased each year of this research study since the completion of the Phase 1 construction in Winter 2015-16 (Fig. 3).

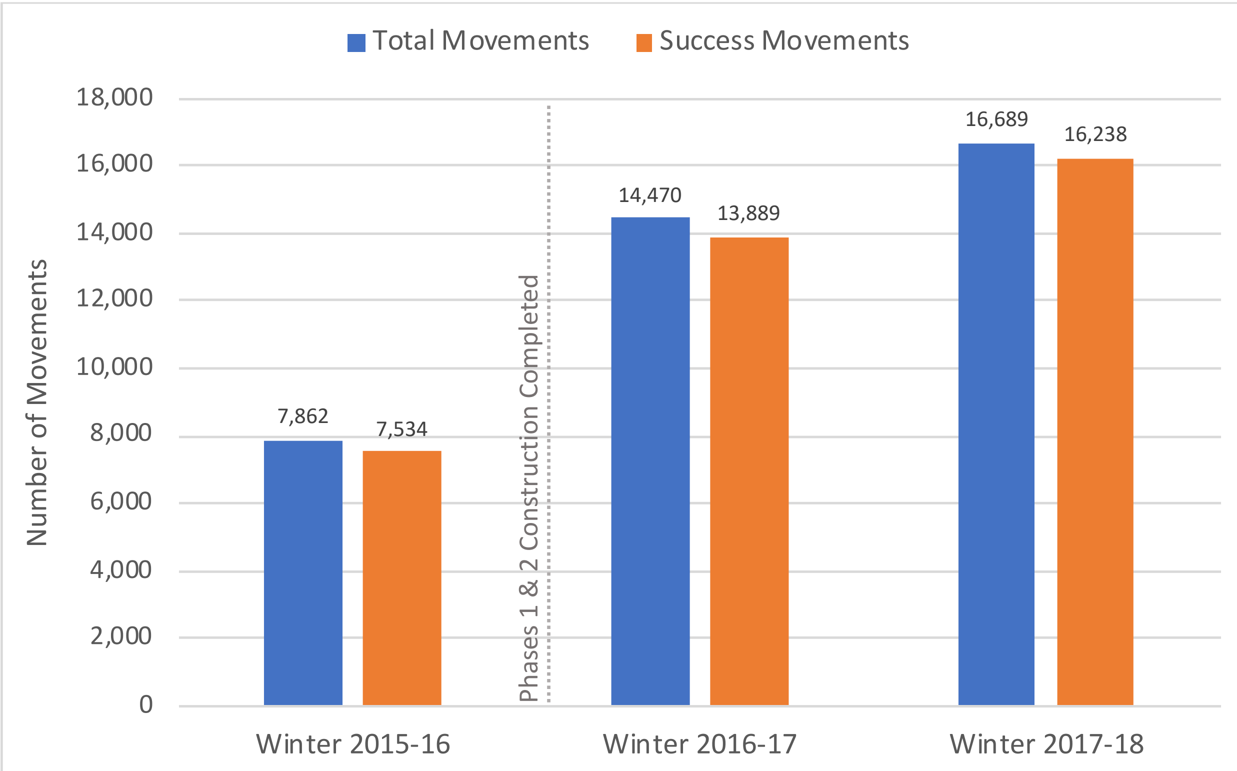

Figure 3. Total number of mule deer movements and successful movements at crossing structures during each winter of the monitoring research study. In Winter 2015-16, only the north portion (Phase 1) of the project area was constructed and monitored.

Table 2 summarizes mule deer activity at each of the crossing structures in Winter 2017-18 and compares changes in success movements to the previous winter. Across all structure locations success rates were 95% to 98%. The highest number of repels was observed at the BVA Underpass and the North Overpass, though the repel rate at each of these locations was only 1% and 2%, respectively. Repel rates decreased at the Williams Peak Underpass and the North Underpass from 10% in Winter 2016-17 to 4% and 3%, respectively, in Winter 2017-18.

As in the previous winter, mule deer activity varied substantially at each of the wildlife crossing structures during Winter 2017-18 (Fig. 4). While overall mule deer success movements at the crossing structures increased by 50%, several changes in the patterns of use at the crossing structures were observed. In Winter 2016-17, the North Overpass had the highest number of mule deer success movements of all the structures. In Winter 2017-18, the number of success movements at this location decreased by 36%; however, this location still had the third highest number of mule deer success movements in Winter 2017-18. The greatest number of success movements occurred at the BVA Underpass. The Williams Peak Underpass remained the structure with the lowest number of mule deer movements, although success movements increased by 214% from the year prior.

Table 2. Mule deer movements at wildlife crossing structures during Winter 2017-18.

Monitoring Location	Total Move-ments	Success Move-ments	Change in Success Move-ments from Winter 2016-17	Average Deer per Winter day	Average Success per Winter Day	Success Rate	Repel Rate	Parallel Rate
MP 127.7 Williams Peak Underpass	726	696	214%	5.2	5	96%	4%	<1%
MP 129.5 South Overpass	2,972	2,919	19%	21.2	20.9	98%	1%	1%
MP 130.8 BVA Underpass	5,246	5,145	30%	37.6	36.9	98%	1%	1%
MP 131.6 Harsha Gulch Underpass	1,645	1,614	112%	11.8	11.5	98%	1.5%	<0.5%
MP 132.5 Middle Underpass	2,102	2,026	37%	15	14.5	96%	2%	2%
MP 134.3 North Overpass	2,870	2,760	-36%	20.5	19.7	96%	2%	2%
MP 136.0 North Underpass	1,068	1,021	44%	7.6	7.3	96%	3%	1%
MP 137.0 Colorado River Bridge	60	57	n/a*	0.4	0.4	95%	5%	0%

**Camera failures at the Colorado River Bridge during Winter 2016-17 prevent this metric from being calculated.*

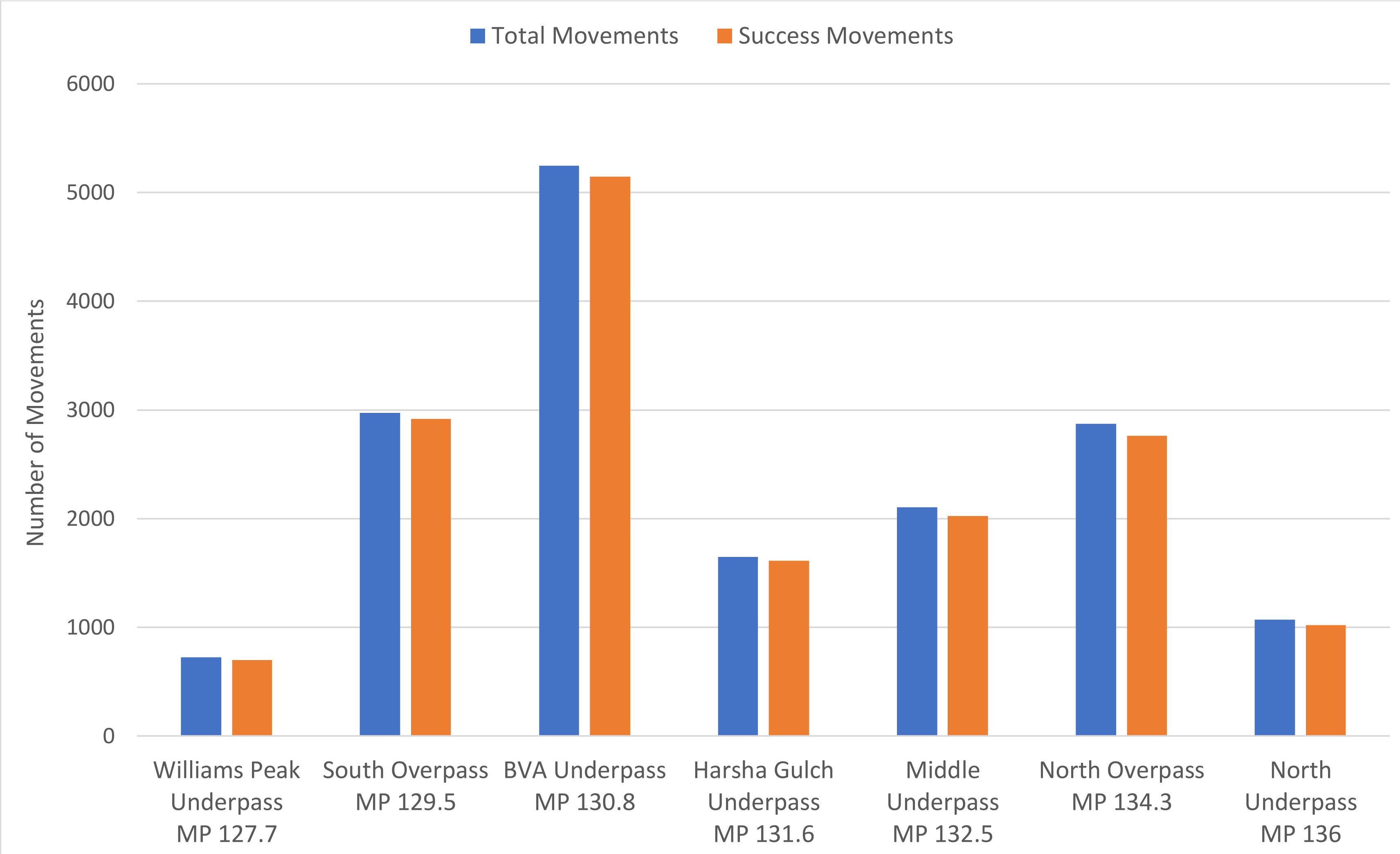

Figure 4. Total number of mule deer movements and success movements at each crossing structure location during Winter 2017-18.

Mule deer use of overpass structures versus underpass structures was compared between Winter 2017-18 and the previous winter (2016-17). Because there are two overpasses and five underpasses in the study area, the averages for the combined number of success movements at underpass structures versus the combined overpass structures was used to account for the unequal number of underpasses and overpasses. Overall in Winter 2017-18, 65% of all mule deer success movements occurred at the five underpasses and 35% at the two overpasses. However, when considered on a per unit basis, mule deer use of an overpass structure remained higher than underpass structures in Winter 2017-18, although not as high as in Winter 2016-17. Figure 5 depicts the average number of success movements across all crossing structure locations as a function of structure type (overpass versus underpass) during both post-construction winters. In Winter 2016-17, mule deer success movements were, on average, 138% higher at overpass structures than at underpass structures. In Winter 2017-18, mule deer success movements were, on average, 34% higher at overpass structures than at underpass structures.

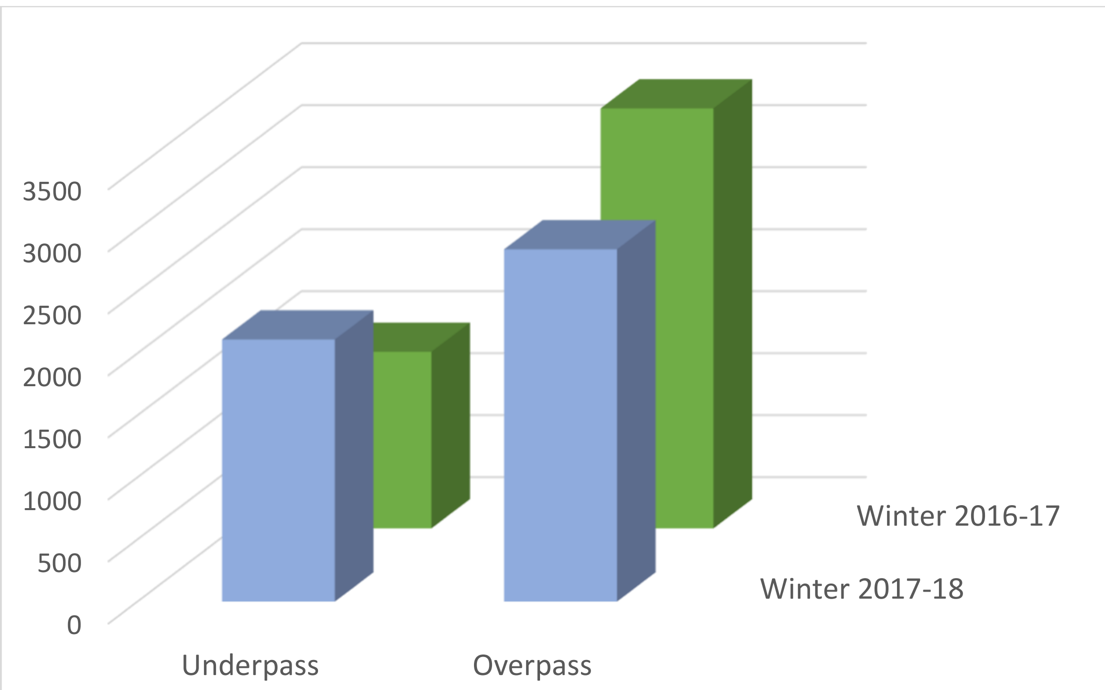

Figure 5. Average number of success movements by mule deer at overpass versus underpass structures during Winter 2016-17 and Winter 2017-18.

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. During the winter months, east-to-west movements (51%) were nearly equal to west-to-east movements (49%). 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. In general, the proportion of east-to-west movements increased during the fall migration and west-to-east movements increased during the spring migration. Movements during the summer months by resident animals occurred in both directions in roughly equal proportions.

Gender of mule deer was noted in photo analysis when possible. The numbers of males, females and fawns were recorded, although, in many cases, gender was undetermined, for example, in males who had shed their antlers or because of photo quality or animal position relative to the camera. Numbers and percentages for each gender of individual mule deer whose movements were detected are presented in Table 3. Across crossing structure locations, males represented 13% of the movements, females 41% and fawns 22%.

Table 3. Gender of mule deer whose movements were detected at wildlife crossing structures, Winter *2017-18.*

Monitoring Location	% Male	% Female	% Fawns	% Unknown
Williams Peak Underpass	13%	31%	27%	29%
South Overpass	7%	26%	21%	45%
BVA Underpass	17%	53%	21%	9%
Harsha Gulch Underpass	24%	49%	21%	6%
Middle Underpass	19%	43%	19%	20%
North Overpass	4%	23%	26%	47%
North Underpass	11%	63%	16%	10%

Mule Deer Use of Wildlife Crossing Structures over Time

Figure 6 displays mule deer success movements at each of the crossing structures from the onset of the study in December 2015 through April 2018. Winter 2015-16 represents the first winter following construction of the Phase 1 (northern) segment of the project area. Monitoring in the Phase 2 (southern) segment began in late November and early December of 2016. Periods of peak mule deer activity differed at each crossing structure location and varied from one year to the next. In general, mule deer numbers began decreasing in April as migratory herds moved to summer range and increased in October as these herds returned to winter range in the study area.

During Winter 2017-18, several locations had more than one peak in mule deer success movements. Mule deer activity peaked at several structures in January and, while there was a dip in activity in February at most structures, there was a peak in activity at the North Overpass during this timeframe. The highest number of mule deer success movements over all the years of the study were at the North and South Overpasses and the BVA Underpass, when compared to the other wildlife crossing structures.

