SR 20/NORTH CASCADES HIGHWAY WILDLIFE SAFETY PLANNING PROJECT

Submitted to:
Federal Lands Access Program

Western Federal Lands Division
U.S. Department of Transportation, Federal Highways Administration

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Washington State Department of Transportation
North Central Region
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North Central Region
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Executive Summary

State Route 20 is a popular scenic byway and the only access to the Okanogan-Wenatchee National Forest Lands surrounding Washington Pass. From the East, the highway passes through the Methow Valley, home to large populations of migratory and resident mule deer and where there is a longstanding history of frequent deer-vehicle collisions (DVC's).

This study aimed to improve understanding of the environmental and roadway factors influencing the frequency of DVC's and to use this knowledge to recommend site-specific engineering solutions to reduce DVC's along SR 20 within project limits (milepost 177.65 to milepost 202.65). This objective was accomplished in three parts: First, environmental and roadway factors that affect the frequency and probability of DVC's throughout the corridor were identified and verified by field data. Second, the correlated factors were used to identify the root cause of these collisions at the historical high DVC spots. Finally, engineering solutions to help reduce the frequency of deer-vehicle collisions were evaluated at specific locations where DVC's were most frequent.

WSDOT partnered with Washington State University's (WSU) School of the Environment to accomplish the first and second goals. Using historical records of carcass removals and DVC's, a study was designed to determine deer abundance and individual crossings within project limits. To collect this data, three different methods were implemented: in-person field observations, installation of game cameras, and radio-collar tracking and remote sensor data logging. Each of these methods helped create a robust dataset that was used to build predictive models, showing what factors at a given location increased the probability of deer crossings and thus DVC's. It was found that environmental factors like proximity to water sources (canals and rivers) and south facing slopes influenced the frequency that deer crossed the road. Roadway factors like reduced vertical and horizontal curve distances as well as steep roadway side slope strongly correlated to increased frequency of DVC's. Using these factors alongside historical data, nine zones were identified as primary candidates for the implementation of engineering countermeasures. Seven countermeasures were deemed suitable for the project area based on the influencing factors, community input, and existing data sources. Engineering solutions involving these countermeasures were categorized into low, medium and high cost recommendations for each of the nine zones. It was determined that DVC's could be reduced by as much as 50% if

engineering recommendations were implemented within just 4 of the 9 zones. Therefore, it is recommended that these locations be prioritized for future wildlife habitat connectivity projects on this corridor.

1.0 Introduction

The number of wildlife-vehicle collisions has been rising in the United States as traffic and population increase on highways that intersect wildlife habitat. The Washington State Department of Transportation (WSDOT) estimates that over 5,000 collisions within the state of Washington are attributed to deer and elk annually [1]. Since the early 1970s, the Washington State Department of Transportation (WSDOT) has been monitoring and fielding reports of wildlife-vehicle collisions along State Route 20 (SR 20). SR 20, also known as the North Cascades Highway, is a state highway route. It starts at an intersection with U.S. 101 near Discovery Bay and ends at a junction with U.S. 2 near the Idaho/Washington state border. A portion of SR 20 runs through the Methow Valley starting at the town of Mazama and ending south of Twisp, at a junction with SR 153. This portion is a part of the Cascade Loop driving tour and boasts scenic views of both the Cascade Mountain Range and Methow River [2]. With recreational stops along the way, in the towns of Winthrop and Twisp, many visitors are attracted to this scenic byway. During summer months the average annual daily traffic counts range from 1300 to 5800 [3]. In addition to the large number of visitors each year, the Methow Valley is home to Washington's largest wintering concentrations of migratory mule deer [4]. The segment of SR 20 located between Twisp and the summit of Rainy Pass has long been observed to have a high number of deer-vehicle collisions, relative to the traffic volumes. These collisions are of concern to WSDOT as they cause human injury, property damage, and affect deer populations. To better understand why these collisions occur, WSDOT was awarded a grant in 2013 from the Federal Lands Access Program (Western Federal Lands) to study deer-vehicle collisions along State Route 20, within the Methow Valley. This grant, alongside WSDOT state funds, produced the North Cascades Highway Wildlife Safety Planning Project.

2.0 Project Background

2.1 Objectives

The goal of this project was to obtain a better understanding of the environmental and roadway factors influencing deer-vehicle collisions and to use this understanding to provide engineering management recommendations to reduce the frequency of deer-vehicle collisions. To accomplish this goal, the project was organized into three parts. The first part was to identify and examine how environmental and roadway factors affect the frequency and probability of deer-vehicle collisions throughout the corridor. The second part was to determine which of these correlated factors were most prominent at each of the historical high deer-vehicle collision zones, to identify the root causes of these collisions. The final part was to provide management options at specific locations within the project limits to reduce the frequency of deer-vehicle collisions.

2.2 Location

The project area focused on a 25 mile long segment of SR 20 from Early Winters Campground to the town of Twisp (milepost 177.65 to milepost 202.65). Originally, the study location of this project was defined from Granite Creek to Winthrop (milepost 148.10 to milepost 192.20). After examining existing deer-vehicle collision data, deer migration corridors, and carcass removal records, it was determined that the area of focus be shifted 20 miles south. This was to include the highway segment between Winthrop and Twisp, which has always been notorious in the valley for frequent deer-vehicle collisions. This shift also moved project limits outside of the annual winter road closure of portions of SR 20. Figure 1 shows the final study area.

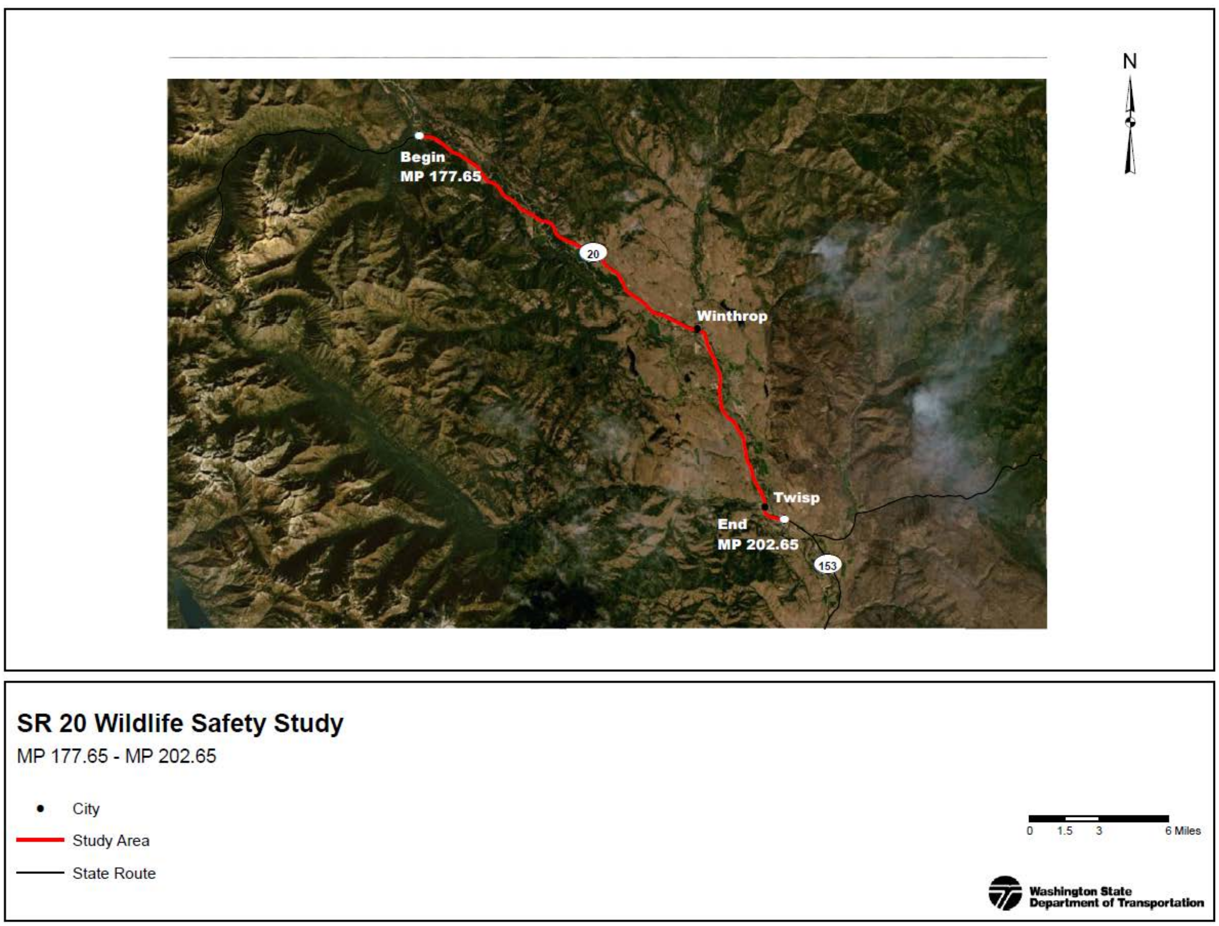

Figure 1. Study Location

3.0 Modeling Environmental Drivers of Wildlife-Vehicle Collisions

In 2016, WSDOT partnered with Washington State University's (WSU) School of the Environment to obtain scientific information identifying environmental and roadway factors affecting deer-vehicle collisions. WSU evaluated existing data sources, performed field surveys, and developed models to determine these factors. These results were used to identify the zones along SR 20 where engineering countermeasures could be implemented to reduce deer-vehicle collisions.

3.1 Temporal and Spatial Patterns

WSU first analyzed existing sources of data for patterns in deer-vehicle collisions and deer-carcass removals. These patterns were used to help plan field sampling studies.

Using 2009-2014 deer-vehicle collision incident reports provided by Washington State Patrol (WSP), temporal patterns of expected frequencies of deer-vehicle collisions were quantified. Figure 2 shows the relationship between time of day and number of deer-vehicle collisions reported to WSP. This data shows that the peak number of reported deer-vehicle collisions occurred seven hours before and after noon, matching expected crepuscular activity patterns for deer.

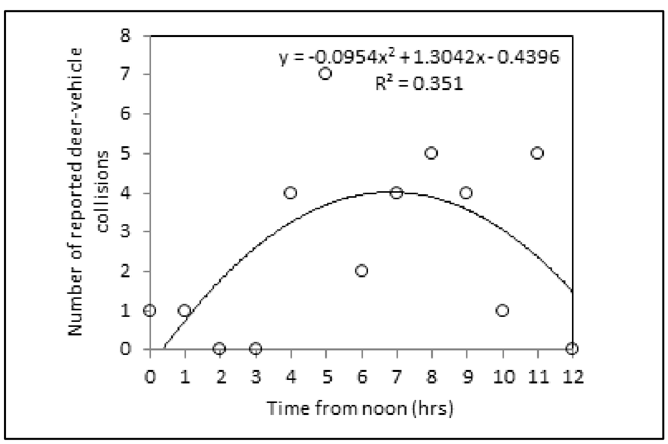

Figure 2. Number of reported deer-vehicle collision incidents as a function of time (2009-2014)

2009-2015 deer carcass removal records provided by WSDOT were also examined for both temporal and spatial patterns. Figure 3 shows the highest number of mule deer carcasses removed occurred in the months of September and July while the highest number of white-tailed deer carcasses removed occurred in January and February. This suggested that the mule deer in this area are residential, while the white-tailed deer in this area are migratory.

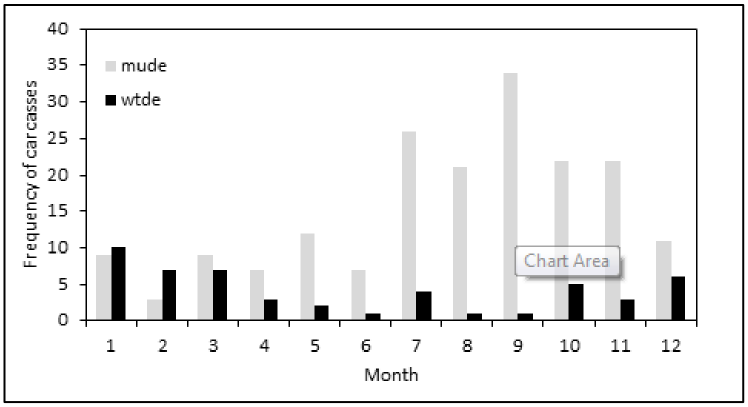

Figure 3. Frequency of white-tailed and mule deer carcasses removed from SR 20 (2009-2015)

Figure 4 shows the spatial patterns found in the carcass-removal records. The cumulative number of carcasses removed over a 7 year period at each one-mile segment within the project area ranged between 0 and 25. The highest cumulative counts of deer carcasses removed occurred around mileposts 190-191, 192-193, and 194-198.

