LAVA BUTTE WILDLIFE CROSSING EFFECTIVENESS

Final Report

2015-2017

Prepared for:

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WEST Inc.

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1 INTRODUCTION

U.S. Route 97 (Route 97) is the main highway running north-south through central Oregon along the east side of the Cascade Mountains. The Oregon Department of Transportation (ODOT) has documented mule deer (*Odocoileus hemionus*) movements across Route 97 during migration season through historical carcass collection records and telemetry studies (Coe et al. 2015). These individuals use the Cascade Mountains for summer range and migrate east across Route 97 to the eastern portions of the Deschutes National Forest, or further, for their winter range. In addition, historical mule deer migration routes were thought to have shifted 30 mile (mi) south where traffic volumes are less (Coe et al. 2015).

Due to actual and projected increases in traffic in the vicinity of Sunriver, an approximately 4-mi section of Route 97 (Figure 1.1) was upgraded by constructing two additional lanes that resulted in separated north- and south-bound traffic with a mostly forested median, a project that was completed in 2011. To help maintain historical migration routes, the highway improvement project incorporated wildlife crossing structures with the goal of reducing vehicle-wildlife collisions while allowing for migration across the highway corridor in this high-traffic stretch of Route 97. One wildlife-specific underpass was constructed in the southern section of the project (hereafter South Lava Butte) specifically to facilitate wildlife passage across Route 97. A second wildlife-human underpass was constructed alongside the seasonally closed Crawford Road. In addition to these two underpasses, four miles of exclusion fencing was installed on both sides of Route 97 to minimize wildlife entries into this stretch of highway. The fencing included four jump-out escape ramps (two on each side of the highway) to allow animals that entered the road corridor to escape without having to cross the highway.

The objective of the Lava Butte wildlife crossing effectiveness study was to monitor the crossing structures using remote motion-detecting cameras in conjunction with documented deer-vehicle collisions to determine the effectiveness of the wildlife crossings at minimizing vehicle-wildlife collisions, while providing safe passage for wildlife across the highway corridor. ODOT commenced with the 5-year monitoring study of the wildlife crossing structures following the completion of construction. The initial monitoring was a collaborative effort between ODOT and Portland State University (PSU) from 2012 to 2014; detailed methods and results can be found in their final report (Bliss-Ketchum and Parker 2015). Following the first two years of monitoring, ODOT contracted with Western EcoSystems Technology, Inc. (WEST) to assist in the completion of the final three years of monitoring. This 2018 final report provides data on wildlife passage from 2015 through 2017, and is a continuation of the wildlife passage monitoring conducted from 2012 to 2014 by PSU.

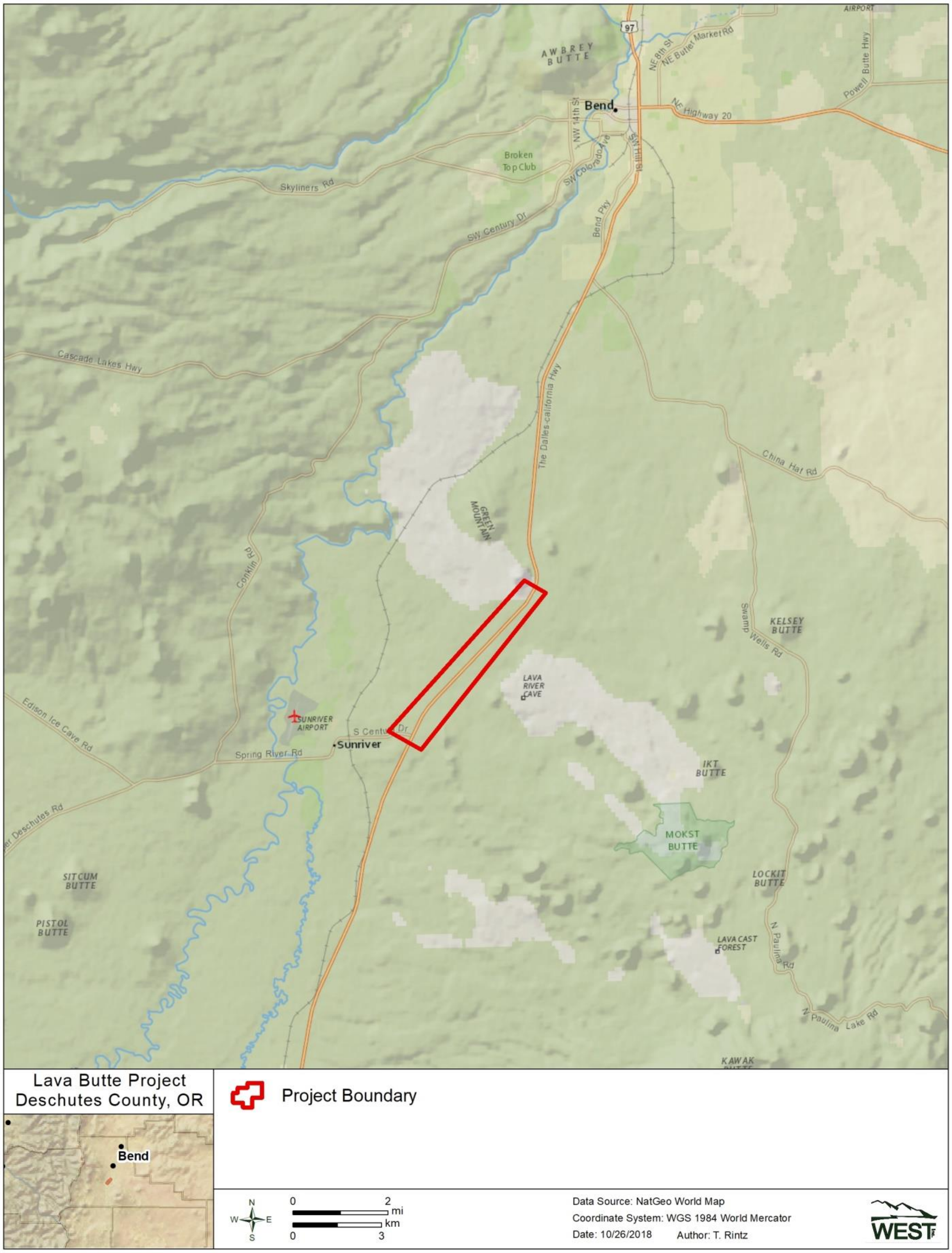

Figure 1.1. Lava Butte study area vicinity map.

