STATE HIGHWAY 9 WILDLIFE CROSSINGS MONITORING – YEAR 4 PROGRESS REPORT

December 2015 through April 2019

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Applied Research and Innovation Branch

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Cover photos (clockwise from upper left): Pair of river otters at the North Underpass; Herd of mule deer crossing over the North Overpass; Mule deer selfie at the BVR Box Culvert; Herd of elk crossing through the North Underpass; Mule deer with nursing fawn at the North Underpass.

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Executive Summary

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 across the highway. This research study evaluates the effectiveness of the mitigation infrastructure through the use of motion activated cameras and analyses of wildlife-vehicle collisions (WVC) carcass and accident data. The study maintained a total of 62 motion-triggered cameras at 49 locations through Year 4 (Winter 2018-19) to record animal movements and behavioral responses to the mitigation including the five wildlife underpasses, two wildlife overpasses, wildlife guards, escape ramps, and the south fence end. The Year 4 Progress Report focuses on the results of post-construction monitoring from December 2015 through April 2019.

Mule deer success movements through or over the crossing structures increased each year, totaling 83,256 mule deer success movements since the start of this research (Fig. E-1). Combined with an overall mule deer success rate of 96%, these results indicate that the mitigation has been highly effective in accommodating mule deer movements and may have increased connectivity for mule deer across SH 9 to a higher level than prior to the construction of the wildlife crossing structures. In Year 4, 'winter' was redefined to include November through April (instead of December – April), thereby altering the presentation of each year's results from what was reported in previous progress reports. Accordingly, in Winter 2018-19, the total number of mule deer success movements increased by 58% relative to the Winter 2017-18, and by 36% in Winter 2017-18 relative to Winter 2016-17, the first winter post-construction.

Across the study area, mule deer made an average of 168 success movements over and through the seven crossings each day during Winter 2018-19. Notably, these success movements represent a portion of the number of potential WVCs that were avoided each day had the mitigation project not been implemented. Both the overpass structures and the underpass structures appear to function well for mule deer passage within the project area; while the total number of success movements was higher at the five underpass structures than at the two

overpass structures, on an average per unit basis, mule deer use of an overpass structure was higher than use of an underpass structure. In this study, landscape factors, including the distribution of species within winter range, may play a greater role influencing the use of the wildlife crossings by mule deer and other species than structure type.

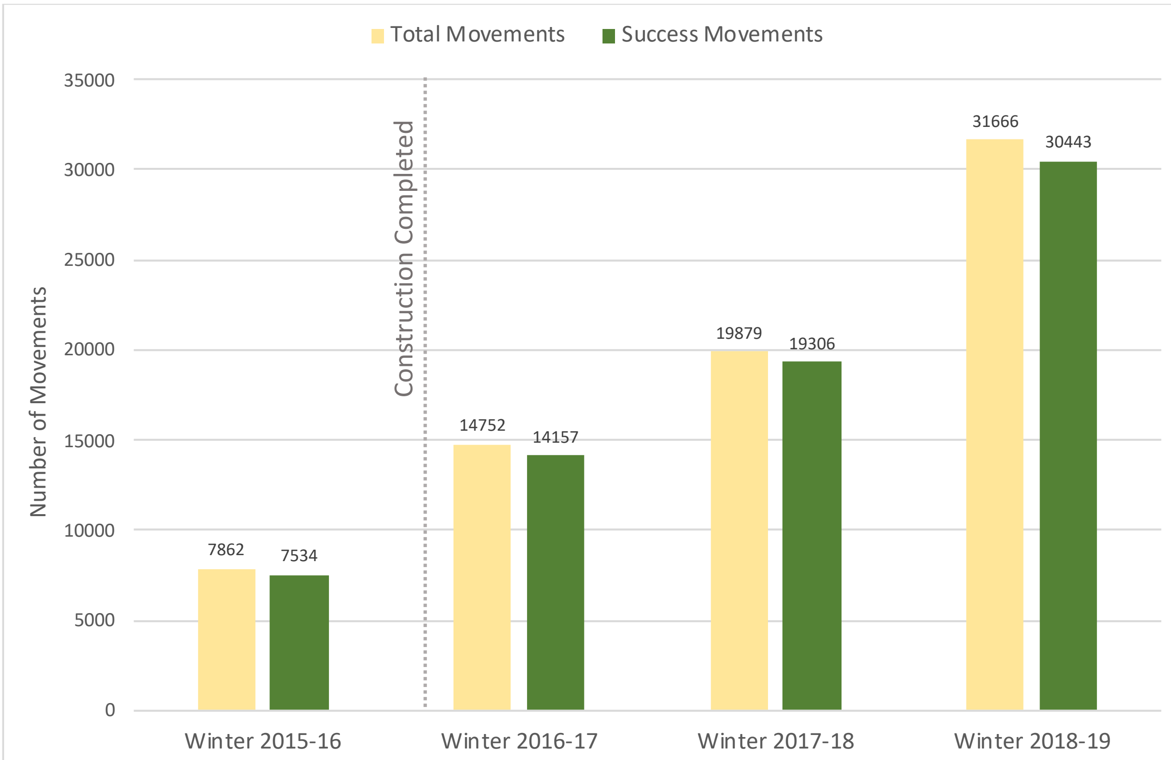

Figure E-1. Total number of mule deer movements and successful movements at crossing structures during each winter of the research. In Winter 2015-16, only the northern portion of the project area was constructed and monitored.

Success movements by elk, pronghorn, moose, bighorn sheep, and white-tailed deer occurred in much lower numbers than mule deer, but generally increased each year of the research. These numbers reflect the relative proportion of these species in this landscape but are expected to continue increasing as more individuals learn to use the structures. The success rates for these ungulate species were 88% or greater in Year 4. In general, elk, moose, pronghorn and white-tailed deer each made more success movements at the underpass structures, while bighorn sheep used underpasses and overpasses in nearly equal numbers. In Winter 2018-19, for the first time, small herds of up to 17 elk were detected at the North Underpass. In each of these events, individuals were hesitant to use the structure but ultimately crossed through, suggesting that the elk were still adapting to the structure.

A diversity of carnivore and other species were also photographed using the crossing structures and provide some evidence of taxa-specific preferences. Black bear, bobcat and mountain lions appeared to prefer the underpass structures. Overall success rates for all non-ungulate species documented at the wildlife crossing structures (including badger, black bear, bobcat, coyote, mountain lion, raccoon, red fox, and striped skunk) ranged from 71% for badger up to 99% for black bear. In addition, river otter and turkey were detected successfully using the crossing structures for the first time in Year 4.

Researchers also evaluated the effectiveness of two different wildlife guard designs (round bar and flat bar). Overall, the wildlife guards deterred ungulates from entering the fenced right-of-way 85% of the time. For all ungulate species the round bar guards were more effective (90%) than the flat bar guards (80%) in preventing animal incursions into the fenced right-of-way.

The project includes multiple escape ramps that provide a one-way escape for wildlife that become trapped on the highway side of the fence. Researchers monitored intercept and escape rates for five escape ramp designs. The overall intercept rate for mule deer and elk combined was 50%, regardless of ramp type, while the overall escape rate was 12%. In general, ramps without perpendicular rail fence had the highest intercept rates (59%). While escape rates were low across all locations regardless of ramp type, 3:1 slope ramps without rail fence had the highest number of successful escapes for both elk and mule deer.

The wildlife mitigation also successfully decreased WVCs, based on reported accidents and carcass counts. Post-construction reported WVC accidents decreased 88% relative to pre-construction levels and carcass counts decreased 90%. Figure E-2 demonstrates the trend of decreasing WVC carcasses since the mitigation construction was completed relative to the five-year pre-construction average of 62.8 carcasses each winter – from 13 carcasses in Winter 2016-17 (79% decrease) to 9 carcasses in Winter 2017-18 (86% decrease) and 6 carcasses in Winter 2018-19 (90% decrease – note, these number are different from what was reported in previous progress reports because of the revised definition of 'winter' as November through April). This 90% decrease in WVC carcasses suggests that roughly 170 WVCs have been prevented in the three years since construction was completed, relative to the pre-construction average. WVC continue to occur beyond the project area, south of the fence end where ongoing ungulate activity indicates that the wildlife-highway mitigation is not fully capturing the wildlife movements across SH 9.

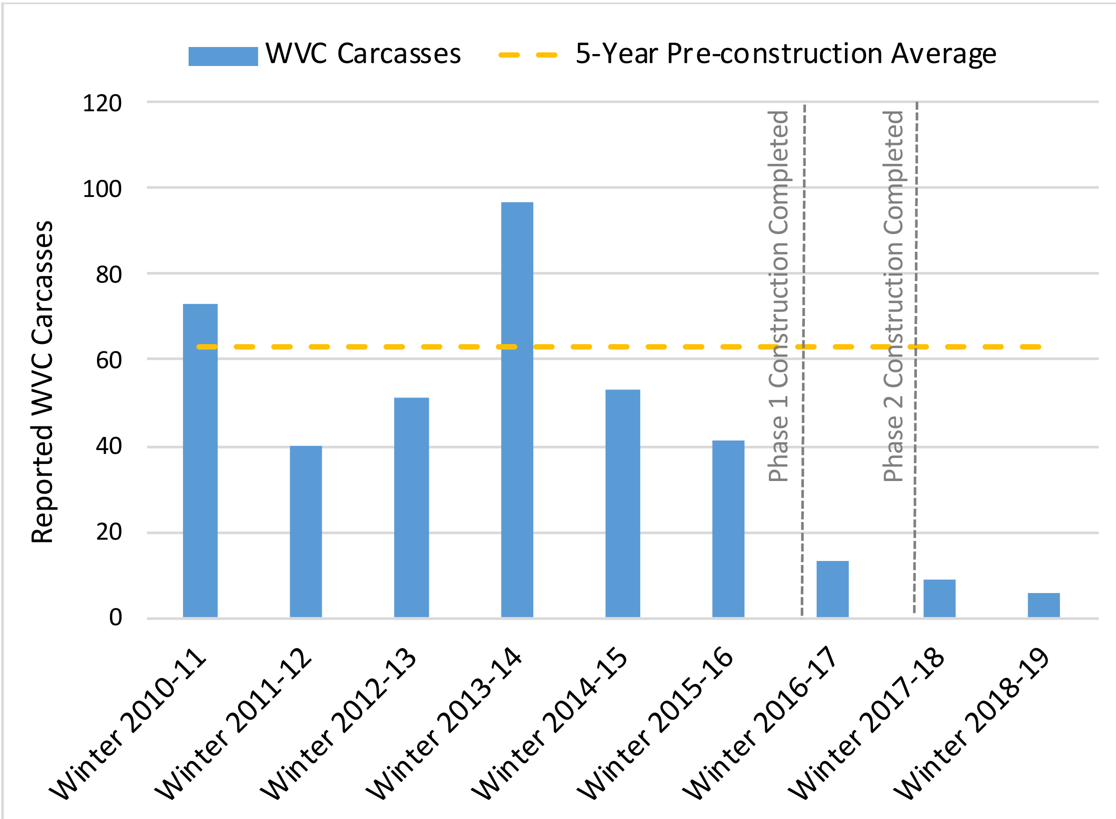

Figure E-2. Mule deer and elk carcass counts recorded by BVR and CPW compared to the five-year pre-construction average of 62.8 carcasses per winter. The carcass counts reported here differ from what was reported in previous progress reports because of an updated definition of 'winter' to include the month of November. These data were not collected consistently through the non-winter months.

The SH 9 mitigation project has met or exceeded most performance measures established at the outset of this research, both in terms of wildlife use of the crossing structures and reduction in WVC. The efficacy of the mitigation project with respect to all performance measures is discussed in this progress report and will continue to be evaluated through April 2020. The researchers will continue to work with CDOT and CPW to use these research results to adaptively manage the mitigation and 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 River 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 (November 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, 62 WVC accidents with mule deer or elk were reported, 2 resulting 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 314 WVC mule deer and elk carcasses – five times 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 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 2019.

Research Objectives

The following research objectives were established by the Study Panel for the five-year 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 (i.e., success 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-construction to post-construction crossing patterns.
8. Compare construction phase 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. A notable update for the Year 4 progress report relates to the definition of 'winter'. Previous progress reports used a definition of winter that included only December through April, in large part, because monitoring activities in 2015 and 2016 were not able to commence until construction concluded in early December. However, defining winter as the months of November through April more fully captures seasonal ungulate activity on winter range including their arrival onto winter range in November and their departure to summer ranges in April. From this point forward, 'winter' is defined as November through April, and all prior year data reflect this change.

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 April 2020. Post-construction monitoring involved the deployment of 62 cameras at 49 locations, including 38 locations that were monitored in Year 4.

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 inside of the right-of-way. 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 primarily 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. 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); Year 4 (May 2018 – April 2019). Gray highlighted rows were not monitored in Year 4.

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 1-4	-
136.9	Thompson Wildlife Guard	Wildlife Guard	Round bar (flat bar Yr. 1)	Years 1-4	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 1-4	-
136.6	Trough Road 3:1 Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-4	Constructed Summer 2016
136.6	Trough Road 2:1 Escape Ramp	Escape Ramp	2:1 slope with rail fence	Years 2-4	-
136.0	North Underpass	Arch Underpass	44'W x 14'H x 66'L	Years 1-4	-
136.0	North Underpass Habitat	Adjacent Habitat	Habitat camera	Years 1-4	-
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 2-4	-
135.1	Culbreath 3:1 Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-4	Constructed Summer 2016
135.1	Culbreath Concrete Box Culvert	Small Culvert	8’W x 7.5’H x 100’L	Years 2-4	-
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 with ped. grate	Year 1	Location gated Summer 2016
134.3	North Overpass Escape Ramp	Escape Ramp	2:1 slope without fence	Years 1-4	-
134.3	North Overpass	Overpass	100'W x 66'L	Years 1-4	70’ wide fence opening
134.3	North Overpass Habitat East	Adjacent Habitat	Habitat camera	Years 1-4	-
134.3	North Overpass Habitat West	Adjacent Habitat	Habitat camera	Years 1-4	-
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 2-4	Plus 30’L concrete trough
132.5	Middle Underpass	Arch Structure	44'W x 14'H x 66'L	Years 1-4	-

MP	LOCATION NAME	MITIGATION TYPE	SPECIFICATIONS	MONITORING PERIODS	NOTES
132.5	Middle Underpass Habitat	Adjacent Habitat	Habitat camera	Years 1-4	-
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 1-4	-
131.6	Harsha Gulch Habitat	Adjacent Habitat	Habitat camera	Years 1-4	-
131.6	Harsha Jump down Escape Ramp	Escape Ramp	Jump down w/o fence	Years 3 & 4	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 2-4	-
130.8	BVA Habitat	Adjacent Habitat	Habitat camera	Years 2-4	-
130.8	CR 1002 Wildlife Guard	Wildlife Guard	Round bar	Years 3 & 4	-
129.7	CR 1000 Wildlife Guard	Wildlife Guard	Flat bar	Years 3 & 4	-
129.5	South Overpass	Overpass	100'W x 66'L	Years 2-4	68.5’ wide fence opening
129.5	South Overpass Habitat	Adjacent Habitat	Habitat camera	Years 2-4	-
129.1	Badger Road Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-4	-
129.0	Badger Road Wildlife Guard	Wildlife Guard	Round bar	Years 3 & 4	Half guard length fenced
128.5	Triangle Road Wildlife Guard	Wildlife Guard	Round bar	Years 2-4	-
128.5	Spring Creek Wildlife Guard	Wildlife Guard	Flat bar	Years 2-4	-
128.5	Spring Creek Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-4	-
128.4	South Spring Creek Escape Ramp	Escape Ramp	3:1 slope with rail fence	Years 2-4	-
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 2-4	-
127.7	Williams Peak Habitat	Adjacent Habitat	Habitat camera	Years 2-4	-
126.7	East Fence End Escape Ramp	Escape Ramp	3:1 slope without fence	Years 2-4	-
126.6	West Fence End Escape Ramp	Escape Ramp	3:1 slope with rail fence	Years 2-4	-
126.6	South Fence End	Fence End	20’ clear zone	Years 2-4	-

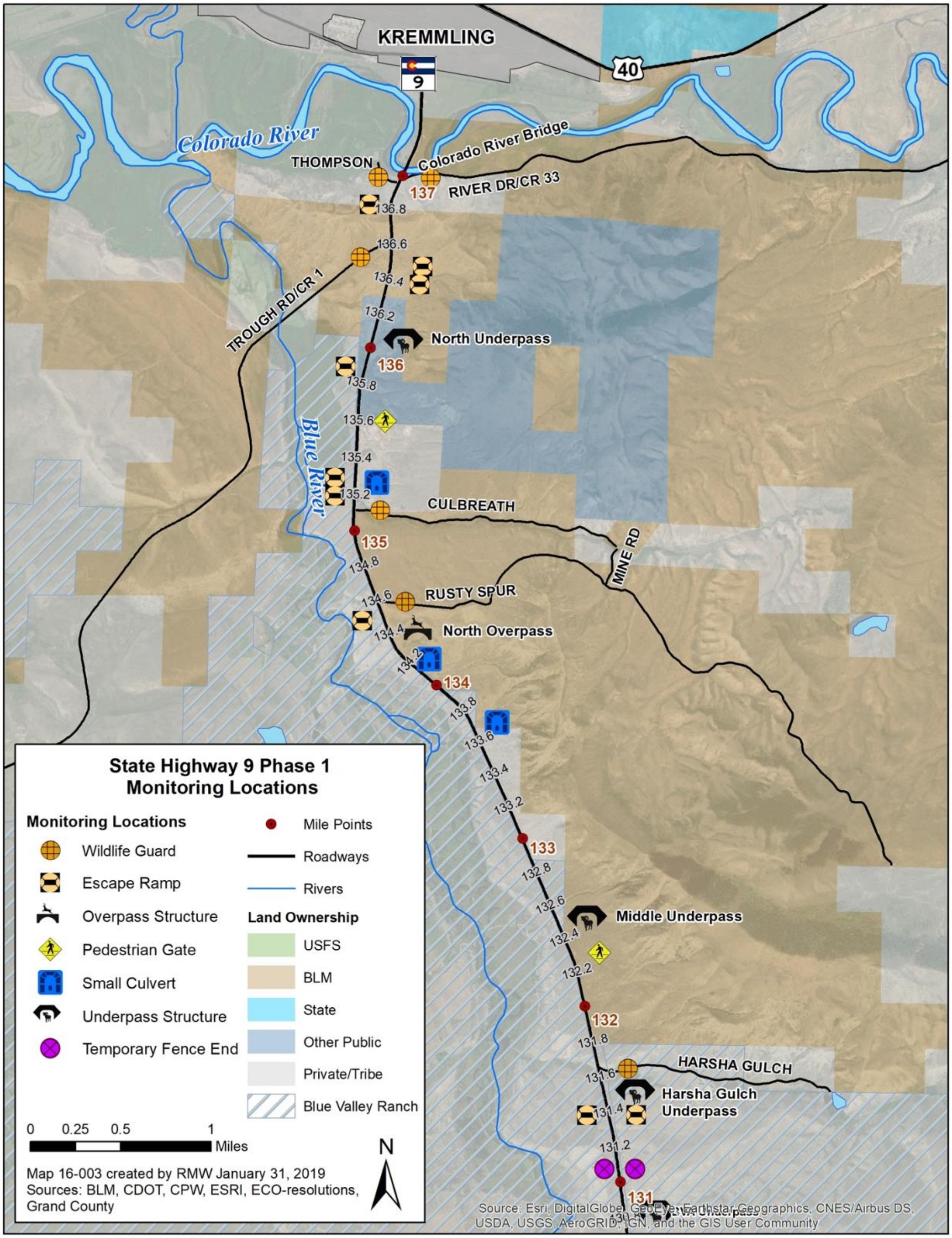

Figure 1. Phase 1 (north segment, MP 131 – 137) monitoring locations through April 2019.