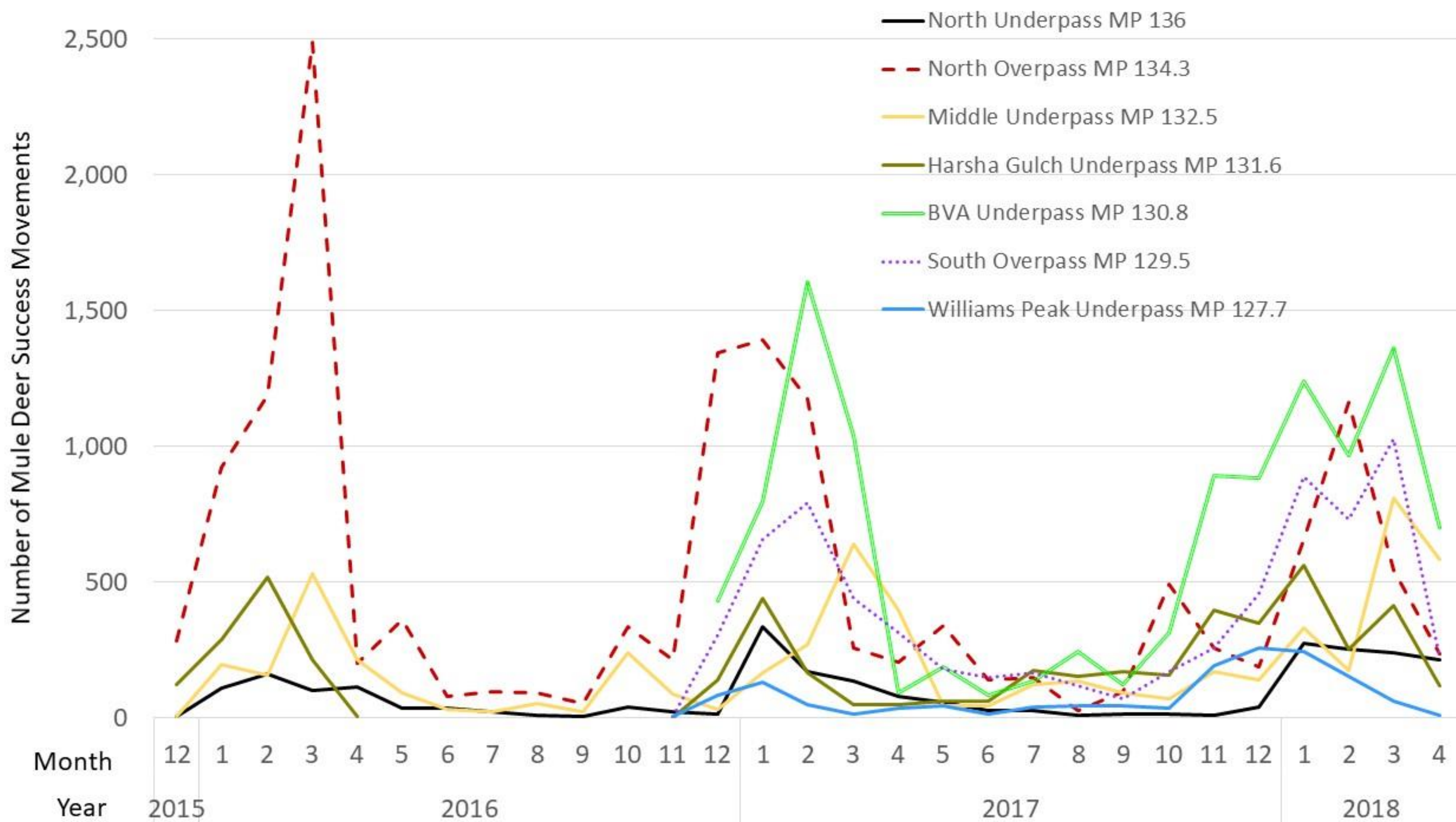

Figure 6. Mule deer success movements by month at each of the wildlife crossing structures from December 2015 through April 2018.

The following subsections describe the camera monitoring results at each crossing structure location. For each crossing structure, the total number of mule deer movements detected relative to mule deer success movements by month of the year is presented (note that the y-axis scale varies for each graph). For a given month, the closer the paired orange and blue bars are in height, the greater the success rate for that month. Mule deer activity was recorded at each structure every month of the year when cameras were active.

Williams Peak Underpass, Milepost 127.7

Figure 7 presents mule deer total movements and success movements by month at the Williams Peak Underpass. Winter movements increased at this structure from Year 2 to Year 3 of this research with the highest peak in Winter 2017-2018 occurring in December and January. Mule deer use continued through the summer months.

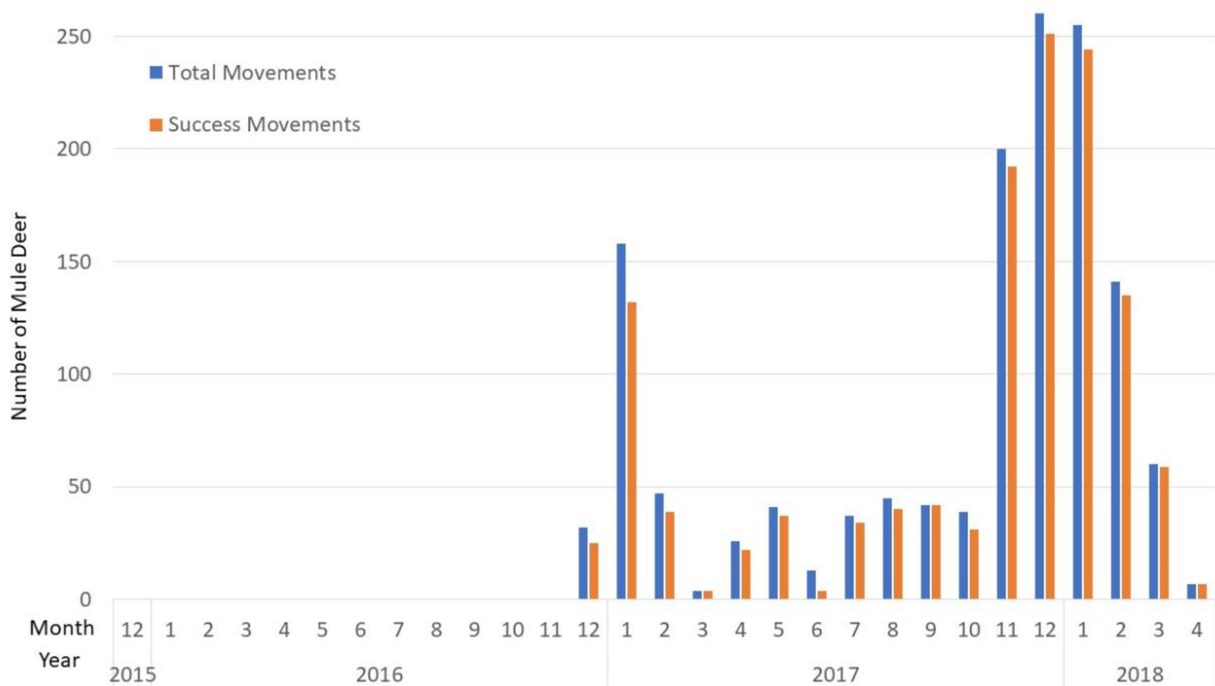

Figure 7. Mule deer total movements and success movements by months of the year at the Williams Peak Underpass (MP 136). Note y-axis scale is 0 – 250.

South Overpass, Milepost 129.5

Figure 8 presents mule deer total movements and success movements by month at the South Overpass. The peak in monthly movements in Year 2 was nearly as high as the peaks observed in Year 3; however, in Year 2 this peak occurred in February, while in Year 3, two peaks were observed in January and March, with a dip in activity in February. Mule deer use continued through the summer months.

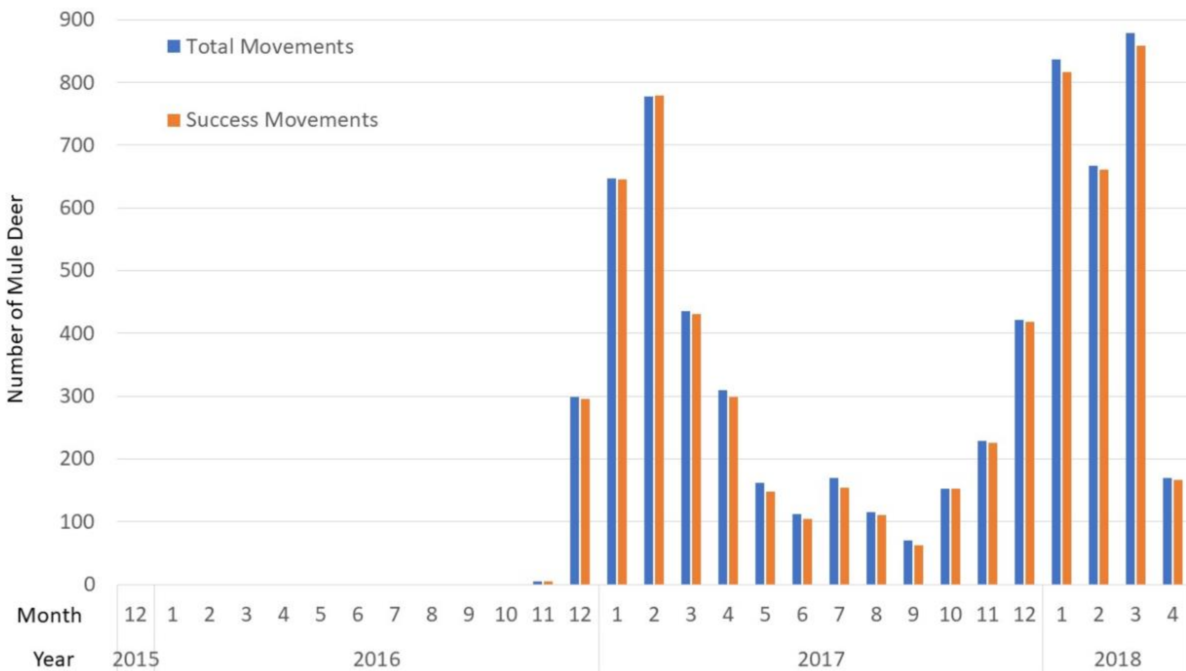

Figure 8. Mule deer total movements and success movements by months of the year at the South Overpass (MP 136). Note y-axis scale is 0 – 900.

BVA Underpass, Milepost 130.8

Figure 9 presents mule deer total movements and success movements by month at the BVA Underpass. The peak in monthly movements in Year 2 was higher than the peak in Year 3; however, in Year 2 there was a single peak in February, while in Year 3, two peaks were observed in January and March, with a dip in activity in February and overall activity was higher throughout the winter months. Figure 10 depicts a success movement at the BVA Underpass. Mule deer use continued through the summer months.

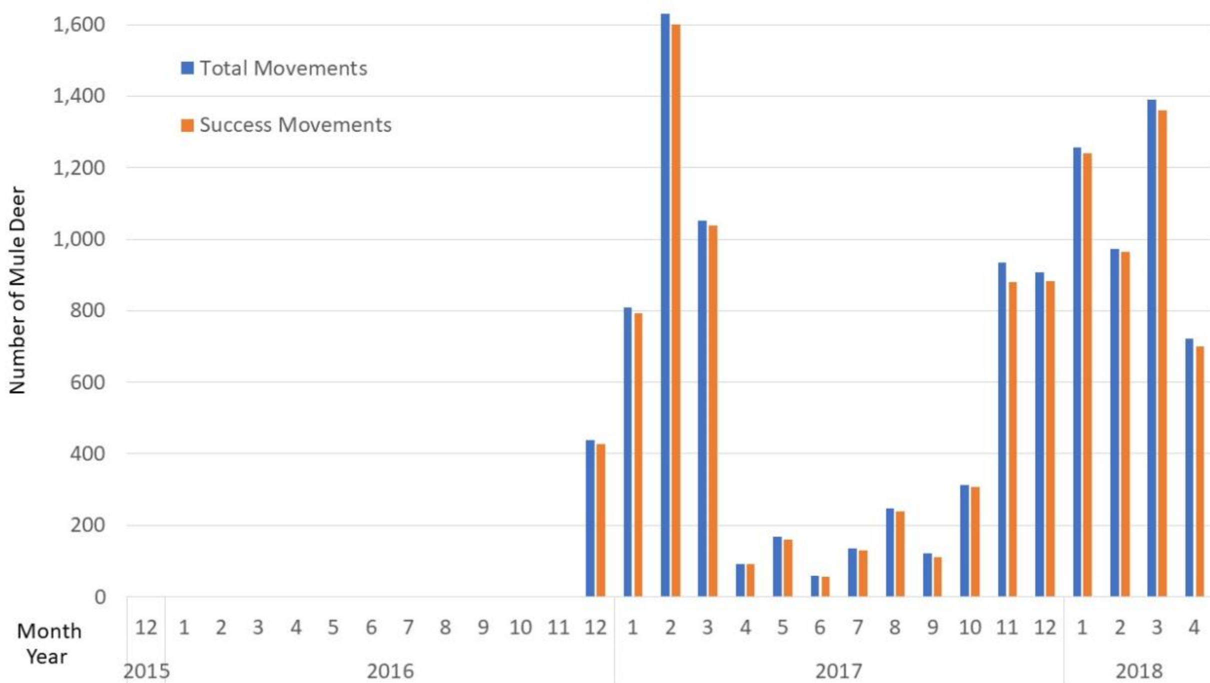

Figure 9. Mule deer total movements and success movements by months of the year at the BVA Underpass (MP 130.8). Note y-axis scale is 0 – 1,600.

Figure 10. Example of mule deer success movement at the BVA Underpass.

Harsha Underpass, Milepost 131.6

Figure 11 presents mule deer total movements and success movements by month at the Harsha Underpass. Winter movements increased each year at this structure with the highest activity recorded in January 2018. The lack of mule deer activity during the non-winter months of 2016 is attributed to ongoing construction activities at this location. In 2017, mule deer movements decreased from March through June and increased in July and again in November.

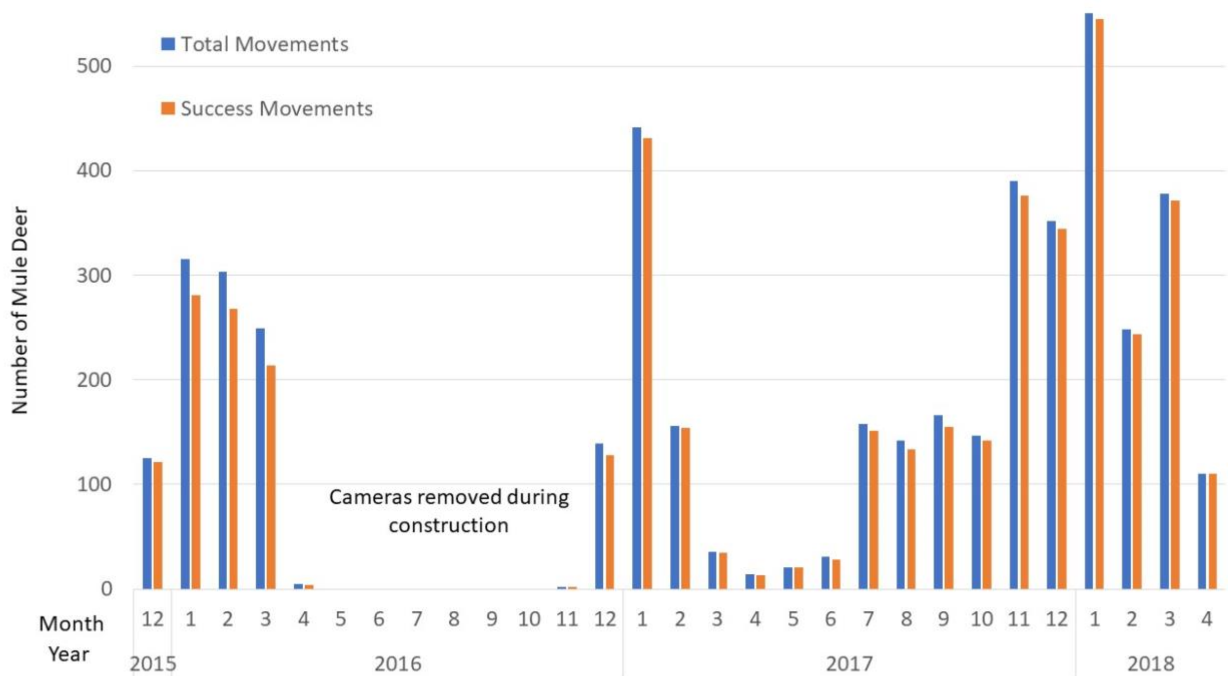

Figure 11. Mule deer total movements and success movements by months of the year at the Harsha Underpass (MP 131.6). Note y-axis scale is 0 – 500.

Middle Underpass, Milepost 132.5

Figure 12 presents mule deer total movements and success movements by month at the Middle Underpass. Winter movements increased each year at this structure with the highest activity recorded in March 2018. Mule deer use during the summer months was greater in 2017 than in 2016.