2 STUDY AREA

The study area is located along Route 97 in the Deschutes National Forest, approximately 15 mi south of Bend, Oregon and immediately east of Sunriver, Oregon (Figure 1.1). More specifically, the north end of the fenced project area is located near Lava Butte within the Newberry National Volcanic Monument at milepost (MP) 149.3, and the south end of the fenced project area at MP 153.08, where it encompasses the South Century Drive exit to Sunriver (Figures 1.1 - 2.1). For purposes of a before-after control-impact (BACI) analysis (Green and Green 1979), we defined the 12-mi stretch of Route 97 from MP 143 – 155 as the Study Area. Within this 12-mi Study Area, the fenced treatment area was defined as the area between MP 149.3 and 153.08, while the sections from MP 143.0 – 149.3 and 153.09 – 155.0 were defined as the control area because they were outside the bounds of the fenced area and contained data on average annual daily traffic (AADT) consistent with the treatment area.

3 METHODS

3.1 Crossing Use

Twenty-three Reconyx Hyperfire™ 800 or 900 cameras were deployed by ODOT during initial monitoring efforts conducted in collaboration with PSU (Bliss-Ketchum and Parker 2015). Of these cameras, four were located near fence-ends or fence corners, seven at the Crawford Road underpass, four at the South Lave Butte underpass, and eight at the escape jump-outs (one tree-based and one ground-based camera at each of the four jump-outs; Figure 2.1; Appendix A). Cameras were initially positioned on 21 June 2012, with the intent of documenting local use by smaller animals and both successful and unsuccessful use of structures by larger animals. In 2015, two additional cameras were deployed at Crawford Road and two at South Lava Butte to increase monitoring effectiveness. All other camera locations remained consistent with previous monitoring efforts to maintain quality of data. However, camera theft and vandalism in early 2017 did impact camera placement and available data for part of the 2017 monitoring period.

Figure 2.1. Location of wildlife crossing structures and exclusion fence ends along US Route 97 between Sunriver and Lava Butte, Deschutes County, Oregon.

Cameras were scheduled to be checked by an ODOT intern every other week, while WEST was tasked with managing the data once collected by ODOT. Secure Digital (SD) cards in cameras were collected, downloaded to ODOT hard drives, and later delivered to WEST for data management and analysis. Photos for each camera were logged into a database and uploaded into MapView Professional™ (Reconyx, Holmen, WI) for review and tagging. Each camera was set to take 1-3 pictures with each motion-activated trigger (each sequence of pictures from a single trigger are hereafter referred to as an event). The first photo from each event was tagged with species identification and structure use data (where applicable). Multiple triggers occurring from the same animal(s) were marked as 'same as previous' to indicate their association with an already identified event and are hereafter referred to as the series. Trigger events or series occurring within 15 minutes were presumed to be part of the same series (Bliss-Ketchum and Parker 2015), unless triggering events were explicitly distinct from one another (e.g., doe and fawn vs. two bucks). This saved time in photo tagging while minimizing duplicate counts of individuals from multiple events. It is important to note that the numbers of detections reported are not a count of the number of individual animals using the structures, but an index of use.

Due to differences in camera placement relative to the structures and trigger sensitivity among the cameras, we were not always able to confirm whether an individual crossed successfully from one side of the structure to the other. Instead, we report a count of detections for each camera to compare structure use by side, as opposed to an estimated number of wildlife crossings. Only pictures of animals positively identified to species were tagged, which resulted in some events being classified as undetermined. For fence-end and tree-based cameras at the jump-outs, we collected additional information relative to use of the structure including direction of travel (i.e., forest side vs. road side) and crossing direction (i.e., forest to road or road to forest) where the movement past the structure was verified through photos in each event or series. To be conservative, only series of photos depicting the entire movement through the structure were tagged as successful. All other photos were tagged as undetermined.

3.2 Deer-Vehicle Collisions

Data on traffic use from MP 143.46 to 153.08 were obtained from ODOT for the years 2006 to 2016. Data from this stretch of highway was used because it was consistently collected over most of study duration (except 2017 when traffic data were not yet available), contained the fenced treatment area and most of the control area, and was assumed to be representative of the entire stretch under study. Wildlife-vehicle collision data were obtained from ODOT for years 2006 to 2017 and deer population estimates for the Upper Deschutes district were obtained from the Oregon Department of Fish and Wildlife for the years 2006 to 2017. Data from the Upper Deschutes district were chosen because this district contains a migratory herd of mule deer that commonly crosses Route 97 while migrating to and from winter ranges to the east in the Paulina district (Coe et al. 2015). These data were analyzed to determine how effective the wildlife crossings were on reducing deer-vehicle collisions (DVC) and what (if any) relationships might occur between deer populations, average annual daily traffic (AADT), and DVC.

Collision rates were calculated by stretch, period, and year, adding zeros for levels where no roadkill were observed with the exception of 2007, for which no data were provided and were assumed missing. We assumed that the proportion of any missed collisions was constant over time. The lengths of each stretch in the study differed so density measurements (animals per mi) were obtained by dividing the number of collisions in each stretch by the length of the stretch. To account for the number of cars using the road each year, a second density estimate (animals per mile per car) was calculated as a standardized index of collision magnitude. Covariate data such as AADT and deer population size were transformed as appropriate so that they scaled appropriately with other data for visual presentation.

Linear models were constructed to account for a BACI design (Green and Green 1979) to examine relationships between DVC in fenced (i.e., treatment) and control areas before (2006-2011) and after (2012-2017) construction was completed, and whether traffic numbers influenced DVC. These models included main effects for stretch (e.g., fenced or control) and period (before or after construction) as well as an interaction term. Using this approach, a significant interaction effect between the stretch and the period would indicate a significant effect in the fenced treatment in the period after construction. Several models were examined, including those incorporating the two density outcomes of interest described above for deer/elk and for deer (DVC) only. Log transformations and random effects for year were considered but not needed. All statistical analyses were conducted using R (R Core Team 2013) and Statistix (Analytical Software 2013).

4 RESULTS AND DISCUSSION

4.1 Crossing Use

4.1.1 General Wildlife

From 2015 to 2017, 174,128 photos were made available to WEST and were analyzed to evaluate the use of wildlife crossing structures within the Study Area (Tables 4.1 – 4.3). These photo counts are lower than the actual number of photos taken and actual crossings because not all photos were available for analysis and data gaps existed among cameras throughout the monitoring period for various reasons (e.g., ODOT intern availability, dead batteries, camera vandalism).