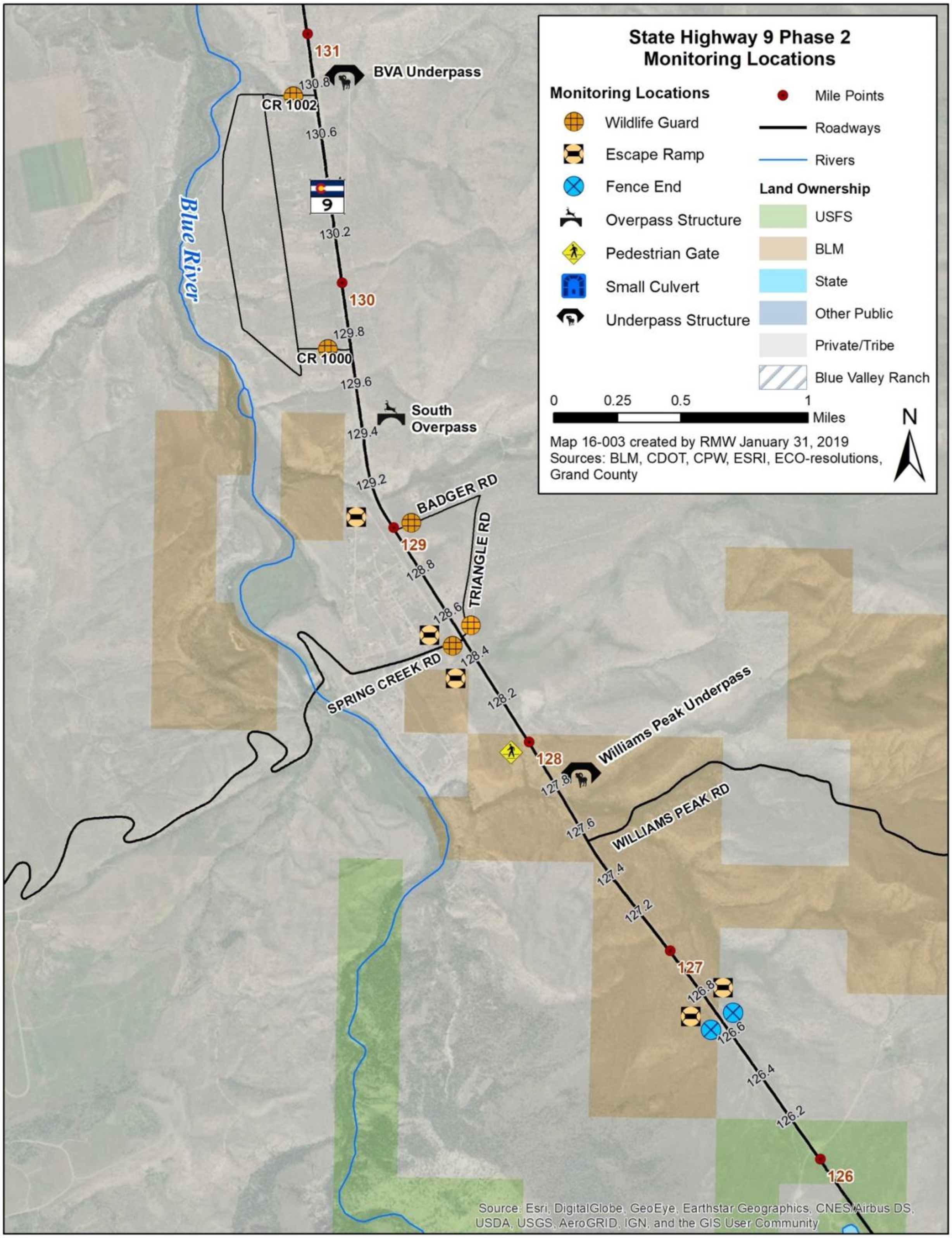

Figure 2. Phase 2 (south segment, MP 126 – 131) monitoring locations through April 2019.

Results

Post-Construction Monitoring

In Year 4, cameras were in operation for 184 days during the non-winter months of 2018 (May 1 – October 31) and 181 days during Winter 2018-19 (November 1 – April 30). 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 research in December 2015, monitoring cameras have recorded a total of 83,256 success movements by mule deer through or over the wildlife crossing structures. For the Year 4 reporting period alone, there were 36,525 success movements through the wildlife crossing structures. In Winter 2018-19, the total number of mule deer success movement increased by 58% relative to the previous winter, following a 37% increase in Winter 2017-18. Over the course of the research, the success rate for mule deer passage through or over the crossing structures has remained consistent between 96-97%.

Each year, mule deer activity was highest during the winter months, corresponding with deer arrival on winter range in November and their departure in April. However, some deer remained in the study area throughout the year. These resident deer made 6,082 success movements during the non-winter months of 2018. Overall, the success rate of resident mule deer during the non-winter months is the same as wintering mule deer at 96%.

In Year 4, there were also 1,916 success movements through or over the wildlife crossing structures by other large and meso-mammal species. This number represents a 55% increase in success movements by species other than mule deer from the previous year. The success rate for these species was 96% for all of the wildlife crossing structures combined – this rate is consistent with previous years. Species such as black bear, moose, red fox, pronghorn, and white-tailed deer were most commonly observed during non-winter months. Others, such as bighorn sheep, bobcat, coyote and moose were observed throughout the year. Coyote, bobcat, and, in particular, mountain lions were most commonly detected during the winter months. Prior to Winter 2018-19, elk were detected primarily during the non-winter months; however, in Winter 2018-19, there were 58 elk success movements through or over the crossing structures. This result was in contrast to the previous winter during which no elk movements were detected; and prior to that, 22 elk made success movements during Winter 2016-17.

Mule Deer Use of Wildlife Crossing Structures During Winter 2018-19

Mule deer activity and success movements through or over the wildlife crossing structures continued to increase each winter since the completion of the Phase 1 construction in Winter 2015-16 (Fig. 3).

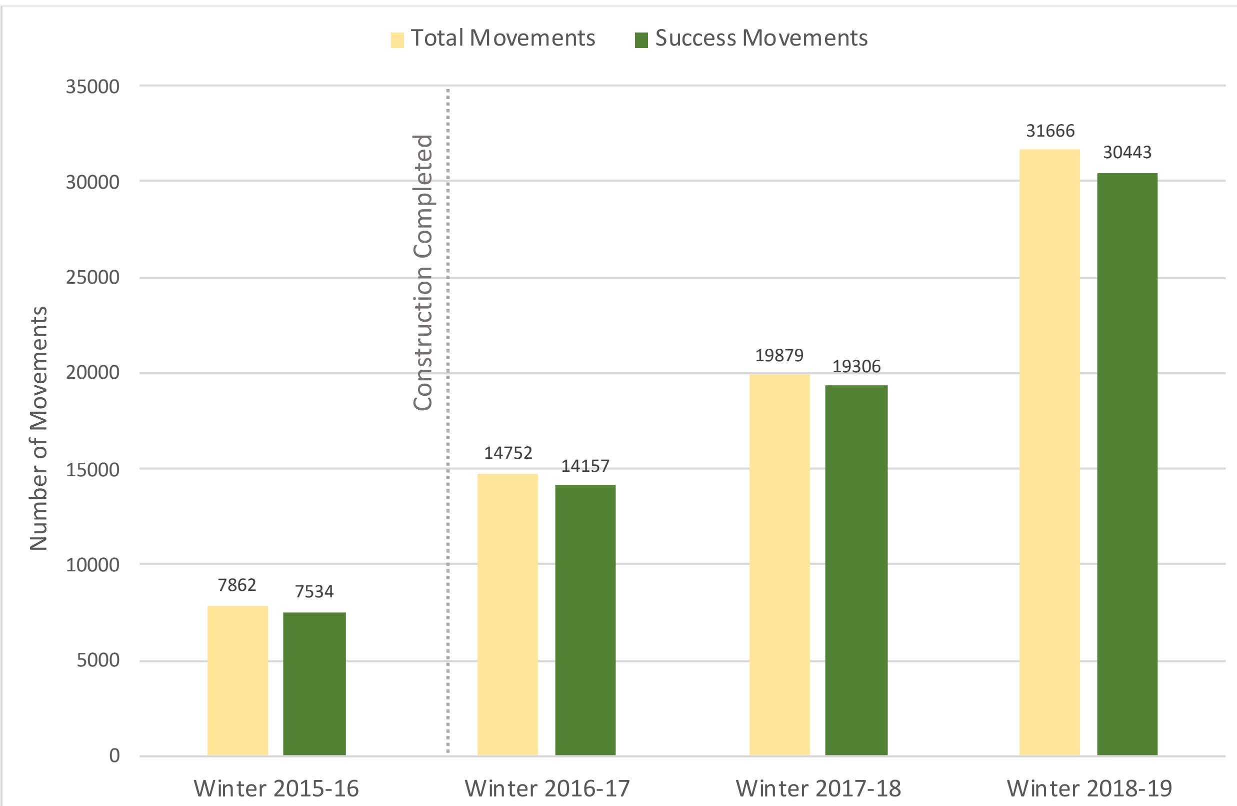

Figure 3. Total number of mule deer movements and successful movements at crossing structures during each winter of the research. In Winter 2015-16, only the northern portion (Phase 1) of the project area was constructed and monitored.

Table 2 summarizes mule deer activity at each of the wildlife crossing structures in Winter 2018-19 and presents the percent change in success movements from the previous winter. Mule deer success movements in the Winter of 2018-2019 increased from the previous winter for all but one of the wildlife crossing structure locations. In total, there were, on average, 168 mule deer success movements over and through the wildlife crossing structures each day during Winter 2018-19, ranging from 7.1 daily success movements at the Williams Peak Underpass to 45 daily success movements at the BVA Underpass.

Table 2. Mule deer movements at wildlife crossing structures during Winter 2018-19.

Monitoring Location	Total Move-ments	Success Move-ments	Change in Success Move-ments from Winter 2017-18	Average Deer per Winter day	Average Success per Winter Day	Success Rate	Repel Rate	Parallel Rate
MP 127.7 Williams Peak Underpass	1,519	1,292	42%	8.4	7.1	85%	13%	2%
MP 129.5 South Overpass	7,586	7,490	131%	41.9	41.4	99%	<1%	<1%
MP 130.8 BVA Underpass	8,429	8,149	27%	46.6	45.0	97%	2%	1%
MP 131.6 Harsha Gulch Underpass	2,485	2,409	13%	13.7	13.3	97%	2%	1%
MP 132.5 Middle Underpass	2,158	2,086	-7%	11.9	11.5	96%	4%	<0.5%
MP 134.3 North Overpass	6,237	5,913	89%	34.5	32.7	95%	3%	2%
MP 136.0 North Underpass	3,252	3,104	161%	18.0	17.1	95%	4%	<0.5%

Generally, mule deer success rates remained high in Winter 2018-19 and were generally consistent with rates reported for the previous winter. The exception was the Williams Peak Underpass where the mule deer success rate dropped from 96% to 85%. Despite this drop in the success rate, the number of success movements at the underpass increased by 42% from Winter 2017-18.

As in the previous winter, mule deer total movements and success movements varied substantially among the wildlife crossing structures during Winter 2018-19 (Fig. 4). The greatest number of success movements was documented at the BVA Underpass and the South Overpass, followed by the North Overpass. This pattern is similar to what was observed in Winter 2017-18.

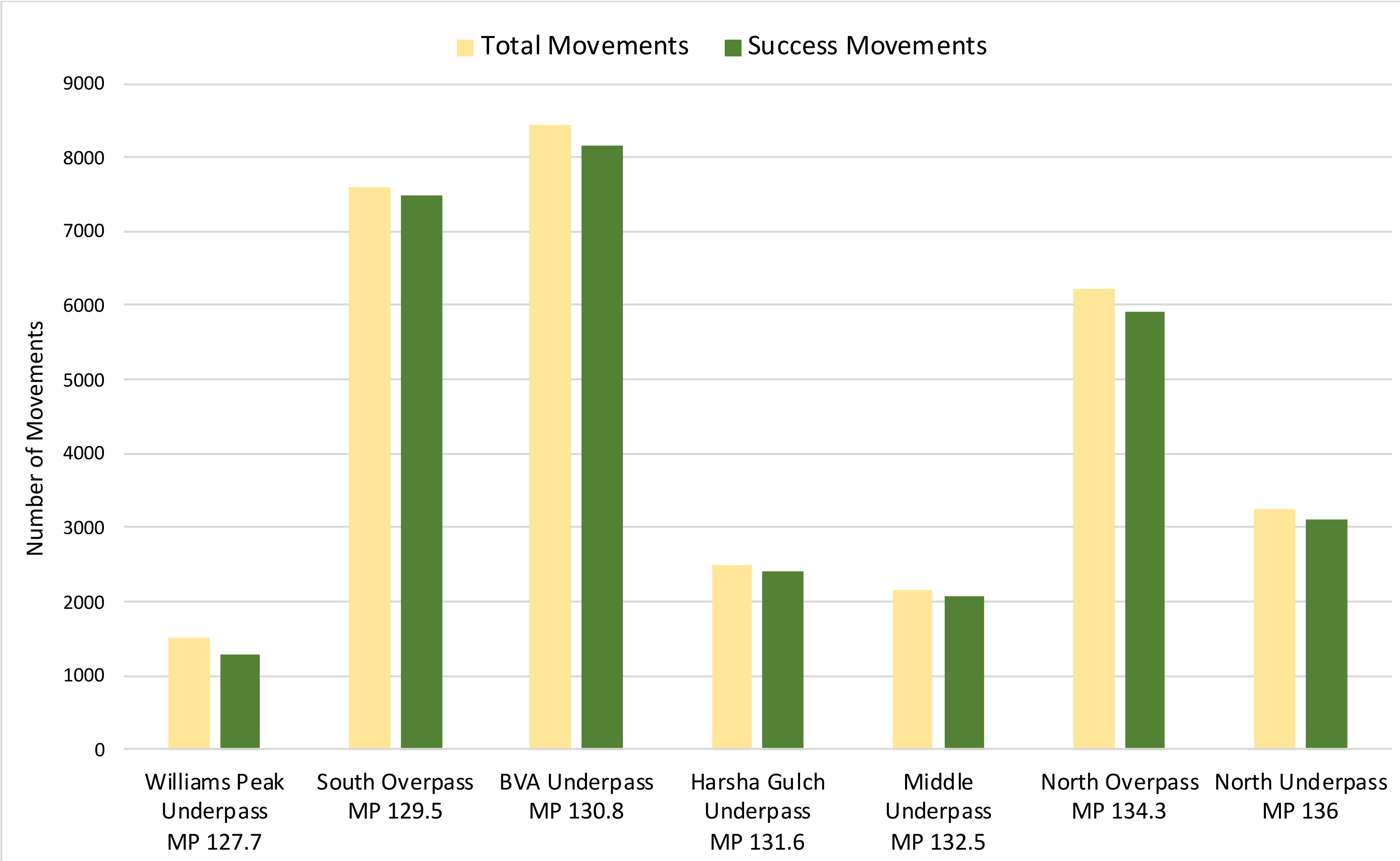

Figure 4. Total number of mule deer movements and success movements at each crossing structure location during Winter 2018-19.

Mule deer use of overpass structures versus underpass structures was compared between Winter 2018-19 and the two previous winters (Fig. 5). The averages for the combined number of success movements at underpass structures (*n*=5) versus the combined overpass structures (*n*=2) was used to account for the unequal number of underpasses versus overpasses. Over all three years of post-construction monitoring, 58% of all mule deer success movements occurred at the five underpasses and 42% at the two overpasses. However, when considered on an average per unit basis, mule deer use of an overpass structure remained higher than use of an underpass structure in all three winters. In Winter 2017-18, mule deer success movements at overpasses and underpasses appeared to be comparable to Winter 2016-17; however, in Winter 2018-19, while the total number of success movements increased at both overpass and underpass structures, the increase in the number of success movements at overpasses (111%) was greater than the increase at underpasses (32%).

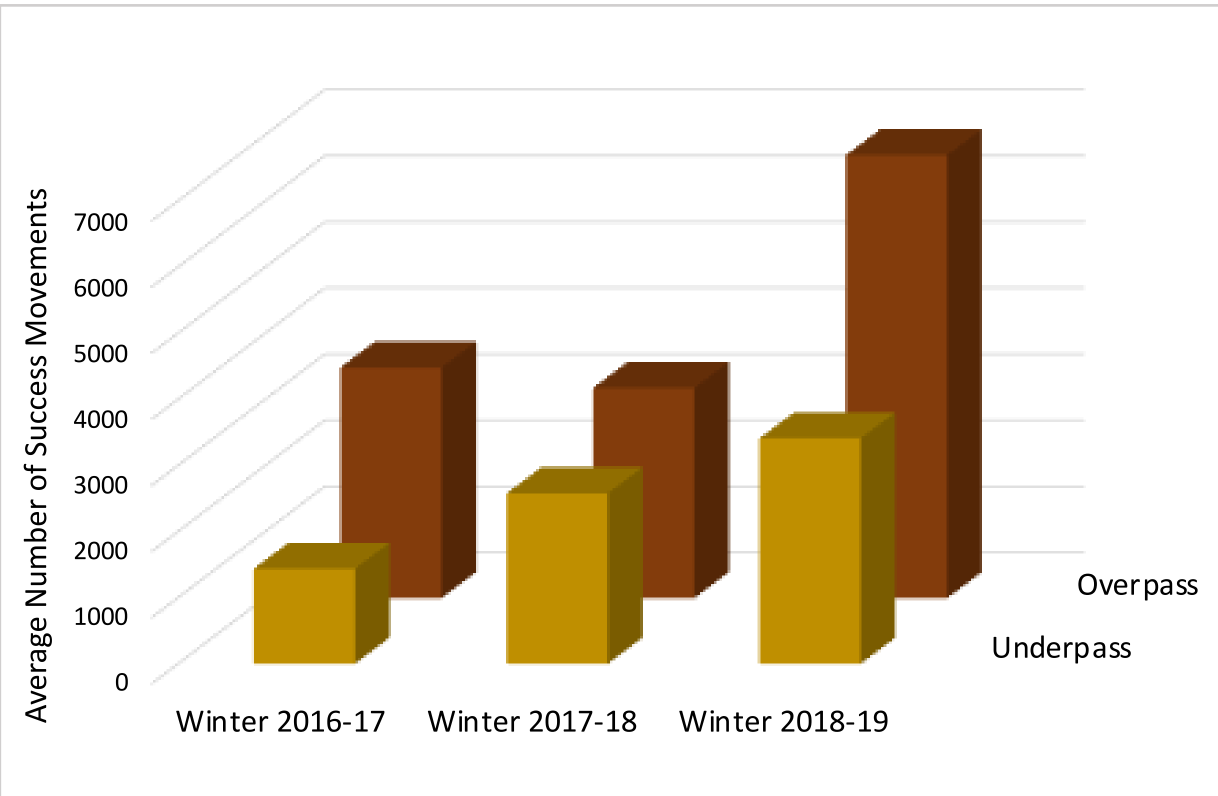

Figure 5. Average number of success movements per winter by mule deer at overpass versus underpass structures each winter from Winter 2016-17 to Winter 2018-19.

Movements through or over the crossing structures occurred in both directions, originating from the east or west. During the winter months, east-to-west movements (52%) were nearly equal to west-to-east movements (48%). The project area is located within mule deer winter range and many of the same animals were 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 nearly equal proportions.

Gender of mule deer was noted in photo analysis as male, female, fawn or unknown. 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. The number of total movements detected and percentages for each gender at each structure are presented in Table 3. In Winter 2018-19, across all crossing structure locations, bucks represented 14% of the movements, does 47% and fawns 21%.

Table 3. Percentage of mule deer total movements at wildlife crossing structures in Winter 2018-19 that were male (bucks), females (does), fawns and unknown gender.

Monitoring Location	% Bucks	% Does	% Fawns	% Unknown
Williams Peak Underpass	13%	41%	19%	26%
South Overpass	18%	53%	23%	6%
BVA Underpass	18%	48%	17%	17%
Harsha Gulch Underpass	24%	55%	15%	5%
Middle Underpass	9%	44%	23%	24%
North Overpass	4%	26%	27%	43%
North Underpass	8%	66%	19%	8%

Mule Deer Use of Wildlife Crossing Structures over Time

Mule deer success movements at the wildlife crossing structures were plotted for each month from the onset of the study in December 2015 through April 2019 (Fig. 6). Periods of peak mule deer success movements 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 within the study area.

Winter 2018-19 saw the greatest number of success movements at five of the crossing structures, while mule deer success movements at the Harsha Gulch and Middle Underpasses remained relatively the same. Mule deer activity peaked at most structures in February and March, except at the Williams Peak underpass, where the greatest number of movements occurred in November. This pattern is in contrast to the previous winter, during which there were two peaks in activity at most of the crossing structure locations, one in January and a second peak in March. Since the completion of construction activities in October 2016, the highest number of mule deer success movements were at the BVA Underpass, the North Overpass and the South Overpass. These three structures account for 71% of all post-construction success movements at the wildlife crossings.