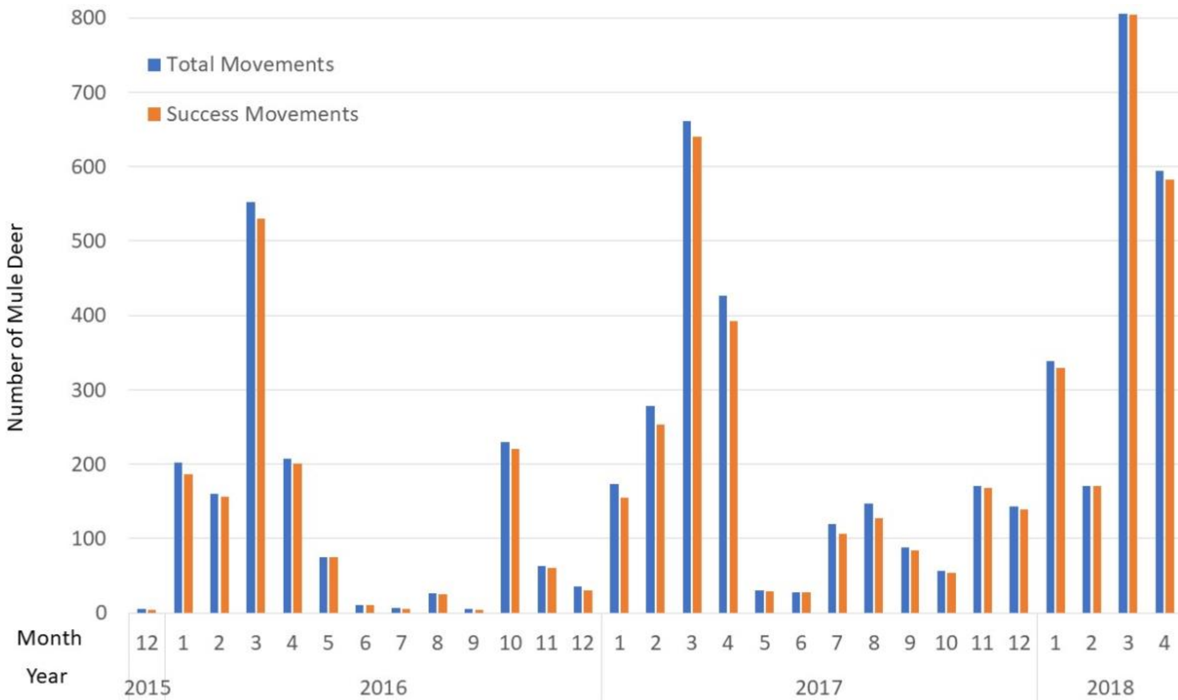

Figure 12. Mule deer total movements and success movements by months of the year at the Middle Underpass (MP 132.5). Note y-axis scale is 0 – 800.

North Overpass, Milepost 134.3

Figure 13 presents mule deer total movements and success movements by month at the North Overpass. This is the only location where mule deer activity decreased from Year 1 to Year 3. The highest peak in success movements occurred in March 2016. Wintertime peaks in activity in Years 2 and 3 were substantially lower, although overall activity at this structure remained high. Mule deer use continued through the summer months. Figure 14 depicts a mule deer success movement at the North Overpass.

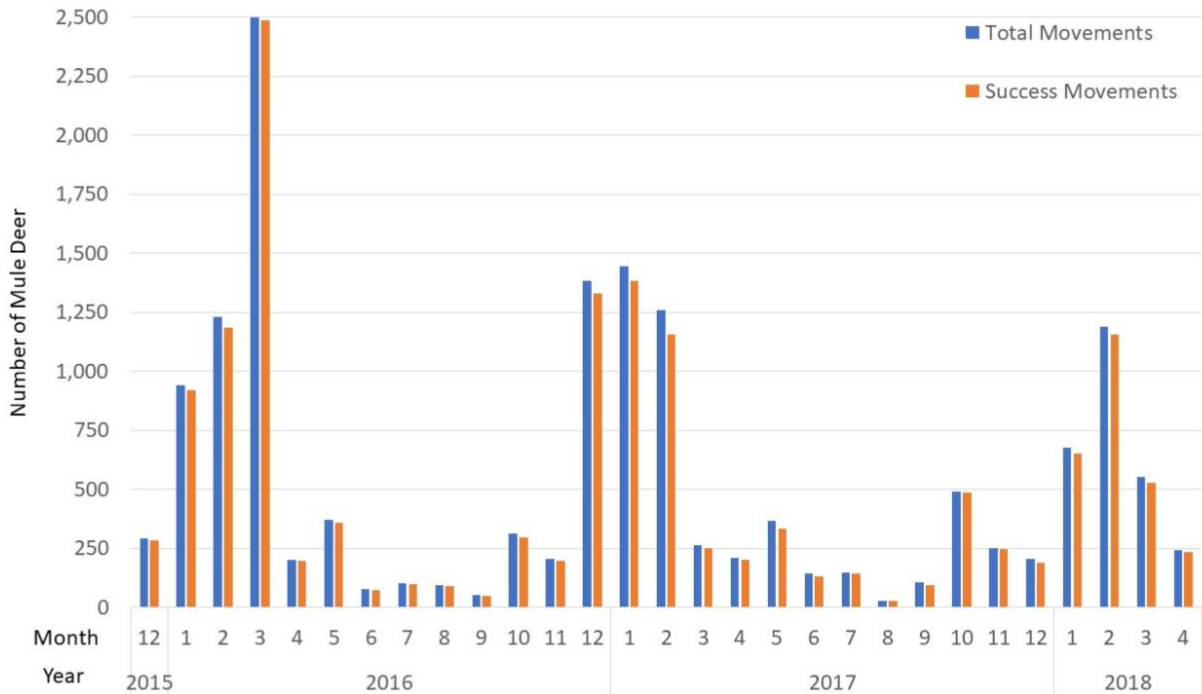

Figure 13. Mule deer total movements and success movements by months of the year at the North Overpass (MP 134.3). Note y-axis scale is 0 – 2,500.

Figure 14. Mule deer doe with two fawns crossing the North Overpass.

North Underpass, Milepost 136.0

Figure 15 presents mule deer total movements and success movements by month at the North Underpass. Mule deer success movements increased from Years 1 to 2 at this location and, while there was not a peak in activity as observed in Year 2, overall activity remained high throughout Winter 2017-18. Each year, mule deer movements sharply increased at this structure in January. Mule deer use of the structure continued during the summer months in low numbers.

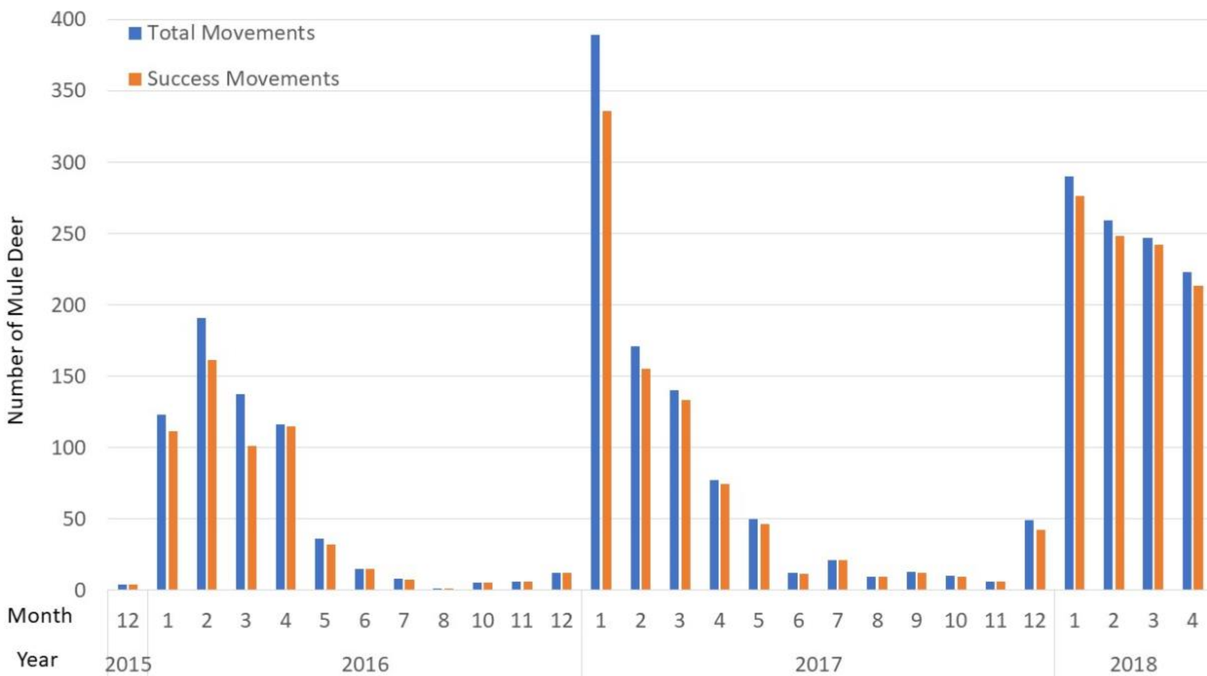

Figure 15. Mule deer total movements and success movements by months of the year at the North Underpass (MP 136). Note y-axis scale is 0 – 400.

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 4 lists the total number of success, repel and parallel movements for each species across all crossing structures and the corresponding success and repel rates for those species. Success rates for all species ranged from 81-100%.

Table 4. Movements by species other than mule deer at wildlife crossing structures, Years 1-3. Success, repel, and parallel movements are the total number of each movement across crossing structures. Success and repel rates are calculated for each species.

Species	Total Movements	Success Movements	Repel Movements	Parallel Movements	Success Rate	Repel Rate
Bighorn Sheep	13	13	0	0	100%	0%
Black Bear	140	139	1	0	99%	1%
Bobcat	85	75	6	4	88%	7%
Coyote	861	820	14	27	95%	2%
Elk	76	69	6	1	91%	8%
Fox, Red	200	161	9	30	81%	5%
Moose	38	33	3	2	87%	8%
Mountain Lion	69	68	1	0	99%	1%
Pronghorn	52	51	1	0	98%	2%
White-tailed Deer	39	36	2	1	92%	5%

Ungulate passage through and over the crossing structures for species other than mule deer remained roughly consistent or increased from Year 2 to Year 3. The number of success movements increased for bighorn sheep (from 2 to 11); moose (from 7 to 22); and pronghorn (from 9 to 42). For elk and white-tailed deer the number success movements decreased slightly between Years 2 and 3. While success rates are high for all of these ungulate species (87% or greater), the total number of movements for these species remains relatively low.

Elk passage continued to be highest at the North Overpass (*n*=12) in Year 3. Elk success movements were observed at most crossing structures, with the exception of the BVA and Williams Peak Underpasses, the two southern-most underpasses in the study area (Fig. 16). Overall in Year 3, elk successfully used the overpasses and underpasses equally (15 each), although more repels were documented at the underpasses (5) than at the overpasses (1). In contrast with years prior, in Year 3, all elk movements occurred during the non-winter months.

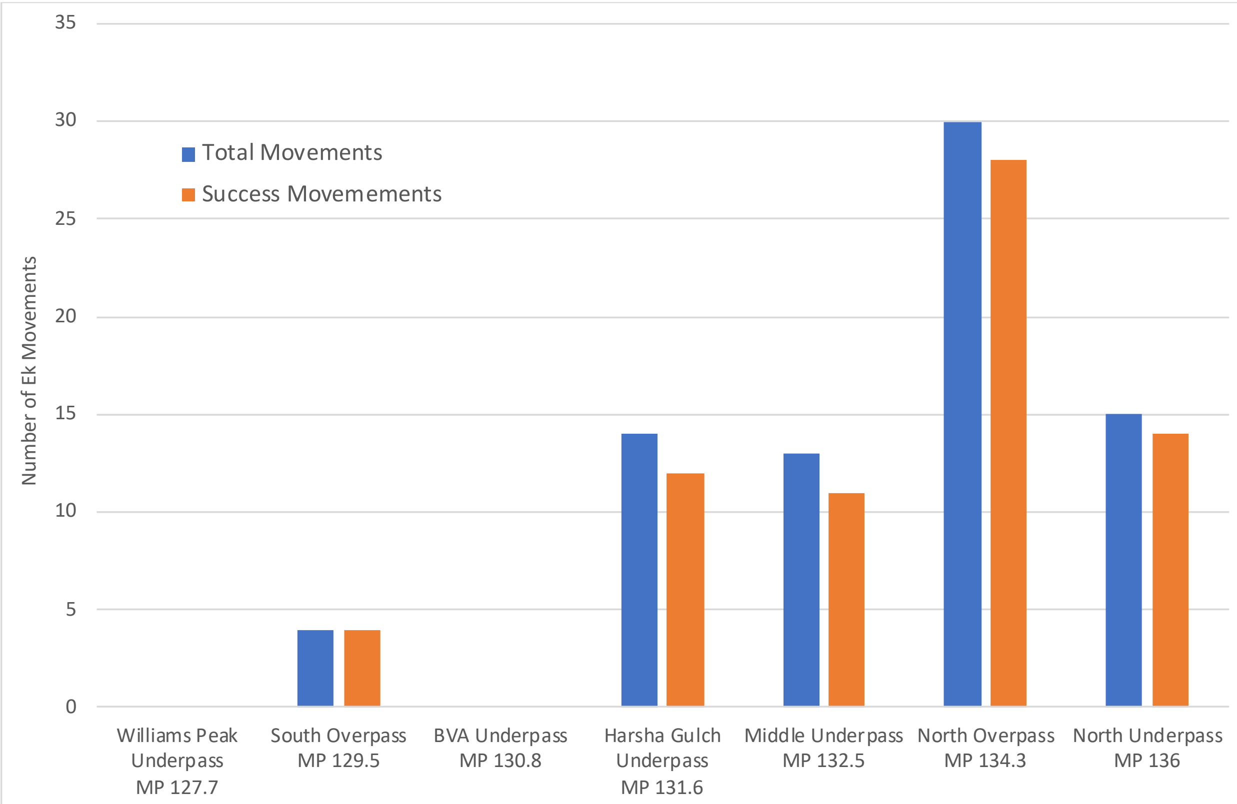

Figure 16. Elk total and success movements detected at wildlife crossing structures, Years 1-3.

Since the onset of this research, pronghorn and white-tailed deer have only been documented using the underpass structures. The majority of pronghorn success movements occurred at the BVA Underpass, while the majority of white-tailed deer success movements occurred at the North Underpass. Moose and bighorn sheep have made success movements at both underpasses and overpasses. The majority of bighorn sheep success movements occurred at crossing structures located in the southern portions of the project area, specifically, at the South Overpass and the Williams Peak Underpass. Of eight total success movements at the South Overpass, four of them were part of a single event by a family group (Fig. 17).

Figure 17. Bighorn sheep ewe, lamb, ram and yearling crossing the South Overpass.

Success movements by a variety of other large and medium-sized mammals were also documented at each of the crossing structures (Fig. 18). Black bears were detected primarily during the warmer months, while mountain lions were primarily detected during the winter months. The other mammal species were detected year-round. Coyote and red fox were the only species other than mule deer documented using every crossing structure. Coyote activity increased markedly in Year 3 at both overpass and underpass structures, although the heaviest use occurred at the two overpasses. Red fox activity also increased in Year 3.

Black bear have not crossed over either of the overpass structures to date and were observed primarily at the Middle Underpass. Other species documented at crossing structures include badger, bird, hare, raccoon, skunk and domestic animals (cats, dogs and cows).

Lower numbers of wildlife have been documented making successful passages under the Colorado River Bridge, including mule deer, moose, bobcat, red fox, mountain lion and white-tailed deer.