Based on the 174,128 photos analyzed, 15 mammal species, seven bird species, and 11 unidentified lizards were documented during the 2015 to 2017 monitoring period (Table 4.2). In comparison, Bliss-Ketchum and Parker (2015) documented 19 mammal species, eight bird species, and eight unidentified lizards during the 2012 to 2014 monitoring period. Neither the 2012 to 2014 nor the 2015 to 2017 data were able to identify reptile detections to species. From the 2015-2017 dataset, 3,094 mammal detections, 32 bird detections, and 11 reptile detections were documented at the Crawford Road underpass (Table 4.2). The South Lava Butte underpass had 1,035 mammal detections and three bird detections (Table 4.2). The jump-outs had 675 mammal detections, and the fence-ends had 346 mammal detections (Table 4.2). The majority of all wildlife detections at Crawford Road were triggered by small mammal species (e.g., golden-mantled ground squirrel [*Callospermophilus lateralis*]) that use the structure as habitat, and not necessarily as a movement corridor. Although small mammals accounted for a majority of detections at Crawford Road, mule deer were consistently detected using the Crawford Road underpass, suggesting that the underpass is successfully being used by mule deer. Wildlife detections at South Lava Butte were dominated by mule deer, followed by coyotes (*Canis latrans*), indicating this structure is also functioning successfully for other large mammal species. Based on the data (304 detections at South Lava Butte compared to 34 at Crawford Road), it appears that coyotes may prefer to use the wildlife-specific crossing structure as opposed to one alongside a road (i.e., Crawford Road). Bobcats (*Lynx rufus*) were relatively common at Crawford Road (n = 26), but rarely documented at other locations. The only large carnivore detected during this study was a cougar (*Puma concolor*) on the forest side of a jump-out (Table 4.2; Appendix A3).

4.1.2 Mule Deer and Elk

4.1.2.1 Crossings

Mule deer were the most commonly detected species from 2015-2017, with 1,834 individuals in 1,211 groups documented (Table 4.1). Mule deer were often detected travelling alone, but the mean group size across all structures was 1.5 individuals (Table 4.1). There were a limited number of series where enough pictures of both the approach and exit of mule deer were captured to evaluate the success of the structures (i.e., animal crossed completely). Crawford Road had 76 such series that resulted in a minimum 11.5% successful group pass rate and 584 (88.5%) where it was undetermined. South Lava Butte had 216 series that resulted in a minimum 75.3% successful group pass rate and 71 (24.7%) where it was undetermined (Table 4.1). Successful pass rates were lower than reported in Bliss-Ketchum and Parker (2015) and Stansbury and Thompson (2016), particularly for Crawford Road. This was likely in part due to the more conservative approach of classifying success during this phase of the study and the fact that some of the undetermined passages may have actually been successful but were not captured on camera.

Based on the evaluation of successful versus undetermined crossing attempts by mule deer, it appears that the South Lava Butte undercrossing is consistently providing mule deer safe passage under Route 97. The Crawford Road undercrossing had a much lower confirmed success rate in the 2015-2017 study period compared to the success rates during 2012 to 2015; however, it is worth noting that although some deer that approached the crossing structures were noted as being undetermined, there was no way to determine if these individuals or groups may have successfully used the crossings on a later attempt. Regardless of the confirmed success rate, mule deer are using the crossings in relatively large numbers compared to other wildlife.

Cameras at the Crawford Road crossing also detected 32 elk (*Cervus elaphus*) in 20 groups during a period of four days in January 2017. It was undetermined whether any of the groups or individuals successfully used the crossing. No elk were detected at the South Lava Butte Crossing.

Table 4.1. Total number of photos analyzed per camera and mule deer detection and use data.

Site	Number of Photos Analyzed	Total Groups	Successful Groups	Undetermined Groups	Group Success Rate (%)	Mean Group Size	Number of Individuals
Crawford Rd	**88,933**	**660**	**76**	**584**	**11.5**	**1.6**	**1,038**
CR1W	38,329	233	41	192	17.6	1.2	271
CR2W	17,039	129	14	115	10.9	1.1	145
CR3W	10,949	150	16	134	10.7	1.1	158
CR4W	7,838	26	4	22	15.4	1.2	30
CRE	327	25	2	23	8.0	2.1	53
CRE5	2,819	50	2	48	4.0	1.2	60
CRE6	705	21	0	21	0.0	11.8	247
CRE7	10,693	164	30	134	18.3	0.4	73
CRW	234	1	1	0	100.0	1.0	1
S Lava Butte	**35,189**	**287**	**216**	**71**	**75.3**	**1.4**	**403**
SL1W	2,343	109	91	18	83.5	1.4	156
SL2W	3,020	13	10	3	76.9	1.1	**14**
SL3E	27,781	92	73	19	79.3	1.4	128
SL4E	1,559	50	36	14	72.0	1.4	68
SLE	408	23	6	17	26.1	1.6	37
SLW	78	0	0	0	0.0	0	0
Jump-outs	**24,504**	**134**	**0**	**134**	**0.0**	**1.4**	**186**
JNE1R	4,019	15	0	15	0.0	1.6	24
JNE1W	1,517	4	0	4	0.0	1.3	5
JNW1R	12,118	37	0	37	0.0	1.5	55
JNW1W	1,534	23	0	23	0.0	1.4	32
JSE1R	635	7	0	7	0.0	1.4	10
JSE1W	1,546	12	0	12	0.0	1.4	17
JSW1R	1,086	12	0	12	0.0	1.1	13
JSW1W	2,049	24	0	24	0.0	1.3	30
Fence-ends	**25,502**	**130**	**17**	**113**	**13.1**	**1.6**	**207**
NEFE	3,889	101	26	75	25.7	1.3	133
NWFE	18,660	11	1	10	9.1	1.0	11
SEFE	738	29	0	29	0.0	1.4	40
SWFE	2,215	19	0	19	0.0	1.2	23
Total	**174,128**	**1,211**	**309**	**902**	**25.5**	**1.5**	**1,834**

Table 4.2. Total number of detections from previous monitoring efforts (Overall Detections 2012-2014) and a breakdown of 2015-2017 species detections by structure.