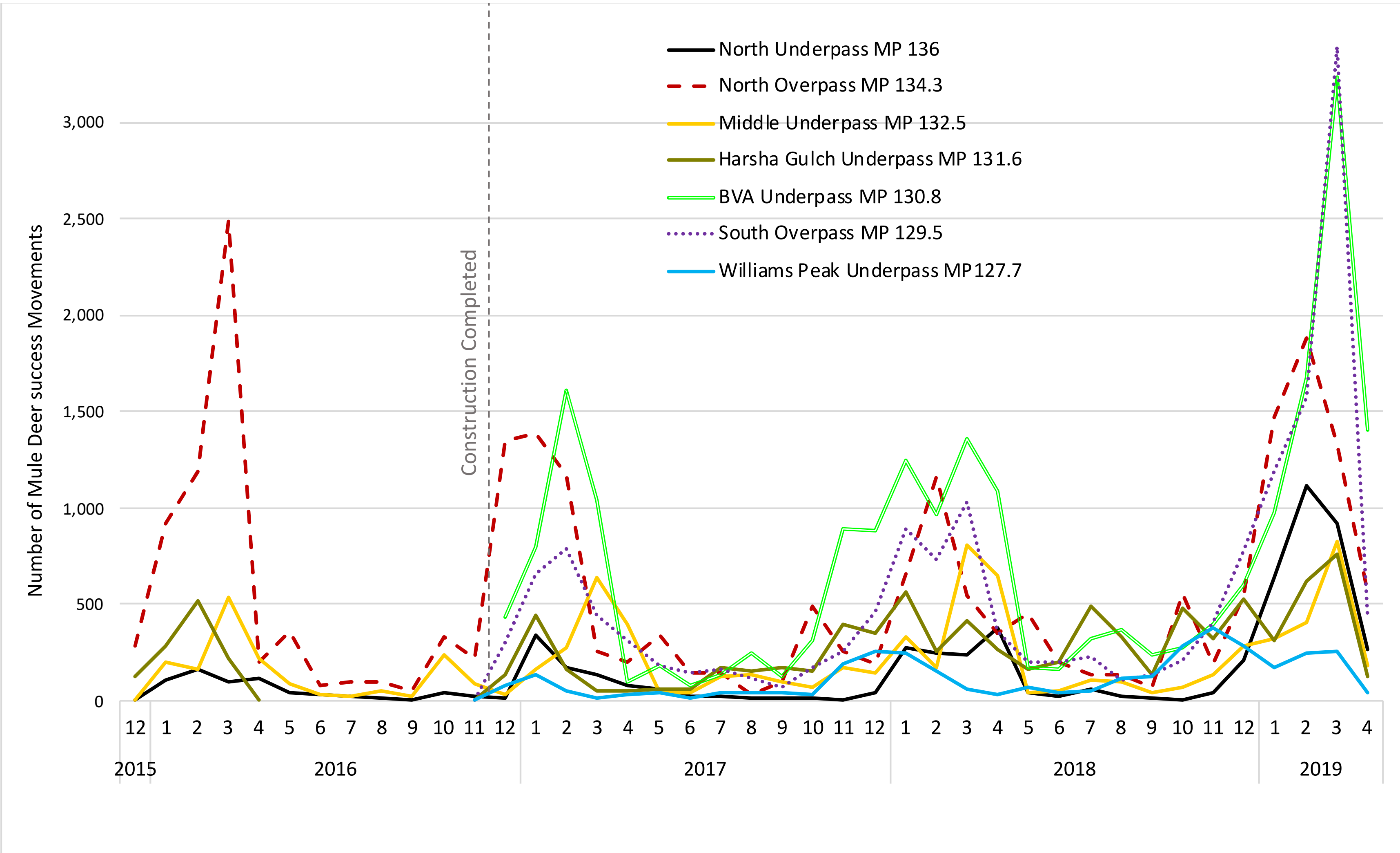

Figure 6. Mule deer success movements by month at each of the wildlife crossing structures from December 2015 through April 2019.

The camera monitoring results at each crossing structure location are described below. For each crossing structure, the total number of mule deer movements detected (including success, repel and parallel movements) is presented relative to mule deer success movements by month of the year (note that the y-axis scale varies for each graph). For a given month, the closer the paired yellow and green bars are in height, the greater the success rate for that month.

Williams Peak Underpass, Milepost 127.7

Mule deer total movements and success movements by month at the Williams Peak Underpass are presented in Figure 7. Wintertime movements increased at this structure each year with the highest peak in Winter 2018-19 occurring in November. Mule deer use continued through the summer months each year of the research. The total number of mule deer success movements at this location since construction was completed was 3,271. The number of annual success movements by calendar year was: 25 (2016, December only); 828 (2017); 1,783 (2018); and 635 (2019, January through April only). Success rates at this location have fluctuated each winter, from 83% in Winter 2016-17, to 96% in Winter 2017-18, and 85% in Winter 2018-19.

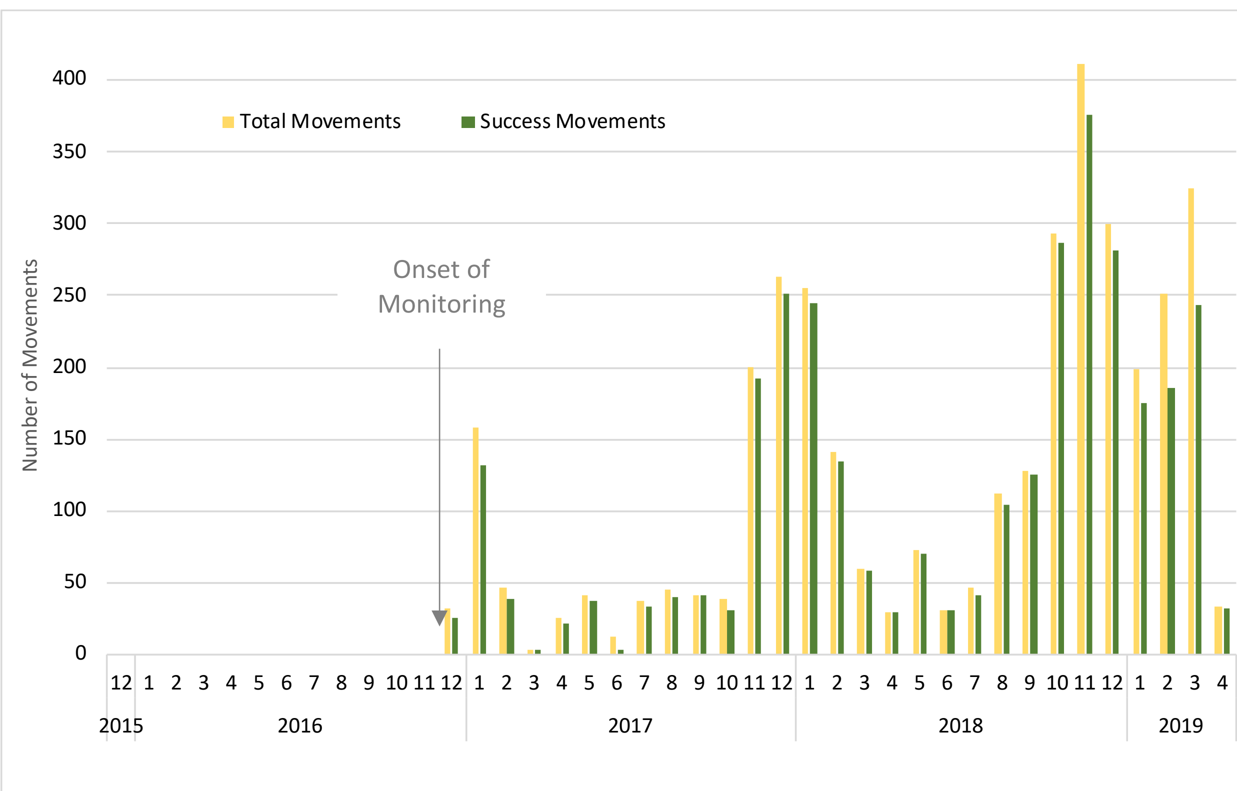

Figure 7. Mule deer total movements and success movements by month and year at the Williams Peak Underpass (MP 136) from December 2016 through April 2019. Note y-axis scale is 0 – 400.

South Overpass, Milepost 129.5

Mule deer total movements and success movements at the South Overpass are presented by month and year (Figure 8). In Years 2 and 3, the peak in monthly movements was nearly the same, although in Year 3, two peaks were observed instead of the single February peak observed in Year 2. The total number of movement and success movements increased sharply in Year 4. Mule deer use continued through the summer months each year of the research. The total number of mule deer success movements at the South Overpass since construction was completed was 14,459. This location had the second highest number of success movements in Year 4 and the third highest number of success movements across all years, post-construction. The number of annual success movements by calendar year was: 299 (2016, December only); 3,530 (2017); 4,217 (2018); and 6,417 (2019, January through April only). Success rates remained stable across each year (98-99%).

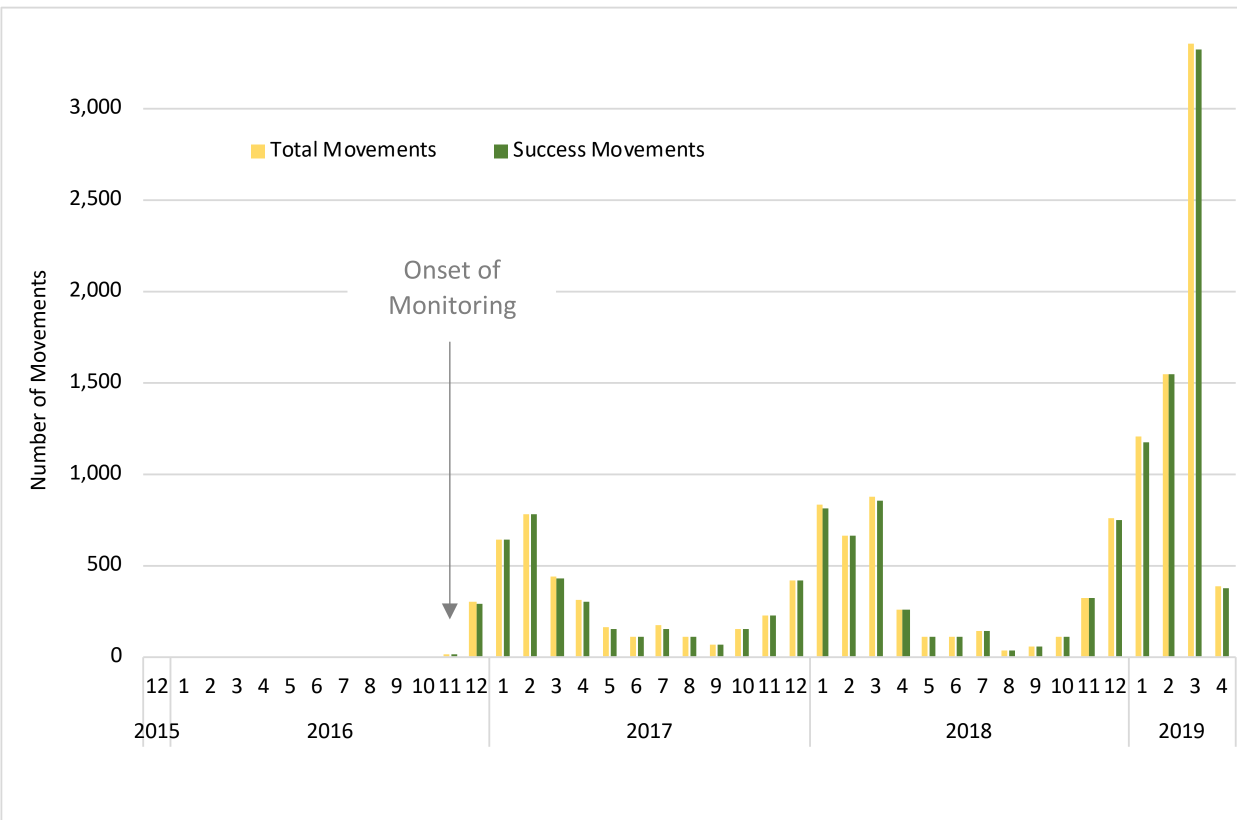

Figure 8. Mule deer total movements and success movements by month and year at the South Overpass (MP 136) from November 2016 through April 2019. Note y-axis scale is 0 – 3,000.

BVA Underpass, Milepost 130.8

Mule deer total movements and success movements at the BVA Underpass are presented by month and year (Fig. 9). Overall total and success movements were high throughout the winter months. Similar to the South Overpass, the total number of movement and success movements increased multifold in Year 4, particularly during the month of March. Mule deer use continued through the summer months each year of the research. The total number of mule deer success movements at the BVA Underpass since construction was completed was 20,951. This location recorded the highest number of success movements each year post-construction and had the highest total number of post-construction success movements. The number of annual success movements by calendar year was: 426 (2016, December only); 6,284 (2017); 7,018 (2018); and 7,223 (2019, January through April only). Success rates remained relatively stable across each year (97-98%).

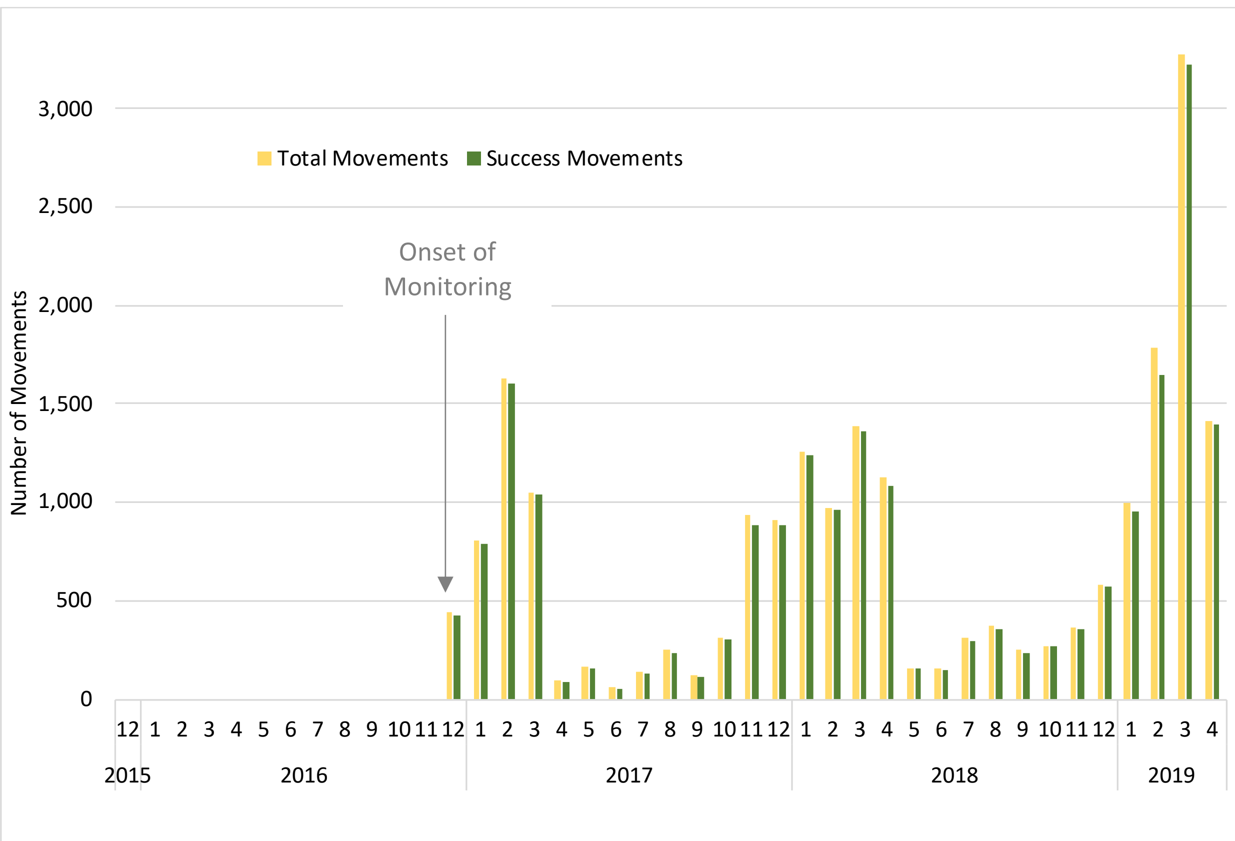

Figure 9. Mule deer total movements and success movements by month and year at the BVA Underpass (MP 130.8) from December 2016 through April 2019. Note y-axis scale is 0 – 3,000.

Harsha Gulch Underpass, Milepost 131.6

Mule deer total movements and success movements by month at the Harsha Gulch Underpass are presented in Figure 10. 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. Mule deer movements remained high through much of Winter 2018-19, with the largest peak in the months of February and March. The total number of mule deer success movements at this location since construction was completed was 7,500. The number of annual success movements by calendar year was: 121 (2015, December only); 899 (2016); 1,984 (2017); 3,748 (2018); and 1,640 (2019, January through April only). After Phase 2 construction was complete, success rates remained relatively stable (97-98%).

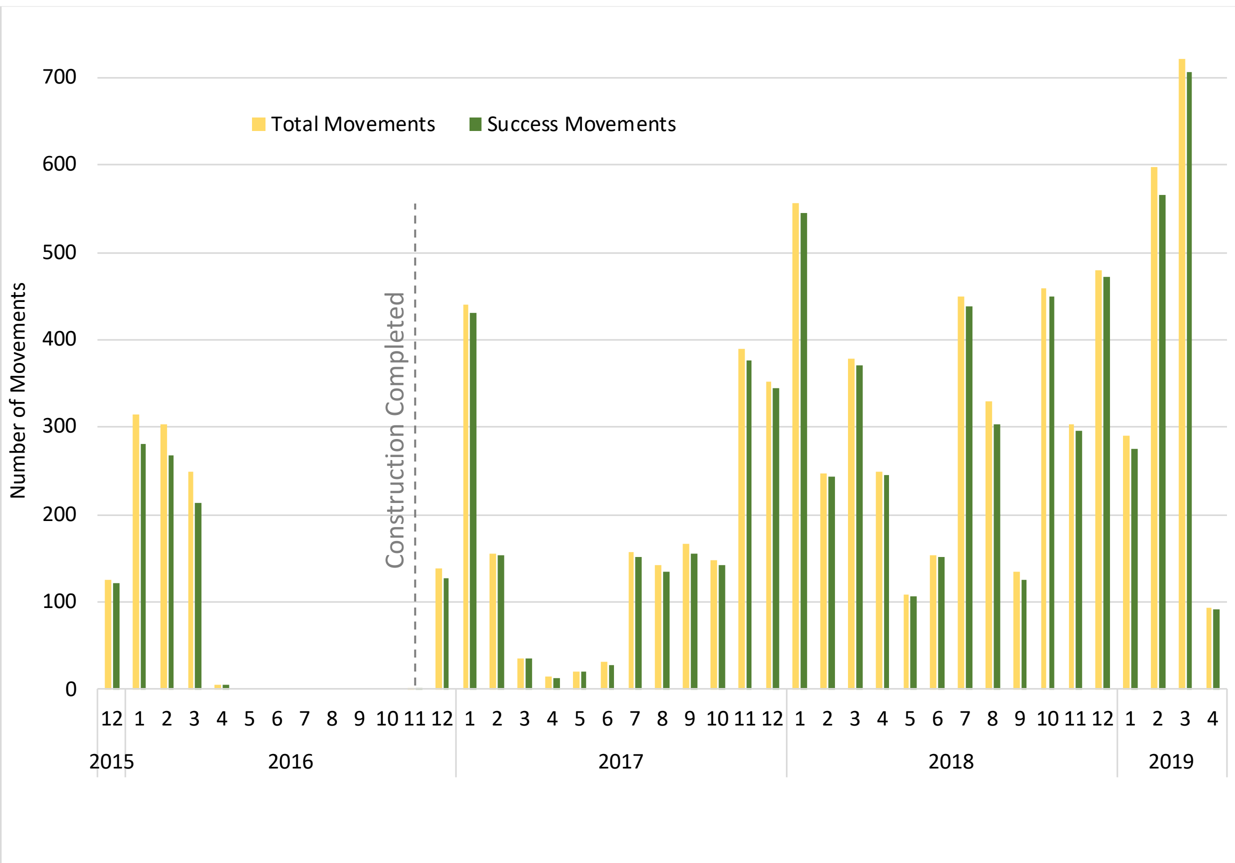

Figure 10. Mule deer total movements and success movements by month and year at the Harsha Gulch Underpass (MP 131.6) from December 2015 through April 2019. Note y-axis scale is 0 – 700.

Middle Underpass, Milepost 132.5

Mule deer total movements and success movements by month at the Middle Underpass are presented in Figure 11. Peak activity has remained consistently in March at this structure and was nearly equivalent in 2018 and 2019. Each year of the research, activity dropped off sharply following these peak movement periods, in April or May. Mule deer use continued through the summer months each year of the research, with the highest levels of summertime activity occurring in 2017. Ongoing construction activities in the project area in Summer 2016 may have inhibited some wildlife activity during that timeframe. The total number of mule deer success movements at this location since construction was completed was 6,526. The number of annual success movements by calendar year was: 4 (2015, December only); 1,506 (2016); 2,178 (2017); 2,617 (2018); and 1,700 (2019, January through April only). Success rates remained relatively stable throughout the research study (94-97%).