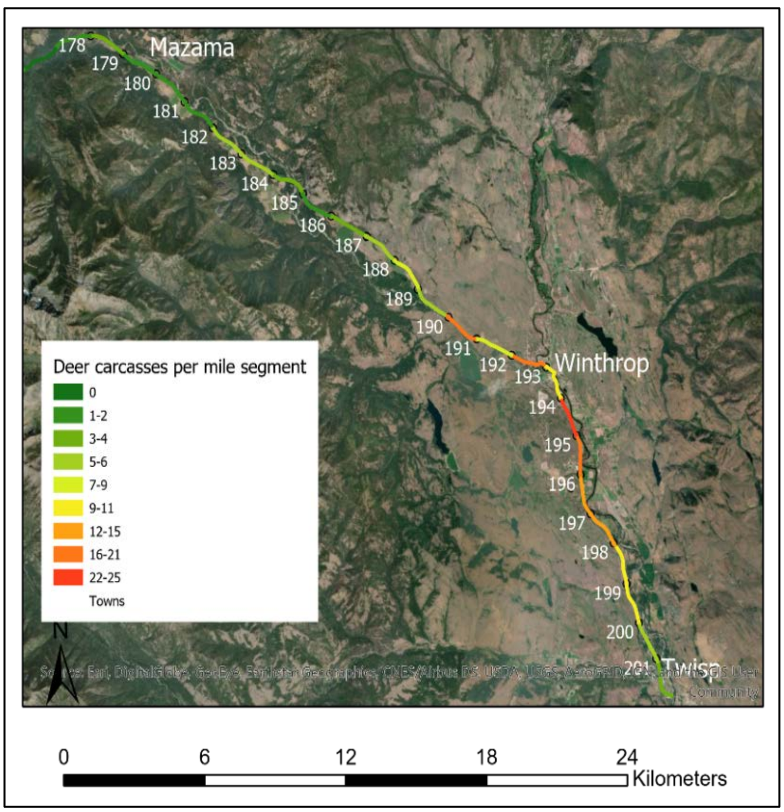

Figure 4. Cumulative counts of both deer species carcasses removed from SR 20 (2009-2015)

In addition to the aforementioned data sources, mule deer migration corridor records were examined. Utilizing a report published by the Washington State Department of Fish and Wildlife

(WDFW), WSU identified ten migration paths that crossed SR 20 within the project limits. Figure 5 shows these migration paths. Several paths correspond to the one-mile segments with the highest number of deer carcasses removed.

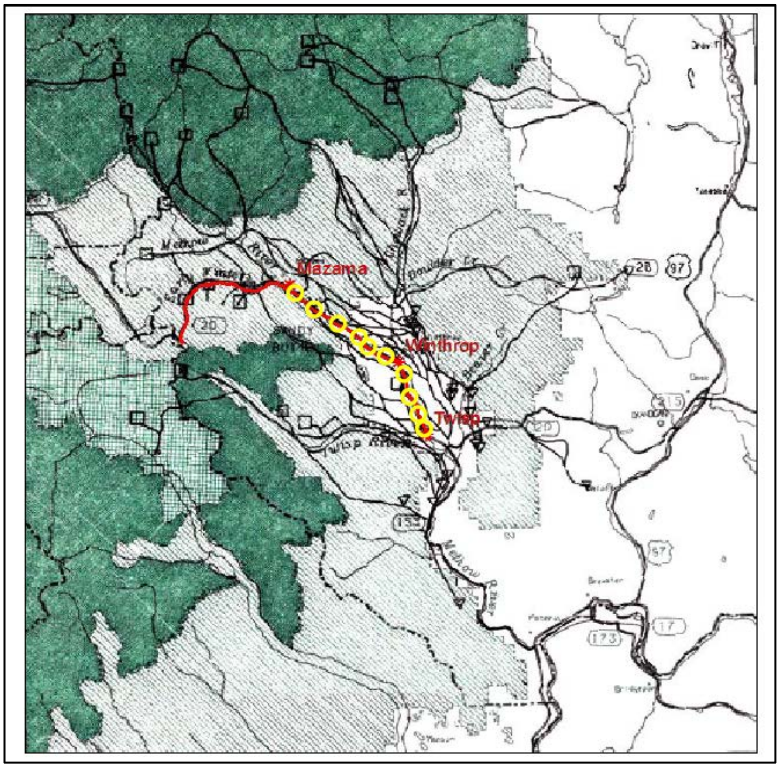

Figure 5. WDFW Mule Deer Migration Paths in the 1980s (source: WDFW; Myers et al. 1989)

While the historical data provided initial direction, it was important to field proof the data sets. The temporal patterns shown in Figures 2 and 3 suggested that field sampling and visual surveys be performed at dusk or dawn and during the seasons of summer and fall. Figure 4 identified spatial patterns and highlighted the “hot spots”, or locations with particularly high frequencies of deer-vehicle collisions, to be further investigated. While the established mule deer migration corridors shown in Figure 5 generally corresponded with the spatial patterns observed in the historical collision and carcass data, assessment of the migration paths was warranted, as these corridors had been defined over 25 years ago.

Field sampling was performed to collect empirical data on the distribution of deer carcasses along SR 20. Field surveys of deer carcasses along the roadside were performed twice in 2017; once in mid-spring and once in mid-fall. Following standard survey procedure, WSU collected data on the condition and location of individual deer carcasses. During the spring survey, scat and tracks sightings were recorded. During the fall survey, the carcass state of decomposition was recorded. Multiple surveys were also performed at certain locations to correct for unintentional detection bias. The detection bias-corrected data was used to estimate carcass abundance at one-mile segments during this time period (Figure 6). The highest estimates of carcass abundance were at mileposts 189-190, 191-192 and 195-197.

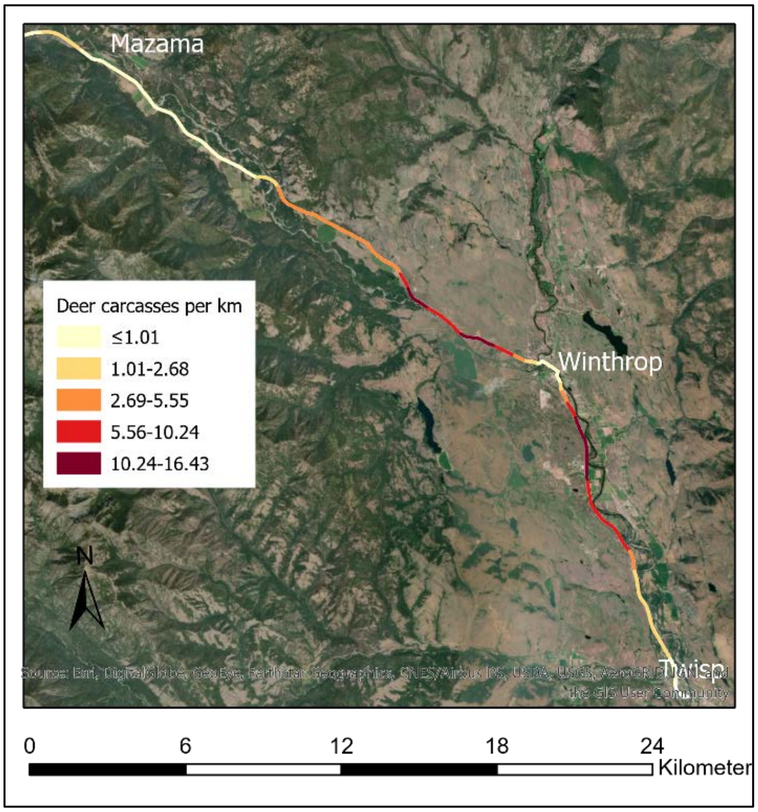

Figure 6. Frequency of DVCs that resulted in a deer fatality, milepost 176-201 (Apr-Oct 2017)

Field sampling produced reliable and current estimates of carcass abundance along SR 20. Performing multiple surveys and correcting for observer detection bias ensured data further improved accuracy. Comparing the data to WSDOT cumulative carcass removal records indicated that general spatial patterns were captured. Combining the survey data with historical records produced comprehensive maps that more accurately depicted the spatial patterns of deer-vehicle collisions within the study area. The next step was to determine where successful deer crossings were located and what factors were influencing crossings.

3.2 Deer Abundance & Individual Crossings

In the design of the study, WSU faculty identified three methods to monitor individual deer movements along and across SR 20 in order to gather additional data on the local patterns of deer crossings, compared to the apparent hot spots of deer-vehicle collisions.

Live Deer Counts – In-person Observations

In the summer of 2017, a pilot study was performed to determine whether there was a correlation between the WSP deer-vehicle collision incident reports and the frequency of successful deer crossings. Figures 7 & 8 show the frequency of live deer and cumulative deer counts within the study area. The highest frequency of live deer was witnessed at mileposts 188 and 193-195. The pilot study also determined that the frequency and cumulative counts of mule and white-tailed deer were negatively correlated (in other words, the two species were seldom occupying the same areas at the same time). The field observations also supported the temporal patterns reflected in Figure 3.

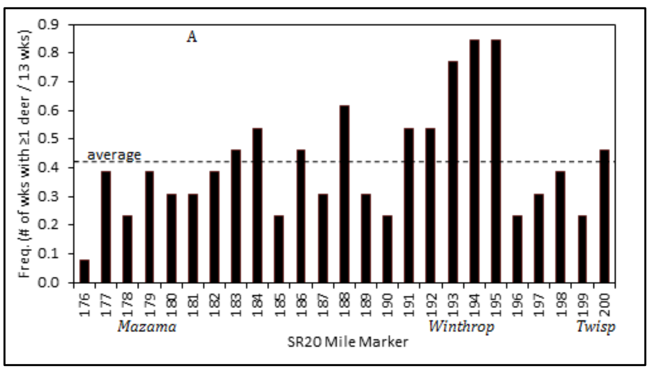

Figure 7. Frequency of Live Deer along SR 20 (May-Aug 2017)

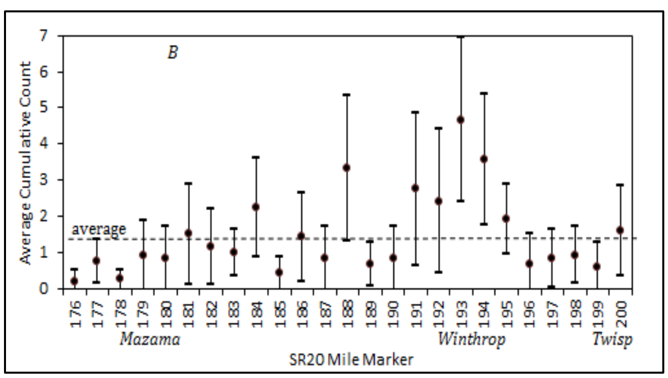

Figure 8. Cumulative Deer Counts along SR 20 (May-Aug 2017)

The sightings of live deer were used to determine the probability of an individual deer crossing at a location and the number of times it would cross at that location. Figures 9A and B show that the higher the abundance of deer at a given location, the higher the probability that a deer will cross the road and also cross the road more than once. This indicated that deer were more likely to cross SR 20 around mileposts 188 and 193-195 due to the abundance of deer at these locations.

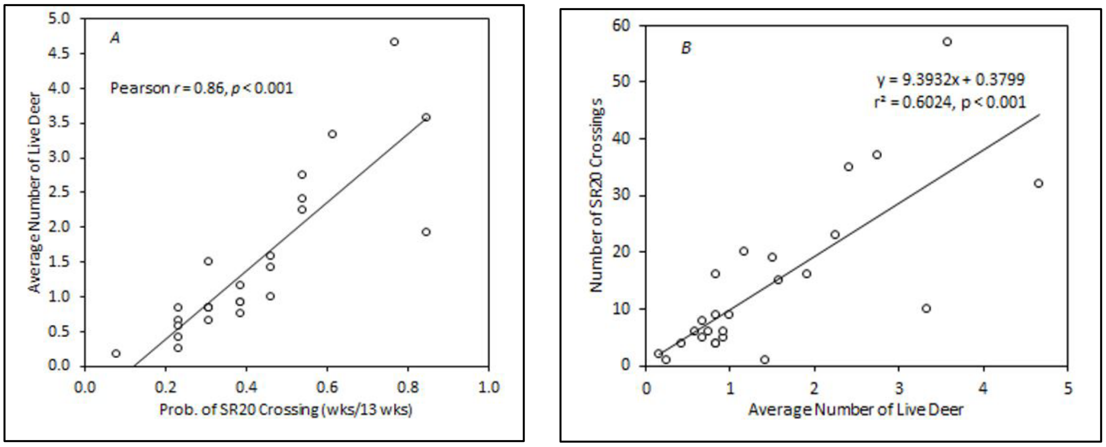

Figure 9. Relationships between number of live deer and probability of crossing the road (A) and number of live deer crossings and number of deer along road (B) (May-Aug 2017)

Live Deer Counts – Game Cameras

In addition to physical observations, 60 game cameras were installed along the highway to gather counts on deer crossing at specific locations. The placement of the cameras was determined by the historic mule deer corridors and identification of fresh deer sign/paths, but was not limited to locations where frequency of deer-vehicle collisions was greatest. Instead, the 60 cameras were divided up into three categories: Low, Medium, & High deer mortality locations (as determined by the historical WSDOT carcass & WSP collision data). The intention with this strategy was to test the common assumption that higher mortality is directly correlated with high frequency of crossings. By placing cameras in select areas of low historic mortality, we would potentially determine if they are seeing low numbers of collisions simply because there are few deer crossings happening or if, instead, deer crossings are occurring more successfully at these locations. Cameras were deployed from April to October 2017 and produced over 500,000 photographs. Figure 10 shows the number of photos of mule and white-tailed deer recorded by game cameras each day. The greatest number of mule deer photographs were captured at mileposts 193-194, 196, and 198 (near the town centers of Winthrop & Twisp). The greatest number of white-tailed deer photographs were captured at mileposts 183-184, 187, and 193.