	2012-2014	2015-2017				
Species	**Overall Detections**	**S. Lava Butte**	**Crawford Road**	**Jump-outs**	**Fence-ends**	**Overall Detections**
Mammals	***5,867***	***1,035***	***3,094***	***675***	***346***	***5,150***
American badger	13	1	1	0	0	2
black bear	1	0	0	0	0	0
bobcat	4	0	26	2	0	28
bushy-tailed woodrat	14	0	44	0	0	44
cottontail	140	1	55	9	0	65
cougar	1	0	0	1	0	1
coyote	214	304	34	18	137	493
deer mouse	50	0	15	0	0	15
Douglas squirrel	219	28	42	123	0	193
elk	27	0	32	0	1	33
golden-mantled ground squirrel	1,953	190	1,219	245	0	1,654
jackrabbit	1	0	0	0	0	0
long-tailed weasel	7	0	0	0	0	0
mule deer	1,260	403	1,038	186	207	1,834
raccoon	101	1	1	1	0	3
snowshoe hare	0	1	0	0	0	1
striped skunk	2	0	2	1	0	3
western gray squirrel	692	77	325	25	1	428
yellow-pine chipmunk	1,156	23	212	21	0	256
yellow-bellied marmot	12	0	0	0	0	0
unidentified rodent	0	6	48	43	0	97
Birds	***199***	***3***	***32***	***0***	***0***	***35***
American robin	7	1	0	0	0	1
band-tailed pigeon	0	0	1	0	0	1
common raven	27	0	1	0	0	1
dark-eyed junco	1	0	0	0	0	0
mountain chickadee	3	0	0	0	0	0
mourning dove	116	0	5	0	0	5
red-breasted nuthatch	3	1	0	0	0	1
red crossbill	41	0	22	0	0	22
spotted towhee	0	0	1	0	0	1
turkey vulture	1	0	0	0	0	0
unidentified bird	0	1	2	0	0	3
Reptiles	***8***	***0***	***11***	***0***	***0***	***11***
unidentified lizard	8	0	11	0	0	11

4.1.2.2 Jump-outs and Fence-ends

Jump-outs

There were four tree-based and four ground-based cameras at the jump-outs, for which additional data on structure use were collected. The tree-based jump-out cameras could ideally capture an event where an individual jumps from the road-side of the fence to the forest-side, indicating that wildlife were using these structures as intended. The ground-based cameras did not provide complete information on mule deer use of the jump-outs as they did not provide a view sufficient to document deer in the road corridor that may not have approached the jump-out. Given their limited view of the jump-out wall, the ground-based cameras could provide information on successful use of the jump-outs only if deer actually used them, but could not document deer approaching the jump-outs on the road side of the fence that did not use the jump-out. Ultimately the ground based cameras only provided data on mule deer walking past the jump-out on the forest side of the fence. As such, only the tree-based cameras were used when analyzing successful use of the jump-outs and deer passage on the road side of the fence, while ground-based cameras were used to document deer movement on the forest side of the fence (Table 4.3).

Table 4.3. Structure use data on trigger events from mule deer at jump-outs and fence-ends. Triggers were categorized as crossing or travelling along a structure. Structure crossing was further broken down to determine directionality of crossing and travelling along structure was broken down to indicate whether the deer was on the outside (forest side) or inside (road side) of the exclusion fence.

Camera ID	Structure crossing		Travelling along structure		Total
	Forest to road	Road to forest	Forest side*	Road side	
Jump-outs	**0**[a]	**0**[a]	**41**[b]	**30**[b]	**71**
JSW1R	0[a]	0[a]	12[b]	0[b]	12
JSE1R	0[a]	0[a]	4[b]	3[b]	7
JNW1R	0[a]	0[a]	24[b]	13[b]	37
JNE1R	0[a]	0[a]	1[b]	14[b]	15
Fence-ends	**17**	**13**	**77**	**23**	**130**
NEFE	17	12	41	8	68
NWFE	0	1	0	6	7
SEFE	0	0	27	2	29
SWFE	0	0	9	7	16

[a] based on raised (tree-mounted) cameras only
[b] based on ground-based cameras only

No events indicating successful use of jump-out structures by mule deer were documented (Table 4.3). A total of 71 mule deer groups were documented travelling along the forest side (n = 41) and along the road side (n=30) of the fence (Table 4.3). It is worth noting that the results (i.e., no successful use of jump-outs) should be interpreted with some caution, as large gaps existed in data for some jump-out cameras, and some successful uses of the jump-outs may have occurred. However, the very low or lack of use of jump-outs is consistent with that documented by Bliss-Ketchum and Parker (2015), who reported only 3% successful use of the jump-outs by mule deer from 2012 to 2014. These data indicate that use of the jump-outs is likely being hindered for some reason, the most likely of which is jump-out design (e.g., structure height too great), as previously noted by Bliss-Ketchum and Parker (2015).

Fence-ends

The north fence-end cameras were positioned at true fence-ends and could capture whether an individual crossed from one side of the fence to the other (see Appendix A4). The south fence-end cameras were not on true ends; instead the southwest fence-end camera (SWFE) was positioned near the farthest southwest corner within the median between the southbound off-ramp to South Century Drive and Route 97, and the southeast fence-end camera (SEFE) was positioned along the exclusion fencing just north of the southeast corner on the outside of the northbound onramp from South Century Drive onto Route 97 (Figure 2.1; Appendix A4). In fact, at the southern end of the project, there are in fact no true fence ends, as the fencing abuts and crosses the on/off ramps to South Century Drive via electric wildlife mats (ElectroMat™) and then wraps along the northern side of South Century Drive to the South Lava Butte underpass abutments (see Figure 4.1). This essentially leaves no way for deer (or other large mammals) to exit the southern end of the fenced treatment area, unless they successfully navigate over the ElectroMats™ to escape via the on/off ramps, use the Route 97 overpass over South Century Drive to exit to the south, or return to the jump-outs approximately half a mile back to the north or beyond to the northern fence ends.

Figure 4.1. South end of exclusion fence as it crosses northbound onramp from South Century Drive and abuts the overpass abutment under U.S. Route 97.