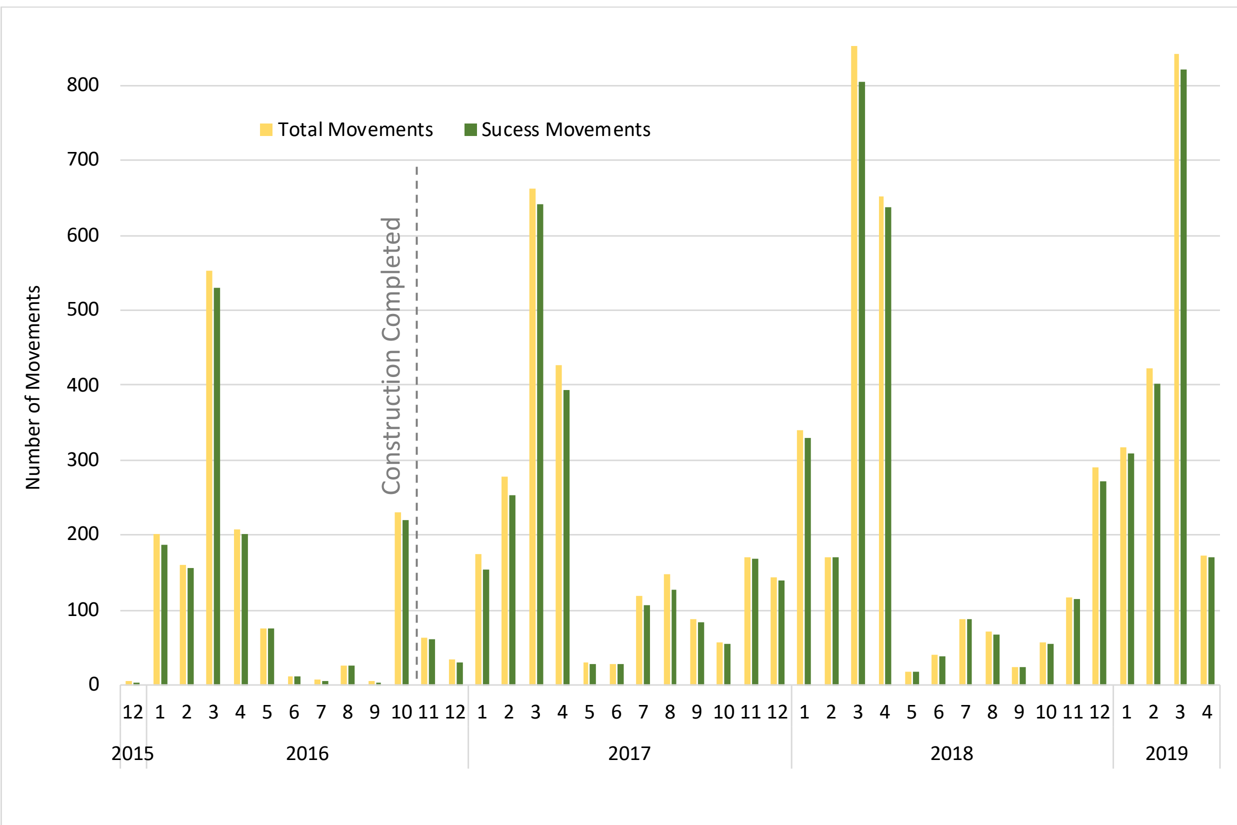

Figure 11. Mule deer total movements and success movements by month and year at the Middle Underpass (MP 132.5) from December 2015 through April 2019. Note y-axis scale is 0 – 800.

North Overpass, Milepost 134.3

Mule deer total movements and success movements at the North Overpass are presented by month (Fig. 12). This is the only location where the peak in wintertime mule deer activity decreased since Year 1 of the research; however, while the Year 4 wintertime peak was not as high as in March 2016 (Year 1), the overall number of mule deer success movements through the winter months was greater. Mule deer use continued through the summer months each year of the research. The total number of mule deer success movements at this location since construction was completed was 16,069. This location had the third highest number of success movements in Year 4 and the second highest number of success movements across all years, post-construction. The number of annual success movements by calendar year was: 284 (2015, December only); 7,288 (2016); 4,649 (2017); 4,897 (2018); and 5,193 (2019, January through April). Success rates remained stable throughout the research study (95-96%).

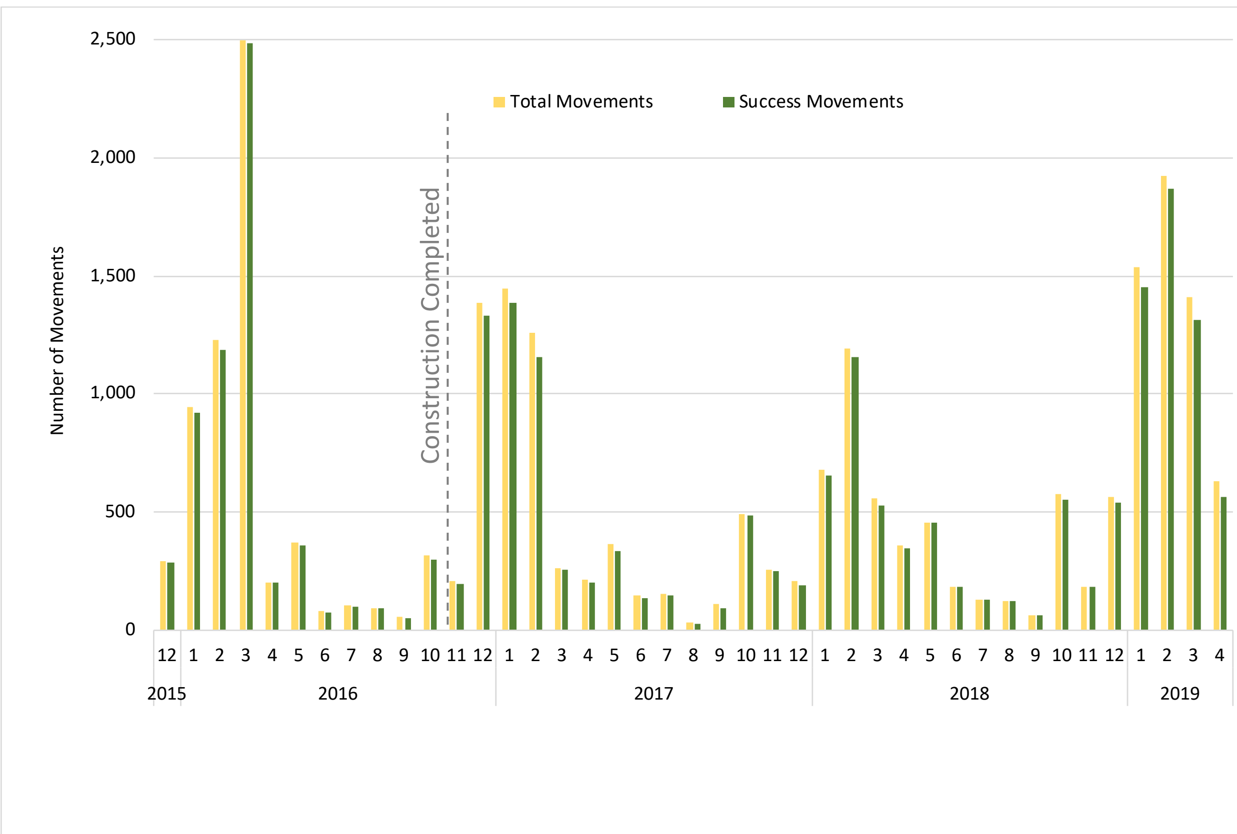

Figure 12. Mule deer total movements and success movements by month and year at the North Overpass (MP 134.3) from December 2015 through April 2019. Note y-axis scale is 0 – 2,500.

North Underpass, Milepost 136.0

Mule deer total movements and success movements by month at the North Underpass are presented in Figure 13. Mule deer total and success movements increased each year of the research, with the greatest increase in Winter 2018-19. Total movements and success movements peaked in February and March 2019. Mule deer use of the structures was seasonal – consistently low during the summer months and higher during the winter months. The total number of mule deer success movements at this location since construction was completed was 5,180. The number of annual success movements by calendar year was: 4 (2015, December only); 566 (2016); 854 (2017); 1,453 (2018); and 2,861 (2019, January through April). Success rates fluctuated somewhat from year to year, ranging from 90% in Winter 2016-17, to 96% in Winter 207-18, and 95% in Winter 2018-19.

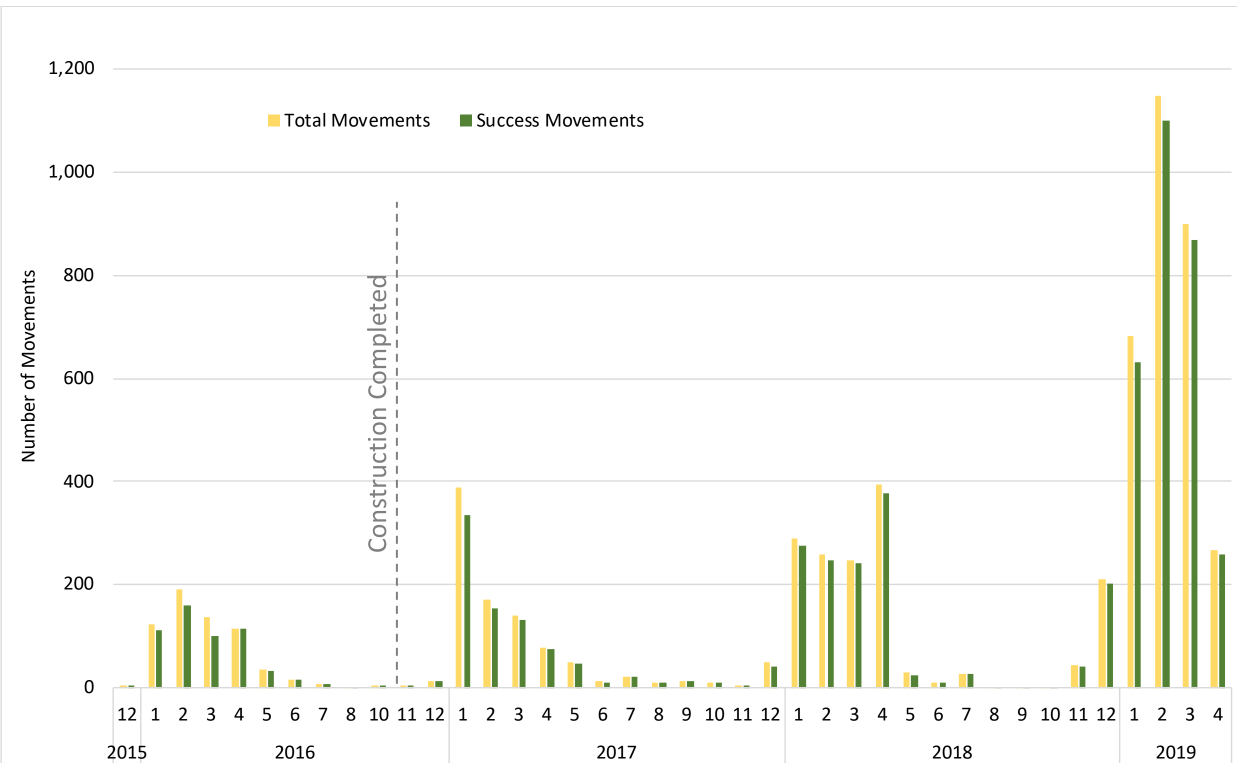

Figure 13. Mule deer total movements and success movements by month and year at the North Underpass (MP 136) from December 2015 through April 2019. Note y-axis scale is 0 – 1,200.

Elk Use of Wildlife Crossing Structures

Elk movements through and over the crossing structures increased each year of the study. Elk success movements were documented year-round each year of the study, with the exception of Year 3, during which success movements and approaches to the crossing structures were documented only during the summer months. Elk success movements also varied across the structure locations (Fig. 14). In Years 1-3 of the research, elk success movements were highest at the North Overpass. During that time there were also approximately a dozen success movements recorded at each the North Underpass, Middle Underpass and Harsha Gulch Underpass. In Year 4, these patterns shifted, with the greatest number of elk success movements occurring at the North Underpass (*n*=45). In Year 4, elk also used the Williams Peak Underpass in limited numbers (*n*=2) for the first time. No elk were documented using or attempting to cross through the BVA Underpass. Overall, elk have successfully used both overpass and underpass structures. More elk success movements have occurred at the five underpasses (*n*=109) than the two overpasses (*n*=63), but the repel rate was higher at the underpasses than at the overpasses (10% and 5%, respectively).

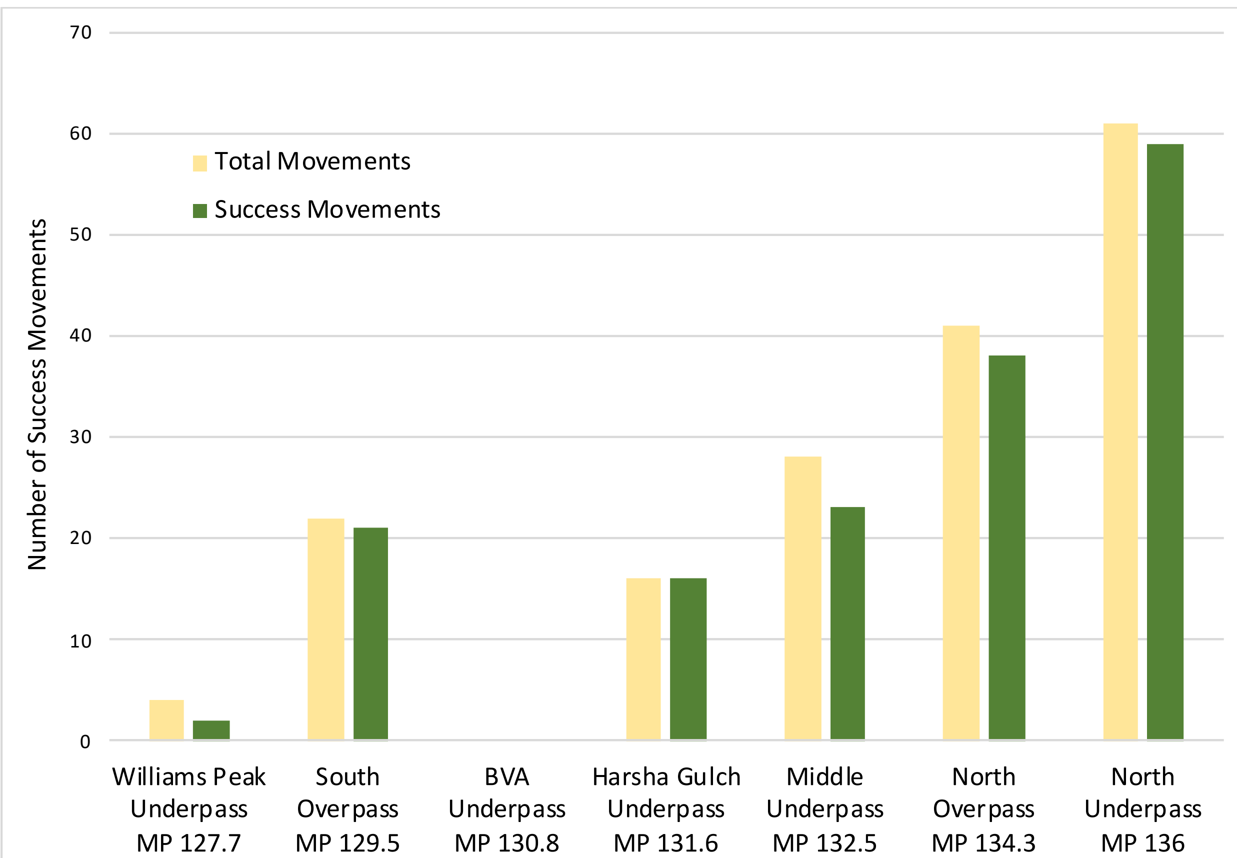

Figure 14. Elk total and success movements detected at wildlife crossing structures, Years 1-4.

Winter 2018-19 marked the first success movements by small herds of elk. In March 2019, two groups of elk composed of cows and calves (numbering 17 and 12 individuals) were documented crossing through the North Underpass on successive days. In the first instance, the crossing event took place over more than five minutes as individual animals repelled multiple times before finally crossing through the structure successfully (Fig 15). During the second of these events, elk and deer movements through the underpass were intermixed over the course of ten minutes.

Figure 15. Group of elk attempting to cross through the North Underpass (left) with some individuals initially repelling from the structure (right) before completing success movements through the structure.

Other Species Use of Wildlife Crossing Structures

Structure Use Over Time

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. Two new species were documented successfully using the crossing structures in Year 4 – river otter (*Lontra canadensis*) and wild turkey (*Meleagris gallopavo*). Each species was recorded in isolated events consisting of multiple individuals: two river otters successfully passed through the North Underpass in February 2019, and a group of six turkeys used the Middle Underpass in April 2019 (Fig. 16).

Most carnivores and meso-mammals also experienced increases in the number of success movements in Year 4, with the exception of bobcat, for which there was no change in the number of movements in Year 4 relative to previous years; and red fox, which saw a decrease in the number of success movements in Year 4. The largest increases were coyote (from a three-year average of 287 to 1,284 success movements in Year 4) and mountain lion (from 23 to 82).

Table 4. Movements by species other than mule deer at wildlife crossing structures, Years 1-4. Success, repel, and parallel movements are the total number of each movement across crossing structures. Success and repel rates were calculated for each species, as well as the change in success movements in Year 4 relative to average number of success movements during the three previous years of the study.

Species	Success Movements (Years 1-4)	Repel Movements (Years 1-4)	Parallel Movements (Years 1-4)	Success Rate	Repel Rate	Change in Success Movements from 3-year Average to Year 4
Badger	5	0	2	71%	0%	100%
Bighorn Sheep	29	6	0	83%	17%	269%
Black Bear	210	1	0	99.5%	>0.5%	47%
Bobcat	101	7	9	86%	6%	0%
Coyote	2,145	31	40	97%	1%	347%
Elk	159	14	1	92%	8%	291%
Fox, Red	202	10	34	82%	4%	-26%
Moose	62	5	2	90%	7%	147%
Mountain Lion	150	1	2	98%	1%	262%
Pronghorn	83	1	0	99%	1%	88%
River Otter	2	0	0	100%	0%	n/a*
Turkey	6	0	0	100%	0%	n/a*
White-tailed Deer	69	3	1	95%	4%	175%

**Species was not documented prior to Year 4.*

Figure 16. Two river otters (left) crossing through the North Underpass and five of six turkeys (right) crossing through the Middle Underpass.

Five species of ungulates other than mule deer have been documented in this study: bighorn sheep, elk, moose, pronghorn and white-tailed deer. In general, success movements for these species have increased each year of the study, with the majority of movements occurring during the summer months (Fig. 17). The exception is elk, for which the number of success movements increased each season, except Winter 2017-18 when no elk movements were recorded. The total number of success movements for each of these species increased in Year 4 by 88% or more relative to the 3-year average for each species and up to 269% for bighorn sheep (from four to 16 passages) and 291% for elk (from 23 to 90 passages). In Year 4, success rates for these ungulate species through or over the crossing structures ranged from 88% for elk (n=34) to 100% for bighorn sheep (n=11).

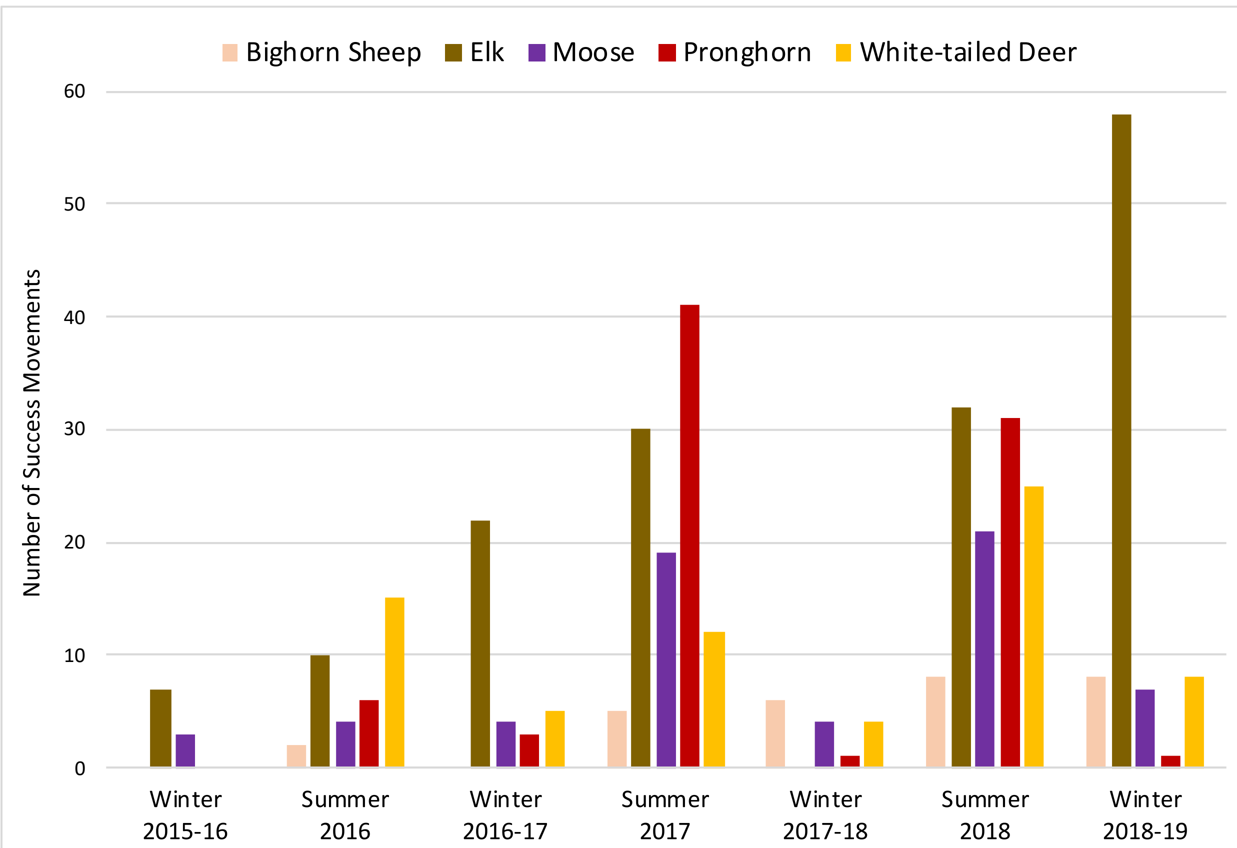

Figure 17. Success movements over time for ungulate species other than mule deer. Winter is defined as November through April; Summer is defined as May through October.