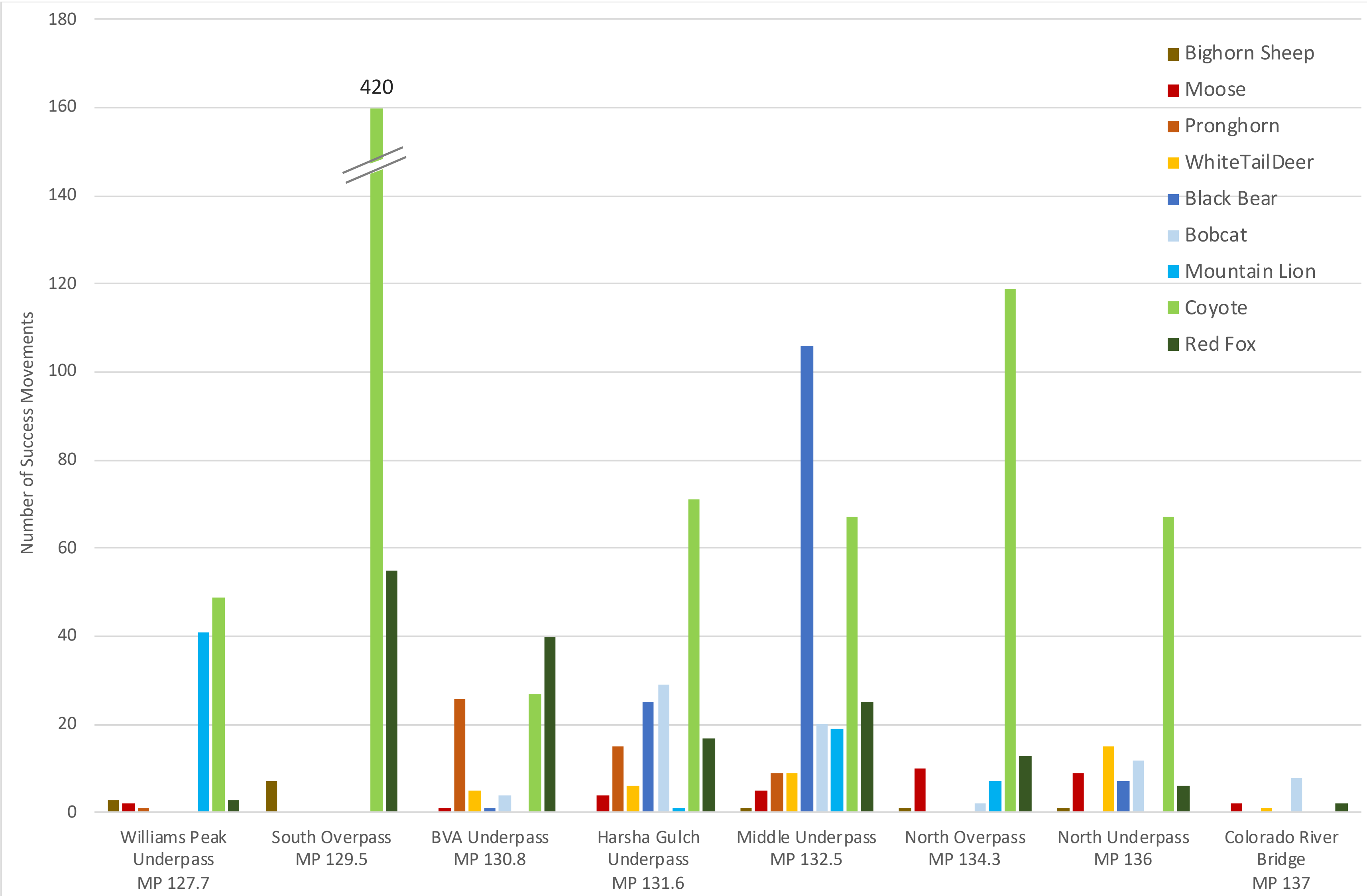

Figure 18. Success movements by medium and large-sized mammals other than mule deer and elk at each wildlife crossing structure from the onset of the study in December 2015 through April 2018.

Habitat cameras were placed approximately 100 feet away from the structure entrances facing outwards to capture wildlife movements in the adjacent habitat. Wildlife movements at habitat cameras relative to movements at crossing structures for species other than mule deer are reported in Table 5. In general, wildlife that were captured at habitat cameras were also captured at crossing structures, although species captured at both locations were not necessarily part of the same individual movement. Figure 19 depicts a mountain lion with three kittens approaching the habitat camera on the east side of the Williams Peak Underpass. In a few cases wildlife that were not captured at the habitat cameras were documented at the structure. However, these events occurred in low numbers and are expected as the habitat cameras are only able to capture a portion of the wildlife activity occurring in the vicinity of a structure.

Figure 19. Mountain lion with 3 kittens approaching the Williams Peak Underpass.

Humans were recorded at each of the crossing structures; this does not include researchers conducting camera checks. Human activity was most common at the Harsha Gulch Underpass, where, during the winter months, humans were documented on average once every ten days in Winter 2017-18. During the first two years of the study some human activity may be attributed to ongoing construction and construction review activities, particularly during the non-winter months.

Table 5. Comparison of species presence (other than mule deer) at wildlife crossing structures and habitat camera locations adjacent to wildlife crossing structures, Years 1-3. Note that movements at structures is the sum of all success, repel and parallel movements. Presence at habitat cameras does not imply that animals were moving to or from a crossing structure.

Species	Monitoring Location	Williams Peak UP	South OP	BVA UP	Harsha UP	Middle UP	North OP	North UP
Bighorn Sheep	Structure	3	7	0	0	1	1	1
	Habitat	1	0	1	0	0	0	0
Black Bear	Structure	0	0	1	25	107	0	7
	Habitat	0	1	0	0	103	2	3
Bobcat	Structure	0	0	5	29	25	5	12
	Habitat	0	1	0	0	74	5	0
Coyote	Structure	52	440	28	74	70	123	74
	Habitat	45	117	19	5	326	325	9
Elk	Structure	0	4	0	12	13	30	15
	Habitat	0	20	7	4	9	103	31
Moose	Structure	2	0	1	4	7	11	10
	Habitat	2	1	1	4	7	2	6
Mountain Lion	Structure	41	0	0	1	19	7	0
	Habitat	21	1	0	0	2	2	0
Pronghorn	Structure	1	0	26	16	9	0	0
	Habitat	0	0	22	0	2	1	0
Red Fox	Structure	4	73	47	22	26	19	7
	Habitat	6	21	6	0	5	46	2
White-tailed Deer	Structure	0	0	5	7	9	0	17
	Habitat	0	0	0	0	18	2	5

UP = underpass
OP = overpass

Wildlife Movements at Small Culverts

The three small culverts were monitored for varying lengths of time. Monitoring at the BVR Pipe Culvert began at the onset of monitoring in December 2015 and continued into October 2016. The Culbreath Box Culvert was monitored from October 2016 through April 2018 and the BVR Box Culvert from March 2017 through April 2018.

Wildlife activity at these small culvert locations occurred primarily during the non-winter months. Figure 20 displays success movements at each small culvert location. Mule deer were documented and made success movements at all three culverts, ranging from one through-passage at the Culbreath Box Culvert to 17 at the BVR Box Culvert. However, less than a third of the mule deer that approached any of these small culverts successfully crossed through.

Black bear, bobcat and coyote were the most common species documented using the small culverts, with much of this activity occurring at the BVR Box Culvert. Domestic dogs and cats were most common at the Culbreath Box Culvert and may have deterred some wildlife activity at this location. Success movements at small culverts were also made by red fox, American badger and northern raccoon.

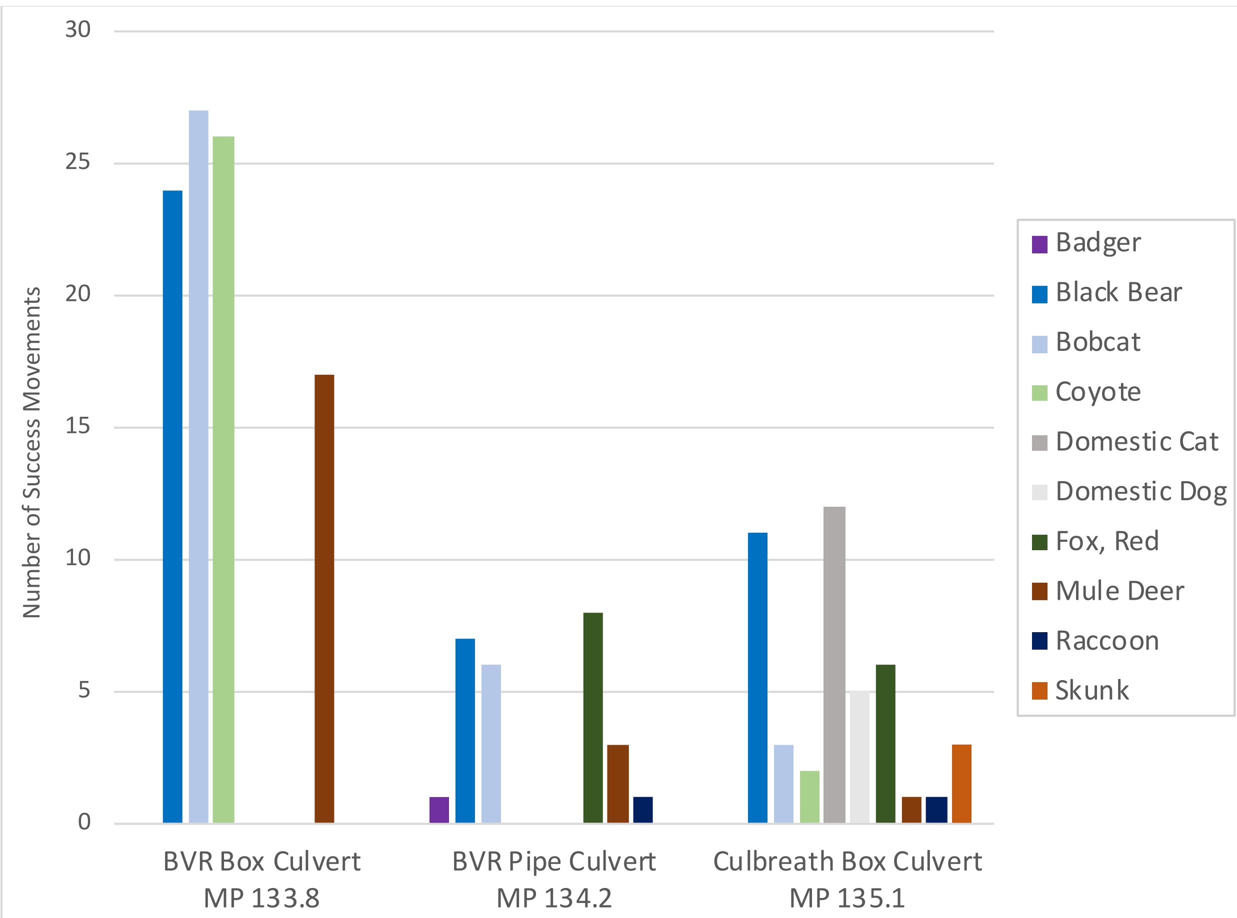

Figure 20. Success movements by species at each of the small culverts. Total monitoring days at each location are: BVR Box Culvert – 408 days; BVR Pipe Culvert – 306 days; Culbreath Box Culvert – 474 days.

Wildlife Movements at Other Mitigation Features

Wildlife Guards

Since the onset of this research, ungulates have made a total of 138 breach movements at wildlife guards. The vast majority of wildlife guard breaches by mule deer, elk and white-tailed deer were from the habitat side into the fenced right-of-way. In general, wildlife guards deterred ungulates from entering the fenced right-of-way 83% of the time. The total number of breach movements by mule deer decreased from 71 breaches in Year 2 to 23 breach movements Year 3.

Table 6 displays the number of breaches and repels, as well as breach rates and repel rates for each species. The flat bar guards were 78% effective in preventing mule deer breaches, while the round bar guards were 90% effective. Elk had a higher repel rate at flat bar guards (81%) than at round bar guards (67%), but the total number of movements by elk at round bar guards was only six, compared 16 at the flat bar guards. White-tailed deer had a higher repel rate at round bar guards (75%; *n*=8) than at flat bar guards (67%; *n*=3). Moose and bighorn sheep repelled from both guard types 100% of the time (*n*=9 and *n*=2, respectively).

Black bear (*n*=6), bobcat (*n*=21) and mountain lion (*n*=1) were infrequent visitors to the guards but breached the guards 100% of the time when they did approach. Red fox (*n*=240) and coyote (*n*=84) approached the guards more frequently, with breach rates ranging from 74-100% depending on the guard type. The breach rate for red fox was the same at both round bar and flat bar guards (92%) and nearly the same for coyote (75% at round bar and 74% at flat bar guards). These species were also observed breaching the guards in either direction. In one instance, a bobcat was documented descending into the vault at the County Road 33 Wildlife Guard (Fig. 21). Mountain lion, raccoon, skunk, hare and domestic dogs and cats were also recorded at the wildlife guards.

Figure 21. Bobcat entering into the vault at the County Road 33 Wildlife Guard.

Table 6. Breach and repel rates for each species at wildlife guards with flat bars (8 locations) versus round bars (4 locations).

Species	Wildlife Guard Type	Total Approach Movements	Breach Rate	Repel Rate
Badger	Flat Bar	1	0%	100%
	Round Bar	0	n/a	n/a
Bighorn Sheep	Flat Bar	1	0%	100%
	Round Bar	1	0%	100%
Black Bear	Flat Bar	3	100%	0%
	Round Bar	3	100%	0%
Bobcat	Flat Bar	15	100%	0%
	Round Bar	6	100%	0%
Coyote	Flat Bar	76	74%	26%
	Round Bar	8	75%	25%
Elk	Flat Bar	16	19%	81%
	Round Bar	6	33%	67%
Moose	Flat Bar	5	0%	100%
	Round Bar	4	0%	100%
Mountain Lion	Flat Bar	1	100%	0%
	Round Bar	0	n/a	n/a
Mule Deer	Flat Bar	372	22%	78%
	Flat Bar with Pedestrian Grate	30	40%	60%
	Round Bar	368	10%	90%
Red Fox	Flat Bar	173	92%	8%
	Flat Bar with Pedestrian Grate	1	100%	0%
	Round Bar	66	92%	8%
White-tailed Deer	Flat Bar	3	33%	67%
	Round Bar	8	25%	75%

Ungulate breach rates varied depending on the guard type. The flat bar guard with a pedestrian grate was only monitored for a short period before it was gated but was breached the most often (12 breaches total for a rate of 0.047 breaches per monitoring day). The flat bar guards were breached on 84 occasions for a rate of 0.026 breaches per monitoring day, and the round bar guards 42 times for a rate of 0.017 breaches per monitoring day. For mule deer, breach movements by walking over snow packed in-between the bars at flat bar guards were the most common breach type in Year 2, while in Year 3, no breaches occurred at any of the guard types by walking on snow (Table 7). In Year 3, mule deer breaches were higher at round bar guards than at flat bar guards, accounting for 74% of all breach movements (n=17). The most common method of breaching, regardless of guard type, was jumping. On several occasions, deer were captured breaching a round bar guard by attempting to walk on top of the bars (Fig. 22) or walking on the support beams despite the presence of angle iron on the beams to prevent these types of breaches (Fig. 23).

Table 7. Comparison of breach type for Mule Deer in Winter 2016-17 and Winter 2017-18 at wildlife guards with flat bars (7 locations), flat bars with a pedestrian grate (1 location), and round bars (5 locations).

Wildlife Guard Type	Study Year	Walk on Top	Walk on Support Beams	Walk on Snow	Jump	Walk on Grate
Flat Bar (*n*=77)	Year 1	11	3	7	5	n/a
	Year 2	10	1	29	5	n/a
	Year 3	0	0	0	6	n/a
Flat Bar with Pedestrian Grate (*n*=18)	Year 1	5	0	0	3	3
	Year 2	1	0	0	3	3
	Year 3	n/a	n/a	n/a	n/a	n/a
Round Bar (*n*=37)	Year 1	n/a	n/a	n/a	n/a	n/a
	Year 2	0	1	2	18	n/a
	Year 3	4	2	0	10	n/a

Figure 22. Mule deer breaching the Badger Road Wildlife Guard by attempting to walk on top of the round bars.

Figure 23. Mule deer breaching the County Road 1002 Wildlife Guard (round bar) by walking on the support beams.

Mule deer breaches were recorded at all monitoring locations but occurred most frequently at County Road 1000 (flat bar), with 29% of all breaches occurring at this location. This was also the location with the highest occurrence of breaches by walking on snow. Breaches by walking on snow also occurred at the Trough Road Wildlife Guard (flat bar) and County Road 1002, which was the only round bar guard location with the breach type. In this case, snow plowing created a snow berm along the side of the guard and the deer used this berm to breach the guard. Walking on top of the guard was the most common method of breaching at County Road 33 and Spring Creek, both flat bar locations. Walking on top was also the most common breach type at the Culbreath Wildlife Guard during Year 1, despite the presence of a pedestrian grate on this guard. Breaches by jumping were documented at nearly all of the guard locations regardless of guard type, and this was the most common method of breaching at the four round-bar locations.

Several wildlife guard monitoring locations were included in a paired analysis, i.e., adjacent locations with different guard types (flat bar versus round bar) in Year 3. The paired locations included in this analysis were the Thompson (round bar) and County Road 33 (flat bar) wildlife guards; Triangle Road (round bar) and Spring Creek Road (flat bar) wildlife guards; and County Road 1002 (round bar) and County Road 1000 (flat bar). The paired analysis included only movements by ungulate species, and only events that occurred between dusk and dawn the following day to equalize the sampling effort among those cameras that are programmed to be off during the daytime due to higher traffic volumes and those that are not. Breach and repel movements for guards in the paired analysis are presented in Table 8.