All but one of the 30 mule deer crossing events documented at fence-end cameras occurred at the northeast fence-end camera (NEFE), with 17 (56.7%) of the crossings being individuals travelling from the forest-side to the road-side of the exclusion fencing (Table 4.3; Appendix A4). However, although mule deer actually crossing the fence-end were more often entering the road corridor than exiting the corridor, the NEFE camera documented more individuals travelling along the forest-side of the fence than the road-side of the fence, suggesting the majority of deer are remaining on the forest-side of the fence outside of the roadway. Only one crossing was detected at the northwest fence-end camera (NWFE; Table 4.3). This fence-end is also the location of high human-activity with hikers and vehicles actively moving through the area (see Appendix A4). Additionally, this fence-end terminates next to a large lava flow which likely further serves as a barrier. This human activity and relative position to the lava flow may deter deer from crossing at this junction, as would be suggested by the low overall number of deer detections at this camera. The majority (93%) of trigger events at the SEFE camera were of mule deer travelling on the forest side of the exclusion fencing whereas the SWFE camera documented similar occurrences of individuals inside and outside of the fencing (Table 4.3). This result is not surprising given the position of the cameras relative to roads and off- and on-ramps for Route 97. The SEFE camera documented the only elk observed at the fence-end cameras, which was moving south on the inside of the exclusion fence. Unfortunately, it was not possible to evaluate if this or other individuals on the road-side of the fence were able to exit via the ElectroMat™ setup across the on/off-ramps on the south end of the project, as there were no cameras setup to document activity at the ElectroMat™ locations. As noted above, these animals on the road-side of the fence at the SEFE and SWFE had no clear way to exit the roadway without returning north to the jump-outs or north fence-ends, crossing the overpass over South Century Drive, or navigating over the ElectroMat™ to escape via the on/off-ramps.

It should be reiterated that gaps in data existed occasionally and randomly due to non-functioning cameras and to cameras being vandalized/stolen. Because no formal analysis of the photo data was conducted, missing data did not likely have a significant influence on the study results and it is not expected that the missing photos affected the primary goal of evaluating mule deer/wildlife use of the crossing structures. However, missing data likely affected the overall species count and may have lowered the chance of detecting less abundant species such as black bear (*Ursus Americana*) and cougar.

4.2 Deer and Elk Vehicle Collisions

A total of 273 mule deer and 15 elk carcasses were collected by ODOT in the 12-mi Study Area from 2006 to 2017 (Figure 4.2), with the number of DVC generally increasing over time while elk-vehicle collisions remained low (Figure 4.3). During the 10-year period from 2006 to 2016, AADT counts on this same 12-mi stretch of Route 97 generally declined from a high of over 17,000 vehicles per day in 2006-2007 to a slightly lower level of about 15,000 to 16,000 vehicles per day over most of the remainder of the period (Figure 4.4). Mule deer population estimates for the Upper Deschutes District generally fluctuated between about 900 and 1,500 animals from 2006 – 2017, with a bit of a spike in 2016 (2,200 animals) followed by a sharp decline in 2017 (565 animals) and generally tracked with DVC during the study period (Figure 4.4).

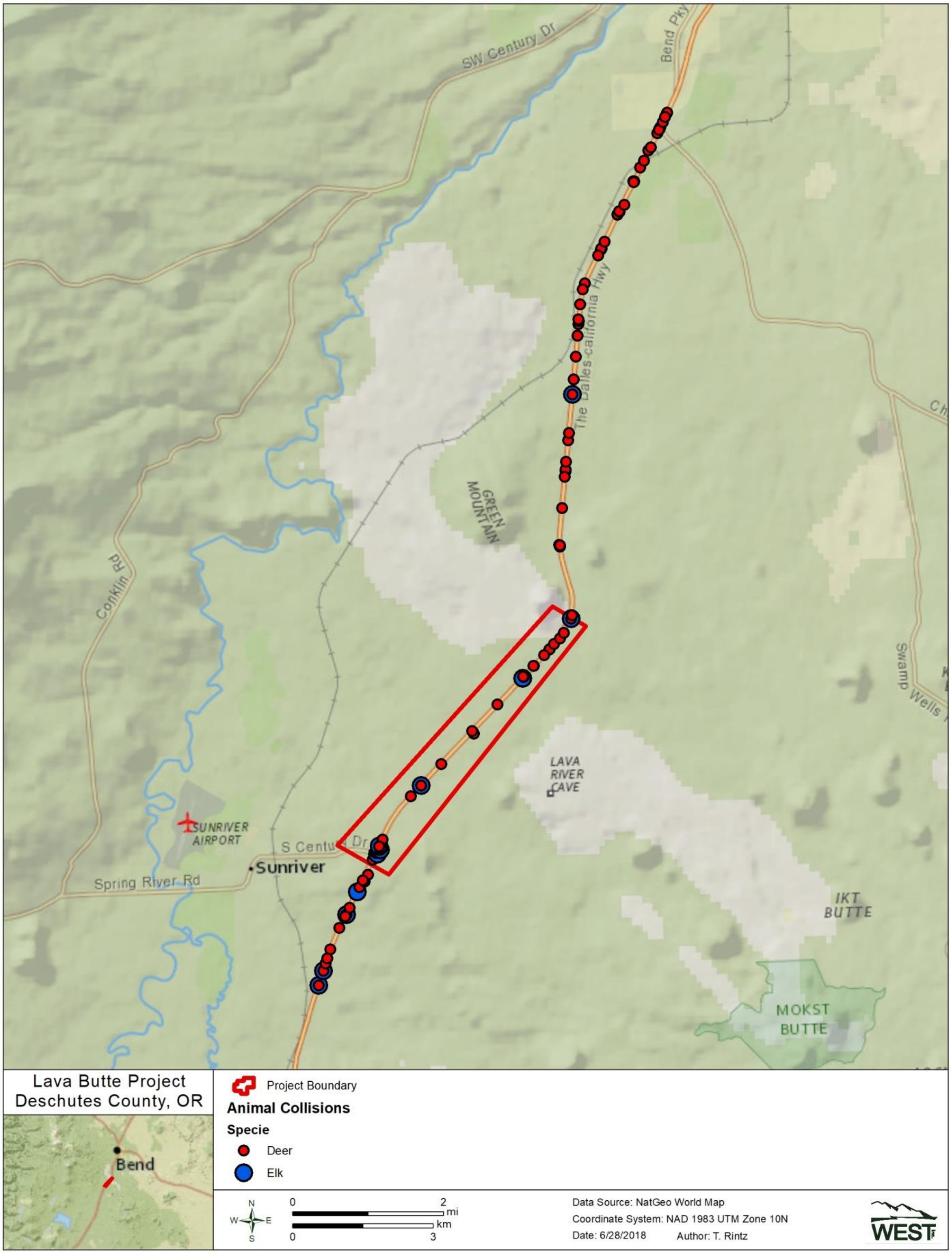

Figure 4.2. Deer and elk vehicle collisions in and around the Lava Butte wildlife crossings study area from 2006 through 2017.