Seasonal and diurnal variations in species use of the crossing structures were also evaluated. Black bear and red fox, in addition to ungulate species other than mule deer and elk were recorded using the crossing structures primarily during the non-winter months; however, bighorn sheep were documented in nearly equal numbers during winter and non-winter months. Mountain lions were documented almost exclusively during the winter months. Carnivore species (black bear, coyote, fox, mountain lion) as well as elk and moose were observed using the crossing structures primarily during the nighttime hours, while other ungulates such as mule deer, pronghorn and white-tailed deer were documented primarily during the daytime, and bighorn sheep success movements were only recorded during the daytime.

Structure Use by Location

Figure 18 displays success movements for ungulate species other than mule deer at each of the wildlife crossing structures in the study area. In previous years of this research, it was reported that pronghorn and white-tailed deer had only been documented using the underpass structures; however, in Year 4, both species were also documented using overpasses, albeit in low numbers. As in previous years, the majority of pronghorn success movements occurred at the BVA Underpass in Year 4, while the majority of elk and white-tailed deer success movements occurred at the North Underpass. Elk, moose and bighorn sheep have made success movements at both underpasses and overpasses. The majority of moose success movements occurred in the northern portions of the study area (the North Underpass, North Overpass and Middle Underpass). Bighorn sheep success movements occurred primarily at crossing structures located in the southern portion of the project area, specifically, at the South Overpass and the Williams Peak Underpass (69% combined), or at the North Overpass (24%).

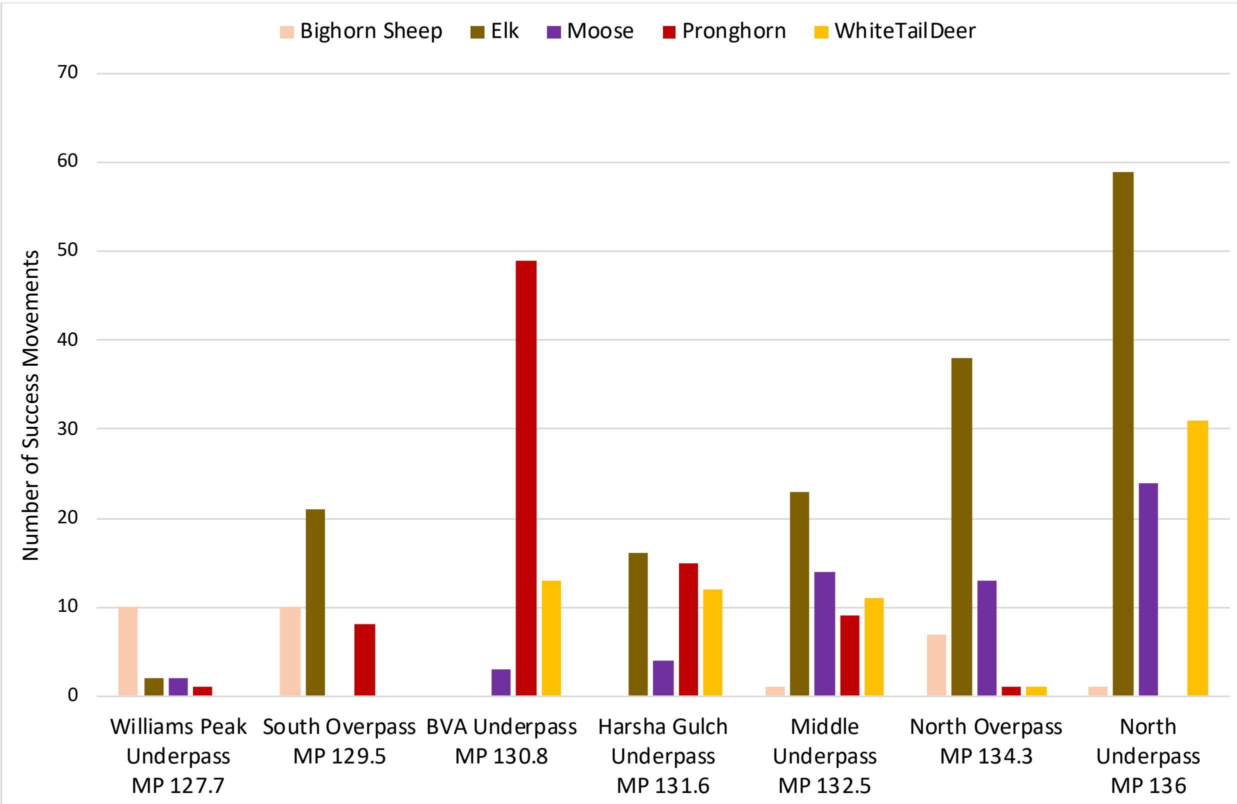

Figure 18. Success movements for ungulate species other than mule deer at each wildlife crossing structure location, Years 1-4.

The success movements of six species of mammals plus wild turkey were plotted at each wildlife crossing structure (Fig. 19). The majority of coyote passages in Year 4 occurred at the South Overpass (*n*=552) and Harsha Gulch Underpass (*n*=303), while mountain lion activity was highest at the Williams Peak Underpass (*n*=78). Black bear continued to be documented primarily crossing through Harsha Gulch Underpass (*n*=33) and the Middle Underpass (*n*=29) and were captured for the first time crossing over an overpass structure, the South Overpass. Other species documented passing through or over wildlife crossing structures include badger, bird, hare, raccoon, skunk, domestic animals (cats, dogs and cows) and, as previously noted, river otter and turkey.

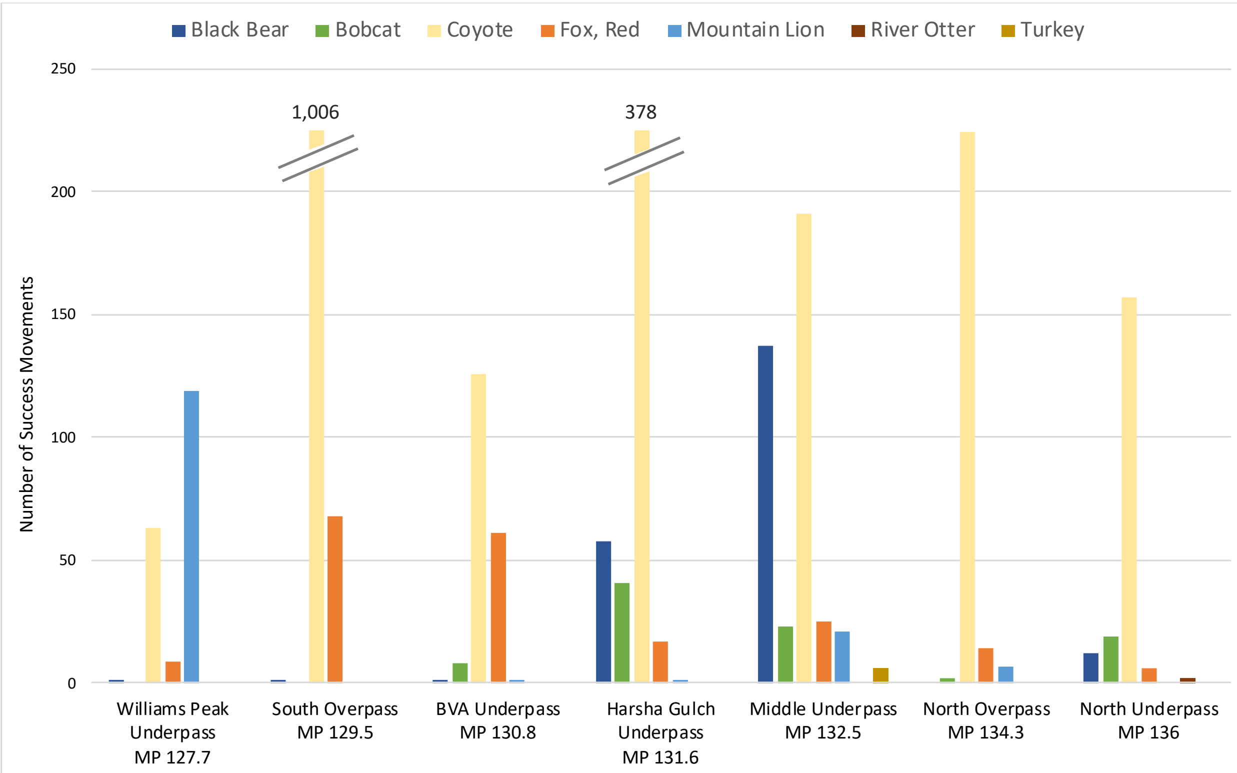

Figure 19. Success movements by non-ungulate species each wildlife crossing structure from the onset of the study in December 2015 through April 2019.

Humans were recorded at each of the crossing structures; this does not include researchers conducting camera checks. As in Year 3, human activity was most common at the Harsha Gulch Underpass (*n*=142); human activity at all other crossing structures was much less ranging from 2-16 events. In Year 4, humans were documented camping out in the underpasses on several occasions. Domestic animals also continued to be occasionally documented at the wildlife crossing structures in Year 4, including dogs, cats, and cows.

Wildlife Movements at Habitat Cameras

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 the same individuals. 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.

Table 5. Comparison of species presence (other than mule deer) at wildlife crossing structures and habitat camera locations adjacent to wildlife crossing structures, Years 1-4. 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. Bolded numbers indicate where a given species was detected by the habitat camera but was not detected at the crossing structure.

Species	Monitoring Location	Williams Peak UP	South OP	BVA UP	Harsha UP	Middle UP	North OP	North UP
Badger	Structure	0	2	1	1	**0**	3	0
	Habitat	0	0	0	0	1	11	0
Bighorn Sheep	Structure	16	10	0	0	1	7	1
	Habitat	8	1	0	0	0	0	0
Black Bear	Structure	1	1	1	58	138	**0**	12
	Habitat	0	1	0	0	111	2	7
Bobcat	Structure	1	**0**	10	42	28	7	20
	Habitat	1	1	0	0	91	6	1
Coyote	Structure	69	1,030	130	385	195	242	165
	Habitat	54	237	31	31	636	632	14
Elk	Structure	4	22	**0**	16	28	42	61
	Habitat	1	43	5	7	24	109	110
Moose	Structure	2	**0**	3	4	17	14	26
	Habitat	2	1	1	4	13	3	17
Mountain Lion	Structure	121	**0**	1	1	21	7	0
	Habitat	21	1	0	0	2	2	0
Pronghorn	Structure	1	8	49	16	9	1	0
	Habitat	0	5	42	0	2	2	0
Red Fox	Structure	10	91	68	22	26	20	7
	Habitat	6	32	8	0	5	46	2
River Otter	Structure	0	0	0	0	0	0	2
	Habitat	0	0	0	0	0	0	0
Turkey	Structure	0	0	0	0	6	0	0
	Habitat	0	0	0	0	2	0	0
White-tailed Deer	Structure	0	0	13	13	12	1	33
	Habitat	0	0	0	1	28	2	19

UP = underpass
OP = overpass

Wildlife Movements at Small Culverts

Two small concrete box culverts were monitored in Year 4. Wildlife activity at the small culverts occurred primarily during the non-winter months, although most species were also documented at the culverts during the winter months. Figure 20 displays success movements by small culvert location. Wildlife species were detected in higher numbers at the BVR Box Culvert, in particular, mule deer, coyote, black bear and bobcat. Domestic dogs and cats were recorded passing through the Culbreath Box Culvert 30 times and may have deterred some wildlife activity at this location. Success movements at small culverts were also made by red fox, hares, northern raccoon, and striped skunk.

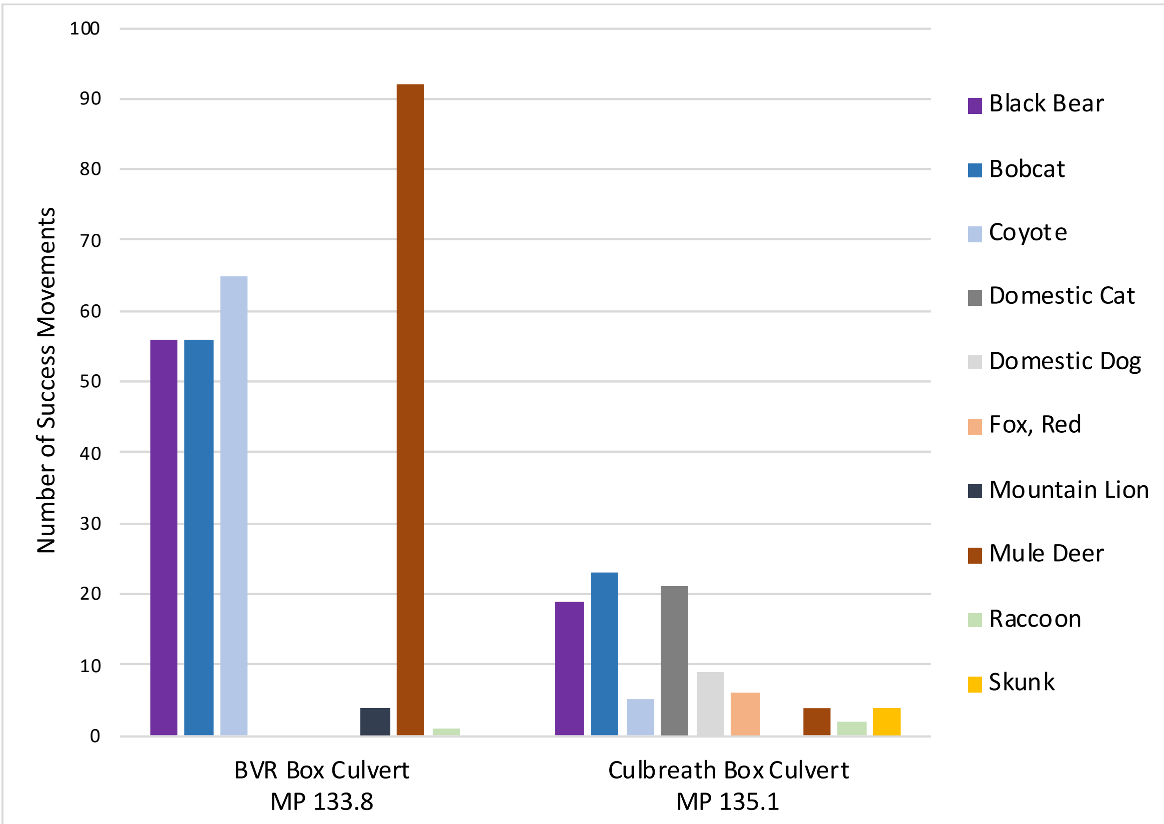

Figure 20. Success movements by species at each of the small culverts. Total monitoring days at each location are: BVR Box Culvert – 816 days; Culbreath Box Culvert – 773 days.

Mule deer were documented at and recorded making success movements through both culverts; however, the number of these movements was substantially higher at the BVR Box Culvert (*n*=92) than at the Culbreath Box Culvert (*n*=4). Repel rates at the small culverts decreased from Year 3 (46%) to Year 4 (31%) but remained higher at the Culbreath Box Culvert. Since monitoring began at these culverts in Year 2, the overall success rate for mule deer was 31%.

Wildlife Movements at Other Mitigation Features

Wildlife Guards

The vast majority of approaches to the wildlife guards were made by mule deer. Since the onset of this research, ungulates have made a total of 171 breach movements at wildlife guards. In Year 4, ungulates made 33 breach movements, representing a 28% decrease from the annual average number of breach movements in Years 1-3. Most ungulate breaches were made from the habitat side into the fenced right-of-way, although, on a few occasions, animals trapped inside the fencing breached the guards to return back to the habitat side of the fencing. The wildlife guards deterred ungulates from entering the fenced right-of-way 85% of the time in Year 4, which is consistent with the ungulate repel rate of 84% reported in Year 3. Across all years of the research, the flat bar guards were 80% effective in preventing ungulate incursions into the fenced right-of-way and round bar guards were 90% effective.

Table 6 displays the number of breaches and repel movements, as well as breach rates and repel rates for each species that approached the guards in Years 1-4. For mule deer, the flat bar guards were 82% (*n*=514) effective in preventing breaches, while the round bar guards were 90% effective (*n*=466). The repel rate for elk was slightly higher at round bar guards (80%) than at flat bar guards (75%), although the total number of elk movements at wildlife guards remains fairly low (*n*=47). White-tailed deer had a higher repel rate at round bar guards (82%; *n*=11) than at flat bar guards (67%; *n*=3). No bighorn sheep approached the guards in Year 4, but for the first time a moose breached one of the guards (Trough Road, flat bar). Pronghorn was documented for the first time at a wildlife guard in Year 4, resulting in a repel movement (County Road 1002, round bar).

As in previous years, black bear infrequently visited the guards but breached both flat bar and round bar guards 100% of the time when they did approach (*n*=8). Red fox (*n*=284) and coyote (*n*=93) approached the guards more frequently, with breach rates of 93% and 69%, respectively. Unlike ungulate species, these carnivore species were observed breaching the guards in both directions, although the majority of breach movements originated from the habitat side of the fence.

Table 6. Breach and repel rates for each species at wildlife guards with flat bars (7 locations) versus round bars (5 locations) from Years 1-4. The Badger Road Deer Guard only has a partial length of wildlife fencing along the sides of the deer guard.

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	5	100%	0%
Bobcat	Flat Bar	19	89%	11%
	Round Bar	9	100%	0%
Coyote	Flat Bar	80	73%	28%
	Round Bar	13	46%	54%
Elk	Flat Bar	32	25%	75%
	Round Bar	13	23%	77%
	Round Bar; partial fence	2	0%	100%
Moose	Flat Bar	8	13%	88%
	Round Bar	7	0%	100%
Mountain Lion	Flat Bar	1	100%	0%
	Round Bar	0	n/a	n/a
Mule Deer	Flat Bar	514	18%	82%
	Round Bar	394	10%	90%
	Round Bar; partial fence	72	10%	90%
Red Fox	Flat Bar	204	93%	7%
	Round Bar	76	92%	8%
White-tailed Deer	Flat Bar	3	33%	67%
	Round Bar	10	20%	80%
	Round Bar; partial fence	1	0%	100%

*Flat bar guards *n*=6; Round bar guards, *n*=4; Round bar guard with partial fence, *n*=1.

Ungulate breach rates varied depending on the guard type. Overall, the flat bar guards were breached by ungulate species on 104 occasions for a rate of 0.025 breaches per monitoring day, and the round bar guards were breached 51 times for a rate of 0.013 breaches per monitoring day. In Year 4, mule deer breaches were recorded at all monitoring locations but continued to occur most frequently at County Road 1000 (flat bar), with 42% of all breaches occurring at this location. This was also the only location where breaches occurred by walking on snow that had become packed in between the bars. Mule deer most commonly breached flat bar guards by walking on top of the bars (*n*=9 out of 18 total) followed by walking on snow that was packed in between the bar (*n*=5). At round bar guards, the most common breach type for mule deer was jumping the guard (*n*=5 out of 8 total). The mule deer repel rate at the Badger Road wildlife guard was the same as other round bar guards at 90%, even though the wildlife fencing runs only along half the length of the guard at this location.

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 Years 3 and 4. 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 7. In two of the pairs, repel rates were higher at the flat bar guards, while in the third pair the repel rate was higher at the round bar guard. However, for each of the pairs, repel rates between the flat bar and round bar guards were within six percentage points. Jumping the guard was the most common breach type and occurred at both the flat bar and round bar guards in each pair, with the exception of the County Road 33 guard. Walking on top of the bars was recorded only at flat bar guards, while walking on the support beams was recorded only at one of the round bar guards.

Table 7. Breach and repel movements at wildlife guards included in the paired analysis (Years 3 & 4).

Monitoring Location	Breach Rate	Repel Rate	Walk on Top	Walk on Support Beams	Walk Snow	Jump
Thompson (round bar)	3%	97%	0	0	0	1
County Road 33 (flat bar)	0%	100%	0	0	0	0
Triangle Road (round bar)	11%	89%	2	0	0	5
Spring Creek Road (flat bar)	5%	95%	2	0	0	2
County Road 1002 (round bar)	13%	88%	1	3	0	6
County Road 1000 (flat bar)	18%	82%	5	0	1	7

Escape Ramps

Since the onset of this research, cameras have recorded a total of 189 elk and 980 mule deer movements at escape ramps on the right-of-way side of the fence. 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, West Fence End Escape Ramp, and the Badger Road Escape Ramp. Elk have been documented at five ramp locations, with the majority of movements occuring at the East Fence End Escape Ramp and only incidental activity at the other ramp locations.