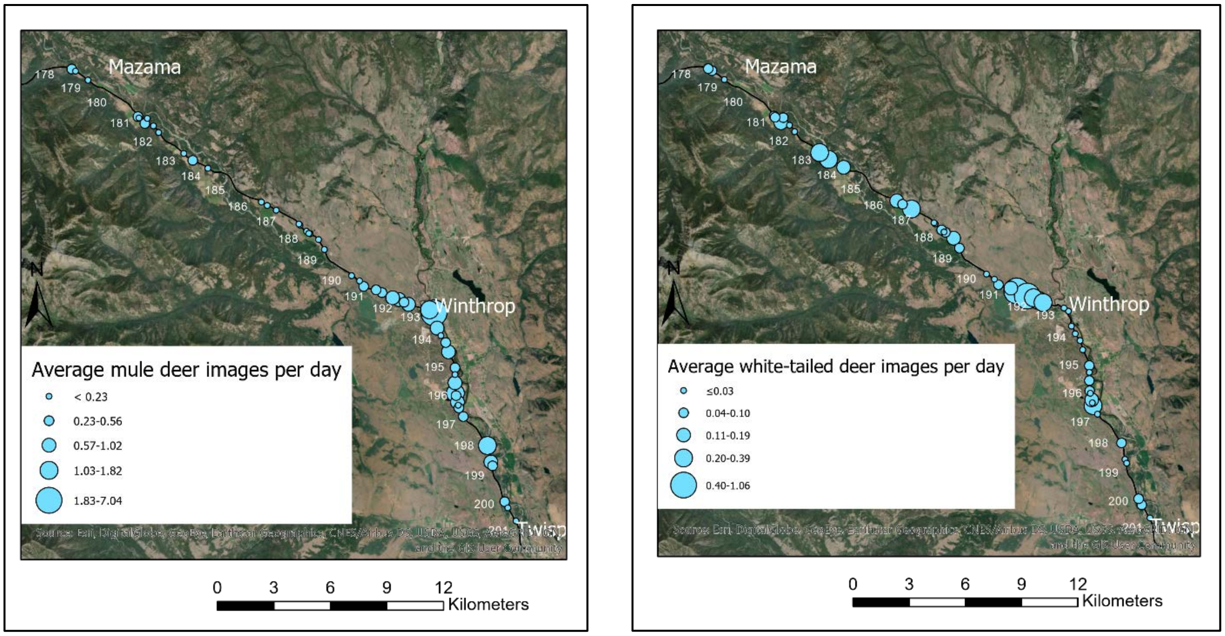

Figure 10. Average mule and white-tailed deer images recorded by cameras per day along SR 20 (April-Oct 2017)

Radio-collar Tracking & Remote Sensor Data Logging

The final method used to monitor individual deer movements and crossings of SR 20 was through radio collars and data loggers. From January to March 2018, 20 adult female mule deer and two adult female white-tailed deer were captured and radio collared. Deer were initially captured throughout the study area at locations determined using the previous deer abundance data. However, due to heavy snow accumulation there was an absence of deer in the northern project limits and capturing was relocated to the southern half of the project limits. Seven of the twenty-two collared deer were radio-tracked until April 2018, when they left the project area. These deer were assumed to be migratory. One white-tailed deer died in May 2018. The 14 remaining collared resident deer were radio-tracked until October 2018. Figure 11 shows the radio-tracked locations of the collared deer. A large number of the collared deer moved in and around the town of Winthrop as well as south of Winthrop at mileposts 196-197.

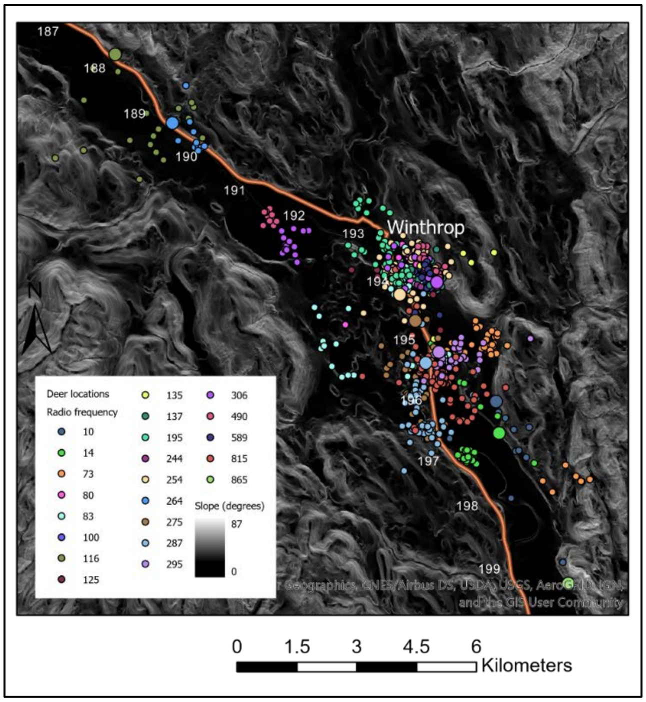

Figure 11. Radio-tracking point locations of individual radio-collared deer (Jan-Aug 2018)

Along with radio-tracking, automatic data loggers were installed in 49 locations along the SR 20 right-of-way. These systems recorded information of each deer when they came within 130 meters of a logger. Figure 12 shows the number of times per day individual radio-collared deer crossed SR 20.

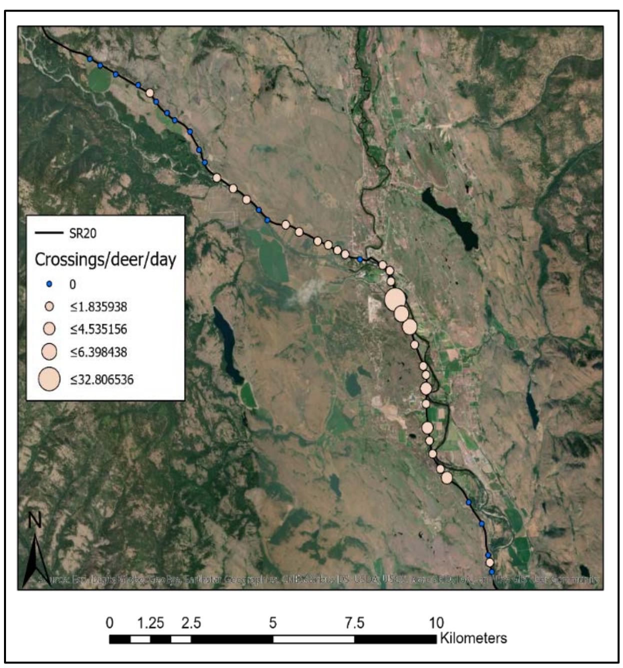

Figure 12. Average number of times per day individual radio-collared deer crossed SR 20 (Jan-Oct 2018)

Tracking individual deer movements provided an overall picture of how deer used the environment around SR 20. Results indicated that there were large abundances of deer crossing near mileposts 183-184, 192-194, and 196-197. Radio-collaring deer also revealed that a high number of resident deer existed within project limits, which make frequent daily crossings over the highway. The photographs recorded by game cameras showed that previously recorded migration paths were still in use. With a thorough understanding of where deer movements were occurring along SR 20, the next step was to determine what environmental and roadway factors were influencing these movements.

3.3 Landscape and Roadway Factors

A number of environmental factors were identified and examined to help understand why deer crossings occurred along SR 20. Two existing sources of land cover data were utilized to identify the landscape features that existed within project limits. The first source was the Gap Analysis Project (GAP) Land Cover Database. This database is a USGS program that provides data for planning and management of biological diversity on a regional and national scale. The second source was the National Land Cover Database. This is a product produced by the Multi-Resolution Land Characteristics Consortium (MRLC). These data sources produced maps and models that were sufficient in providing an initial analysis at a regional scale. However, as the need for a higher level of detail increased, these models yielded a higher level of error. To correct for these inaccuracies, WSU students recorded landscape features at numerous locations along SR 20 to field-truth the available databases. The landscape features recorded during the field work were then compared to the vegetation mapping. It was determined that the NLCD map was the more accurate of the two sources. Therefore, it was used to create a base layer with environmental and habitat features projected on top (Figure 13).

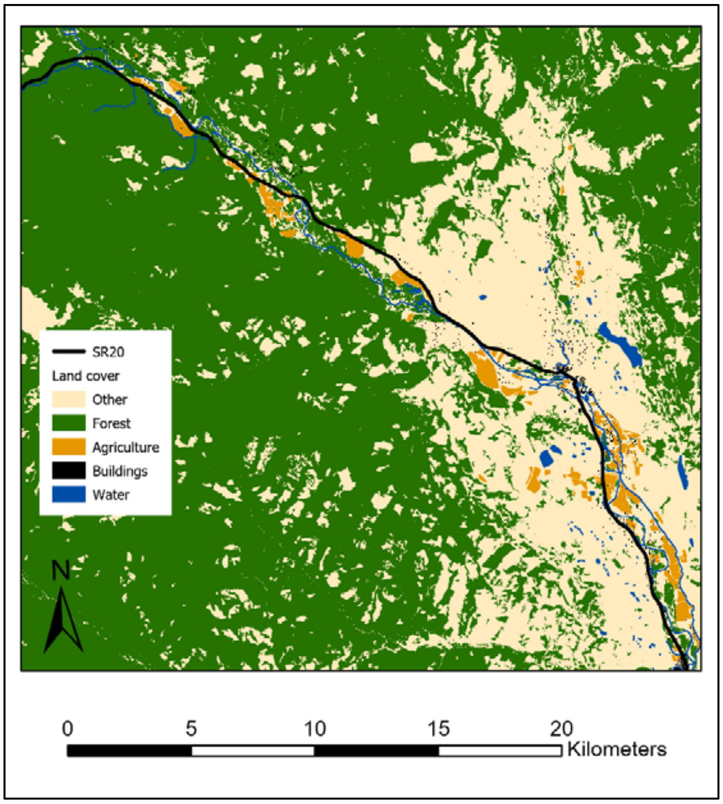

Figure 13. Land cover types within the Methow Valley (2016-2019)

Habitat features included but were not limited to: forest, water sources (canals and rivers), standing water sources (ponds and lakes), agriculture, buildings, and open south-facing slopes.

In addition to landscape and habitat features, the relationship between roadway factors and the frequency of deer-vehicle collisions was examined. Using a Digital Elevation Model (DEM) tool, a surface was created to identify the maximum slopes adjacent SR 20. This was used to determine whether the steepness of a slope could influence when a driver sees a deer and thus when a deer-vehicle collision occurs. Vertical and horizontal curve sight distances were also evaluated. Using field data provided by WSDOT, the length of these curves were projected on to the established base map. (Figure 14)

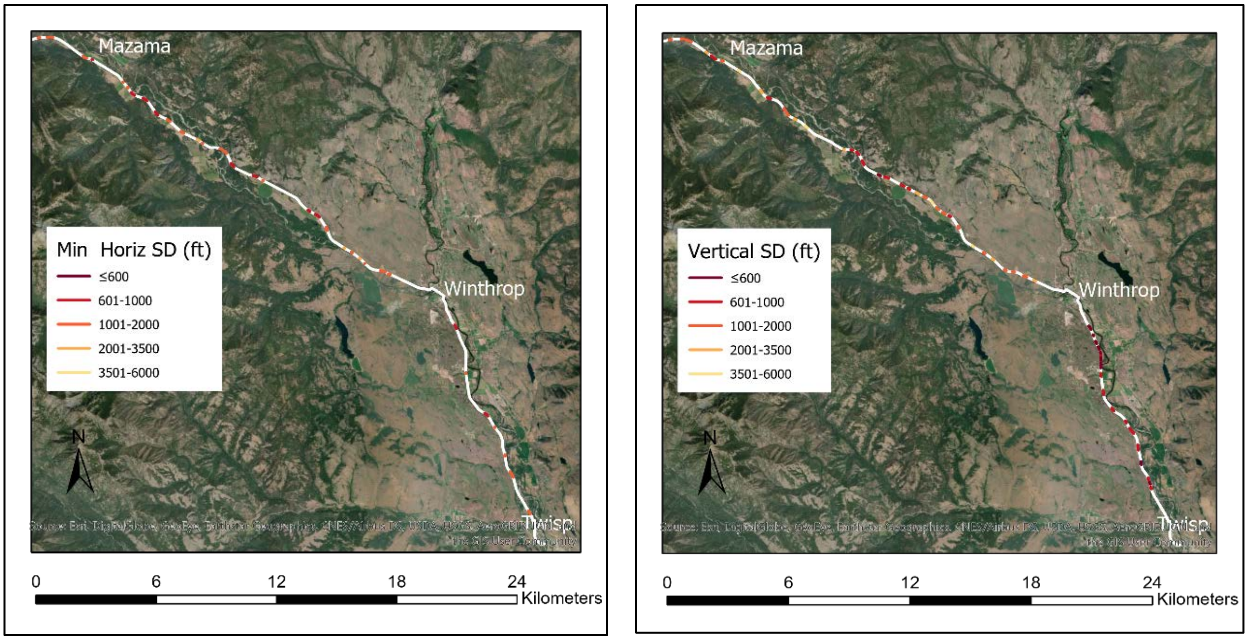

Figure 14. Horizontal & Vertical Curve Sight Distances along SR 20

Once the environmental and roadway factors were identified, several models were constructed. The frequency of crossings at each data logger were used to model the relationship between environmental factors and frequency of deer crossings. The detection-bias corrected estimates of carcass abundance at game camera locations were used to model the relationship between roadway factors and frequency of deer-vehicle collisions. The models that best fit the datasets were chosen based on the least number of assumptions and variables, these were called the global models. The global model that best predicted the frequency of deer crossings, identified two environmental factors: distance to water features and distance to open south-facing slopes. Water features included rivers and canals, and were negatively correlated to the frequency of deer crossings (the number of crossings increased the closer to the water source). Open south-facing slopes, geographic features that provide deer with thermal protection and forage in the winter, were positively correlated to the frequency of deer crossings (the number of crossings decreased the closer to the slope).