Table 8. Breach and repel movements at wildlife guards included in the Year 3 paired analysis.

Monitoring Location	Breach Movements	Repel Movements	Walk on Top	Walk on Support Beams	Walk Snow	Jump
Thompson (round bar)	1	14	0	0	0	1
CR 33 (flat bar)	0	2	0	0	0	0
Triangle Rd (round bar)	5	36	0	0	0	5
Spring Creek Rd (flat bar)	3	40	1	0	0	2
CR 1002 (round bar)	6	48	0	2	0	4
CR 1000 (flat bar)	6	34	2	0	0	4

Across all of the pairs, jumping the guard was the most common breach type and occurred at the flat bar and round bar guards in nearly equal numbers for each of the pairs. Walking on top of the bars was recorded only at flat bar guards in this paired analysis, while walking on the support beams was recorded only at one of the round bar guards.

Escape Ramps

Since the onset of thise research, cameras have recorded a total of 171 elk and 645 mule deer movements at escape ramps on the right-of-way side of the fence. Elk and mule deer movements at escape ramps occurred mostly from December through March. In Year 3, no elk were documented inside of the right-of-way fence at the escape ramps and 279 mule deer movements were recorded – slightly fewer than in Year 2. Mule deer have been documented at each of the 13 monitored escape ramp locations, with the highest frequencies at the East Fence End Escape Ramp at MP 126.7, Badger Road Escape Ramp at MP 129.1 (both 3:1 slope with no rail fence) and the North Overpass Escape Ramp at MP 134.3 (2:1 slope with no rail fence).

When an animal approached an escape ramp on the right-of-way side of the fence, it either walked around the ramp or ascended (intercepted) it. Table 9 summarizes elk and mule deer approaches and intercept rates for the different escape ramp types. For elk, 3:1 slope ramps without perpendicular rail fence had the highest intercept rate (54%). For deer, ramps without perpendicular rail fence (both 2:1 and 3:1 slopes) had the highest intercept rates (72% and 55%, respectively).

Table 9. Intercept rate by elk and mule deer at escape ramps with 2:1 versus 3:1 slopes and with or without perpendicular rail fence through Year 3. Intercept rate is the percentage of the total movements by animals that ascended the ramp relative to the total number of movements by animals that approached the ramp.

Species	Escape Ramp Type	Total Approaches	Intercept Rate
Elk	2:1 slope with rail fence (*n*=5)	3	33%
	2:1 slope without rail fence (*n*=1)	0	n/a
	3:1 slope with rail fence (*n*=2)	0	n/a
	3:1 slope without rail fence (*n*=5)	168	54%
Mule Deer	2:1 slope with rail fence (*n*=5)	65	43%
	2:1 slope without rail fence (*n*=1)	106	72%
	3:1 slope with rail fence (*n*=2)	126	34%
	3:1 slope without rail fence (*n*=5)	348	55%

Animals whose movements were intercepted by a ramp either walked up and turned around or jumped down to the habitat side. Table 10 summarizes jump down (escape) rates for deer and elk at each of the different escape ramp types. The highest number of mule deer escapes were at the North Overpass Escape Ramp (2:1 slope without rail fence; *n*=14) and the Badger Road Escape Ramp (3:1 slope without rail fence; *n*=12), with escape rates of 18% and 26%, respectively. All of the other ramps recorded four or fewer escape movements. For example, the Culbreath 3:1 Escape Ramp (no rail fence) had the highest escape rate of 33% but only twelve total movements were recorded at this location including four successful jump downs. The East Fence End Escape Ramp (3:1 slope ramp without rail fence) had the highest number of mule deer walk up the ramp (*n*=83), but none of these deer jumped down to the habitat side.

In Year 3, bighorn sheep were recorded ascending the South Spring Creek Escape Ramp (3:1 slope with rail fence), but no successful escape movements were recorded. Moose, pronghorn and white-tailed deer were not recorded at any of the ramps. Humans were recorded in low numbers at most of the ramps, and in most cases appear to be curious passersby, including people on foot, dirt bikes, ATVs, and snowmobiles.

Table 10. Escape rates by elk and mule deer at escape ramps with 2:1 versus 3:1 slopes and with or without perpendicular rail fence through Year 3. Escape rate is the percentage of the total movements by animals that escaped to the habitat side of the fencing relative to the total number of movements by animals that ascended the ramp.

Species	Escape Ramp Type	Total Ascend Ramp	Escape Rate
Elk	2:1 slope with rail fence (*n*=5)	1	100%
	2:1 slope without rail fence (*n*=1)	n/a	n/a
	3:1 slope with rail fence (*n*=2)	0	n/a
	3:1 slope without rail fence (*n*=5)	90	8%
Mule Deer	2:1 slope with rail fence (*n*=5)	28	11%
	2:1 slope without rail fence (*n*=1)	76	18%
	3:1 slope with rail fence (*n*=2)	43	14%
	3:1 slope without rail fence (*n*=5)	192	11%

A number of ungulates, other wildlife and domestic cows were documented on the habitat side of the escape ramps. No ungulates attempted to jump up onto the ramp from the habitat side. On one occasion a bighorn sheep ewe appeared to investigate the ramp from the habitat side of the fence but made no attempt to jump up. Bobcat is the only species captured climbing up the backside of a ramp from the habitat side to enter into the fenced right-of-way.

Pedestrian Walk-Through Gates

All of the pedestrian walk-through gates in the study area were gated by CPW in Summer 2017 and monitoring ceased. Monitoring results for the pedestrian walk-through gates are available in the *State Highway 9 Wildlife Crossings Monitoring Year 2 Progress Report* (Kintsch et al. 2018).

South Fence End

Wildlife exclusion fence runs along the right-of-way line throughout the project area. The northern terminus ties into the Colorado River Bridge south of Kremmling. The southern terminus is at MP 126.6. At this fence end the fence line angles in towards the pavement, ending 20' from the pavement edge so that it is not inside the clear zone. Monitoring at the south fence end commenced on October 10, 2016 and will continue through the duration of this research.

A total of 777 movements were recorded of deer and elk at the south fence end. Movements into the fenced right-of-way occurred when animals moved from the habitat side of the fence and either walked around the fence end into the right-of-way on the same side of the road 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 fenced area of the right-of-way moved out to the habitat side of the fence. Movements beyond the fence include 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. The majority of movements for all species occurred beyond the fence end without movements into or out of the fenced right-of-way, including 91% of all deer movements and 62% of all elk movements. Some human movements were documented at the fence end, primarily involving ATVs, dirt bikes or snowmobiles driving around the fence end on the west side.

The total number of ungulate movements at the south fence end increased from Winter 2016-17 to Winter 2017-18 by 40% and the majority of all movements continue to occur beyond the fence end (Fig. 24). Total movements decreased during the non-winter months as migratory herds moved out of the study area to high elevation summer ranges.

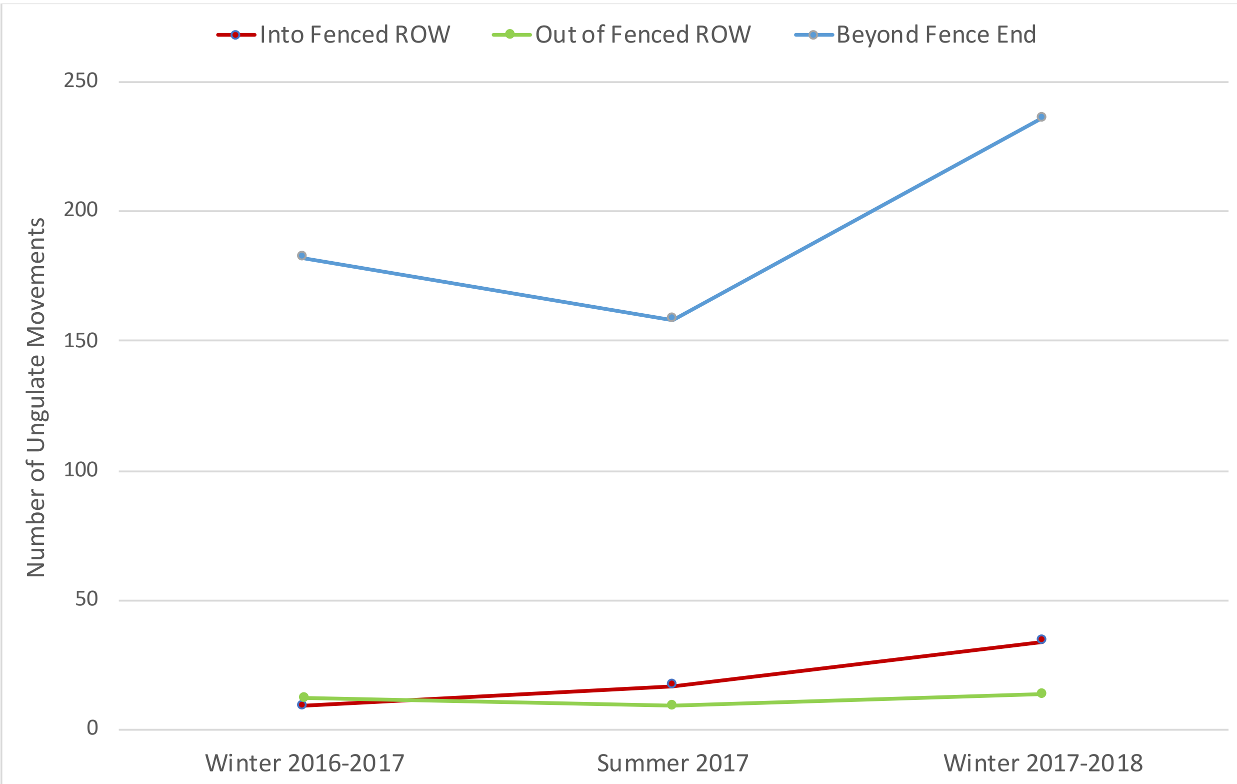

Figure 24. Ungulate movements at the south fence end.

Wildlife-Vehicle Collision Rates

BVR/CPW Carcass Data

In Winter 2017-18, six mule deer and no elk carcasses were reported inside the project area, for a decrease of 89% relative to the pre-construction average (Fig. 25). This decrease was slightly greater than Winter 2016-17 which saw a decrease of 86% (eight carcasses reported). In Winter 2016-17, three additional deer carcasses were reported within a mile south of the south fence end, while in Winter 2017-18, this number increased to six. Four of these WVC carcasses were located less than 30 meters from the fence end. At the north end of the study area, one deer carcass was reported within a mile of the north fence end in Winter 2017-18; no elk or pronghorn carcasses were recorded.

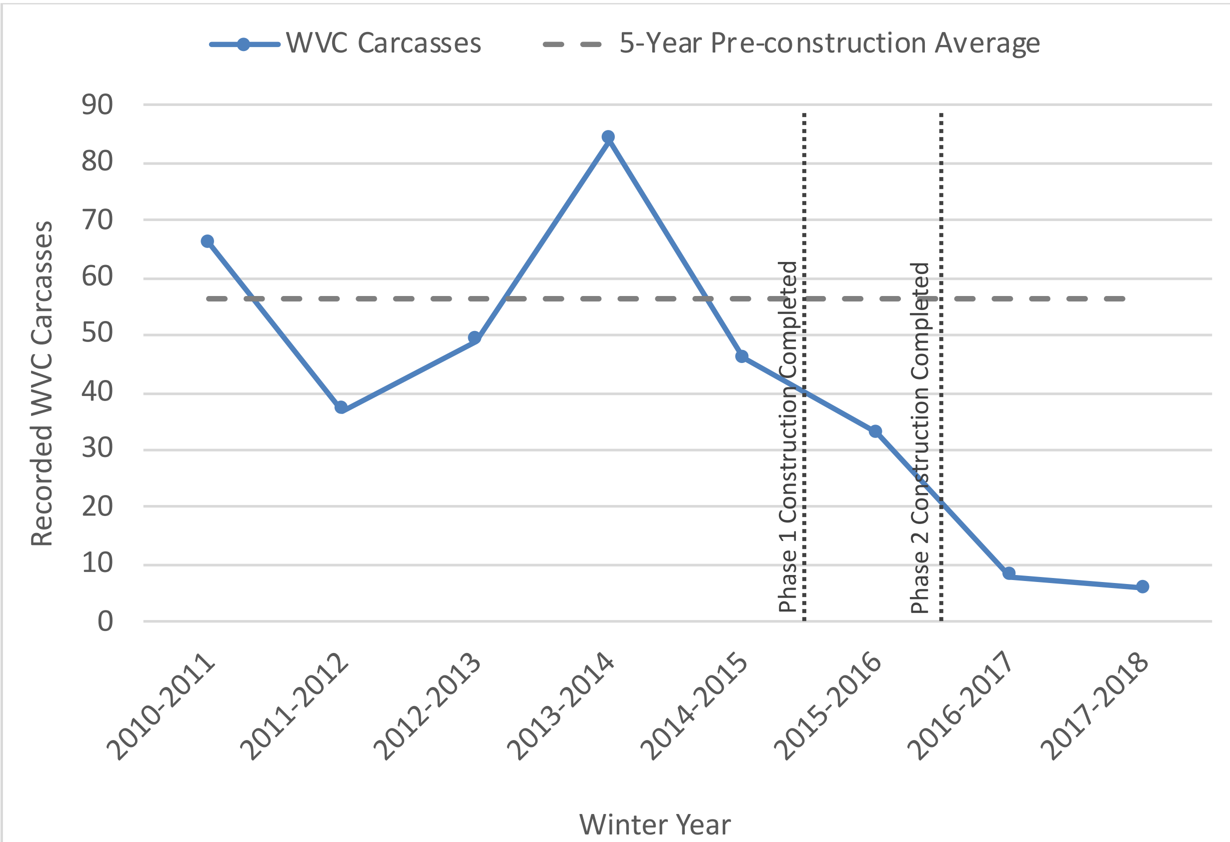

Figure 25. Mule deer and elk carcass counts recorded by BVR and CPW compared to the five-year pre-construction average of 56.4 carcasses per year.

CDOT Maintenance Carcass Data

In Winter 2017-18, no WVC carcasses were reported by CDOT Maintenance patrols inside the project area; nor were any reported the previous winter (Fig. 26). Since construction was completed, one carcass was reported during the non-winter months inside the project area – this WVC event occurred near the south fence end in late November 2017, during the fall migration. However, carcasses continue to be recorded beyond the fence ends, particularly south of the project area (Fig. 27). Since construction was completed, 12 WVC carcasses have been reported within 1.5 miles of the south fence and one WVC carcass was reported north of the project area.

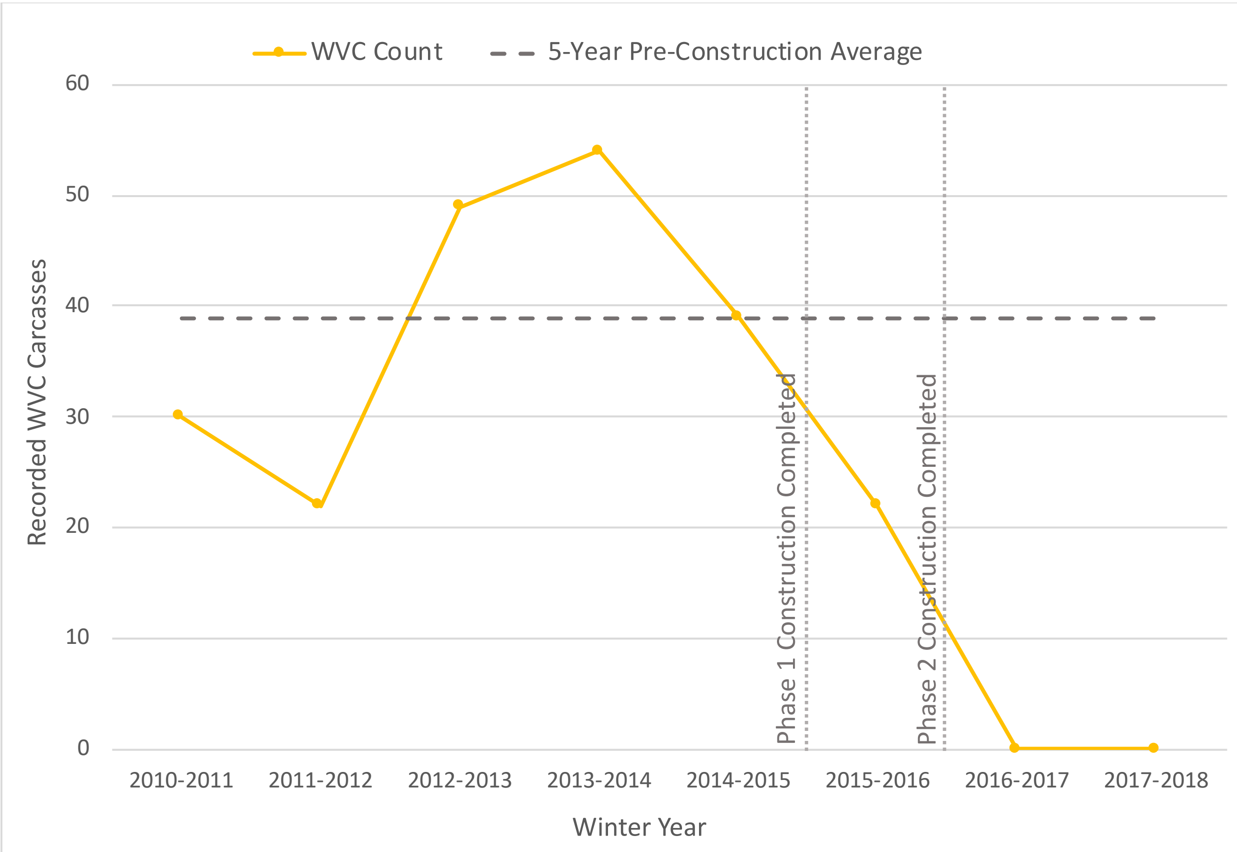

Figure 26. Wintertime mule deer and elk carcass counts recorded by CDOT Maintenance within the project area (MP 216.6 – 137.0) compared to the five-year pre-construction average of 38.8 carcasses per year.