Mule deer and elk activity at the escape ramps have varied through each year of this research (Fig. 21). Activity for mule deer was highest during the winter months. Few elk have been detected inside of the right-of-way fencing at the escape ramps with the exception of Winter 2016-17, when 169 movements were documented; otherwise, elk activity was low during both winter and summer months. Successful escape movements are a fraction of the total approach movements for both species.

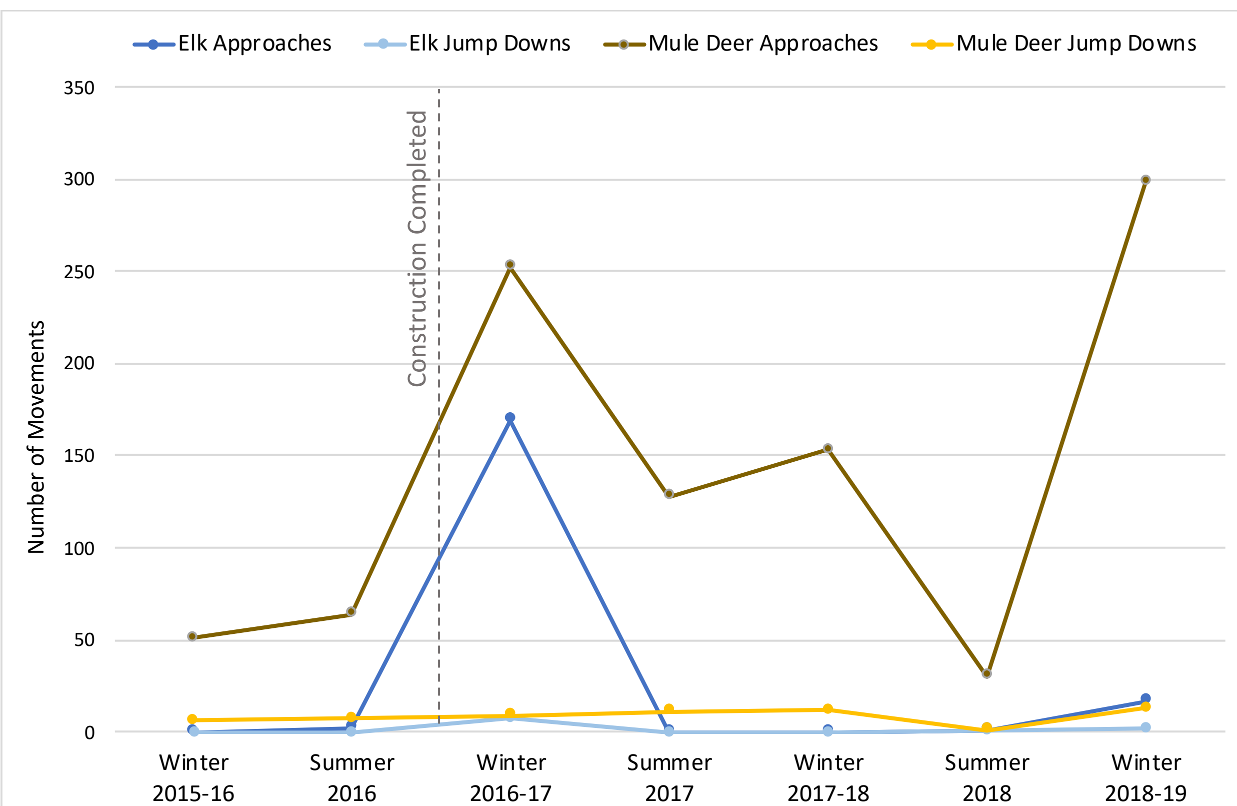

Figure 21. Mule deer and elk activity at monitored escape ramp locations over time.

When an animal approached an escape ramp on the right-of-way side of the fence, it either walked around the ramp or ascended it (intercepted). Table 8 summarizes elk and mule deer approaches and intercept rates for the different escape ramp types for Years 1-4. In general, ramps without perpendicular rail fence had higher intercept rates than those with the rail fence. For mule deer, 2:1 sloped ramps without perpendicular rail fence and the jumpdown ramp at Harsha Gulch had the highest intercept rates (71% and 70%, respectively). Ramps with a 3:1 slope without rail fence had an intercept rate of 59%. For elk, 3:1 slope ramps with perpendicular rail fence had an intercept rate of 100%, but with a sample size of just one elk. Otherwise, 3:1 sloped ramps without perpendicular rail fence had an intercept rate of 53% for elk with a sample size of 185. Ramps with a 2:1 slope with perpendicular rail fence had the lowest intercept rate for elk at 33% but also with a low sample size. In general, these patterns of intercept rates for each ramp type were similar to those reported in Year 3. The overall intercept rate for mule deer and elk combined regardless of ramp type was 50%.

Table 8. Intercept rates for mule deer and elk at escape ramps with 2:1 versus 3:1 slopes and with or without perpendicular rail fence through Year 4. 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
Mule Deer	2:1 slope with rail fence (*n*=5)	53	34%
	2:1 slope without rail fence (*n*=1)	111	71%
	3:1 slope with rail fence (*n*=2)	286	26%
	3:1 slope without rail fence (*n*=5)	503	59%
	Jumpdown (*n*=1)	27	70%
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)	1	100%
	3:1 slope without rail fence (*n*=5)	185	53%
	Jumpdown (*n*=1)	0	n/a

Animals whose movements were intercepted by a ramp either walked up and turned around or jumped down to the habitat side. Table 9 summarizes escape rates for deer and elk at each of the different escape ramp types for Years 1-4. 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*=14), with escape rates of 18% and 25%, respectively. Other ramps recorded seven or fewer escape movements with escape rates ranging from 0-19%. Three ramps had both high intercept rates and relatively high escape rates for mule deer, none of which have perpendicular rail fence but, otherwise represent different ramp types, including 2:1 slope (North Overpass Escape Ramp), 3:1 slope (Culbreath 3:1 Escape Ramp), and the sole jumpdown ramp in the project area (Harsha Jumpdown). The overall escape rate for mule deer and elk combined regardless of ramp type was 12%.

Table 9. Escape rates by mule deer and elk at escape ramps with 2:1 versus 3:1 slopes and with or without perpendicular rail fence through Year 4. 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
Mule Deer	2:1 slope with rail fence (*n*=5)	18	6%
	2:1 slope without rail fence (*n*=1)	79	18%
	3:1 slope with rail fence (*n*=2)	74	18%
	3:1 slope without rail fence (*n*=5)	295	9%
	Jumpdown (*n*=1)	19	16%
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)	1	100%
	3:1 slope without rail fence (*n*=5)	98	9%
	Jumpdown (*n*=1)	n/a	n/a

In Year 4, white-tailed deer approached and ascended both of the Culbreath ramps and both of the Trough Road ramps but did not successfully escape off any of these ramps. The only successful escape by white-tailed deer was at the Overpass Escape Ramp. Bighorn sheep, moose and pronghorn were not recorded at any of the ramps. Other carnivore and meso-mammal species were also documented by the escape ramp cameras, and 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.

South Fence End

In total, 1,277 elk and mule deer movements have been recorded at the south fence end since the completion of construction activities. The total number of ungulate movements at the south fence end increased by 16-17% each year post-construction. Of these, 10% were movement by deer and elk into the fenced right-of-way (*n*=132). The majority of movements for all species occurred beyond the fence end without movements into or out of the fenced right-of-way, including 84% of all deer movements and 60% of all elk movements. Other species documented at the south fence end include coyote, red fox and mountain lion.

Ungulate movements at the south fence end were highest during the winter months, although some movements continue to occur during the summer months. Figure 22 displays activity by movement type for each season since construction was completed. The greatest number of ungulate movements occurred in Winter 2018-19, with most movements occurring beyond the fence, from one side of the roadway to the other (*n*=322; 79%). Often a group made multiple approaches toward the roadway and were repelled by passing traffic before completing the movement.

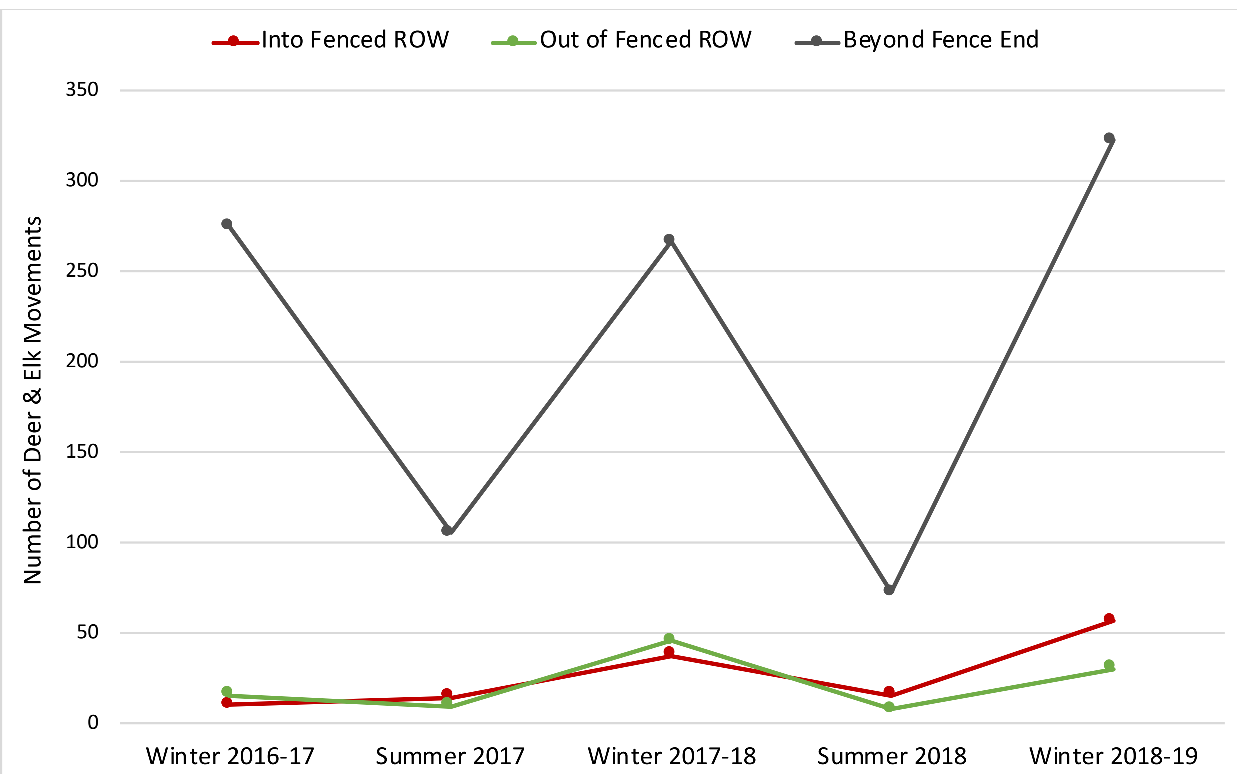

Figure 22. Post-construction mule deer and elk movements at the south fence end.

Wildlife-Vehicle Collision Rates

BVR/CPW Carcass Data

In Winter 2018-19, six mule deer and no elk carcasses were reported inside the project area, for a decrease of 90% relative to the five-year pre-construction average of 62.8 carcasses each winter (Fig. 23). South of the project area, one mile beyond the fence end, 13 deer carcasses and one elk carcass have been reported since the completion of construction. Five of these reports were from Winter 2018-19 – a slight decrease from the six carcass reports in this mile segment in Winter 2017-18. Overall, seven of these WVC carcasses were located less than 30 meters from the fence end. In addition to deer and elk, a bear cub carcass was reported just beyond the fence end in May 2017.

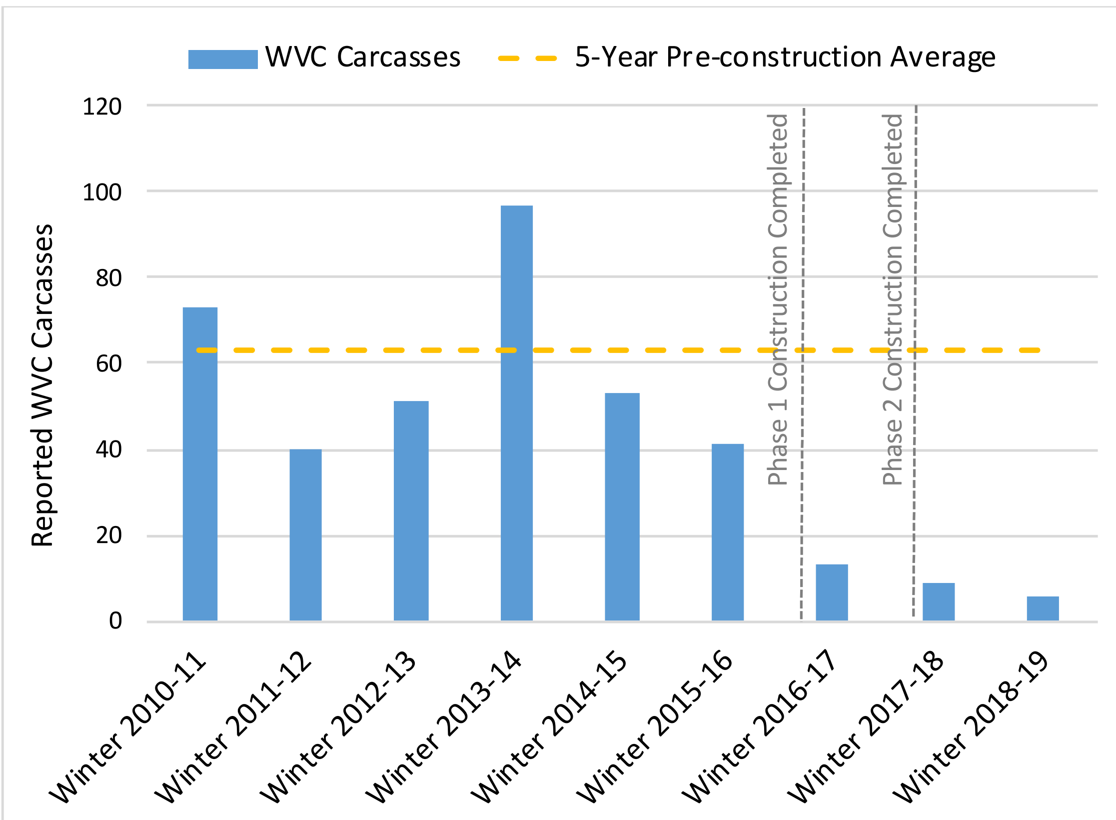

Figure 23. Mule deer and elk carcass counts recorded by BVR and CPW compared to the five-year pre-construction average of 62.8 carcasses per winter. The carcass counts reported here differ from what was reported in previous progress reports because of an updated definition of 'winter' to include the month of November. These data were not collected consistently through the non-winter months.

CDOT Maintenance Carcass Data

Post-construction WVC carcass reports remained low in Winter 2018-19 within the mitigation project area. Two mule deer carcasses were reported inside the project area in Winter 2018-19, which is up slightly from one each in Winter 2017-18 and Winter 2016-17, but well below the five-year pre-construction average of 40.2 carcasses per winter, representing a 95% decrease in WVCs (Fig. 24). Only one WVC carcass has been reported during the summer months since construction was completed.

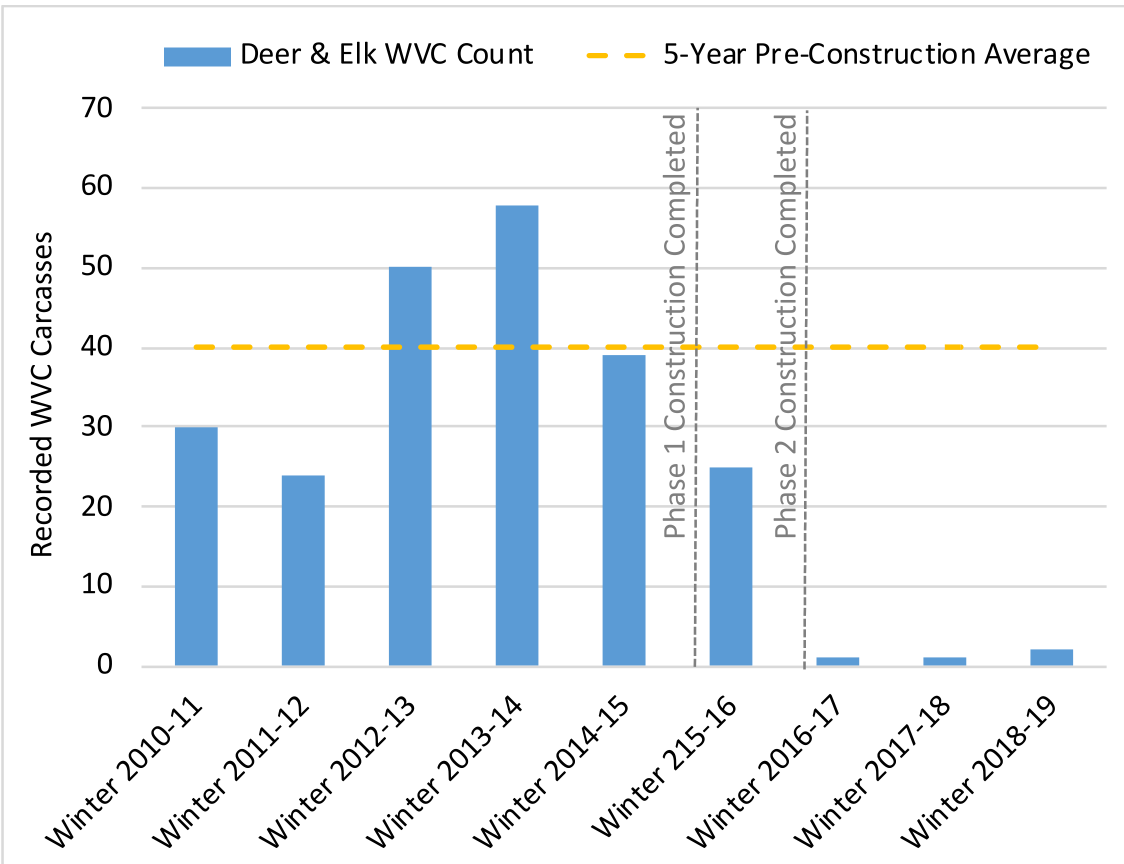

Figure 24. Wintertime mule deer and elk carcass counts recorded by CDOT Maintenance within the project area (MP 216.6 – 137.0) compared to the five-year pre-construction average of 40.2 carcasses each winter.

CDOT WVC carcass pickups were also recorded beyond the fence ends, particularly south of the project area (Fig. 25). In the five years prior to construction, 18 WVC carcasses were reported within 1.5 miles of the south fence end (to Milepost 125.0) and three WVC carcass were reported in the half-mile north of the project area. These numbers have increased in the three years post-construction, during which 30 WVC carcasses were reported in the segment south of the project area and one was reported north of the project area. Half of these events (n=16) occurred in Year 4 alone.

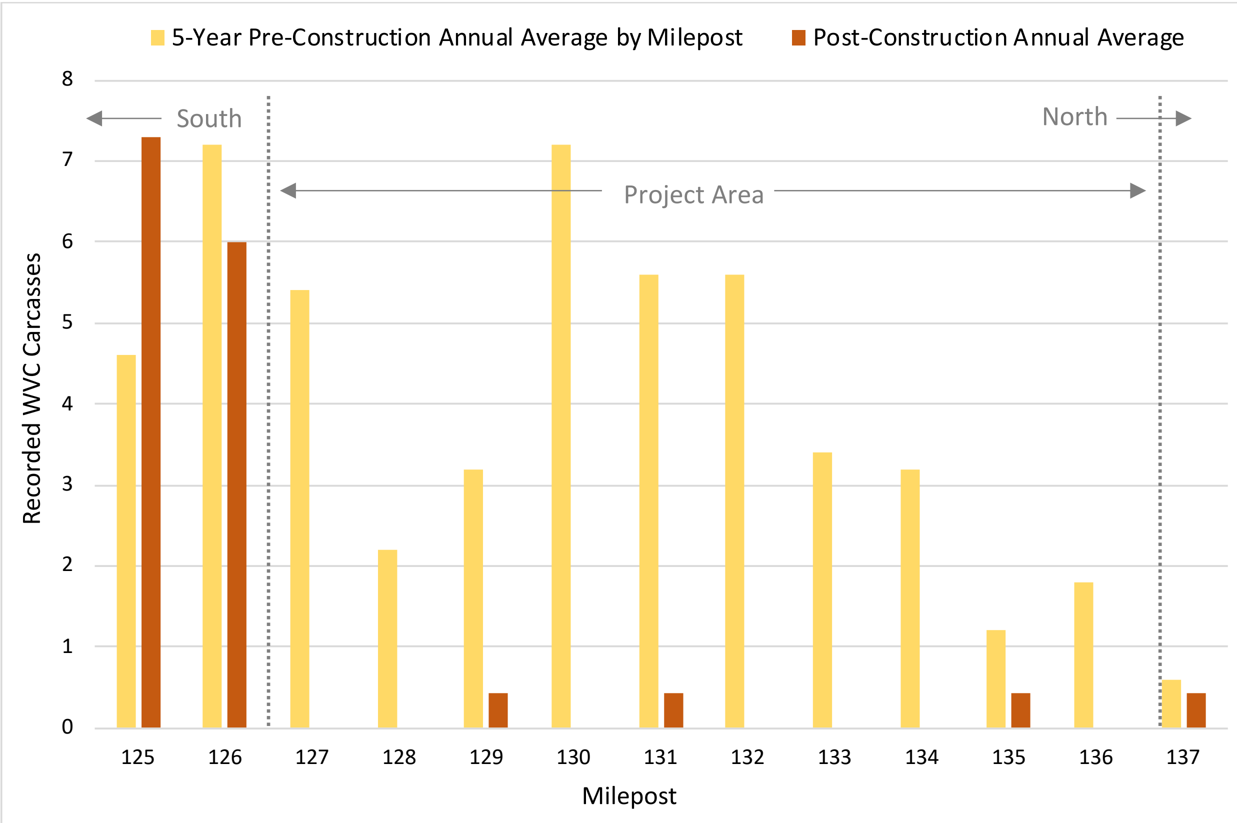

Figure 25. Five-year pre-construction annual average and post-construction annual average mule deer and elk carcass counts recorded by CDOT Maintenance by milepost. The post-construction annual average is based on the timeframe from 11/1/2016 through 4/30/2019).