The global model that best predicted the frequency of deer-vehicle collisions, identified a combination of roadway factors. It was determined that segments of the highway where deer-vehicle collisions were predicted to occur had a high abundance of deer, minimum sight distance (vertical or horizontal) and maximum side slope within 60 meters of the highway. These segments were characterized as zones and presented spatially along SR 20 (Figures 15 & 16).

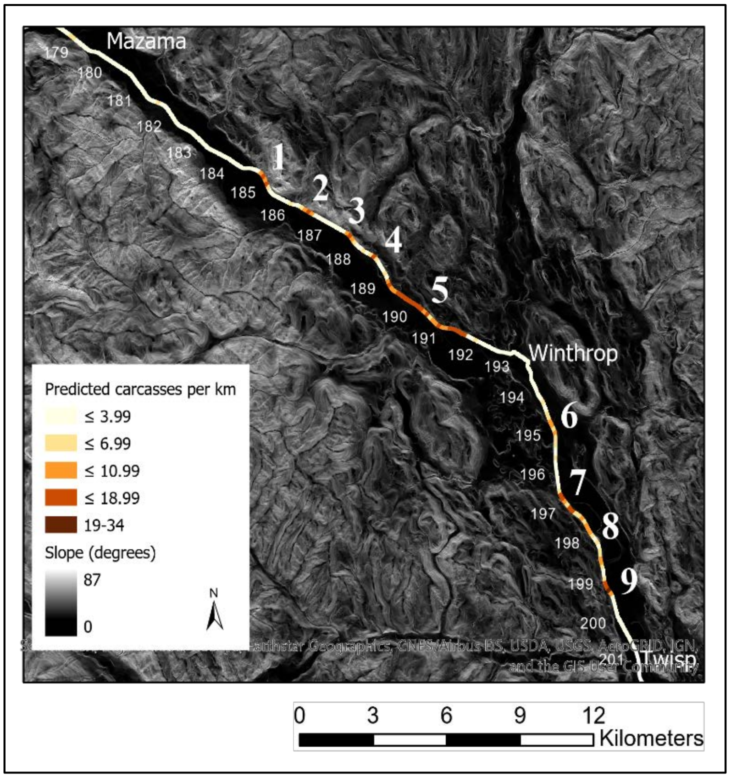

Figure 15. Spatial Representation of Slope (degrees) Model and Predicted Carcasses per km

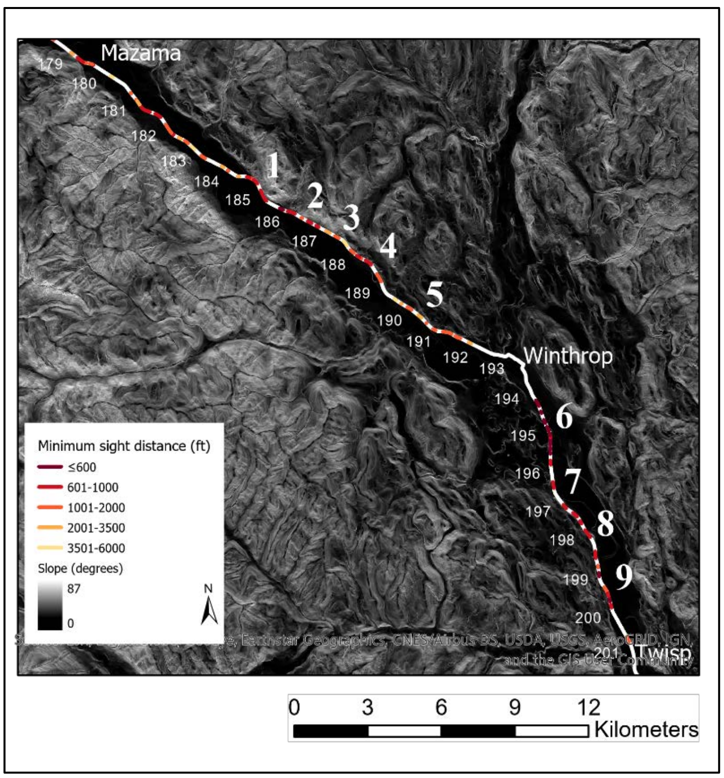

Figure 16. Spatial Representation of Road Geometry Model and DVC Frequency

To ensure the models could be used for site-specific application, WSU compared the model predicted locations of deer-vehicle collisions to the historical data mentioned earlier in this report. Figure 17 shows there was a high level of agreement between both datasets.

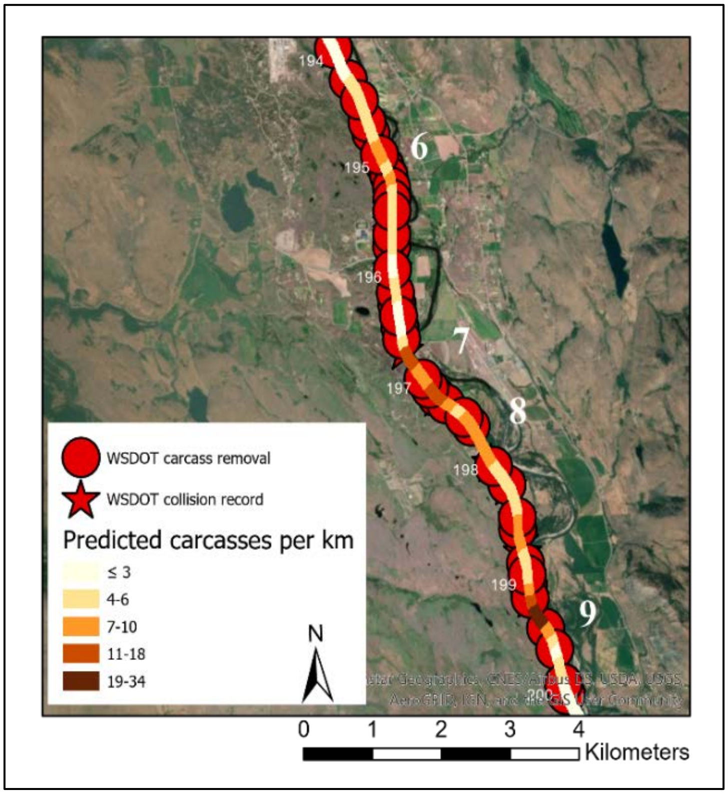

Figure 17. Predicted DVCs compared to Historical Records of DVCs

3.4 Identification of Primary Zones for Engineering Countermeasures

With the primary influencing factors of deer-vehicle collisions isolated, the final step was to identify specific zones where engineering countermeasures could be implemented to maximize reductions in deer vehicle collisions on SR 20. Using the global models and historical records, nine zones were established between mileposts 184-200. Figure 18 shows the nine zones and zone extensions. Zone extensions were established to include adjacent highway increments that contained a WSDOT documented carcass removal or collision. Although a high abundance of deer were observed around the town of Winthrop (milepost 192-194), low numbers of deer-vehicle collisions and carcasses removals led to this location not being identified as a recommended zone. Each of the zones range from 0.20-2.70 miles in length. White-tailed deer are the dominant species in zones 1-4, while mule deer are the dominant species in zones 8-9. Zones 5-7 are used by both species of deer.

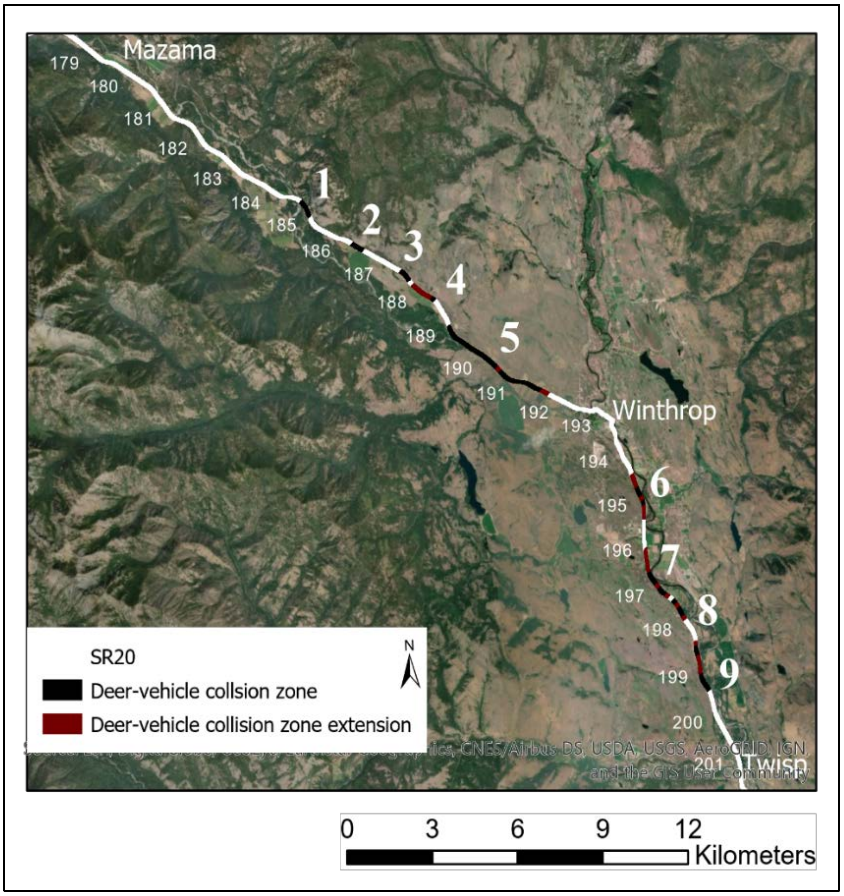

Figure 18. Recommended Zones for Engineering Management Solutions

With the assumptions that engineering solutions would be implemented over time, WSU faculty ranked the nine zones to help guide engineering decision making. Two criteria were used for rankings. First, the percent reduction in overall deer-vehicle collisions with regard to the study area. Second, the biological benefit to local deer herds (refer to Table 1, footnote 7). Table 1 shows the ranking and individual characteristics of each zone. Zones 5, 6, 7, and 9 are the highest ranking zones; meaning they contain the highest percentage of deer-vehicle collisions (Figure 18) and carcasses as well as the greatest biological importance.

Table 1. Characteristics and Ranking of Recommended Zones for Engineering Solutions

Zone	Coordinates at north-end[1] Northing	Easting	Linear length (km)	Percent of length Model output[2]	Carcass/ collision data[3]	Minimum sight distance[4] (ft)	Target species[5]	Ranking by deer-vehicle collisions[6]	Ranking by biological importance[7]
1	5380199	697612	0.64	100	0	650 V	WTDE	8 (0.3)	8
2	5378775	699398	0.48	100	0	875 V	WTDE	9 (0.0)	7
3	5377855	701116	0.48	100	0	4,491 V	WTDE	7 (0.4)	9
4	5377403	701544	0.96	16	84	799 V	WTDE	5 (4.6)	5
5	5376044	702834	4.32	89	11	1,058 H	BOTH	1 (18.6)	2
6	5371052	709279	1.60	30	70	220 V	BOTH	3 (11.9)	1
7	5368570	709750	1.92	42	58	668 V	BOTH	4 (8.7)	3
8	5366839	710720	0.80	60	40	739 H	MUDE	6 (0.6)	4
9	5365464	711521	1.76	55	45	902 V	MUDE	2 (12.6)	6

[1] NAD83, Zone 10.
[2] From road geometry model; see Figures 26 and 27 and Table 2.
[3] From WSDOT carcass data from 2009 to 2015 independent of the road geometry model.
[4] V = vertical sight distance, H = horizontal sight distance (whichever was shorter).
[5] WTDE = white-tailed deer, MUDE = mule deer, BOTH = both deer species.
[6] Determined from the percentage of deer-vehicle collisions (number of carcasses and deer-vehicle collisions during a given year / total number between SR 20 mile posts 178-201 during that year) averaged over 7 years (2009-2015). Average percentages in parentheses. Ranking ranges from 1-9, with 1 being highest. Carcass and collision data from WSDOT.
[7] Determined from the proportion of deer mortality (number of carcasses relative to local abundance of mule deer) predicted along SR 20 between April and October during the study period (see text for details). Ranking ranges from 1-9, with 1 being most biologically important (i.e., engineering solutions in this zone would reduce the greatest proportional loss (attributed to deer-vehicle collisions) to the local deer herd).

Figure 19 shows that 10-20% of deer-vehicle collisions occur within each of these high ranking zones, thus a reduction of this magnitude in each zone could occur if highly effective engineering solutions were implemented in these highway segments. With the effective implementation of engineering solutions in all four high ranking zones, deer-vehicle collisions between the towns of Mazama and Twisp could be expected to reduce by half annually.