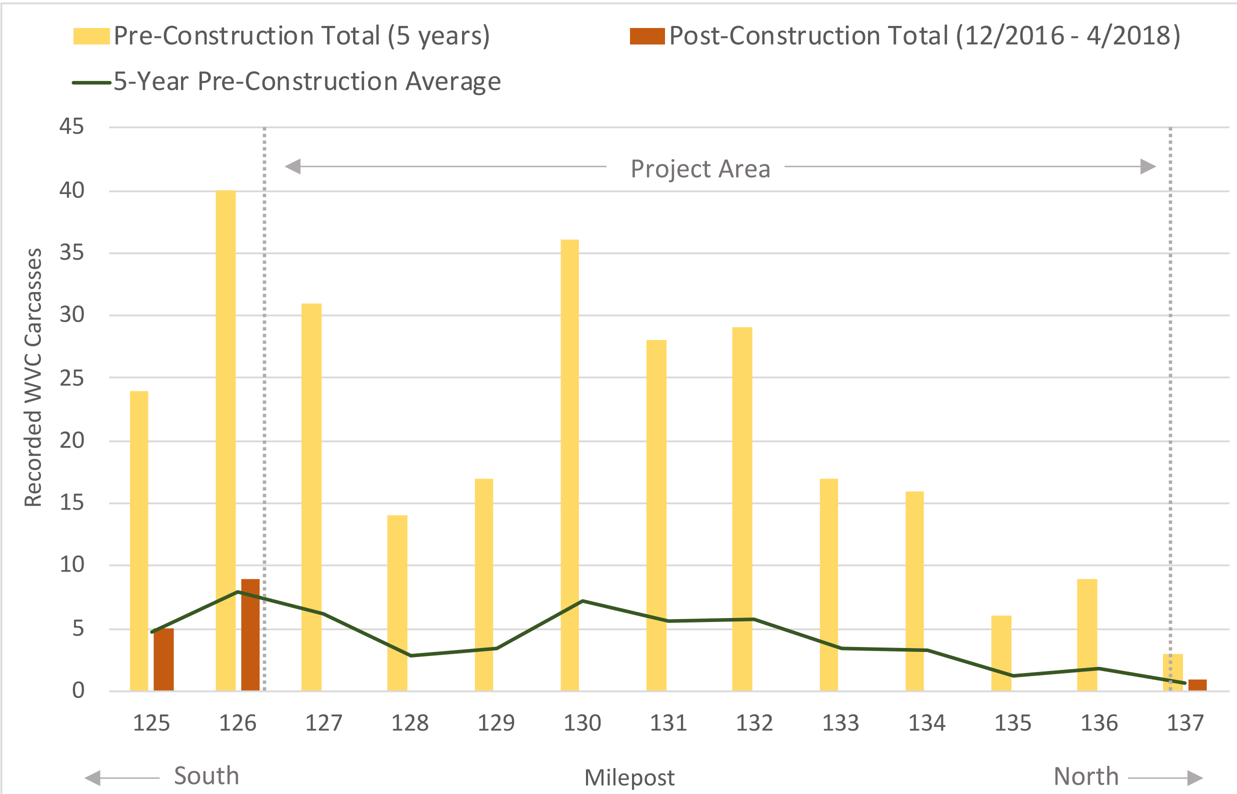

Figure 27. Mule deer and elk carcass counts recorded by CDOT Maintenance by milepost. Pre-construction totals comprise 5 years; post-construction totals comprise two winters and the intervening non-winter months. The 5-year pre-construction average was calculated for each one-mile segment.

CDOT Traffic and Safety Accident Report Data

Within the project area, the number of reported WVC accidents dropped 100% in Winter 2016-17, the first winter following construction of the entire mitigation project. During the five winters prior to mitigation construction (Winter 2010-11 through 2014-15), WVC were the most common accident type on this segment of highway, accounting for 60% (*n*=51) of all accidents reported to law enforcement. These data demonstrate that WVC accidents occur year-round, with the highest WVC rates occurring during the winter months (Fig. 28). No WVC accidents were reported immediately north or south of the project area since construction was completed. Post-construction data for April 2017 through April 2018 were not available at the time of this analysis.

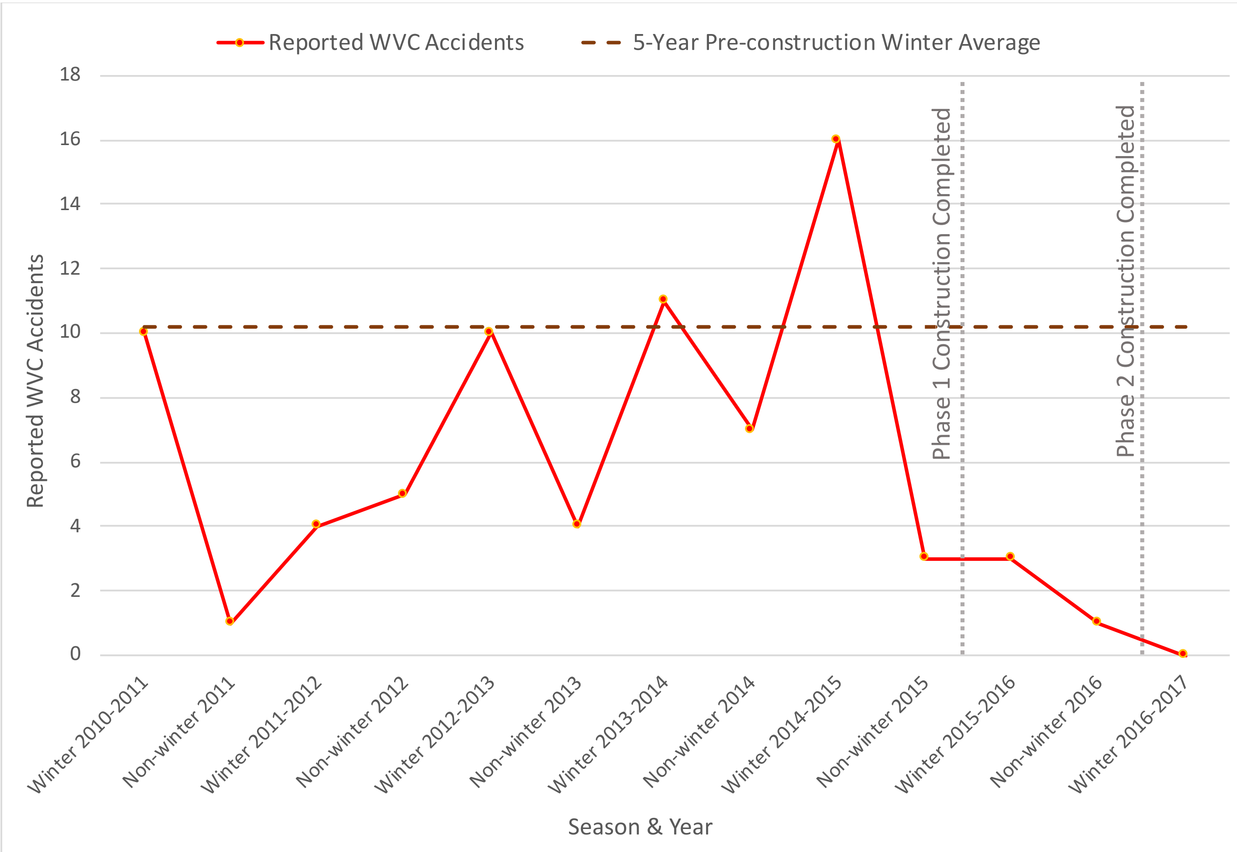

Figure 28. Wildlife-vehicle collision accidents within the project area (MP 216.6 – 137.0) reported to law enforcement involving mule deer or elk compared to the 5-year pre-construction average of 10.2 reported accidents, which is calculated for the winter months only so that it may be compared to the BVR carcass data.

Wildlife-vehicle Collision Rates on US 40

In addition to WVC rates on SH 9, the researchers also analyzed the CDOT Maintenance carcass dataset for US 40 from MP 182-190, an east-west highway that runs through the town of Kremmling, north of the project area. Comparisons were made between the number of ungulate (mule deer, elk and pronghorn) carcasses five-years pre-construction and two years post-construction (Fig. 29). Data from Winter 2015-16 were excluded from the analysis as this corresponds with the timeframe during which only the Phase 1 portion of the project area had been constructed. The purpose of this analysis was to determine whether the mitigation on SH 9 may have contributed to a shift in wildlife movements, particularly elk, from SH 9 north across US 40, with a resulting increase in WVC on US 40. During the five years pre-construction, 28 deer carcasses and eight elk carcasses were recorded. Post-construction, four carcasses of each species have been recorded during Winter 2016-17 and Winter 2017-18.

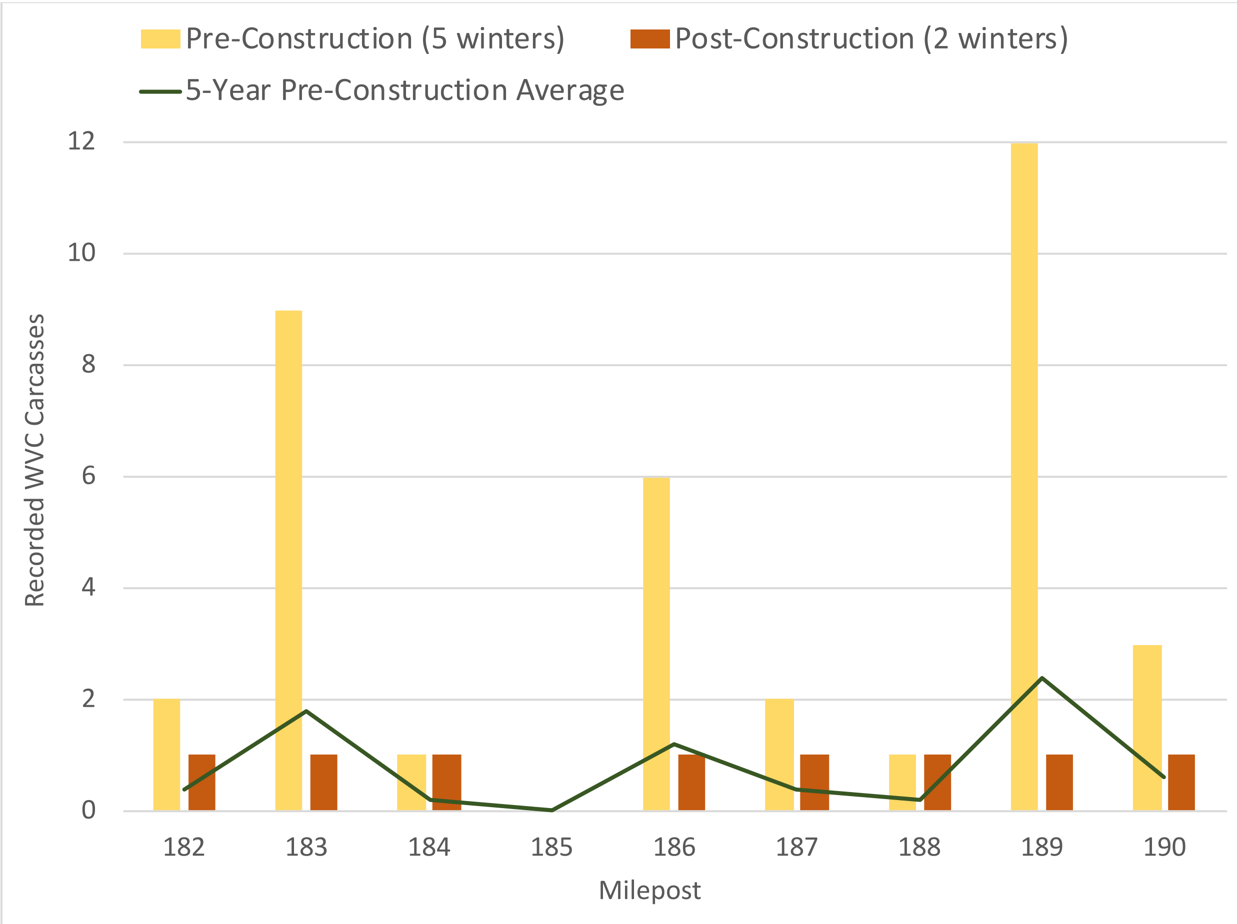

Figure 29. Ungulate carcass counts recorded by CDOT Maintenance on US 40 east and west of Kremmling (MP 185) for five winters prior to mitigation construction and two winters post-construction. The 5-year pre-construction winter average was calculated for each one-mile segment.

Discussion

Wildlife Use of Crossing Structures

Mule deer activity and success movements through or over the crossing structures increased each year of this research. The 45,759 mule deer success movements at wildlife crossing structures in addition to the mule deer success rates ranging from 95% to 98% demonstrate the success of this mitigation system for mule deer. The 89% reduction in WVC carcasses collected by BVR and CPW in addition to the reduction in WVC carcasses reported by CDOT Maintenance and WVC accidents reported to law enforcement further attest to the success of the mitigation in reducing wildlife hazards for motorists. The observed changes in the number of success movements by mule deer and other species over time, as well as variations in the patterns of use across the seven structures can inform a greater understanding of wildlife movements in the study area and the effectiveness of the different wildlife crossing structure types.

Mule Deer Structure Use and Periods of Peak Activity

The 17% increase in mule deer movements in Winter 2017-18 relative to the winter prior suggests that the mitigation is succeeding in improving connectivity for mule deer across SH 9. The high number of mule deer movements and the high success rates at each of the crossing structures reflect regular movements that appear to be have been made by many of the same individuals on winter range. Periods of peak mule deer activity varied among crossing structures and from one winter to the next. In general, activity increased in October, marking the onset of migratory herds arriving on winter range, and began decreasing again in April as these herds moved to high elevation summer ranges. While in Winter 2016-17 peak activity was concentrated in January and mid-February, in Winter 2017-18, peak activity at several locations didn’t occur until March. Given that crossing structures in the Phase 2 segment were completely new in Winter 2016-17, shifts in peak activity are expected in the first few years of post-construction monitoring. Fluctuations in snowfall is another likely contributor to annual variability.

In addition to movements by migratory mule deer on winter range, resident mule deer continued to use the crossing structures during the non-winter months with an overall success rate of 95%. Mule deer success movements were recorded at all of the wildlife crossing structures during the non-winter months of 2017 and accounted for 29% of all movements at crossing structures in

Year 3. These results demonstrate that the wildlife-highway mitigation provided safe passages for resident herds as well as wintering migratory herds. The mitigation has also successfully reduced WVC conflicts for resident herds, as no WVC crashes or carcasses were reported during the non-winter months in Year 3 (based on CDOT Maintenance carcass reports and CDOT Traffic and Safety accident reports; BVR does not collect carcass data during the non-winter months).