CDOT Traffic and Safety Accident Report Data

During the five winters prior to mitigation construction (Winters 2010-11 through 2014-15), WVC were the most common accident type on this segment of highway, accounting for 60% of all accidents reported to law enforcement, including two human fatalities and 60 accidents with property damage only. In total, three WVC accidents have been reported to law enforcement since the completion of construction, including one during the summer months of 2017 and two in Winter 2017-18, representing an 84% decrease from the five-year pre-construction average of 12.2 WVCs each winter (Fig. 26).

In addition, one WVC accident was reported within the half-mile south of the south fence end post-construction (in Winter 2017-18), and two additional WVC accidents were reported in December 2018. Complete data for Winter 2018-19 were not available at the time of this analysis.

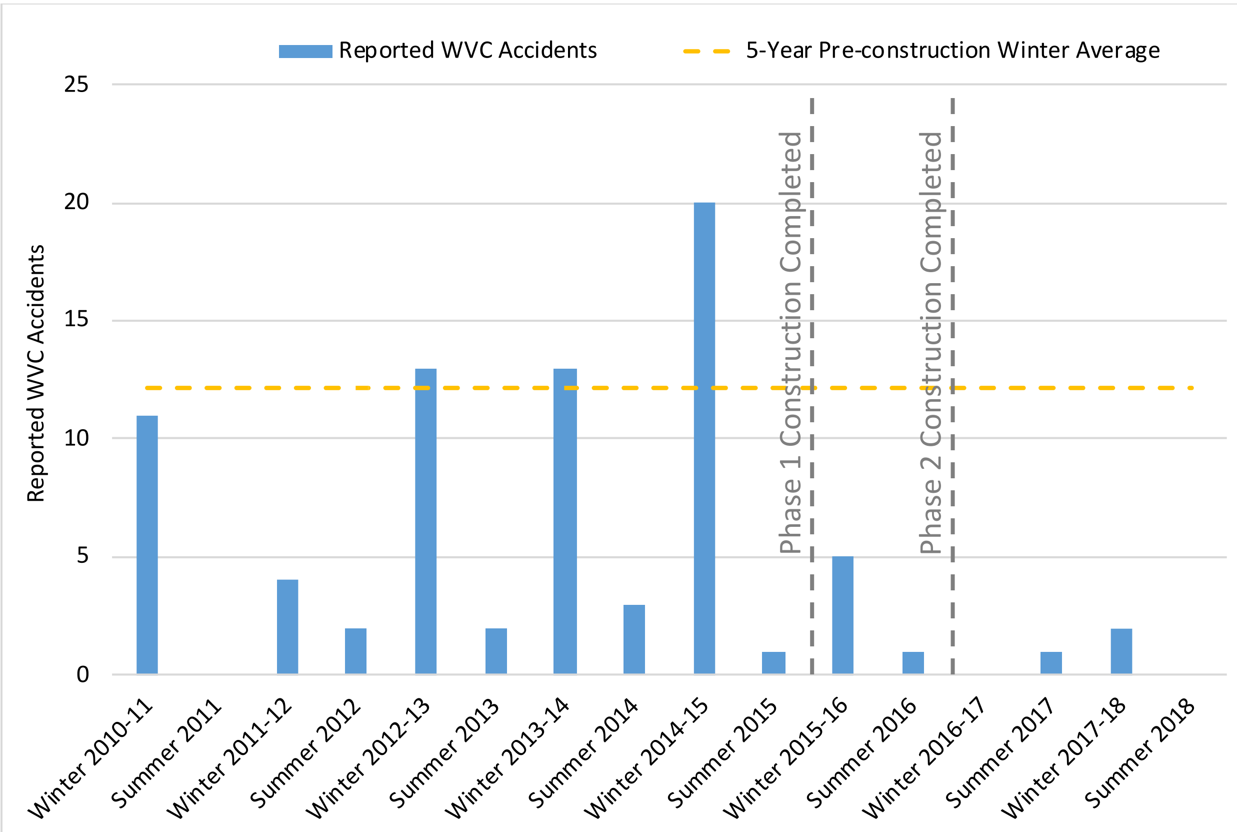

Figure 26. Wildlife-vehicle collision accidents within the project area (MP 126.6 – 137.0) reported to law enforcement involving mule deer or elk compared to the 5-year pre-construction average of 12.2 reported accidents, which is calculated for the winter months only so that it may be compared to the 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, to the north of the project area. Comparisons were made between the number of ungulate (mule deer, elk and pronghorn) carcasses five winters pre-construction and three winters post-construction (Fig. 27). 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, resulting in a potential increase in WVC on US 40. During the five years pre-construction, 29 deer carcasses and eight elk carcasses were recorded in this segment (equivalent to an average of 5.8 mule deer and 1.6 elk carcasses per winter). Post-construction, five mule deer carcasses and four elk carcasses were recorded during Winters 2016-17, 2017-18, and 2018-19 (equivalent to an average of 1.7 mule deer and 1.3 elk carcasses per winter). The average number of carcasses by milepost each winter has remained at or below the five-year pre-construction average on this segment of US 40.

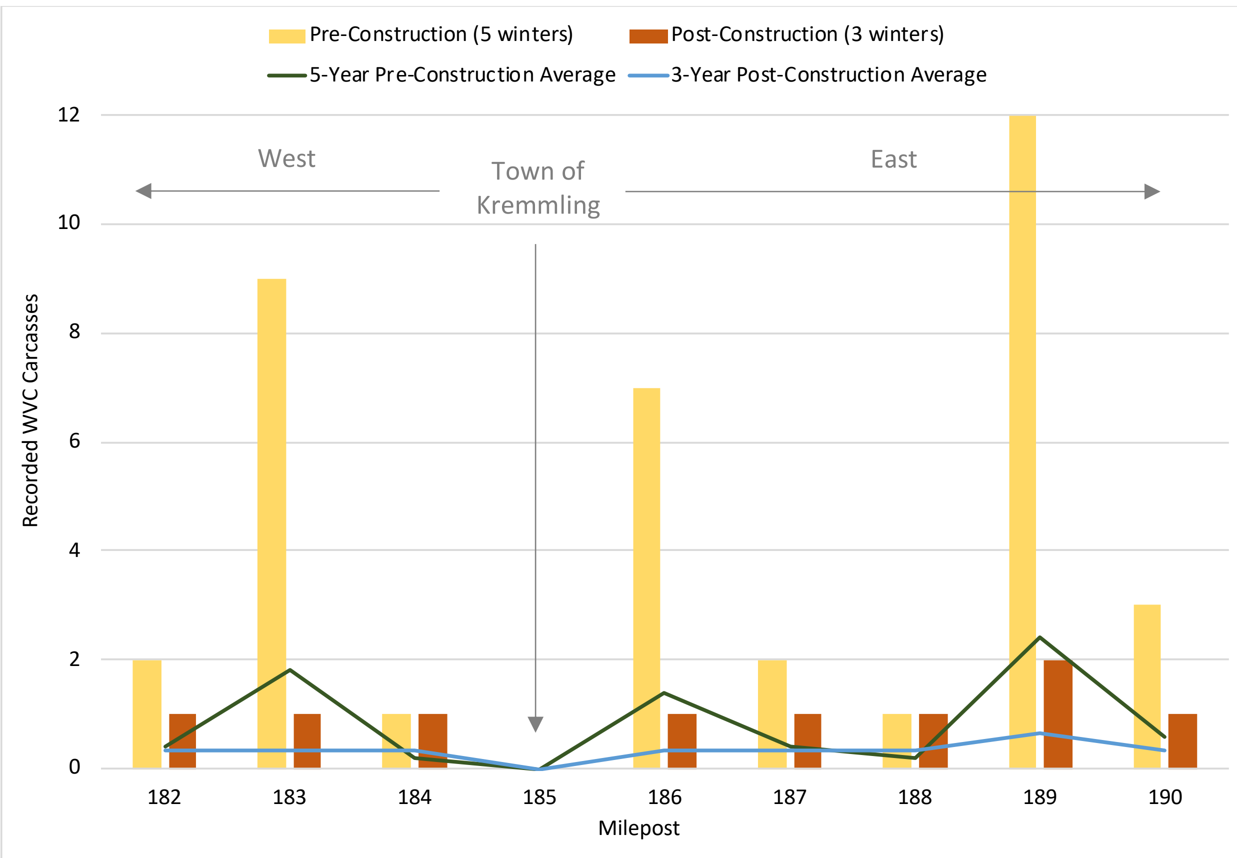

Figure 27. Ungulate carcass counts recorded by CDOT Maintenance on US 40 east and west of Kremmling (MP 185) for five winters prior to mitigation construction and three winters post-construction. The 5-year pre-construction winter average was calculated for each one-mile segment.

Discussion

The results of this research study provide a wealth of information on the wildlife crossing structure use by mule deer and other species, as well as the efficacy of several wildlife guards and escape ramp designs, and the use of these mitigation strategies to reduce incidence of WVCs. The study's documentation of over 83,000 mule deer success movements, and the use of the seven wildlife crossing structures by sixteen other species provides a robust dataset from which recommendations can be generated for other wildlife mitigation projects in Colorado and across North America with similar species. The 90% decrease in reported carcasses and 88% decrease in reported WVC accidents in the study area are also important factors in demonstrating the success of this wildlife mitigation project. 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 wildlife mitigation.

The discussion is presented in five sections, beginning first, with the use of wildlife crossing structures by mule deer and continuing second with structure use by other wildlife. The third section addresses the efficacy of the wildlife guards, escape ramps, and the south fence end. The fourth section examines WVC accident and carcass rates. The discussion ends with an overview of next steps for the research study.

Mule Deer Use of Wildlife Crossing Structures

Progress Towards Performance Measures

Mule deer use of the seven wildlife crossing structures continued to exceed the performance measures defined at the outset of the research and even surpass numbers reported from other similar studies in the western U.S. All seven wildlife crossing structures exceeded performance measure one: the success rates for mule deer were well above the 60% minimum goal and the 80% final goal. The overall success rate across all wildlife crossing structures was 96%. In Winter 2018-19, six of the seven wildlife crossing structures had success rates of 95% or higher. The structure with the lowest success rates was the Williams Peak Underpass at 85%, still above the final 80% goal.

The crossing structures have also partially met performance measure seven: there will be an increase in mule deer success movements each year until a plateau is reached. Mule deer activity and success movements through or over the wildlife crossing structures have continued to increase each year of this research. In Winter 2018-19, the number of mule deer success movements increased 58% from the previous winter for a total of 83,256 success movements since the start of this research – numbers that rival those from other successful mitigation projects across western states. Cramer and Hamlin (2019) recorded 78,610 mule deer success movements through seven structures over five years in Utah. Stewart (2015) recorded 35,369 successful crossings by migratory mule deer at five wildlife crossings (two overpass and three underpasses) on U.S. Highway 93 in Nevada. In Wyoming, Sawyer and LeBeau (2011) reported over 49,000 success movements by migratory mule deer through seven wildlife underpasses. The number of success movements documented by this research, combined with a successful passage rate of 96% across all of the wildlife crossing structures, indicates that the mitigation has been highly effective in accommodating mule deer passage. Given that the Middle Park deer herd has decreased in size each year from 2016-2018 (Lamont 2019) due to herd management practices, the mitigation may have improved connectivity for mule deer across SH 9 to a level greater than was possible prior to the construction.

Mule Deer Success Rates and Success Movements

Overall, mule deer success movements through or over the crossing structures have increased each year of this research. However, the redefinition of the winter months to include November through April has altered the presentation of these results from what was reported in previous progress reports. Accordingly, in Winter 2018-19, the total number of mule deer success movements increased by 58% relative to the Winter 2017-18, following a 38% increase in Winter 2017-18. Mule deer success rates have remained high at all locations and during all monitoring periods, indicating that mule deer adapted quickly to the crossing structures and fencing. On average, mule deer made 168 success movements over and through the seven crossing structures each day during Winter 2018-19; notably, these success movements represent the number of potential WVCs that were avoided each day had the mitigation project not been implemented. In comparison, 107 mule deer success movements were made each day during Winter 2017-18.

There remained significant variation in the number of mule deer success movements among the wildlife crossing structure locations. Since the completion of construction activities in December 2016, the highest number of mule deer success movements were at the BVA Underpass (MP130.8, *n*=20,951), the North Overpass (MP 134.3, *n*=16,069), and the South Overpass (MP 129.5, *n*=14,459). These three structures account for 71% of all post-construction success movements at the wildlife crossings. The BVA Underpass and the South Overpass are located within 1.3 miles of one another in the southern portion of the project area. These structures may accommodate mule deer connectivity on a portion of the winter range that hosts a greater density of mule deer than other portions of the lower Blue Valley winter range. Towards the north end of the project area, the North Overpass and North Underpass (MP 136) had the third and fourth highest number of success movements, respectively, representing another high activity area for mule deer. In the center of the study area are the Harsha Gulch (MP131.6) and the Middle (MP 132.5) Underpasses. These structures had moderately-low numbers of mule deer movements. The least amount of mule deer activity was documented at the Williams Peak Underpass (MP 127.7) at the very south end of the project, nearly two miles south of the South Overpass.

Year 4 of this research lends further credence to the notion that landscape factors may influence wildlife crossing structure use. As the structure designs and dimensions between the two overpasses and among the five underpasses were the same throughout the project, structure dimensions may be eliminated as a variable influencing wildlife use of the crossing structures in this study. In the Year 3 progress report, a comparison of mule deer activity at overpass structures versus underpasses in the project area suggested a leveling out of mule deer activity based on structure type. In Year 4, the increase in the number of success movements at overpasses (111%) was substantially greater than the increase at the number of underpasses (32%), potentially suggesting a preference by mule deer for overpass structures. However, as the structure with the highest number of success movements was an underpass (BVA) rather than an overpass, it is also possible that these results reflect variations in mule deer winter range habitat use – that is, structures located in portions of the winter range with the greatest density of mule deer receive the most use. Other factors that may influence spatial variation in mule deer use of the crossing structures include local terrain features at each structure, winter severity and snow accumulations, or variability in mineral composition and forage quality (e.g., Peterson 2008). 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. In addition, each year post-construction, mule deer have been documented making success movements at all three small culverts (n=99), although the majority of mule deer approaches to small culverts were parallel (n=102) or repel movements (n=126).

Mule deer success movements also varied throughout the year. Periods of peak mule deer activity varied at each of the wildlife crossing structures and from one winter to the next. In general, mule deer 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. In Winter 2018-19, most structures experienced a peak in mule deer activity in February and March. This pattern is similar to observations from Winter 2015-16 in the Phase 1 segment prior to construction being completed, but differs from Winter 2016-17, when peak activity was concentrated in January and mid-February, and Winter 2017-18 when peak activity at several locations didn't occur until March. Fluctuations in the onset of winter conditions at high elevations, winter severity and winter snowpack are likely contributors to annual variability in peak activity.

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. Mule deer success movements continued to be recorded at all of the wildlife crossing structures from May through November 2018, with a small peak in activity observed at the Harsha Gulch Underpass and the BVA Underpass in July and August. These movements by resident mule deer accounted for 20% of all movements at crossing structures in Year 4, demonstrating 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; no WVC carcasses and only one WVC crash was reported during the non-winter months since construction was completed (based on CDOT Maintenance carcass reports and CDOT Traffic and Safety accident reports; BVR does not collect carcass data during the non-winter months).

Figure 29. Mule deer fawn nursing at the Harsha Gulch Underpass.

Figure 28. Mule deer crossing through the Middle Underpass along the narrow pathway adjacent to the drainage trough.

Various anecdotal movements were also documented in Year 4. In particular, the research documented multiple events of mule deer resting in the shade of the underpasses or foraging – and in one event, a fawn nursing – in front of the structure entrances during the summer months (Fig. 28). These types of lingering behaviors indicate a high level of comfort at the crossing structures among resident mule deer. At the Middle Underpass, mule deer and other wildlife were observed using the narrow path between the culvert wall and the concrete drainage trough to move through the structure, despite the narrow, confined nature of this pathway (Fig. 29). In another crossing event at the North Underpass, a group of elk approached the structure entrance and several individuals passed through successfully while the others initially repelled; however, in the intervening moments, a group of mule deer also passed through the structure, leading the remaining elk to successfully cross through the structure.

Wildlife Crossing Structure Use by Other Species

Sixteen species of wildlife other than mule deer have been documented making success movements through the wildlife crossing structures, although in much lower numbers than mule deer. Ungulates, being prey species, use structures differently than carnivores. Elk are a species of special interest because of their general hesitancy to use wildlife crossing structures. This section discusses ungulate use of the structures, with an emphasis on elk, followed by a discussion of carnivore use, and ends with discussions of other species, including humans, at the wildlife crossing structures.

Elk and Other Ungulate Use of Wildlife Crossing Structures

Elk, pronghorn, moose, bighorn sheep, and white-tailed deer were all documented using the wildlife crossing structures to varying degrees. Movements by these species occurred in much lower numbers than mule deer; however, success movements by these species have generally increased each year of this research. The lower number of movements reflect the relatively lower proportion of these species in this landscape compared to mule deer but are expected to continue increasing through the duration of this research as these species become more comfortable with the crossing structures and as more individuals learn to use the structures.

Elk

Performance measure for elk established at the outset of this research have all been met or partially met. Elk success movements have increased across the structures and over each year of the study. In Year 4, elk success movements increased 291% relative to the three-year annual average from Years 1-3. This increase in elk success movements demonstrates progress towards performance measure eight: there will be an increase in elk success movements each year until a plateau is reached. The overall success rate for elk across all of the wildlife crossings was 92%. This exceeds the benchmark set in performance measure two of a minimum of 60% and 75% by the final year of the study. Performance measure six sets the goal that elk movements at the crossing structures each year will be at least 50% the number of elk movements captured at the habitat cameras. This objective was met in both Year 3 (81%) and Year 4 (70%).

Elk continue to be photographed primarily in the northern portions of the study area, with the greatest number of elk success movements at the North Underpass (MP 136, *n*=59) and the North Overpass (MP 134.3, *n*=38). In Year 4, elk success movements were recorded for the first time at the Williams Peak Underpass (MP 127.7, *n*=2) at the southern end of the study area. These results are consistent with elk activity at the habitat cameras, which documented the highest level of elk activity at the North Underpass (*n*=110) and the North Overpass (*n*=109). In contrast, pre-construction monitoring detected the greatest elk activity in the southern portions of the study area, particularly, around the Williams Peak Underpass. As with mule deer, these results suggest that elk use of the structures may be influenced by a structure's location relative to where elk activity is highest in the landscape. These results may also reflect changing patterns in elk use of the winter range habitat from one year to the next.

In Winter 2018-19, for the first time, small herds of elk were detected at the North Underpass. In each of these events, hesitancy behavior was detected, with individual animals making multiple attempts over several minutes before completing a successful through passage. This behavior may suggest that elk are still learning to adapt to the crossing structures. Prior to Year 4, elk success movements were comprised of single animals or groups of up to five individuals. In Year 4, there were several crossings made by herds of up to 17 animals composed of cows and calves. Movements by these elk herds tend to be characterized by one or more approaches into the structure and initial repel movements before a successful passage was completed. In one event, over five minutes were required for the entire group to successfully pass through the crossing structure. These behaviors indicate that while elk in the project area are becoming increasingly familiar with the crossing structures, there remains quite a bit of hesitancy and caution in adapting to the crossing structures.