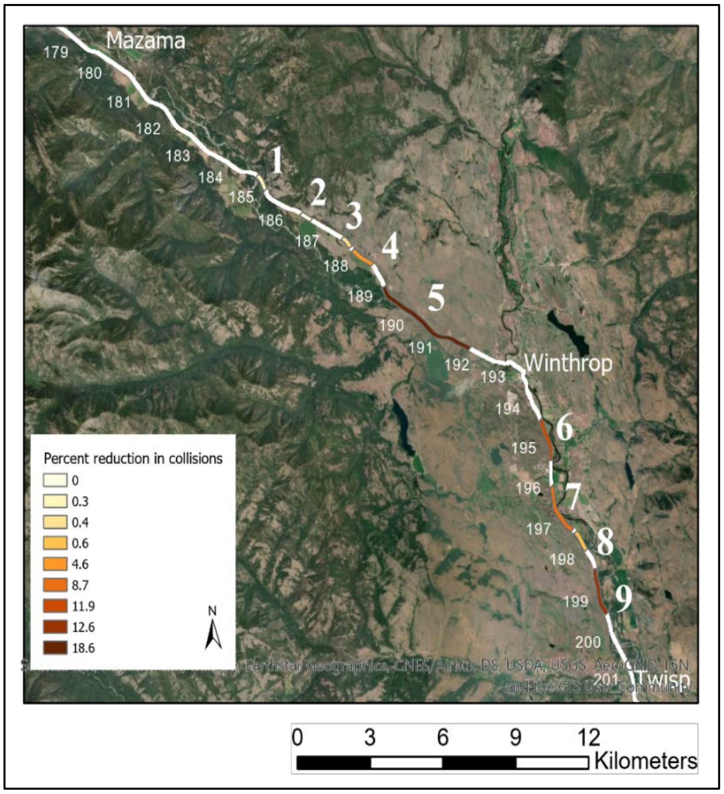

Figure 19. Percentage of DVCs in each of the 9 Recommended Zones

With the nine zones identified, the final step of this project was to identify site specific engineering management recommendations. WSDOT chose to approach this process in a holistic manner; not only evaluating engineering recommendations based on cost and effectiveness, but also based on public support and best value. WSDOT reached out to community members and travelers through the Methow Valley to help determine what solutions would best fit the needs and preferences of visitors and local residents.

4.0 Community Outreach

In 2019, WSDOT attended and presented on this project at the 2019 Mule-Deer Summit in Okanogan, Washington. WSDOT used this summit to learn more about local resident's opinions on deer-vehicle collisions and inform residents of the steps WSDOT was taking to reduce these collisions. In addition to the Mule-Deer Summit, an online-survey was distributed by WSDOT in 2019 to gain a better understanding of community needs within the project area. This survey was published on-line and advertised through the project website, WSU, and social media outlets. The survey asked participants about their relationship to the project area, experience with deer-vehicle conflicts/views on deer within the Methow Valley, and opinions of what successful methods could be used to reduce deer-vehicle collisions. 362 people from both the local area and other parts of Washington participated in this survey. One of the questions asked survey participants to rank the engineering countermeasures they would most be in favor of (Table 2). Respondents ranked installation of animal detection/warning system, wildlife structures, and speed limit reduction during dusk/dawn as the top three preferred countermeasures (Figure 18). One thing to note is that, while fencing solutions ranked mid-range in this survey question, in the general comment portion, 11% of those surveyed made statements in opposition to constructing fences along the highway, namely for aesthetic reasons and to not interfere with natural movements of wildlife.

Table 2. Survey Question 6: Rank the following methods to reduce deer-related collisions in terms of which you would be most in favor of (1 being highest)

#	Method	Score
1	Installing animal detection/warning system (flashing beacons when animals are near the road)	5.77
2	Constructing a wildlife overcrossing/undercrossing	5.44
3	Reduce the speed limit during the hours around dusk & dawn	4.7
4	Fencing around specific crops that may attract deer across the highway	4.64
5	Fencing along the highway to exclude deer from the road	4.35
6	Roadside vegetation management	4.12
7	Conduct location-specific deer population monitoring and/or control	4.04
8	Constructing alternative water sources on the side opposite the river	3.7

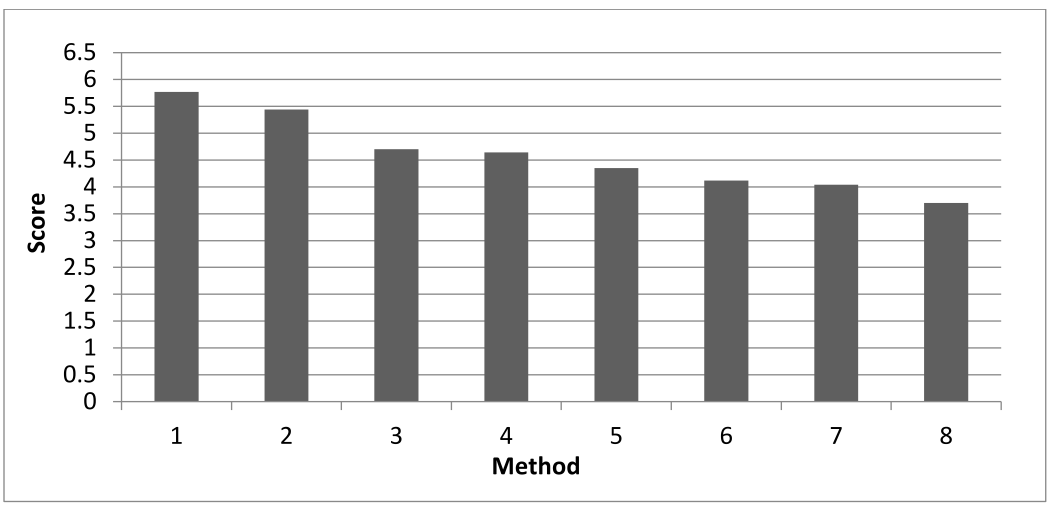

Figure 20. Survey Question 6 Results

The results of this survey helped inform the direction of countermeasure research and was taken into consideration when evaluating the value and contextual fit of engineering solutions at each zone.

5.0 Engineering Recommendations

After the nine zones were identified and community input received, WSDOT began the assessment of suitable engineering solutions, based on the primary influencing factors at each zone determined through the modeling. Using the environmental and roadway factors provided by WSU, Table 3 was derived.

Table 3. Influencing Factors at each Zone

Zone	Environmental Factors			Roadway Factors		
	Adjacent Canals & Rivers	Adjacent Open South-Facing Slopes	Proximity to Agriculture	Steep Roadway Side Slopes	Vertical Curve Sight Distance	Horizontal Curve Sight Distance
1	x	x		x	x	
2		x	x	x	x	
3		x	x	x	x	
4	x	x	x	x	x	
5	x	x	x	x		x
6	x		x	x	x	
7	x		x	x	x	
8				x		x
9	x			x	x	

Although agriculture was not a primary predictor in the models WSU produced, it was still considered a factor in influencing deer crossings within the project limits due to the observable correlation between the identified zones and presence of adjacent agricultural fields. Therefore, proximity to agriculture was also evaluated for each zone. The appropriate countermeasures were selected to help minimize the impacts these factors have on deer crossings and thus, deer-vehicle collisions. Refer to Section 3 and Appendix B for more details on the driving factors of deer crossings and deer-vehicle collisions.

5.1 Influencing Factors Related to Engineering Countermeasures

Using Table 3 in conjunction with existing literature and site data, seven engineering countermeasures were considered for the project area. Table 4 shows the recommended countermeasures that would correspond to each influencing factor. Each of these fall into one of the following three categories; countermeasures that influence driver behavior, countermeasures that influence deer behavior, and countermeasures that physically separate drivers and deer.

Table 4. Influencing Factors Corresponded to Possible Engineering Countermeasures

	Engineering Countermeasures	Environmental Factors			Roadway Factors		
		Adjacent Canals & Rivers	Open South-Facing Slopes	Proximity to Agriculture	Steep Side Slope	Vertical Curve Sight Distance	Horizontal Curve Sight Distance
Influence Driver Behavior	Signage	x	x	x	x	x	x
	Animal Detection Systems	x	x	x	x	x	x
	Modify Road Geometry				x	x	x
	Modify Road Operations	x	x	x	x	x	x
Influence Deer Behavior	Roadside Maintenance	x	x	x	x		x
Physical Separation	Highway Fencing	x	x	x	x	x	x
	Over/Underpass Structures	x	x	x	x	x	x

Countermeasures that influence driver behavior

Several countermeasures fall within the category of influencing driver behavior. The countermeasures evaluated for this project include: roadway signage, animal detection systems (ADS), modifying road geometry, and modifying roadway operations.

Currently, standard wildlife warning signs exist within project limits in several locations. However, within the recommended zones, there is opportunity to upgrade and utilize these signs differently. Placing temporary signage during periods of mule deer migration or performing routine maintenance of the existing enhanced signs could better inform drivers. Additionally, adding images of wildlife, permanent flashing lights, or red flags attached to existing signs could help improve drivers' awareness [6]. Advantages of this countermeasure include: low cost and low maintenance. However there is debate on the actual effectiveness of sign enhancements due to driver habituation, therefore it is important further benefit-cost analysis are performed to determine which sign enhancement, if any, be implemented

Animal Detection Systems (ADS) use sensors to detect when deer and larger animals approach a roadway. These sensors then send messages to warning signals that flash to alert drivers when animals are on or near the roadway. When installed with fencing, they have been estimated to be 82% effective in reducing wildlife-vehicle collisions [6]. It is recommended ADS systems be implemented in areas with high volumes of animal movement and at longer sections of roadway. The advantages of ADS include: low cost, mobility, and short installation time. The disadvantages include: inconsistent detection systems, driver habituation, and creating a funnel effect (where animals are funneled to one location at a roadway and deer-vehicle collisions increase). Additionally these systems require regular maintenance to stay operational and have a 10 year lifespan [6].

The modification of existing roadway geometry includes: improving vertical and horizontal curve sight distances as well as widening the roadway. Vertical curve sight distance could be improved by raising or lowering the roadway. Horizontal curve sight distance could be improved by performing maintenance to remove sight obstructions within the roadway or re-aligning the roadway. Widening the roadway could improve driver visibility and expand highway clear zones. Since modifications to expand and/or change roadway geometry often involve substantial earthwork and surfacing, in addition to possible need for right-of-way acquisition, this solution is typically considered to fall on the higher end of the cost scale. However, it is still mentioned because, in the right location, such modifications could offer additional benefits to transportation safety and multimodal mobility, which can increase the value of this solution.

The modification of roadway operations includes: speed limit reduction and re-striping roadway passing lanes. Currently the speed limit of SR 20 within project limits is 60 mph with speed limits decreasing to 35 mph upon entering and exiting Winthrop and Twisp and 25 mph within town limits. The high abundance of deer versus low frequency of deer-vehicle collisions within the town of Winthrop suggests that limiting speed might be an effective solution in other locations to reduce the frequency of deer-vehicle collisions. An advisory speed limit of 45 mph for deer at dawn and dusk also applies along some stretches of roadway within project limits. Changing the nighttime speed limit from advisory to regulatory with enforcement might also help to decrease the frequency of deer-vehicle collisions.

SR 20 is a two-lane highway with segments where passing is periodically permitted. Restriping and restricting passing, especially through zones with high frequency of deer crossings and reduced sight distance beyond the pavement, may also help reduce deer-vehicle collisions for very little cost.

Countermeasures that influence deer behavior

Based on the primary roadway and environmental drivers within this area, roadside maintenance was the only countermeasure examined within this category.

Roadside maintenance is a broad term encompassing many techniques to help reduce deer-vehicle collisions. In regards to influencing deer behavior, maintenance techniques can include planting low-value nutritional vegetation and removing standing water. Additionally mowing, trimming, and clearing roadside vegetation can also detract deer and improve roadside visibility. Studies have shown that clearing roadside vegetation can be anywhere from 20-50% effective in reducing wildlife-vehicle collisions. [7]

Countermeasures that physically separate drivers and deer

The final set of countermeasures examined work by constructing a physical separation between drivers and deer to eliminate conflicts in the roadway. These countermeasures consist of wildlife undercrossing and overcrossing structures, fencing, and the retrofit of other types of existing crossing structures.

Wildlife crossing structures are currently the most effective countermeasure in reducing deer-vehicle collisions. They not only reduce deer-vehicle collisions, but also provide connectivity for wildlife; a priority for WSDOT per Secretary's Executive Order E 1031.02 "Protections and Connections for High Quality Natural Habitats". When coupled with wildlife fencing, 80-95% of wildlife-vehicle collisions are reduced [6]. Undercrossing structures are typically open-span bridges or culverts. Usually they are made out of concrete or steel. WSDOT recommends these structures are a minimum of 20 feet wide and 10 feet high with an openness index factor of at least 2.0 (width x height/length in feet). Usually they are installed at areas where the roadway fill is high compared to the surrounding terrain, providing clearance to install these tunnel-like structures under the existing roadway profile. Overcrossing structures are typically steel or concrete arches or bridge spans. They can be rectangular or hour glass shaped. Overcrossings are typically installed in areas where surrounding terrain is higher than the roadway. Both under and over-crossing structures can be installed as standalone countermeasures.