Raw counts of collisions between deer/elk and vehicles in the fenced area increased from 30 (29 deer and 1 elk) during the 5-year period (2006-2011) prior to completing construction of the wildlife crossings project to 38 (32 deer and 6 elk) during the 5-year period after completing construction (2012-2017), while collisions in the unfenced (i.e., control) area increased from 62 (60 deer and 2 elk) before construction to 158 (152 deer and 6 elk) after construction. Given the available DVC and AADT data within the fenced and adjacent control areas, a linear model accounting for BACI effects found a significant decrease in DVC/mile/car in the fenced area after construction (P = 0.0017; adj. R^2 = 0.61) for the period 2006 – 2016 (AADT data were not available for 2017), suggesting that the wildlife crossing structures are not only being used by wildlife, but have been effective in reducing DVC in the fenced portion of Route 97 on a per mile per vehicle basis (Figure 4.5). This is evidenced by the consistent rate of DVC within the fenced treatment section relative to the increased DVC in the control section (Figure 4.5), even though the raw count of DVC and deer/elk-vehicle collisions actually increased during the same time period.

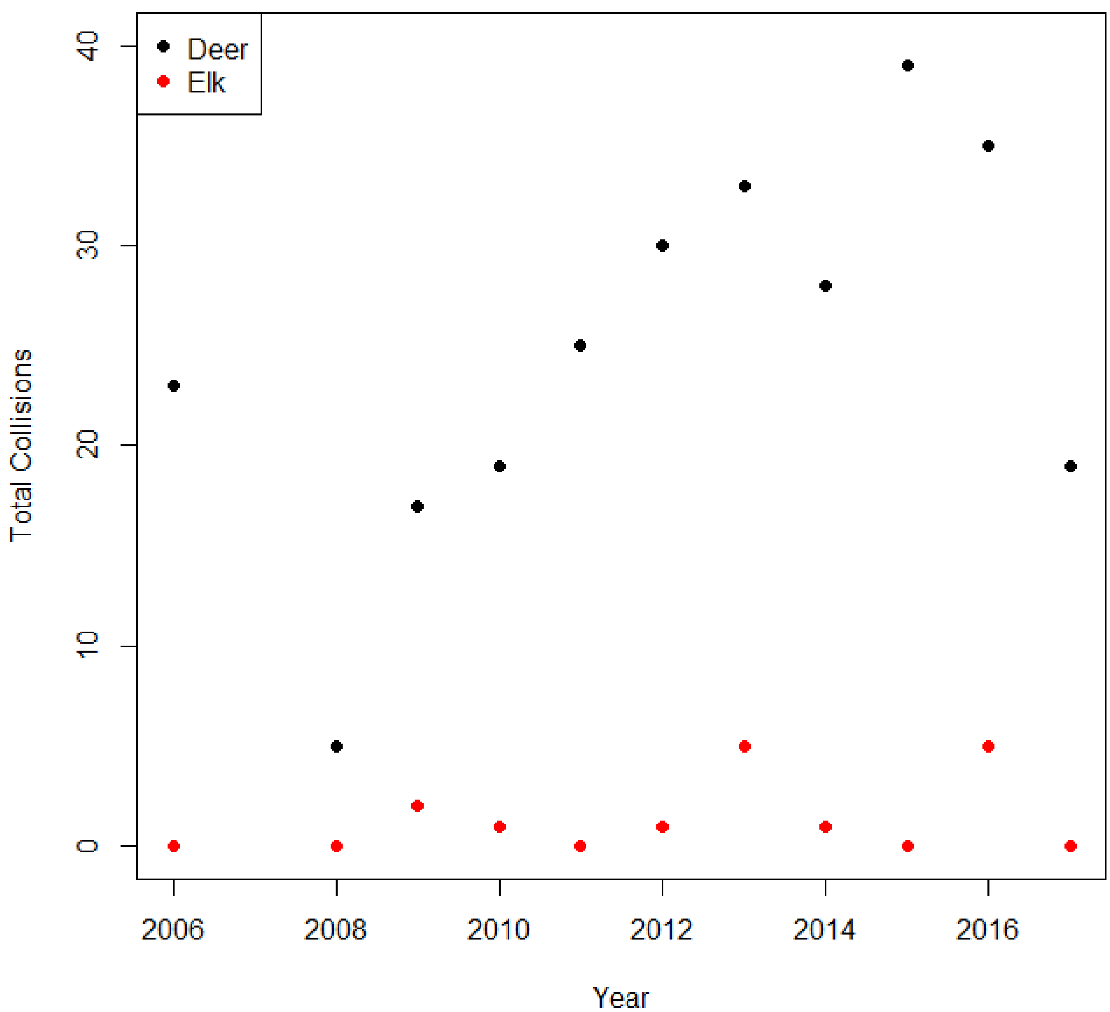

Figure 4.3. Deer and elk vehicle collisions over time in the 12-mile long Lava Butte Study Area, Deschutes County, Oregon.