Across the study area, elk have been detected nearly twice as frequently at the underpasses than the overpasses. Repel rates were low regardless of structure type, but the repel rate was higher at the underpasses than the overpasses (10% and 5%, respectively). Cows and calves, in particular, were more common at the underpass structures, while bulls were documented with a slightly greater frequency at the overpass structures, although bulls made up only 16% of total elk detections. However, given the low numbers of overall elk activity and indications that elk in the study area are still in the process of adapting to the mitigation features, a preference for underpasses versus overpasses cannot be confirmed.

Other Ungulates

Success rates for all other ungulate species documented at the wildlife crossing structures, including bighorn sheep, moose, pronghorn and white-tailed deer were 83% or greater. Success rates by species were 83% for bighorn sheep (n=29), 90% for moose (n=62), 95% for white-tailed deer (n=69), and 99% for pronghorn (n=83). These results met the objective set for less common ungulate species in performance measure three: the success rate for all meso and large mammals other than elk and mule deer will reach a minimum of 60% and have a goal of 80% success for each structure final year this research. Performance measure nine has also been met for ungulates: each year post-construction, there will be one or more success movements by each of the less common species of large ungulates.

A study of a major pronghorn migration route in Wyoming (Sawyer et al. 2016) documented a preference for overpass structures by pronghorn. However, in the first three years of this research, pronghorn was documented using only underpass structures and it wasn't until Year 4 that they were documented crossing over the overpass structures. Across all years, pronghorn was detected crossing through the BVA Underpass more than any other structure. In general, the greatest number of pronghorn movements occurred at wildlife crossings in the middle portions of the study area (South Overpass, BVA Underpass, Harsha Gulch Underpass and Middle Underpass) more than those at the north end or far south end of the project area.

Similarly, in Years 1-3, white-tailed deer was documented using only underpass structures, but in Year 4 was documented crossing over the North Overpass in one event. White-tailed deer was not documented at either of the southern-most crossing locations (Williams Peak Underpass and the South Overpass), and the greatest number of success movements by white-tailed deer occurred at the North Underpass, the northern-most structure.

Bighorn sheep movements continued to be most common in the southern portion of the study area with most success movements occurring at the South Overpass and the Williams Peak Underpass. Bighorn sheep have been detected using all of the crossing structures except the Harsh Gulch and BVA Underpasses and have used the two overpasses slightly more (n=17) than the three underpasses (n= 12). All of the bighorn sheep success movements were made during the daytime hours. These movements were made by individuals or small groups including both ewes and rams and, in one event, a young lamb. While the overall numbers of bighorn sheep were low in this landscape, these results suggest increasing familiarity with the mitigation.

Moose made success movements at each of the wildlife crossing structures except the South Overpass. The greatest number of success movements by moose were in the northern portions of the study area, at the North Underpass (MP 136, n=24), the North Overpass (MP 134.3, n=13), and the Middle Underpass (MP 132.5, n=14). In general, moose, pronghorn and white-tailed deer each made more success movements at the underpass structures, while bighorn sheep used underpasses and overpasses in nearly equal numbers.

For each of these ungulate species, seasonal and annual movements varied from year to year. Success movements by bighorn sheep and moose have increased each year of the study, while pronghorn movements peaked in Year 3 and white-tailed deer movements peaked in Years 2 and 4. In general, these species made more movements at the crossing structures during the summer months (May through October) than during the winter months. These species not only occur in the study area in lower numbers than mule deer, they may also move to other areas for the winter.

Carnivores and Other Species

A diversity of carnivore and other species were also photographed using the crossing structures and provide some evidence of taxa-specific preferences. Overall success rates for non-ungulate species documented at the wildlife crossing structures (including badger, black bear, bobcat, coyote, mountain lion, raccoon, red fox, and striped skunk) ranged from 71% for badger up to 99% for black bear. In addition, river otter and turkey were detected successfully using the crossing structures for the first time in Year 4 (for each species, n=1). These results met the objective set for less common non-ungulate species in performance measure three: the success rate for all meso and large mammals will reach a minimum of 60% and have a goal of 80% success for each structure in the final year this research. Performance measure nine has also been met for most of these species: each year post-construction, there will be one or more success movements by each of the less common non-ungulate species. However, neither badger nor skunk were recorded in Year 4.

Coyote and red fox were the only species other than mule deer documented using every crossing structure. The number of coyote success movements remained greatest at the South Overpass and doubled from Year 3, potentially suggesting that one or several individuals have incorporated the overpass into their home ranges and are making regular movements to either side of the highway. Of all the non-ungulate species, coyote made the greatest number of success movements at each of the wildlife crossing structures, and do not appear to exhibit a preference for one structure type over the other. Red fox success movements decreased in Year 4 by 62% relative to Year 3. As in previous years, red fox success movements in Year 4 were greatest at the BVA Underpass and the South Overpass. These two structures are located within 1.3 miles of one another. Fox movements were substantially lower at all of the other structure locations, suggesting that location may be a more important factor than structure type influencing fox movements.

Black bear success movements continued to be concentrated at the Middle Underpass (MP 132.5), with 137 success movements. It is likely these were primarily by a small number of individuals moving regularly back and forth at this location. In addition, 56 black bear success movements were recorded at the 8'x8' BVR Box Culvert (MP 133.8). Both of these structures are located in ephemeral drainages with a more diverse and complex vegetation component than the other crossing structures. This diversity may also help explain why the Middle Underpass had the highest level of species diversity of all of the wildlife crossing structures, including both carnivores and ungulates. In Year 4 a single black bear movement was detected at the South Overpass, but an overwhelming use of the underpasses by this species suggests a preference for the underpass structures.

While mountain lion success movements have been documented at most of the wildlife crossing structures, the majority of these movements occurred at the Williams Peak Underpass, where mountain lion activity increased substantially in Winter 2018-19 (*n*=78). Mountain lion movements at this structure culminated in an interesting event during which a small group of mountain lions appeared to 'take over' the underpass for a period of several days. On February 25, 2019, two lions crossed through the underpass and later the same day a mule deer passed through. Then, between February 26 and March 1, a total of 60 lion movements were recorded, including a lion marking the underpass with urine on the 27th (Fig. 30). From March 2-4, no wildlife activity was recorded, and on the 5th mule deer began returning to the crossing structure. Mule deer did not permanently avoid the underpass as suggested by recent research in California (Caldwell and Klip 2019); however, deer and other wildlife did avoid the underpass during and immediately following the mountain lion 'take over'.

Figure 30. Mountain lion scent marking at the Williams Peak Underpass.

There were 101 bobcat success movements recorded at the wildlife crossings, with an overall success rate of 86%. Bobcat success movements were greatest at the Harsh Gulch Underpass (MP 131.6, *n*=41), and no bobcat activity was recorded at the two southern-most structures, the South Overpass and Williams Peak Underpass. It appears bobcat may prefer underpass structures over overpass structures – only two success movements were documented at the North Overpass and none at the South Overpass.

Other species documented using the crossing structures include badger, raccoon and striped skunk, albeit in very small numbers (*n*=5-12). There may be several reasons for these low numbers, including: these species may occur in low numbers in the study area; there may not be sufficient cover through and around the crossing structures to promote passage by these species; or they may not be consistently triggering the cameras. Two new and unanticipated species were documented using the crossing structures in Year 4 – river otter and wild turkey. While the project area is defined by a rolling sagebrush landscape, the North Underpass, which was used by a pair of river otters in February 2019, is located one mile south of the Colorado River and a half-mile from the Blue River to the west. River otters are a semi-aquatic species associated with riparian corridors and are known to cross upland areas between waterways, though they have rarely if ever been documented using crossing structures that are not associated with or adjacent to a riparian corridor. Wild turkeys have been documented crossing through culverts and bridges in Utah (Cramer 2014) and Montana (Cramer and Hamlin 2017). The group of six turkeys were captured passing through the Middle Underpass in April 2019, which is the crossing structure location with the greatest amount of treed cover in the approaches to the structure.

Interspecies interactions captured at the crossings structure included an owl hunting a hare on top of the South Overpass; coyotes chasing deer through the Middle and BVA Underpasses; and, on several occasions, domestic dogs that were observed chasing mule deer across the South Overpass. While harassment by domestic dogs did not appear to negatively affect overall mule deer use of the overpass, CPW has been notified of these events and has spoken with the dog owners.

Human activity continued to be documented intermittently across the crossing structures. During the summer months of 2018, people were detected on several occasions camping in the underpasses (Fig. 31). Camping at the underpasses is not desirable – in addition to deterring wildlife from the structures for the duration that people are present, in the event pictured, mule deer were not detected at the structure again for two days following the departure of the campers.

Figure 31. Camper at the Williams Peak Underpass.

Wildlife Activity at Other Mitigation Features

Wildlife Guards

Overall, the wildlife guards have been 85% effective in preventing ungulate breaches into the fenced right-of-way. These results met the objective for performance measure ten: at least 80% of ungulate approaches to the wildlife guards will be deterred from entering the right-of-way.

The number of attempted breaches made by ungulates at the 12 monitored wildlife guards decreased each year since construction was completed. In Year 2, 400 attempted breaches were recorded at monitored wildlife guards. In Year 3, this number decreased by 11% and, in Year 4, by an additional 27% to 260 attempted breaches. Successful breaches by ungulates also decreased from Year 2 to Year 3 (from 79 to 29), whereupon in Year 4, total number of successful breaches by ungulates (n=33) and the breach rate (13%) remained fairly consistent. These results may indicate that as wildlife habituate to the mitigation, ungulates are not attempting to breach guards as much although the breach rate has remained relatively stable.

For all ungulate species the round bar guards were more effective (90%) than the flat bar guards (80%) in preventing animal incursions into the fenced right-of-way, though for elk this difference was negligible. The partial fence at the Badger Road Wildlife Guard did not appear to influence breach rates for mule deer or elk, as the repel rate for both species was as high or higher than at other round guards. Despite these preliminary results, partial fencing along the sides of the wildlife guards is not recommended except where necessary to accommodate traffic.

Sample sizes for ungulate species other than mule deer are small and the monitoring results must be cautiously interpreted. Bighorn sheep approached each guard type only once, with both events resulting in the animal being repelled from the guard. Given the small sample size, it is impossible to determine whether these results are a function of the species' reluctance to approach or breach the wildlife guards regardless of their design, or simply a reflection of the small population of bighorn sheep in the study area. Since the onset of the research, only one moose has been recorded breaching a wildlife guard (Trough Road, flat bar guard) although they have been observed in nearly equal numbers at both guard types (*n*=15)

Jumping the guard was the most common method for ungulates to breach a round bar guard (*n*=35; Fig. 32), while walking on top of the bars was the most common breach type at the flat bar guards (*n*=34). Breaching the guards by walking on snow packed in-between the bars continued to occur at the CR 1000 Wildlife Guard (flat bar) in Year 4 (*n*=34), although it's likely that this issue is due to plowing technique at this location. No breaches by walking on snow have been detected at the Trough Road Wildlife Guard (flat bar) since Year 2 when the problem was first identified. Breaches by walking on the support beams occurred at both round bar and flat bar guards equally (*n*=8), despite the presence of the angle iron on the support beams at the round bar guards. Overall, however, this is one of the least common methods of breaching a wildlife guard.

Figure 32. Mule deer breach at the Triangle Road Deer Guard (round bar).

An analysis of three pairs of wildlife guards was conducted to determine differences in approach numbers, breach rates and breach types for ungulates at flat bar guards and round bar guards that are located in close proximity to one another. The data from the paired analysis rely on a subset of the data from Years 3 and 4, and photos taken during the daytime were omitted from the analysis to ensure equal sampling effort. Consequently, the findings of the paired analysis neither clearly refute nor confirm the findings of the overall analysis.

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 WVCs) 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, while ungulates were much more likely to attempt breaching a guard from the habitat side into the fenced right-of-way, carnivore species were documented breaching the guards both to get into and out of the right-of-way.

Escape Ramps

Mule deer and elk activity was variable across the different escape ramp locations. Overall, deer and elk approached the ramps 1,169 times with an intercept rate of 50% and an escape rate of 12%. These results did not meet the objective of performance measure eleven: 50% of the mule deer and elk that ascend an escape ramp will escape to the habitat side of the fence. The researchers suspect that the height of the ramps, at six feet, may be negatively influencing escape rates. A recent study in Utah calculated an escape rate of 70% for mule deer at four escape ramps, each of which were five feet height (Cramer and Hamlin 2020).

Mule deer were documented 332 times at ten of the 11 monitored ramp locations in Year 4, while elk were documented primarily at the East Fence End Escape Ramp. These results suggest that elk are primarily entering into the fenced right-of-way via the south fence end, while for mule deer there were multiple points of entry into the fenced right-of-way in different portions of the project area. For both species, the majority of these events resulted in animals walking around the ramp and avoiding it altogether or walking up the ramp but then turning around. Only 5% of these events resulted in a successful escape back to the habitat side of the fencing.

This research has documented a large amount of variation in mule deer and elk movements at each of the ramps (*n*=16 to 413) and subsequent variation in intercept rates (17-92%) across the monitored ramp locations (excluding ramps that were monitored for less than a year). The three ramps with the highest intercept rates (Culbreath 3:1 Escape Ramp, Harsh Jumpdown, and the Overpass Escape Ramp) did not have perpendicular rail fence. However, each represents a different ramp slope (3:1 slope, jumpdown and 2:1 slope, respectively). In general, ramps without perpendicular rail fence had the highest intercept rates (59%). Notably, escape rates were low across all ramp types (11-17%), although individual ramps had higher escape rates, such as the Badger Road Escape Ramp (25%; 3:1 without rail fence) and the South Spring Creek and West Fence End Escape Ramps (both 19%; both 3:1 with rail fence).

These results were only partially validated by the paired ramp analysis. When examining only the subset of ramps including in this analysis, intercept rates were substantially higher at the two new 3:1 slope ramps without rail fence than at the two older 2:1 slope ramps with rail fence (92% and 62% versus 38% and 35%). However, escape rates were highest at the Culbreath 3:1 Escape Ramp and the Trough Road 2:1 Escape Ramp (both 17%; *n*=4 and *n*=2, respectively).

In addition to mule deer and elk, multiple other ungulate, carnivore and meso-mammal species have been documented inside of the right-of-way fence at the escape ramps. Several of these species, including black bear, bobcat, coyote, red fox, mountain lion and white-tailed deer have used the ramps to escape back to the habitat side of the fencing. All of these species were also documented by the cameras on the habitat side of the fence line; in general, animals passed by without consideration for the ramps, although on a few occasions, animals were curious to check out the backside of the ramps although they made no attempts to jump up onto the ramp (Fig. 33). The high number of parallel movements indicates 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 escape movements.

Figure 33. Cow elk investigating an escape ramp from the habitat side of the fencing.

South Fence End

Mule deer and elk movements captured by the cameras at the fence end indicate that animals moving across the highway at-grade beyond the fence end, suggesting that animals in this area may not be finding and using the nearest wildlife crossing structure which lies 1.1 miles north of the fence end (Williams Peak Underpass, MP 127.7). The total number of ungulate movements at the south fence end as well as the number of movements by deer and elk into the fenced right-of-way increased each winter of the research. Despite this increase, the level of movement into the fenced right-of-way remains below the objectives set in performance measure thirteen: the proportion of ungulate movements at the south fence end that enter into the fenced right-of-way will decrease to 20% or less.

As reported previously, the vast majority of ungulate movements at the south fence end occurred beyond the fence end (81%); 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*=974), although elk were also photographed moving across the roadway beyond the fence end (*n*=75). 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 (Fig. 34).

Figure 34. Mule deer attempting to cross SH 9 at-grade just beyond the south fence end.

Ongoing and increasing ungulate activity at the south fence end may indicate that the wildlife-highway mitigation is not fully capturing the wildlife crossing movements across 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. Further consideration of this situation may be warranted.

Wildlife-vehicle Collisions

Each of the WVC datasets document a decreasing trend in WVCs following the completion of mitigation construction in the SH 9 project area. The BVR/CPW carcass database, which is the most comprehensive of the three WVC datasets (Kintsch et al. 2018), depicts a 90% decrease in WVCs relative to the five-year pre-construction average of 62.8 carcasses each winter. These results demonstrate a continuing trend of decreasing WVC carcasses since the construction was completed from 13 carcasses in Winter 2016-17 (79% decrease) to 9 carcasses in Winter 2017-18 (86% decrease) and 6 carcasses in Winter 2018-19 (90% decrease) relative to the five-year pre-construction average of 62.8 carcasses each winter (note, these numbers are different from what was reported in previous progress reports because of the revised definition of 'winter' as November through April). In addition, WVC carcasses reported by CDOT Maintenance and WVC accidents reported to law enforcement decreased by 95% and 84%, respectively, relative to pre-construction winter averages. These results met the objective of performance measures 14, 15 and 16, which state that for each WVC dataset, WVCs will decrease by at least 80% when compared to the five-year pre-construction average.

Overall, 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 90% decrease in WVC carcasses (based on the BVR/CPW carcass dataset), suggests that roughly 170 WVCs have been prevented in the three years since construction was completed, relative to the pre-construction average. In addition, the construction project, which included other safety improvements in addition to the wildlife mitigation, has resulted in a decrease in all accidents from a five-year pre-construction average of 20.8 accidents each winter to four in Winter 2016-17 and two in Winter 2017-18 (the latter of which were both WVC accidents).

Both the BVR/CPW carcass dataset and the CDOT Maintenance carcass dataset demonstrate that WVCs continued to occur beyond the fence ends, particularly south of the project area. However, WVCs do not appear to be increasing relative to pre-construction WVC rates. Therefore, the mitigation project has not increased the WVC problem south of the project area, but nor has it fully addressed the WVC hotspot in this area.

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, each winter post-construction, WVC rates were lower than the pre-construction average. These variations in WVC rates on US 40 may be due to a number of factors outside of the mitigation on SH 9, such as annual weather and snow depths, variation in mule deer and elk population numbers, traffic volumes, and human activity in the landscape.

Next Steps

The results from the first four years of monitoring on SH 9 are promising and multiple performance measures for the mitigation project regarding mule deer use of crossing structures have already been achieved. Other objectives will continue to be monitored and evaluated, for example, regarding ungulate use of the escape ramps. The research team will continue post-construction monitoring through April 2020, whereupon a final report will be produced. The results of this study are expected to inform future wildlife-highway mitigation projects in Colorado and beyond.

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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-construction monitoring continued at Phase 2 crossing structure locations through November 2016 and was conducted by the ECO-resolutions team with support from CPW.

Construction Phase: From the onset of this research study (December 2015) through the completion of Phase 2 construction (November 2016). Construction Phase monitoring involved the deployment of 40 cameras at 24 locations. Construction Phase 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 code-locked and secured with master locks and/or cable locks. The cameras were motion-triggered and took photos day and night with a rapid-fire setting and no down time. Cameras were set to take burst of 10 photos per trigger and 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.

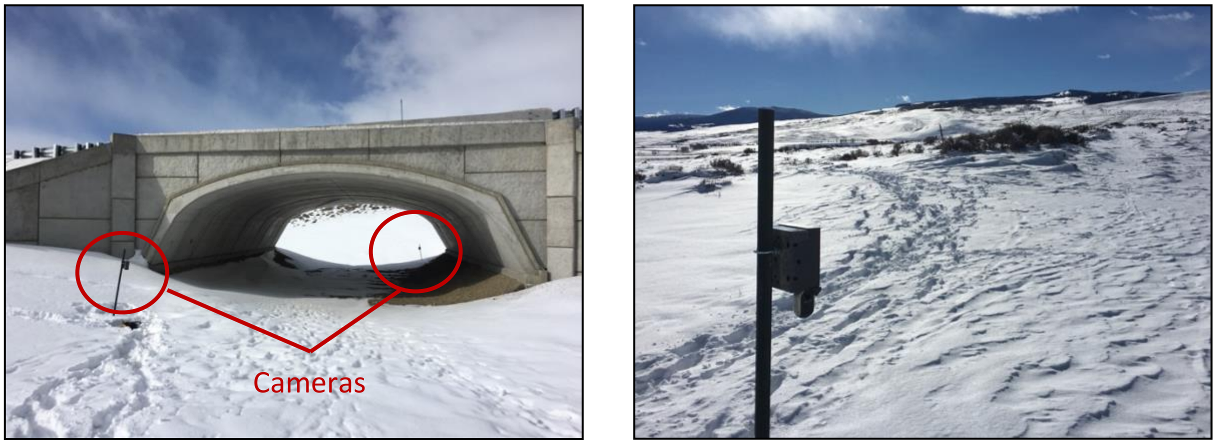

Figure A-1. Two cameras were positioned at each underpass at opposite corners (left). Habitat camera placed 50-100 feet in front of a structure, facing out into the adjacent habitat (right).

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 escapes 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. A-2). 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 A-2. 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).

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. 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 south 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. 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 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 inside the right-of-way 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. 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 4 progress report includes WVC accident data analysis through April 2018, as data for 2019 were not available at the writing of this report.

Winter was defined as the months of November 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.

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 right-of-way side to the habitat side, as well as breaches into the right-of-way – 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 – Purdue 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

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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**