To increase the effectiveness of crossing structures, cattle guards at driveways, escape features, and wildlife fencing can be implemented. It is important wildlife fencing be 8 feet tall and terminated at safe crossing locations to avoid funneling or releasing deer into the roadway with poor sight distance or other unfavorable features. WSDOT has effectively implemented safe crossing opportunities along Interstate 90 and U.S. Route 97.

Figure 21. I-90 Snoqualmie Pass East Project Overcrossing Structure

Existing structures, like cattle crossings and bridges over waterways can also act as wildlife crossing structures if the minimum aforementioned criteria are met. Zone 1 provides an opportunity to utilize an existing structure that meets the required criteria (Figure 23).

Figure 22. SR 20 - WSDOT Bridge Num. 020/618 (milepost 185.10)

As illustrated, many countermeasures exist to mitigate deer-vehicle collisions. The final step to producing engineering recommendations for each of the zones within the project limits was to further evaluate specific locations of roadside features within the zones and apply general costs to the aforementioned countermeasures.

5.2 Low/Medium/High cost recommendations for each zone

Using the community input, influencing environmental and roadway factors, and countermeasure research, Table 5 was produced. Table 5 (Page 28) provides site specific recommendations and categorizes the recommended countermeasures based on low, medium, and high costs.

					Table 5. Recommended Engineering Countermeasures														
					Low Cost					Medium Cost					High Cost				
Zone	Mile Post Start	Mile Post End	Zone Length	% of Deer Collisions in Zone	Description	Cost Magnitude	% Effectiveness (or % reduction)[1]	Lifespan (years)[1]	Costs per % reduction per mile	Description	Cost Magnitude	% Effectiveness (or % reduction)[1]	Lifespan (years)[1]	Costs per % reduction per mile	Description	Cost Magnitude	% Effectiveness (or % reduction)[1]	Lifespan (years)[1]	Costs per % reduction per mile
1	184.75	185.15	0.4	0.3	- Add seasonal or enhanced wildlife warning signs at MP 184.5 RT & 185.15 LT - Reduce speed limit to 50 mph through curve	<$10,000	20	5-10	$ 1,250	- Add flashing beacon wildlife signs at MP 184.5 RT & 185.15 LT - Clear brush & trees within highway RW at MP 185.0-185.15 - Reduce speed limit to 50 mph through curve	$50,000-$100,000	30	5-10	$ 8,333	- Install roadside fencing MP 184.7-185.1 with cattle guard on Goat Creek Rd, utilizing existing bridge (num 020/618) as a crossing structure - Add flashing beacon wildlife signs both directions at fence end (MP 185.1)	$200,000-$300,000	95	25-75	$ 7,895
2	186.2	186.5	0.3	0.0	- Add seasonal or enhanced wildlife warning signs at MP 186.2 RT & 186.6 LT - Reduce speed limit to 50 mph continuously through Zones 2, 3, & 4	<$10,000	20	5-10	$ 1,667	- Clear brush & trees within highway RW at MP 186.2-186.4 LT - Add flashing beacon wildlife signs at MP 186.2 RT & 186.6 LT - Reduce speed limit to 50 mph through Zones 2, 3, & 4	$50,000-$100,000	30	5-10	$ 11,111	- Flatten fill slopes to 4:1 and remove existing guardrail from MP 186.53-186.68 RT & MP 186.24-186.40 RT - Clear brush & trees within highway RW at MP 186.2-186.4 LT - Add flashing beacon wildlife signs at MP 186.2 RT & 186.6 LT	$300,000-$500,000	35	10	$ 47,619
3	187.5	187.8	0.3	0.4	- Clear brush & trees within highway RW at MP 187.46-187.82 LT - Add flashing beacon wildlife signs at MP 187.4 RT & 187.9 LT - Reduce speed limit to 50 mph through Zones 2, 3, & 4	$50,000-$100,000	30	5-10	$ 11,111	- Flatten fill slopes to 4:1 and remove existing guardrail from MP 187.46-187.82 RT - Clear brush & trees within highway RW from MP 187.46-187.82 LT - Add flashing beacon wildlife signs at MP 187.4 RT & 187.9 LT	$300,000-$500,000	35	5-10	$ 47,619	- Clear brush & trees within highway RW from MP 187.46-187.82 LT - Construct fencing MP 187.40-187.80 LT & RT with underpass structure at 187.75 - Add flashing beacon wildlife signs on either end of fence	$500,000-$1M	95	25-75	$ 35,088
4	188	188.6	0.6	4.6	-Add wildlife warning signs at MP 187.9 RT & 188.7 LT - Reduce speed limit to 50 mph continuously through Zones 2, 3, & 4	<$10,000	NA	5-10	NA	- Remove small fill berms at MP 188.42 & 188.46 RT - Add flashing beacon wildlife signs at MP 187.9 RT & 188.7 LT - Reduce speed limit to 50 mph through Zones 2, 3, & 4	$10,000-$80,000	NA	5-10	NA	- Flatten side slopes to 4:1 & remove existing guardrail from MP 188.03-188.11 RT, 188.23-188.4 RT, & 188.55-188.66 RT - Remove small fill berms at MP 188.42 & 188.46 RT - Add flashing beacon wildlife signs at MP 187.9 RT & 188.7 LT - Reduce speed limit to 50 mph through Zones 2, 3, & 4	$350,000-$500,000	NA	5-10	NA
5	189	191.68	2.68	18.6	- Clear brush & trees within highway RW from MP 189.0-190.55 RT & 191.3-191.75 RT - Add wildlife warning signs at MP 188.9 RT, 190.5 RT/LT, 191.1 RT, 191.8 RT/LT (flashing beacons) - Reduce speed limit to 35 mph from MP 192.16 to 191.50, reduce speed limit to 50 mph from 191.50 through Zones 2, 3, & 4	$10,000-$50,000	30	5-10	$ 622	-Construct limited fence run in vicinity of existing Cattle Crossing (MP 191.3) from MP 191.21-191.57 RT/LT - Clear brush & trees within highway RW from MP 189.0-190.55 RT & 191.6-191.75 RT - Add flashing beacon wildlife signs - Reduce speed limit to 35 mph from MP 192.16 to 191.50, reduce speed limit to 50 mph from 191.50 through Zones 2, 3, & 4	$300,000-$500,000	50	10-25	$ 3,731	-Construct complete fence run on LT side MP 189.05-191.7 & two segments on RT from MP 189.05-189.45, 190.59-191.7 (excluding steep slopes above river) - Construct underpass structure to replace existing Cattle Crossing (MP 191.3) - Reduce speed limit to 35 mph from MP 192.16 to 191.60	>$1M	95	25-75	$ 3,928
6	194.5	195.49	0.99	11.9	- Enhance existing wildlife warning signs - Reduce speed limit to 50 mph between Winthrop & Twisp	<$10,000	10	5-10	$ 1,010	- Upgrade existing wildlife warning signs to flashing beacons - Clear brush & trees within highway RW from MP 194.3-195.7 - Reduce speed limit to 50 mph between Winthrop & Twisp	$100,000-$200,000	30	5-10	$ 6,734	- Clear brush & trees within highway RW from MP 194.3-195.7 -Modify roadway geometry by widening roadway shoulders/cut back steep cut slopes OR - Construct fencing MP 195.55-195.69 LT & RT with underpass structure at MP 195.61	>$1M	95	25-75	$ 10,633

					Table 5. Recommended Engineering Countermeasures														
					Low Cost					Medium Cost					High Cost				
Zone	Mile Post Start	Mile Post End	Zone Length	% of Deer Collisions in Zone	Description	Cost Magnitude	% Effectiveness (or % reduction)[1]	Lifespan (years)[1]	Costs per % reduction per mile	Description	Cost Magnitude	% Effectiveness (or % reduction)[1]	Lifespan (years)[1]	Costs per % reduction per mile	Description	Cost Magnitude	% Effectiveness (or % reduction)[1]	Lifespan (years)[1]	Costs per % reduction per mile
7	196	197.19	1.19	8.7	- Upgrade existing wildlife warning signs to flashing beacons - Clear brush & trees within highway RW from MP 195.7-197.0 RT & 196.45-197.2 LT - Reduce speed limit to 50 mph between Winthrop & Twisp	$100,000-$200,000	30	5-10	$ 5,602	- Construct fencing MP 196.65-197.65 LT, with ADS at MP 196.65-196.94 - Clear brush & trees within highway RW from MP 195.7-197.0 RT	$300,000-$500,000	75	10-25	$ 5,602	- Construct fencing MP 196.60-196.86 LT & MP 196.45-196.70 RT with underpass structure at MP 196.64 providing connectivity for migration routes and access to the Methow River - Clear brush & trees within highway RW from MP 195.7-197.0 RT	>$1M	95	10-25	$ 8,846
8	197.5	198	0.5	0.6	- Upgrade existing wildlife warning signs to flashing beacons - Clear brush & trees within highway RW from MP 195.2-198 RT & LT - Reduce speed limit to 50 mph between Winthrop & Twisp	$10,000-$100,000	30	5-10	$ 6,667	Merge with Zone 9: - Construct fencing MP 198.30-199.00 LT & RT with underpass structure at MP 198.68 OR - Construct fencing MP 198.70-199.15 LT & 198.86-199.10 RT with underpass structure at MP 199.00 OR Construct fencing MP 198.00-198.30 LT & 198.30-197.20 with overpass structure at MP 198.12	>$1M	95	25-75	$ 21,053	Merge with Zone 9: - Construct fencing MP 198.00-199.15 LT & RT - Construct two underpass structures at MP 198.68 and MP 199.00 and/or overpass structure at 198.12. Providing a wildlife connectivity corridor and accommodating existing migration routes	>$5M	95	25-75	$ 105,263
9	198.75	199.75	1	12.6	- Upgrade existing wildlife warning signs to flashing beacons - Clear brush & trees within highway RW from MP 198.0-199.75 RT & LT - Reduce speed limit to 50 mph between Winthrop & Twisp	$100,000-$200,000	30	5-10	$ 6,667	Merge with Zone 8, see above	NA	NA	NA	NA	Merge with Zone 8, see above	NA	NA	NA	NA

[1] Source: U.S. Department of Transportation, Federal Highway Administration. (2008). Wildlife Vehicle Collision Reduction Study: Best Practices Manual. Retrieved from: https://training.fws.gov/courses/csp/csp3112/resources/Transportation_Projects/Wildlife_Vehicle_Collision_Reduction_Study_2008.pdf

The recommendations at each zone utilize a combination of the seven countermeasures evaluated as studies have shown coupling techniques can increase the effectiveness in reducing deer-vehicle collisions [6]. Based on historical costs and countermeasure research, low cost countermeasures were considered anything less than $100,000, medium costs ranged from $100,000 to $500,000 and high costs countermeasures were greater than $500,000. Referring to Table 5, numerous countermeasures at each of the cost methods could be effective in reducing the number of deer-vehicle collisions within these zones. From a wildlife connectivity standpoint, it is highly recommended options physically separating deer while allowing natural movement and migration be prioritized. Zones 1, 3, and 5-9 in particular have opportunities to provide safe crossings. From a cost standpoint Zone 1 is the least expensive due to the existing bridge at milepost 184.6. Coupled with cattle guards, fencing, and flashing beacon signs at fence ends deer-vehicle collisions could greatly reduce within this important migration corridor crossing. An existing cattle crossing within Zone 5 (milepost 191.3) is already voluntarily used by small numbers of deer, this helps support the installation of an undercrossing coupled with fencing at this location. Zones 8-9 provide an opportunity to develop a wildlife corridor. Numerous locations with zones 8 & 9 were found to be suitable for undercrossing or overcrossing installation with fencing. In addition to reducing deer-vehicle collisions, this would provide connectivity for migratory deer through public land as well as safe passage for resident populations making frequent crossings between range land and the Methow River.

In addition to the site-specific recommendations and costs, general percent effectiveness (or percent reduction) was applied to the recommendations. These percentages were obtained through existing sources of literature. This, in turn, produced the cost per percent reduction per mile to compare the relative value of each level of recommendation. Additionally, the lifespan of each countermeasure was provided to help further explain the relative value of each recommendation. It is important that multiple factors like percent effectiveness, lifespan, and habitat connectivity are taken to fully understand the value of a countermeasure.

Many of the low cost recommendations proposed involve countermeasures with little supporting documentation or high variability, which is likely due to the wide range of site specific variables and difficulty quantifying the improvements in a metric that is universally comparable. However, these options should not be discounted, especially given the relatively minimal investment needed to implement the countermeasures and the apparent community support for less-invasive/restrictive solutions. Many of the identified zones are nearly abutting one another, so whichever level of recommendation is selected for a given zone, it is important that the implementation take a holistic approach to understand the factors targeted by the specific solutions and the potential effect on adjacent zones if they are not addressed in tandem.

6.0 Conclusions

The purpose of the North Cascades Highway Wildlife Safety Planning Project was to obtain a better understanding of the environmental factors influencing deer-vehicle collisions and to use this understanding to provide engineering management recommendations to reduce the frequency of deer-vehicle collisions.