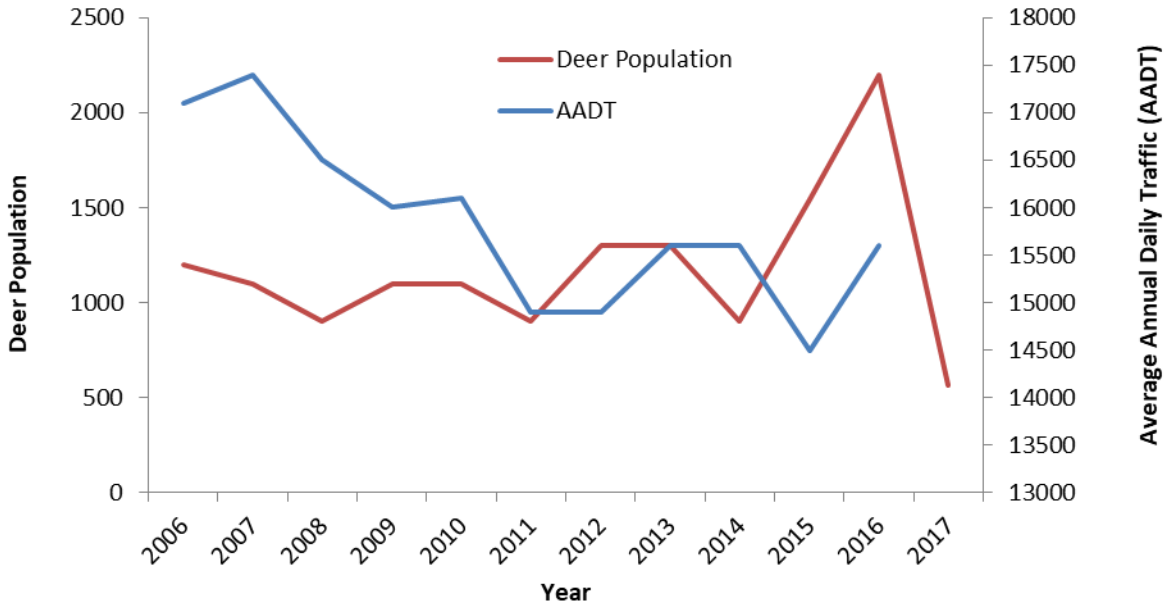

Figure 4.4. Average Annual Daily Traffic (AADT) from mileposts 143.46 to 153.08 on U.S. Route 97, Deschutes County, Oregon and Upper Deschutes District mule deer population estimates from 2006 to 2017. AADT were divided by 10 for scaling purposes.

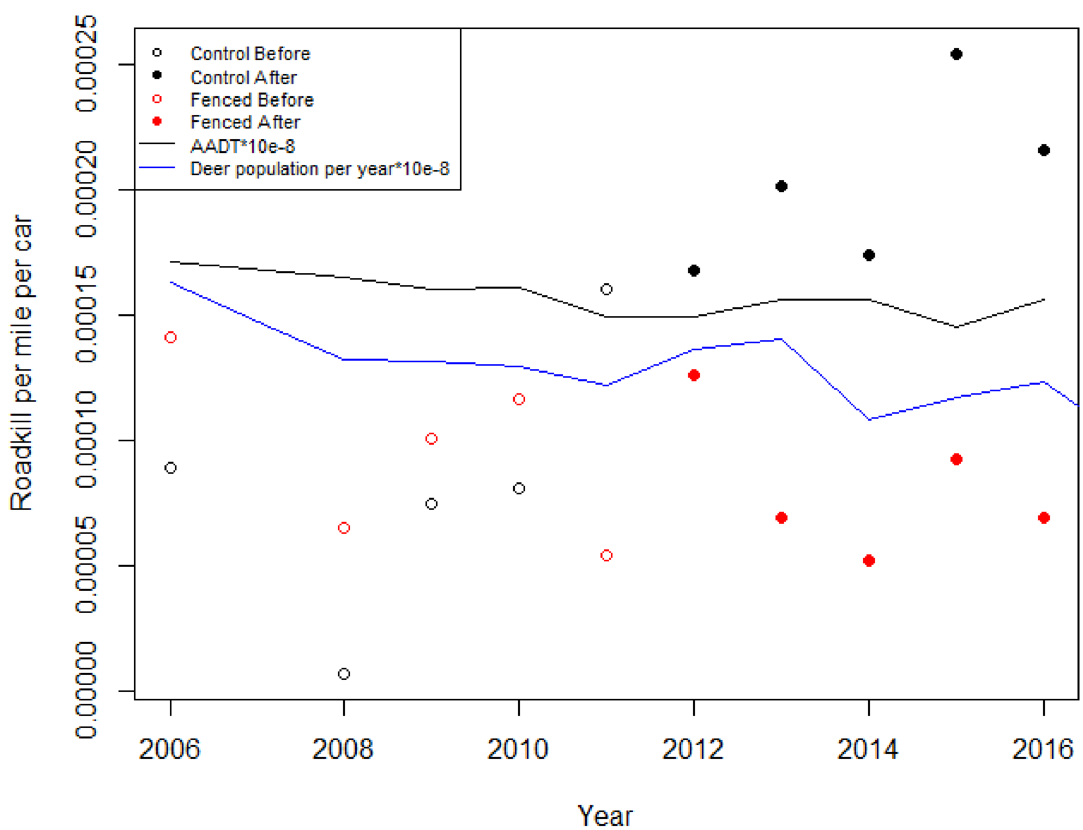

Figure 4.5. Deer-vehicle collisions (DVC) per mile per car by year, period (before or after), and stretch (control or fenced), Deschutes County, Oregon, 2006-2016.

While the BACI analysis indicated a significant decrease in DVC per mile per car within the fenced treatment area as a whole, it was noted during the data formatting and analysis that DVC occurring within the fenced area tended to be clustered spatially, with more collisions appearing to occur toward the ends of the fenced treatment area (see Figure 4.2). To investigate this, we looked at edge areas at both the northern and southern ends of the fenced area, inclusive of a 0.5 mile section (0.25 mi within the fence and 0.25 mile outside the fence) of roadway at each end, compared to the control (control area >0.25 mi from the fence ends) and a smaller fenced treatment (interior fenced areas from >0.25 mi from the fence ends), to see if there was a significant edge effect that differed from the entire fenced area. While the results were not significant (P = 0.3, adj R^2 = 0.62), an analysis scatterplot of the estimates suggested that there was a difference in effect, with the DVC rate in the interior of the fenced area being lower post-construction than pre-construction, while the DVC rate at the edge was greater post-construction than pre-construction (Figure 4.6). The lack of significance may have simply been an artifact of a low sample size given the additional stretch (i.e., edge) category, as the clustering was not as substantial near the northern end of the fenced treatment area, where five DVC were documented in the first 0.25 mi of the fence (one prior to completion and four after), compared to the southern end of the fence, where 27 DVC were documented within the first 0.25 mi of the fence (four prior to completion and 23 after). Five elk collisions were also documented at the southern end of the treatment area (one prior to completion of construction and four after).