Variations in Mule Deer Structure Use from Prior Winter

Mule deer activity varied substantially among the wildlife crossing structures during Winter 2017-18, and patterns in crossing structure use also varied relative to the previous winter. While the number of mule deer success movements at the North Overpass remained high relative to other crossing structures through both post-construction winters, this was the only location where a decrease in success movements was observed in Winter 2017-18. Meanwhile, success movements at the two adjacent structures to the north (North Underpass) and south (Middle Underpass) increased by 44% and 37%, respectively. The highest levels of mule deer activity occurred at the BVA Underpass (n=5,246), which, in Winter 2017-18 surpassed the North Overpass as the crossing structure with the greatest number of success movements. Regardless of this variation, success rates were high at all locations and during all monitoring periods, indicating that mule deer have adapted quickly to these mitigation features.

Landscape factors may influence wildlife crossing structure use. Given the relatively homogenous nature of the project area (rolling terrain and sagebrush vegetation) and that the structure designs for the two overpasses and five underpasses were the same throughout the project, spatial variations in mule deer use of crossing structures may be due to a combination of factors, such as the location of each structure relative to where mule deer wintered, local terrain features at each structure, winter severity and snow accumulations, or variability in mineral composition and forage quality (e.g., Peterson 2008). A comparison of mule deer activity at overpass structures versus underpasses in the project area further suggest a leveling out of mule deer activity based on structure type. Whereas in Winter 2016-17 overall mule deer success movements were 138% greater at overpass structures than at underpasses on a per unit basis, in Winter 2017-18 success movements at overpasses were only 34% greater than at underpasses on a per unit basis. Overall, mule deer success movements were high at overpasses and underpasses, and both structure types appear to function well for mule deer passage within the project area. Mule deer were also documented making success movements at all three small culverts (*n*=17), although the majority of mule deer approaches to small culverts were parallel (*n*=46) or repel movements (*n*=39).

Mule Deer Preferences with Respect to Gender and Age Class

Gender and age status appeared to affect mule deer use of underpass versus overpass structures, Male mule deer may have a potential preference for underpass structures – while buck movements comprised 11-24% of total mule deer movements at the five underpass structures, bucks were only 4-7% of movements on the two overpasses. In Year 3, the research team began recording fawns as a separate category. Accordingly, the percentage of deer categorized as unknown gender decreased in Year 3. Fawn movements were recorded at all of the crossing structures and were highest at the BVA underpass (*n*=1,127) and the North Overpass (*n*=734) and lowest at the North Underpass (*n*=170). The final report for this study will compare the ratio of bucks and does in the population to the buck:doe ratios at the crossing structures, based on photographic data taken from when antler growth is sufficient to determine gender.

The Diversity of Species

Movements by other ungulate species occurred in much lower numbers than mule deer. Success movements by species such as bighorn sheep, moose and pronghorn increased from Year 2 to Year 3 but decreased slightly for elk and white-tailed deer. These numbers reflect the relative proportion of these species in this landscape but are expected to increase through the duration of this research as individual animals become more comfortable with the crossing structures and as more individuals learn to use the structures. Overall success rates at wildlife crossing structures for these ungulate species ranged from 87% for moose (*n*=38); 91% for elk (*n*=76); 92% for white-tailed deer (*n*=39); 98% for pronghorn (*n*=52); and 100% for bighorn sheep (*n*=13). Success movements by other large and medium-sized mammals were also detected at all the wildlife crossing structures.

Elk were photographed primarily in the northern portions of the study area, with the highest number of elk detected at the North Overpass (*n*=30). In the Phase 2 segment, elk were only documented at the South Overpass (*n*=4). In pre-construction monitoring, the greatest number of elk were documented in the Phase 2 segment (*n*=66) and only one elk was detected in the Phase 1 segment. Elk were not detected as often at the cameras in Year 3 when compared with the previous year and winter. In Year 3, 32 elk were detected, but none occurred during the winter months, whereas in Year 2, 34 elk were detected, and 22 of those were during the winter months. Notably, Winter 2017-18 was a mild winter and fewer elk may have been present on winter range in the lower Blue River valley. The majority of elk success movements at crossing structures have been made by individual animals or, in some cases, small groups of up to four animals. Across crossing structure locations, elk have used overpasses and underpasses in nearly equivalent numbers (n=32 and n=37, respectively), although underpass structures outnumber overpasses in the study area. At this stage of the research and given the low amount of overall elk activity and the complete absence of larger groups of elk at the crossing structures, a preference for underpasses versus overpasses cannot be assessed.

Since the onset of this research, pronghorn and white-tailed deer were documented using only underpass structures, although the overall number of movements by these species are still low (*n*=52 and *n*=39, respectively). Both species have been detected by the habitat camera at the North Overpass, although neither has been observed using the structure. Moose and bighorn sheep successfully used both underpass and overpass structures throughout the study area. Moose used overpasses 10 times, and underpasses 21times. Moose movements were most common in the northern portion of the project area, with the most success movements occurring at the North Overpass and North Underpass. Bighorn Sheep movements were most common in the southern portion of the study area with most movements occurring at the South Overpass and the Williams Peak Underpass. Bighorn sheep used both overpasses a total of eight times and used underpass structures five times. Success movements at the crossing structures by bighorn sheep included both movements by individuals and use by a family group, documenting use by both genders and all age groups.

In addition to ungulates, a diversity of carnivore species was also photographed using the crossing structures and provide some evidence of taxa-specific preferences. Coyote and red fox were the only species other than mule deer documented using every crossing structure. The high number of coyote passages at the South Overpass (*n*=420) may suggest that one or several individuals have incorporated the overpass into their home ranges and are making regular movements to either side of the highway, although such use cannot be confirmed by this study.

Black bear activity was concentrated at the Middle Underpass, with 106 success movements – it is likely these were primarily by the several individuals moving regularly back and forth at this location. This structure is located in an ephemeral drainage with a more diverse and complex vegetation component than the other crossing structures. This diversity may help explain why this structure had the highest level of carnivore species use of all the structures. No black bear movements were detected at either of the overpass structures, suggesting a potential preference for the underpass structures.

Success movements at the small culverts were made primarily by carnivore species, including black bear, bobcat, coyote and red fox. The greatest species diversity is documented at the Culbreath Box culvert; however, the greatest number of success movements occurred at the BVR Box Culvert (*n*=94, including black bear, bobcat, coyote and mule deer). Domestic cats and dogs were most commonly photographed using the Culbreath Box Culvert, which is near a private ranch and home site, and may affect wildlife use of this culvert.

Wildlife Activity at Other Mitigation Features

Wildlife Guards

From Year 2 to Year 3, the total number times mule deer attempted to breach the wildlife guards decreased by 30% and the number of successful breaches decreased 68% to a total of 23 breaches at all guard types. In Year 3, breach rates were nearly the same at both guard types (9% for round bar guards and 8% for flat bar guards), although the total number of breaches by ungulate species was higher at round bar guards (*n*=20) than at flat bar guards (*n*=9). In addition, regardless of guard type, jumping the guard was the most common method of breaching a guard, both in the general analysis and in the paired guard analysis. In contrast with Year 2, walking on snow packed in-between the bars was the most common method of breaching a guard, yet in Year 3, no breach events of this type were recorded. This may be attributed to more mild winter conditions or to conversations with plow drivers to bring their attention to this issue. In the Year 2 progress report the authors speculated that the round bars may prevent deer from breaching by walking on top of the bars. However, in Year 3, four breach movements were documented of deer walking on top of the round bars and two of deer walking on the support beams, despite the presence of angle iron on the support beams of the round bar guards.

Carnivore species continued to have the highest breach rates regardless of guard type. The wildlife guards are designed to primarily target ungulates (the species most frequently involved in WVC) to prevent them from entering the fenced right-of-way, and breaches by non-ungulate species are unsurprising, as their paws can more easily traverse the guards. In addition, these species were more likely to be documented breaching the guards both to get into or out of the right-of-way.

Escape Ramps

While fewer mule deer movements were detected in Year 3 than in Year 2 inside of the right-of-way at the escape ramps and no elk movements were detected, there were still 279 mule deer movements at the ramps in Year 3, demonstrating that animals continued to get on the right-of-way side of the wildlife exclusion fence. Mule deer were documented at all 11 monitored ramp locations across the project area in Year 3, suggesting that there were multiple points of entry into the fenced right-of-way in different portions of the project area.

Overall, there was a large variation in mule deer activity (n=1–135) and intercept rates (0-100%) by location. Ramps without perpendicular rail fence had a higher intercept rate (61%) than ramps with perpendicular rail fence (36%), while ramp slope appeared to have less influence on mule deer intercept rates. As elk were not detected at most ramps and were only present in high numbers at one escape ramp, ramp location relative to elk presence in the landscape appears to be the greatest factor influencing intercept rates for elk.

Mule deer and elk escape rates off the ramps were comparatively low, and results were mixed with respect to the two different slope designs and the presence of perpendicular rail fences. The presence of perpendicular rail fence regardless of ramp slope did not have a discernable influence on escape rates for mule deer as both ramps with and without rail fence had escape rates of 13%. However, in the paired ramp analysis, both intercept rates and escape rates for mule deer were higher at the two new 3:1 slope ramps without rail fence than at the two older 2:1 slope ramps with rail fence. Overall, these preliminary results suggest that multiple variables may influence both intercept rates and escape rates, including 1) species; 2) species activity in the landscape; 3) ramp location; 4) landscape situation relative to the roadway; 5) ramp slope; and 6) presence or absence of perpendicular rail fence. These variables will continue to be evaluated through this research.

The number of times mule deer and elk used the monitored escape ramps to escape to the habitat side of the wildlife exclusion fence, (*n*=53), was a small fraction of the total number of times they were photographed at the ramps in the right-of-way (n=816). These results are typical of other study results (Cramer, unpublished data; Arizona Game and Fish Department, unpublished data). As time goes on, mule deer and elk may adapt to the ramps and use them more often, but the best result would be a lowered number of deer in the right-of-way.

In addition to mule deer and elk, bighorn sheep, moose and white-tailed deer were documented by the cameras on the habitat side of the fence line. The high number of parallel movements by these species indicate that animals had many opportunities to breach the wildlife exclusion fencing by jumping up from the back side of a ramp, but no such attempts were made, suggesting that the ramp height of six feet is sufficient in discouraging a jump up attempt by deer or elk. However, given the low escape rates even at ramps with higher intercept rates, the six-foot ramp height may be too high to encourage successful escapes.

South Fence End

Mule deer and elk movements captured by the cameras at the fence end indicate there may still be a problem with animals moving into the fenced right of way section of the highway, and with animals in this area finding and using the wildlife crossing structures farther to the north. The total number of ungulate movements at the south fence end increased 40% from Winter 2016-17 to Winter 2017-18. While the total number of ungulate movements into the fenced right-of-way were low in Winter 2017-18 (*n*=34), in Winter 2016-17 there were only nine such movements, representing a 278% increase. More mule deer were documented entering the fenced right-of-way than were captured exiting it, although some of these movements in both directions appear to have been made repeatedly by the same individuals.

As in the previous year, the vast majority of ungulate movements at the south fence end occurred beyond the fence end (91%); that is animals that approached and potentially crossed the highway at-grade without entering into the fenced right-of-way. Most of these movements were made by mule deer (*n*=619), although elk were also photographed beyond the fence end (*n*=95). In several cases, the cameras documented a group of animals approaching the road and repelling several times before either finally making a successful at-grade highway crossing or completely repelling from the highway.

Ongoing and increasing ungulate activity at the south fence end may indicate that wildlife-highway mitigation is not fully capturing the wildlife crossing zone on SH 9. These findings are consistent with CPW's understanding of wildlife movements in the lower Blue River valley prior to the mitigation construction; however, there was no obvious location for an additional wildlife crossing structure south of this location, so the design team opted to end the wildlife fence at MP 126.6 rather than risk blocking wildlife movements with additional wildlife exclusion fencing along this section of SH 9.

Wildlife-vehicle Collisions

Each of the WVC carcass and accident datasets demonstrate a decreasing trend in WVC following the completion of mitigation construction in the SH 9 project area, although accident data through Winter 2017-18 are not yet available from CDOT Traffic and Safety. Within the project area, WVC carcasses decreased 89% in Winter 2017-18 compared to the five-year pre-construction average (based on BVR/CPW carcass data). This decrease is slightly greater than the 86% decrease reported the previous winter. These results support the assertion that wildlife crossing structures and other mitigation features have been effective in reducing WVC along SH 9, while also providing wildlife connectivity across the highway.

The BVR/CPW carcass reporting is the only source to document WVC carcasses inside the project area during Winter 2017-18. No WVCs were documented in either the CDOT

Maintenance carcass dataset or the CDOT Traffic and Safety accident database. However, as described in the Year 2 progress report (Kintsch et al. 2018), only 18% of the WVC carcasses recorded by BVR/CPW were captured in Traffic and Safety accident reports, and 68% were captured in the CDOT Maintenance carcass database.

The CDOT Maintenance carcass databased demonstrates that WVCs continued to occur beyond the fence ends, particularly south of the project area, but do not appear to be increasing. These results may suggest that wildlife-highway mitigation on SH 9 is not completely capturing the WVC hotspot. Still, there was no increase in WVC carcasses at the south fence end and terminating the mitigation at this location does not appear to have affected WVC rates south of the project area. Further analysis through the next two years of this research study will help to determine whether there are additional mitigation needs south of the project area.

As of Year 3 of this research, the wildlife-highway mitigation on SH 9 does not appear to be influencing WVC rates on US 40. Wildlife-vehicle collision carcasses on US 40 were relatively high in Winter 2010-11 and again in Winter 2015-16, the latter timeframe corresponding with construction of Phase 1 mitigation on SH 9. However, in Winter 2016-17 and Winter 2017-18 WVC rates on US 40 dropped again. These variations in WVC rates on US 40 may be due to a number of factors, such as annual weather and snow depths, traffic volumes and human activity in the landscape.

Next Steps

The results from the first three years of monitoring on SH 9 are promising and several performance measures for the mitigation project regarding mule deer use of crossing structures have already been achieved. Other objectives, for example, regarding elk use of crossing structures or mule deer use of escape ramps, have not yet been achieved, but will continue to be monitored and evaluated. The research team will continue post-construction monitoring through Winter 2019-20 and will continue to provide recommendations to adaptively manage the mitigation as appropriate. The results of this study are expected to inform future wildlife-highway mitigation projects in Colorado and beyond.

References

Kintsch, J., P. Cramer, P. Singer, M. Cowardin, and J. Phelan. 2018. State Highway 9 wildlife crossings monitoring year 2 progress report. Study Number 115.01. Applied Research and Innovation Branch, Colorado Department of Transportation, Denver, CO.

Peterson, C.C. 2008. Conservation implications of winter-feeding policies for mule deer in Utah. PhD Dissertation, Graduate School of Utah State University. Paper 108.

APPENDICES

Appendix A: Monitoring Methods

Mitigation effectiveness was measured with two general types of measures: the number of movements made by mule deer, elk and other wildlife through the crossing structures and success vs. repel rates for each species; and the reduction in WVC. The research methods used to evaluate these measures are presented below.

Camera Monitoring

Monitoring locations are listed in Table 1; Figures 1 & 2 depict the locations of all monitoring sites across the project area. Monitoring was conducted in three discrete phases:

Pre-construction: From November 2014 to the onset of mitigation construction in April 2015. Pre-construction camera monitoring was conducted by CPW at all crossing structure locations. At each location, a camera was set up on either side of the highway.

Pre-completion: From the onset of this research study (December 2015) through the completion of Phase 2 construction (November 2016). Pre-completion monitoring involved the deployment of 40 cameras at 24 locations. Pre-completion monitoring was conducted by the ECO-resolutions team with support from CPW.

Post-construction: Following the completion of all construction activities (December 2016) through Winter 2019-20. During Year 3, post-construction monitoring involved the deployment of 62 cameras at 49 locations. Post-construction monitoring is being conducted by the ECO-resolutions team with support from CPW.

Monitoring was conducted using motion-triggered Reconyx Professional Series cameras (PC800 and PC900). 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. All cameras were codelocked 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 continued triggering as long as movement was detected. Exceptions were at wildlife guards with heavy traffic, where cameras were set to 3 or 5 photos per trigger and were scheduled to trigger only between before dusk to after dawn (from 4:30pm to 8am).