Partnering with Washington State University's (WSU) School of the Environment provided the additional research and modeling expertise to help WSDOT develop a deeper understanding of the environment and roadway factors influencing deer-vehicle collisions. Analyzing historical records, performing field sampling, and tracking individual deer movements/crossings provided a rich dataset to build predictive models. It was determined that deer abundance and also frequency of deer crossings were located near environmental features like water sources and south-facing slopes. After accounting for deer abundance, roadway factors like side slopes topography and curve sight distances were determined to be strong predictors influencing the frequency of deer-vehicle collisions. In addition to identifying and modeling factors, deer patterns and migratory status were analyzed. Through individual deer monitoring, it was found that 68% of the collared sample deer were non-migratory [5]. This was unique, as mule deer typically exhibit this type of behavior in areas with variable precipitation and snow cover. These results revealed that a population of non-migratory mule deer may be growing around the town of Winthrop. Using these results, WSU recommended nine zones where engineering solutions should be targeted to achieve the greatest reduction in deer-vehicle collisions. These zones were ranked based on frequency of deer-vehicle collisions and biological benefit to deer. Zones 5 (milepost 189-191.68), 6 (milepost 194.5-195.49), 7 (milepost 196-197.19) and 9 (milepost 198.75-199.75) were the highest ranked zones. Models indicated that if engineering solutions could be implemented within these zones, annual deer-vehicle collisions could be reduced by as much as 50%.

Knowing these zones, WSDOT incorporated community input and performed countermeasure research to better understand what solutions would work best within the project area. Community outreach helped better understand community needs and guide the selection of engineering countermeasures. Using the driving environmental and roadway factors, seven countermeasures were selected in three different categories of countermeasures; countermeasures influencing driver behavior, influencing deer behavior, and physical separation. Locations within each zone were then evaluated and site specific low, medium, and high cost countermeasures were recommended. In addition to cost, percent effectiveness was investigated through existing data sources. Countermeasures ranged from high cost items like the installation of an overpass structure in Zone 8 to a low cost item of speed limit reduction and enhanced wildlife warning signs in Zone 1. Cost range was purposefully provided to ensure countermeasure implementation could occur under a wide range of project budget.

Based on the results of this project it is recommended that zones 5, 6, 7 and 9 be prioritized for habitat connectivity projects. Recommendations at any level of cost would help reduce deer-vehicle collisions within this area. Additionally projects within all zones can be staged and built upon later. It is also suggested further research be performed to understand the changing status of the mule deer population, the correlation between time of day and deer-vehicle collisions as well as the implementation of lower cost engineering countermeasures like roadside vegetation maintenance and operational modifications.

7.0 References

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8.0 Appendices

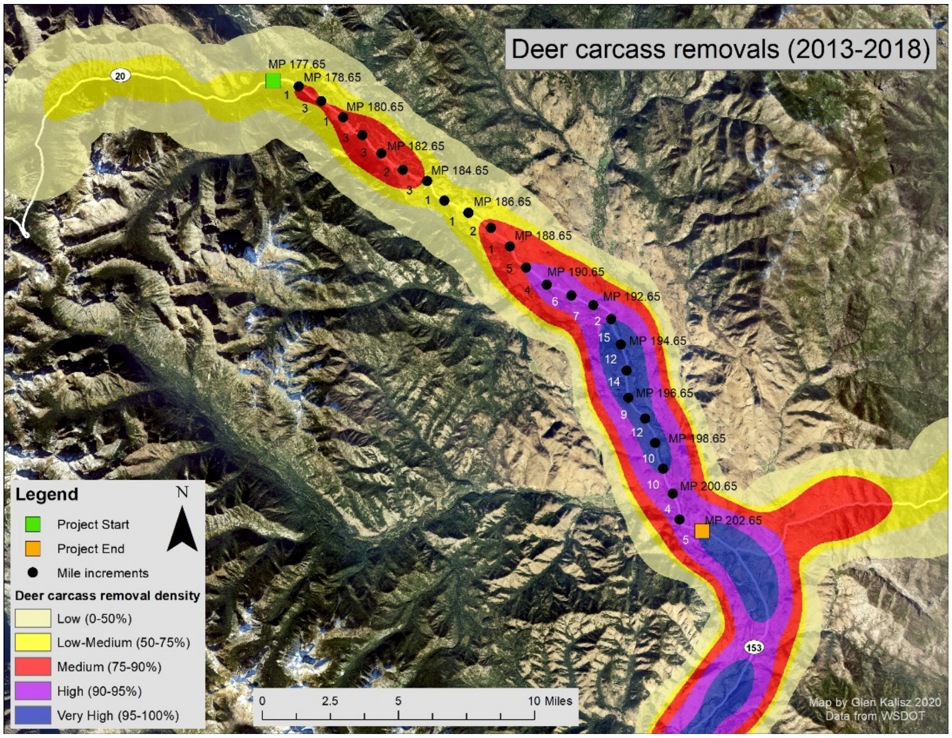
Appendix A. WSDOT 2013-2018 Project Area Carcass Removals and Collisions Hotspot Maps

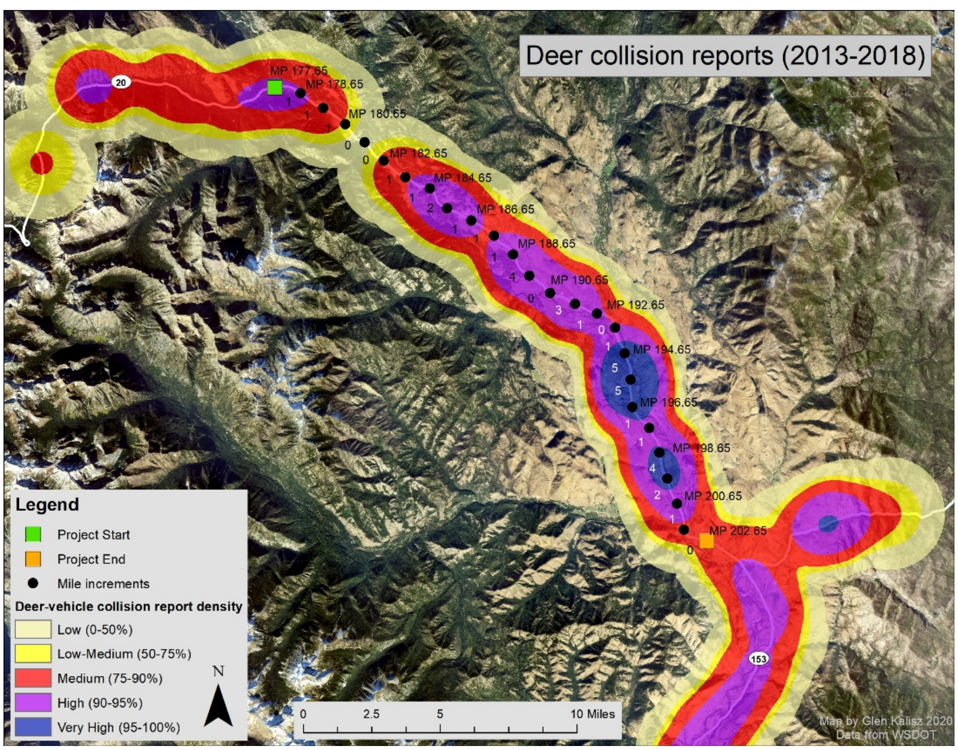
Appendix B. Modeling Environmental Drivers of Wildlife-Vehicle Collisions in the Methow Valley, Washington to inform Engineering Solutions

Appendix C. WSDOT Community Outreach 2019 Survey Questions & Results

Appendix D. Zones 1-9 Digital Photographs from WSDOT SRview 3 Application

Appendix A. WSDOT 2013-2018 Project Area Carcass Removals and Collisions Hotspot Maps





Appendix B. Modeling Environmental Drivers of Wildlife-Vehicle Collisions in the Methow Valley, Washington to inform Engineering Solutions

Modeling Environmental Drivers of Wildlife-Vehicle Collisions in the Methow Valley, Washington to Inform Engineering Solutions

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Final Report
***Submitted to*:**

Washington State Department of Transportation
North Central Region
Office: (509) 667-2876

March 30, 2020

WSDOT Contract No. T1462-15

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The purpose of this study was to provide the Washington State Department of Transportation (WSDOT) with scientific information regarding the patterns of mule deer use, road crossings, and wildlife-vehicle collisions along State Route 20 within north-central Washington's Methow Valley. This work was established under WSDOT's Federal Lands Access Program funded project titled "SR 20/ North Cascades Highway State Route 20 (Forest Service Road #32)."

This report describes the findings from 60 remote game cameras from April through October 2017, visual surveys to locate live deer from May through August 2017, mark-resight surveys for deer carcasses in April and October 2017, radio-tracking of 22 adult female deer January 2018 – August 2018, and 49 UHF data loggers recording radio-tracked deer along State Route 20 January 2018 – October 2018.

This study was funded by WSDOT, under contract T1462-15; all research activities were authorized under Washington State University Institutional Animal Use and Care Committee Animal Subjects Approval Form 04968, Washington Department of Fish and Wildlife (WDFW) Scientific Collecting Permit 17-339, and WDFW Right-of-Entry permit 110381,110366,110309, dated January 22, 2018. Results from this study were presented at regional venues (Appendix C)

INTRODUCTION

Wildlife-vehicle collisions constitute a substantial component of mortality in many resident and migratory wildlife populations (Bissonette 2002). With traffic increasing on highways intersecting wildlife habitats across the United States, numbers of wildlife-vehicle collisions continue to rise, causing concern for human safety, financial burdens, and impacts on wildlife populations. Nationally, deer-vehicle accidents result in approximately 200 human fatalities each year and insurance payments of nearly $2 billion annually (Figure 1). Across Washington State, the average number of deer carcasses attributed to deer-vehicle collisions that were removed from highways between 2009 and 2014 exceeded 3,500 per year [Washington State Department of Transportation (WSDOT) unpublished data] compared to 1,200 carcasses per year less than a decade earlier (Myers et al. 2008). Mule deer-vehicle collisions along portions of numerous state and federal highways have been routinely documented in eastern Washington (Myers et al. 2008, WSDOT unpublished data). This information was used to identify high levels of mule deer-vehicle collisions (>10/year) along 5 distinct highway stretches, including State Route (SR) 20 in Okanogan County, situated within the Washington Department of Fish and Wildlife (WDFW) East Slope Cascades Mule Deer Management Zone (MDMZ)(WDFW 2016).

State Route 20 lies within the Methow Valley in Okanogan County, where Washington's largest wintering concentrations of migratory mule deer exist (Zeigler 1973). The majority (80 - 90%) of mule deer comprising herds in the Methow Valley are believed to migrate seasonally between alpine meadow and subalpine basin summer ranges along the Cascade Crest and lower elevation (<4,500 ft) winter ranges, such as the Methow Valley (Zeigler 1973, Myers et al. 1989). The Methow Valley supports mule and white-tailed deer, both of which have been implicated in deer-vehicle collisions in the area (WSDOT, unpublished data). Resident year-round mule deer herds also appear to be present (W. Myers, pers. comm.), as indicated by year-round deer-vehicle collisions (WSDOT, unpublished data). For these reasons, this region has received much attention with regard to deer-vehicle collisions. The WSDOT, in partnership with NGOs and other agencies, is working to identify where to install engineering solutions to reduce deer-vehicle collisions in this wildlife management zone, with a particular focus along SR 20 (WDFW 2016).

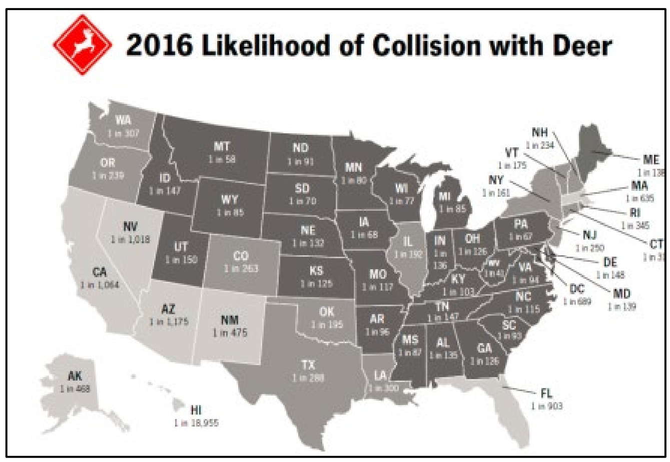

Figure 1. Likelihood of an insured driver being involved in a deer-vehicle collision between 7/1/2015 through 6/30/2016 (source: file:///C:/Users/jam780/Downloads/deer-collision-map-2016.pdf).

Deer-vehicle collision and carcass records collected across space and time provide a rich dataset from which to evaluate patterns and investigate habitat associations. Myers et al. (2008) analyzed deer-vehicle collision patterns in Washington State, described traffic levels, speed limit, and roadside features influencing deer-vehicle collisions, and recommended that future studies focus on reviewing existing site-specific deer location data and mapping of sites where high levels of deer collisions are known to occur. These data document the occurrence of unsuccessful highway crossings, and additional information on successful highway crossings (i.e., when a deer crosses a highway without getting hit by a vehicle) can further improve our understanding of deer-vehicle collision risk and the success of engineering solutions intended to reduce deer-vehicle collisions and simultaneously minimize impacts to deer populations. For example, additional mapping of spatially explicit deer locations and counts along highways are necessary for differentiating between where deer successfully and unsuccessfully cross a highway. Such data, coupled with a detailed geodatabase of deer-collision data maintained by WSDOT, can be used to examine individual and interactive influences of vehicle traffic level and speed, as well as road geometry from the frequency of deer crossings. Using both sources of data can help inform engineering solutions and deer management strategies identified under the Washington Mule Deer Management Plan and Mule Deer Initiative (WDFW 2016).