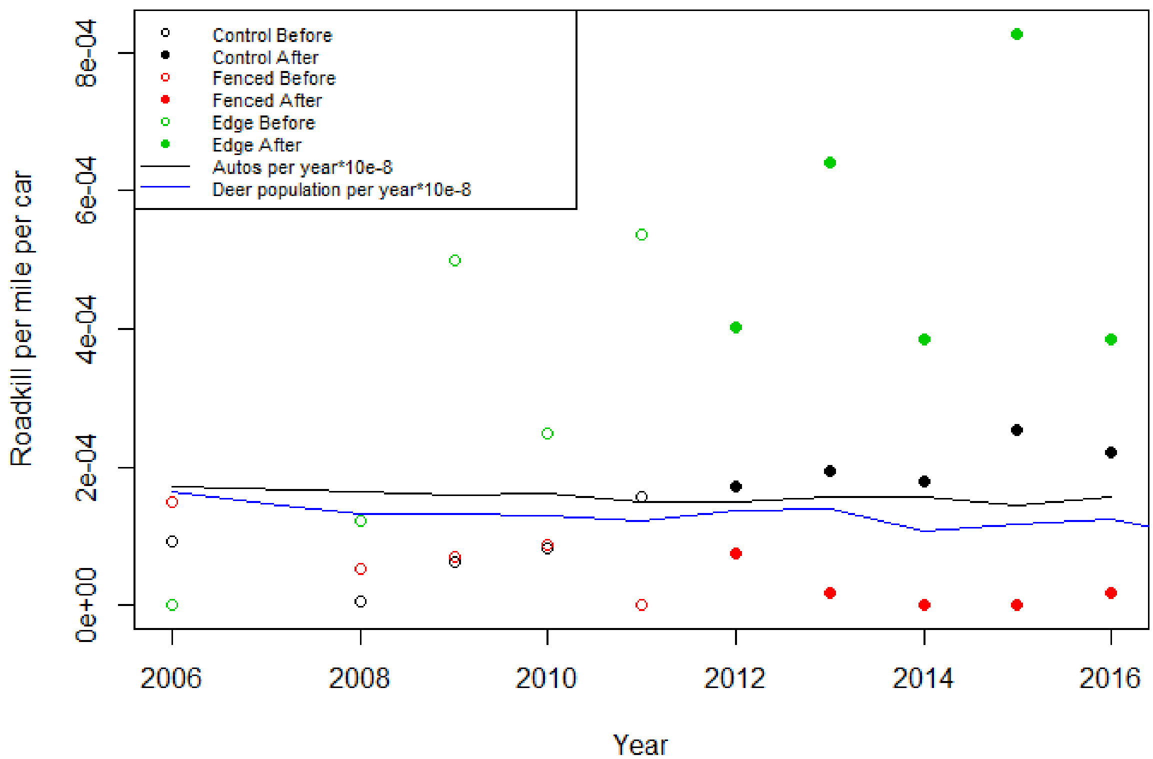

Figure 4.6. Deer-vehicle collisions per mile per car by year, period (before or after), and stretch (control, edge, or fenced), Deschutes County, Oregon, 2006-2016.

5 SUMMARY AND CONCLUSIONS

While overall post-construction DVC rates appear to be down within the fenced treatment area as a whole compared to pre-construction DVC rates, project effectiveness does not appear to be consistent throughout the fenced treatment area. Data indicate that mule deer (and elk) routinely get into the roadway, but do not appear to be using the jump-outs to escape. As noted by Bliss-Ketchum and Parker (2015), it is likely that the jump-outs are too tall and thus not being used by deer and other mammals. While some of the clustering observed within the fenced area may be an artifact of ODOT reporting (i.e., carcasses reported to the nearest mile-marker) the number of carcasses reported at/near the southern fence end seems to suggest an issue with project design in this area. Although deer are using the wildlife underpasses and are clearly moving along the fence (both inside and outside), the lack of any exit at the southern end of the fenced treatment area (i.e., there are no true fence ends) may be creating a zone of increased collision risk in this area, as evidenced by the substantially higher post-construction DVC count within the southernmost 0.25 mi of the treatment area. While deer and elk are clearly using the wildlife underpasses at Crawford Road and South Lava Butte, there is some suggestion that the fencing and jump-out designs may be contributing to an increase in DVC risk in some areas of the project (e.g., the southern end).

In conclusion, it appears that the wildlife crossings have provided a means of safe passage for mule deer and other wildlife that routinely cross Route 97; however, the fence and jump-out configuration may be limiting the overall effectiveness of the project. While the project has resulted in a lower DVC over its full length, given the spatial variability observed in DVC since the fencing and wildlife crossings were constructed, consideration of potential modifications to the design of jump-outs and fence-ends are recommended. Should any modifications be made, additional monitoring and analysis to document the effectiveness of modifications would also be recommended to ensure that the project achieves its full potential of minimizing risk to both human and animal safety.

6 REFERENCES

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Appendix A: Views from remote cameras at wildlife crossing structures along U.S. Route 97 between milepost 149 to MP 153 from Lava butte to South Century Drive.

Appendix A1. Views from remote cameras at the multi-use Crawford Road (CR) wildlife underpass on U.S. Route 97. Photos are labeled with the camera ID. Photos 1a-e represent views from cameras situated on the west side and 1f-i represent cameras on the east side of the underpass.

1a. CR1W

1b. CR2W

1c. CR3W

1d. CR4W

1e. CRW

Appendix A1. Views from remote cameras at the multi-use Crawford Road (CR) wildlife underpass on U.S. Route 97. Photos are labeled with the camera ID. Photos 1a-e represent views from cameras situated on the west side and 1f-i represent cameras on the east side of the underpass.

1f. CR5E

1g. CR6E

1h. CR7E

1i. CRE

Appendix A2. Views from remote cameras at the South Lava Butte (SL) wildlife underpass on U.S. Route 97. Photos 2a-c and 2d-f represent views from cameras situated on the west side and east side of the underpass, respectively.

2a. SL1W

2b. SL2W

2c. SLW

2d. SL3E

2e. SL4E

2f. SLE

Appendix A3. Views from remote cameras at the jump-outs in the exclusion fencing along U.S. 97. There are two cameras for each jump-out; one tree-based and one ground-based camera.

3a. JSW1R. Southwest tree-based camera.

3b. JSW1W. Southwest ground-based camera.

3c. JSE1R. Southeast tree-based camera.

3d. JSE1W. Southwest ground-based camera.

3e. JNW1R Northwest tree-based camera.

3f. JNW1W. Northwest ground-based camera.

Appendix A3. Views from remote cameras at the jump-outs in the exclusion fencing along U.S. 97. There are two cameras for each jump-out; one tree-based and one ground-based camera.

3g. JNE1R. Northeast tree-based camera.

3h. JNE1W. Northeast ground-based camera.

Appendix A4. Views from motion detecting cameras at the fence-ends or fence-corners in the exclusion fencing setup along U.S. Route 97.

1a. NWFE. Northwest fence-end that terminates at a lava mound.

1b. NEFE. Northeast fence-end that terminates at lava mound.

1c. SWFE. Southwest fence corner near U.S. 97 south-bound off-ramp and Hwy 42.

1d. SEFE. Southeast fence line near U.S. 97 north-bound on-ramp along fence.