Fourteen pre-construction cameras documented species presence and relative abundance of non-mule deer species at future wildlife crossing locations during Winter 2014-15. At each future structure location, a camera was deployed on either side of SH 9 approximately 50' (15 m) from the highway. Prior to the construction of the wildlife crossing structures and wildlife exclusion fence, wildlife could cross SH 9 at any point along the highway rather than at discrete crossing locations. Therefore, pre-construction monitoring could only capture a snapshot of this dispersed wildlife activity near the roadway. The objective of pre-construction monitoring was to compare species that were present near the roadway prior to mitigation construction with their relative abundance post-mitigation construction. Accordingly, species presence for all non-mule deer species was tallied without a categorization of animal behavior. Movements across SH 9 or repel movements from the highway right-of-way were not captured in pre-construction monitoring.

For post-construction monitoring, cameras were set up at each monitoring location 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 success movements (passage through a crossing structure) 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 from the structure entrance, directed toward the habitat facing away from the road (Fig. A-1). The two overpass structures have steep entrance slopes leading to the top of the structures, so in addition to the two cameras on top of each structure, additional cameras were placed at the bottom of the slopes on either side of the structure. These 'entrance' cameras were more likely to capture repels and parallel movements, while the structure cameras could be used to confirm through-passage. Habitat cameras were placed on each side of the overpass facing outward to capture wildlife movements in the adjacent habitat.

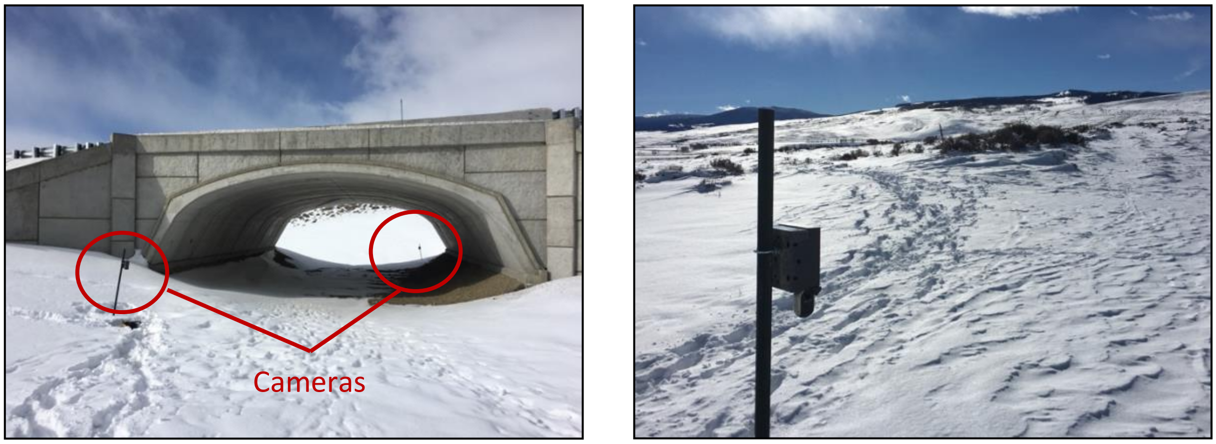

Figure A-1. Two cameras were positioned at each underpass at opposite corners (left). Habitat camera placed 50-100 feet in front of a structure, facing out into the adjacent habitat (right).

Cameras at other monitoring locations were positioned to capture specific wildlife behaviors. At wildlife 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). All wildlife guard cameras were set to 5 pictures per trigger and locations with high vehicular traffic were programmed to be off from 8am – 4:30pm Mountain Standard Time year-round.

Cameras were deployed at 13 wildlife guard locations for varying amounts of time. Flat bar guards were installed at all locations during Phase 1 construction. In Phase 2, round bar guards were installed at five locations, including replacement of two flat bar guards that had been previously installed in the Phase 1 segment. Flat bar guards were installed at all remaining sites. Four round bar wildlife guards were installed at locations in close proximity to flat bar wildlife guards. These parings will help in evaluating wildlife responses to the wildlife guards where the motivations for breaching or repelling from the guards are expected to be similar, thereby helping to minimize confounding factors that may influence guard effectiveness. Wildlife guards are just under 16' long with the bars spaced 4" apart, and of varying widths, corresponding to the width of the road or driveway. The size of the wildlife guards and the spacing between bars is the same for both the flat bar and round bar designs.

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. Through Year 3, 13 escape ramps have been monitored for varying lengths of time. In the Phase 1 (north) segment, all ramps were constructed with a 2:1 slope and perpendicular rail fence, except for the North Overpass Escape Ramp, on which rail fence was not constructed. Based on preliminary observations and recommendations by the research team, during Phase 2 construction all ramps were constructed with a 3:1 slope instead of a 2:1 slope (Fig. 24). In general, ramps were constructed with perpendicular rail fence, except for select locations where rail fence was omitted per the request of the researchers, who wanted to evaluate the effectiveness of ramps with and without perpendicular rail fence. In addition, two new 3:1 slope escape ramps were constructed in the Phase 1 segment near existing 2:1 slope ramps. These two ramps are also situated at lower topographic positions relative to the roadway, while the 2:1 slope ramps are at higher topographic positions above the roadway. All of the ramps built in both construction phases are six feet high at the jumping off point, with a 16' wide fence gap.


Figure 30. Example of an escape ramp with a 2:1 slope with perpendicular rail fence (left) and a ramp with a 3:1 slope with no rail fence (right).

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.

Photo Analysis

Cameras were visited every 4-5 weeks during the winter months and every 6-8 weeks the rest of the year to exchange memory cards and batteries. Photo data were systematically processed to identify movement events every time a camera is triggered. Events are defined by the movements of individuals or groups at crossing structures, wildlife 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 their gender (if possible), 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 either headed in a direction beyond the structure entrance or were 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.

Numbers for all non-mule deer species were tallied at the habitat cameras directed toward the habitat facing away from the road. 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 only meant to document species presence and abundance, the photos are analyzed without a categorization of animal behavior.

Three small culverts were monitored, including two 8’ x 8’ box culverts and one 8’ diameter concrete pipe culvert. The pipe culvert also had an open-top concrete trench at the outlet, effectively increasing the structure length. One camera was placed at either the east or west entrance of each culvert. Success movements at small culverts were tallied when an animal entered and did not reemerge from the culvert within 15 minutes, or when an animal emerged from the culvert without previously having entered it.

At wildlife 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 from the habitat side of the guard into the highway right-of-way or vice versa. At escape ramps, four different types of movement were recorded, 1) animals walking along the fence line inside the right-of-way that did not ascend (intercept) the ramp, but instead walked around the base of the ramp; 2) animals that ascended the ramp and then turned back down the ramp inside the right-of-way; 3) animals that ascended the ramp and jumped down (escaped) to the habitat side; and 4) animals that attempted to climb or jump up to the top of the ramp from the habitat side. 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*.

- **Success 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 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 wildlife 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.
- **Intercept rate** –This metric is calculated for deer and elk at escape ramps. It is the total number of times deer/elk were recorded ascending an escape ramp divided by the number of times deer/elk approached an escape ramp.
- **Escape 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 wildlife guards, escape ramps, pedestrian walk-through gates, and fence ends. It is the total number of times individual deer/elk breached the mitigation feature divided by the total number of times deer/elk approached that mitigation feature. For example, at a wildlife 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 (not individuals) 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 of 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 wildlife 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 patrols; 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. To complement these data, in 2013 CPW also began collecting carcass data south of Spring Creek Road to the southern end of the project area (MP 126). Carcass data were collected daily from November through April, when WVC are most common, with incidental reports compiled through the remainder of the year. Data collection included all species, with a focus on ungulates and large and medium-sized animals.

CDOT maintenance patrols have been recording carcasses due to WVC since 2005. Carcass reporting by maintenance personnel is non-compulsory. It is likely that reporting effort in the first years of the program was inconsistent. As the program became more established, reporting effort is believed to have become more consistent. WVC carcass pickups are reported year-round for all species, although the majority of carcass reports are deer and elk.

The study is also examining WVC accident reports compiled by CDOT Traffic and Safety. Wildlife-vehicle collision crashes, while underreported, are reported statewide and offer a useful standard for comparing WVC accident rates inside the project area with those outside of the project area pre- and post-mitigation construction. The Year 3 progress report includes WVC accident data analysis through April 2017, as data for late 2017 and 2018 were not available at the writing of this report.

Winter was defined as the months of December through April for all analyses. Analyses of all three datasets focused on the winter timeframe; however, non-winter months were included in the analysis of reported WVC accidents to demonstrate the seasonality of WVC in the project area. Each WVC dataset was 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 WVC averages (Winter 2010-11 through Winter 2014-15) for each dataset with post-construction WVC rates.

Because CDOT maintenance reports are collected statewide, this dataset was selected for additional analyses of SH 9 one mile north and south of the project area and on a nearby segment of US 40 to identify a potential influence of the project on WVC rates beyond the project area. Both segments of highway are maintained by the same CDOT patrol eliminating potential data collection variations that may occur between patrols. Comparing WVC rates inside the project area with those beyond the project area, but within habitat used by the same ungulate herds and affected by the same weather patterns, helped the researchers to generalize reasons for potential changes in WVC in time and space, and the extent to which these changes may be due to the mitigation project. 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 wildlife mitigation system on SH 9 is evaluated with respect to wildlife connectivity and traffic safety. Specifically, wildlife connectivity performance measures address how well the crossing structures allow wildlife populations to access habitat on both sides of the highway; and traffic safety performance measures address how well the mitigation reduced WVC. Performance measures were generated by the researchers in conjunction with the research Study Panel.

The research team and study panel re-evaluated the performance measures following the first winter of post-construction monitoring (Winter 2016-17) in light of preliminary research results and recently published reports from comparable studies. No alterations were made to success thresholds established in Year 1 of the study. The team considered adding a measure evaluating intercept rates at escape ramps, but ultimately declined to do so; however, the team will report on intercept rates and escape rates at escape ramps. Performance Measure #12, which evaluates pedestrian walk-through gates, was eliminated as the walk-through gates were closed off with swing gates in Fall 2017. The research team observed deer breaching the gates – in some cases moving back from the ROW side to the habitat side, as well as breaches into the ROW – and CPW determined that these gaps should be closed. No additional changes to the performance measures will be made for the duration of the study to ensure that the measures remain unbiased by the study results.

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 on 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 (other than deer and elk) 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 bighorn sheep, pronghorn, moose, white-tailed deer (Odocoileus virginianus)*, 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, elk and other ungulate approaches to each wildlife guard will be deterred from entering the road right-of-way (based on Utah – Cramer and Flower 2017; Flower 2016).

11. By the end of the study, 50% of the individual mule deer and elk that ascend an escape ramp will escape to the habitat side, and no animals will jump up onto the ramp from the habitat side. (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 performance measure will no longer be evaluated. In Year 2, breach rates for mule deer at the pedestrian walk-through gates ranged from 5-21% (Kintsch et al. 2018). In total, 32 breaches were made by mule deer and 2 by elk out of total of 304 and 47 movements, respectively. CPW determined that these breaches – and potential WVC – could be eliminated entirely with the installation of swing gates across the gate openings. By September 2017, all of the pedestrian walk-through gates in the project area were equipped with swing gates to block ungulate movements and monitoring activities ceased at these locations.

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).

Appendix A References

Clevenger, A.P. and M. Barrueto (eds.). 2014. Trans-Canada Highway wildlife and monitoring research, final report, part B: Research. Report to Parks Canada, Radium Hot Springs, British Columbia, Canada. Summary of 17 years of wildlife-highway mitigation research on the Trans-Canada Highway.

Cramer, P. 2016. US 89 Kanab-Paunsaugunt Wildlife Crossings and Existing Structures Research Project 2016 Spring Report to Utah Department of Transportation. October 2016. 45 pp.

Cramer, P. 2014. Wildlife crossings in Utah: determining what works and helping to create the best and most cost-effective structure designs. Report. Utah Division of Wildlife Resources, Salt Lake City, Utah.

Cramer, P. 2012. Determining wildlife use of wildlife crossing structures under different scenarios. Final Report to Utah Department of Transportation, Salt Lake City, UT. 181 pp.

Cramer, P. and J. Flower. 2017. Testing new technology to restrict wildlife access to highways. Report No. UT-17.15 Utah Department of Transportation, Salt Lake City, UT. 59 pp.

Cramer, P. and R. Hamlin. 2016. Evaluation of wildlife crossing structures on US 93 in Montana's Bitterroot Valley. MDT # HWY – 308445-RP. Final Report to Montana Department of Transportation, Helena MT.

Dodd, N. L., J.W. Gagnon, K.S. Ogren, and R.E. Schweinsburg. 2012. Wildlife-vehicle collision mitigation for safer wildlife movement across highways: State Route 260. Final report from the Arizona Game and Fish Department to the Arizona Department of Transportation. Final Report 603. 134 pp.

Flower, J.P. 2016. Emerging technology to exclude wildlife from roads: Electrified pavement and deer guards in Utah, USA. Master's Thesis. Utah State University, Logan, UT. 130 pp.

Gagnon, J.W., N.L. Dodd, K.S. Ogren, and R.E. Schweinsburg. 2011. Factors associated with use of wildlife underpasses and importance of long-term monitoring. Journal of Wildlife Management, 75 (6):1477-1487.

Gagnon, J., C. Loberger, S. Sprague, K. Ogren, S. Boe, and R. Schweinsburg. 2015. Cost-effective approach to reducing collisions with elk with fencing between existing highway structures. Human-Wildlife Interactions. 9(2):248-264.

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament, and P.T. McGowen. 2009. Cost-benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada: a decision support tool. Ecology and Society 14:15.

Kintsch, J., P. Cramer, P. Singer, M. Cowardin, and J. Phelan. 2018. State Highway 9 wildlife crossings monitoring year 2 progress report. Study Number 115.01. Applied Research and Innovation Branch, Colorado Department of Transportation, Denver, CO.

McAllister, K., M. Reister, R. Bruno, L. Dillin, D. Volsen, and M. Wisen. 2013. A wildlife barrier fence north of Wenatchee, Washington: learning experience involving rugged country and custom designed wildlife guards and jumpouts. Proceedings of the 2013 International Conference on Ecology and Transportation. Retrieved from http://www.icoet.net/ICOET_2013/proceedings.asp

Purdum, J.P. 2013. Acceptance of wildlife crossing structures on US Highway 93, Missoula, Montana. Master's Thesis. University of Montana, Missoula, MT.

Sawyer, H., C. LeBeau, and T. Hart. 2012. Mitigating roadway impacts to migratory mule deer – a case study with underpasses and continuous fencing. Wildlife Society Bulletin 36(3):492-498.

Siemers, J. L., K.R. Wilson, and S. Baruch-Mordo. 2015. Monitoring wildlife-vehicle collisions: analysis and cost-benefit of escape ramps for deer and elk on U.S. Highway 55. Report No. CDOT-2015-05. Colorado Department of Transportation, Denver, CO. 45 pp.

Appendix B: Pre-Construction Monitoring Results

Mule deer were observed at all locations during pre-construction monitoring. Given their pervasiveness in the project area, mule deer presence and abundance was not tallied. Of all other wildlife species, elk and coyote were the most commonly documented species (Table B-1). Elk were most common in the southern portions of the project area, at the future sites of Williams Peak Underpass and the South Overpass. In the northern portion of the project area, bobcat was the most commonly documented species (other than mule deer) and occurred only at the future North Underpass site. Other species detected during pre-construction monitoring included red fox, American badger, hare/rabbit, striped skunk, and domestic dogs and cats.

Table B-1. Wildlife presence by species other than mule deer during pre-construction at future wildlife crossing structure locations. Pre-construction monitoring was conducted at all locations from November 2014 – March 2015. Additional pre-construction monitoring was conducted in the Phase 2 (south) segment during Winter 2015-16.

Monitoring Location	Elk	Moose	Pronghorn	Mountain Lion	Bobcat	Coyote
Phase 1 (North) Segment						
MP 136.0 – North Underpass	1	0	0	0	26	10
MP 134.3 – North Overpass	0	0	0	0	0	0
MP 132.5 – Middle Underpass	0	0	0	0	0	0
MP 131.6 – Harsha Gulch Underpass	0	0	0	0	0	3
Total Non-Mule Deer Wildlife	**1**	**0**	**0**	**0**	**26**	**13**
Phase 2 (South) Segment						
MP 130.8 – BVA Underpass	0	1	0	2	1	8
MP 129.5 – South Overpass	25	0	1	0	1	50
MP 127.7 – Williams Peak Underpass	41	0	0	0	0	8
Total Non-Mule Deer Wildlife	**66**	**1**	**1**	**2**	**1**	**66**