To investigate competing hypotheses regarding various environmental and road geometry factors that may influence deer-vehicle collisions along SR 20 within the Methow Valley region, we: a) summarized existing deer carcass removal and deer-vehicle collision datasets, b) conducted a pilot study involving direct field observations, and c) completed a larger, main study that involved deploying remote game cameras, radio-collaring and tracking, and proximity sensor datalogger technology along the SR 20 right-of-way.

OBJECTIVES

General objectives were to:

1. Determine environmental factors associated with the frequency of deer-vehicle collisions
2. Expand our understanding of why deer-vehicle collisions occur
3. Provide management recommendations to reduce the frequency of deer-vehicle collisions

Specific objectives were to:

1. Quantify expected (mean) frequencies of deer-vehicle collisions along SR 20
2. Determine individual deer movements and use of SR 20
3. Assess status of historical and current mule deer migration corridors
4. Quantify roadway and roadside landscape and habitat features
5. Determine importance of landscape and local habitat features on the frequency of deer-vehicle collisions
6. Recommend locations for consideration of engineering solutions to minimize deer-vehicle collisions

STUDY AREA

The study area was comprised of the landscape surrounding Washington State Route 20 from Twisp, WA west to the U.S. Forest Service Early Winters Campground near Mazama, WA (Figure 2); this is slightly constrained from the original study area from Twisp to Rainy Pass.

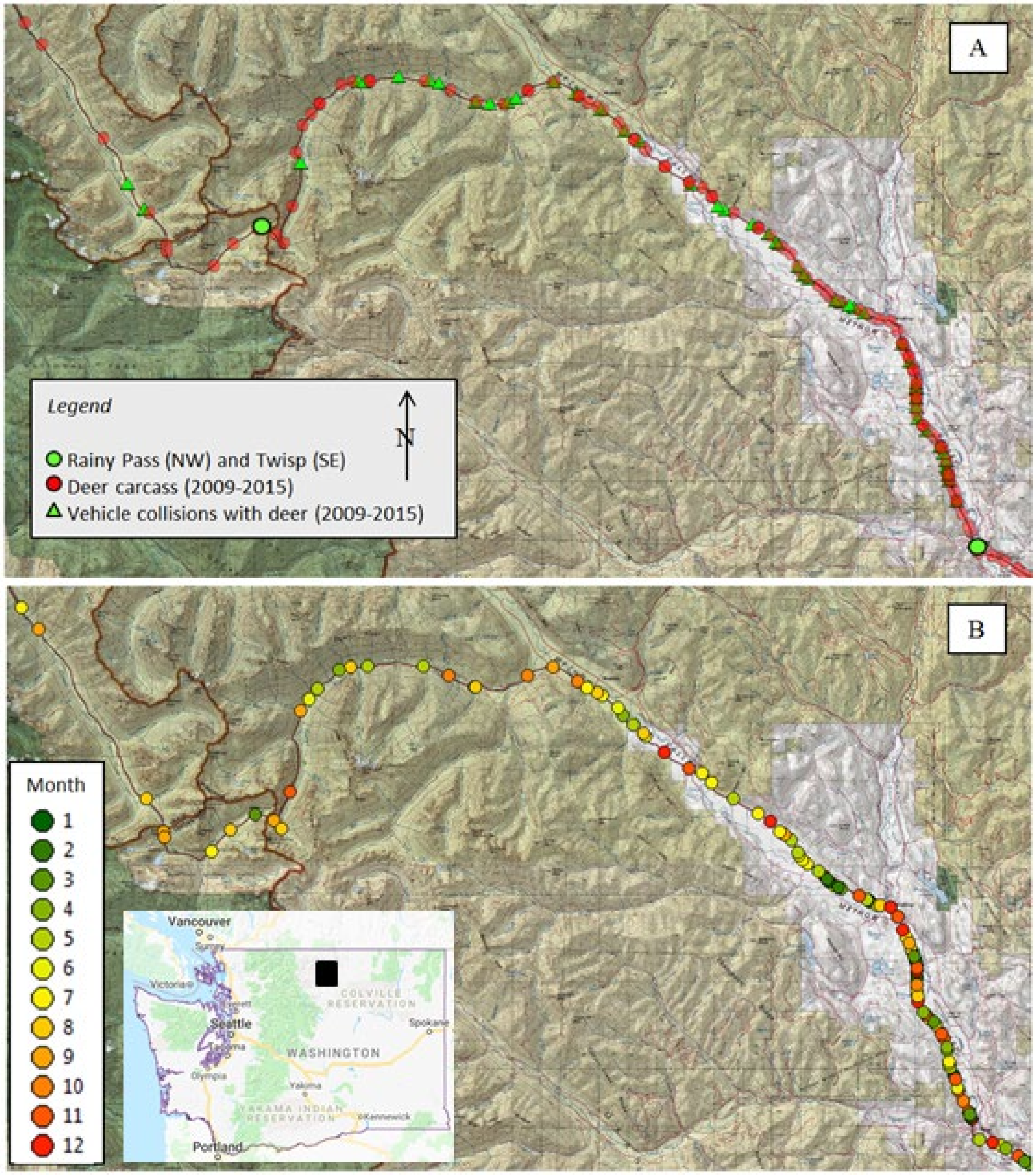

Figure 2. Study area, deer carcass and collision locations (a), and deer carcass locations by month (b) recorded by WSDOT from 2009-2015 along State Route 20 through the Methow Valley between Twisp and Rainy Pass, Washington.

Permits and Authorizations

All animal, capture, handling, and release activities associated with this study were approved and carried out under Washington State University Institutional Animal Use and Care Committee Animal Subjects Approval Form 04968, Washington Department of Fish and Wildlife (WDFW) Scientific Collecting Permit 17-339, and WDFW Right-of-Entry permit 110381,110366,110309, dated January 22, 2018. Field activities occurred on both, private and public lands with prior approvals. Private landowners were contacted, received a description of project activities, and granted authorization where activities took place on private lands. We posted signs at capture locations that described project activities, provided contact information, and coordinated activities with local US Forest Service and WDFW personnel.

SPATIAL AND TEMPORAL PATTERNS OF DEER-VEHICLE COLLISIONS

Existing Deer Carcass and Collision Databases

To summarize existing information on deer-vehicle collisions and inform the timing of sampling during the field component of this study, we used two existing geodatabases to quantify and examine spatial and temporal patterns of expected (mean) frequencies of deer-vehicle collisions: a) deer carcass data recorded by WSDOT personnel during carcass removal efforts from 2009-2015 (n = 242) and b) deer-vehicle collision incidents that were reported to state law enforcement from 2009-2014 (n = 34). From these data, frequencies of deer carcasses (mule deer and white-tailed deer combined) were calculated yearly and monthly in each 1-mile highway segment along the entire study area, and these were used to stratify highway segments into deer-vehicle collision frequency categories (low, medium, and high frequency) to develop stratified random sampling designs the main study presented below. Average monthly number of carcasses that were removed from 1-mile segments by WSDOT personnel were grouped and presented according to the biological seasons characterizing deer use of the study area: summer (Jun, Jul, Aug, Sept), fall migration (Oct, Nov), winter (Dec, Jan, Feb, Mar), spring migration (Apr, May).

Deer-vehicle collision incidents are typically an ideal data type for examining spatial and temporal patterns, but the low number of incident reports precluded a detailed assessment. This low number of deer-vehicle collision records was likely due to an underrepresentation of reports by drivers involved in a deer-vehicle collision where no vehicle damage or human injury occurred regardless of whether a deer was fatally injured. This bias may have contributed much to the weak relationship between these two datasets (Figure 3). Despite the low number of deer-vehicle collision reports, diurnal patterns of deer-vehicle collisions showed a distinct unimodal pattern through time of day, with a peak number of collisions occurring approximately 7 hours before and after noon (Figure 4).

The WSDOT carcass removal data were used to assess spatial patterns in deer-vehicle collisions by examining frequencies that occurred in each 1-mile segment (Figures 2 and 8). The number of carcasses removed increased southward from mile post 176, peaking near the town of Winthrop at mile 194 (Figures 5, 6, 7, and 8). Numbers declined southward from Winthrop to Twisp (mile 201) (Figure 5). This pattern did not hold across seasons, with peaks emerging around Winthrop and between Winthrop and Early Winters Campground during fall and spring migration periods

(Figure 6). Interestingly, the abundance of mule deer carcasses peaked between July and November, whereas the abundance of white-tailed carcasses peaked in December and January (Figure 7), revealing the different seasonal patterns of use by these two species in this area of the Methow Valley.

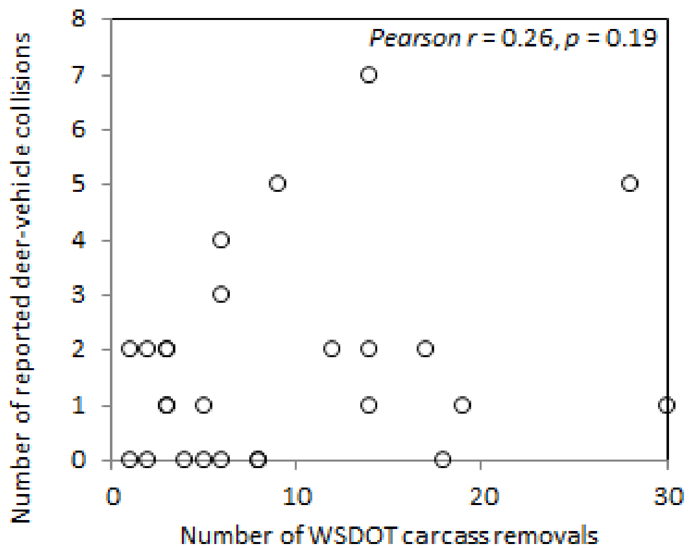

Figure 3. Scatterplot of reported numbers of WSDOT carcass removals (n=241) and deer-vehicle collision incident reports (n=34) between SR 20 mile markers 176-201 from 2009-2015. A correlation coefficient (r) is included.

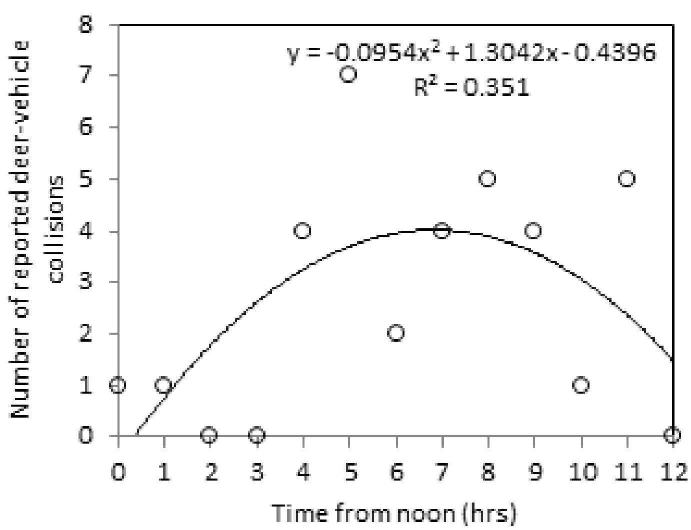

Figure 4. Number of reported deer-vehicle collision incidents (n=34) as a function of time + time^2 from noon (hrs) (x = 0 represents 12 noon, x = 1 represents both 1pm and 11am, x = 6 represents both 6pm and 6am, etc.). Data are from 2009-2014.

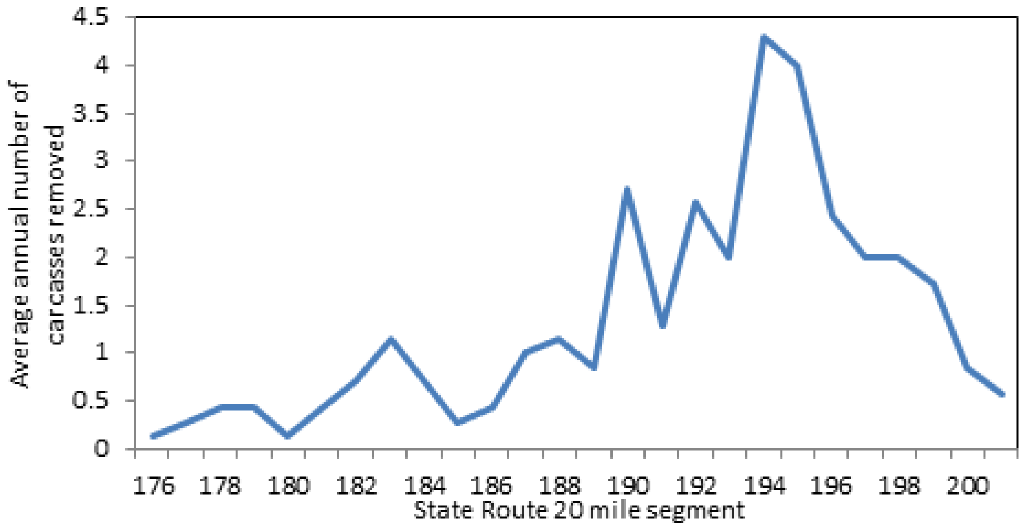

Figure 5. Average annual number of deer carcasses (mule deer (n=191) and white-tailed deer combined (n=51)) removed from 1-mile segments of SR 20 between mile markers 176-201 from 2009-2015.

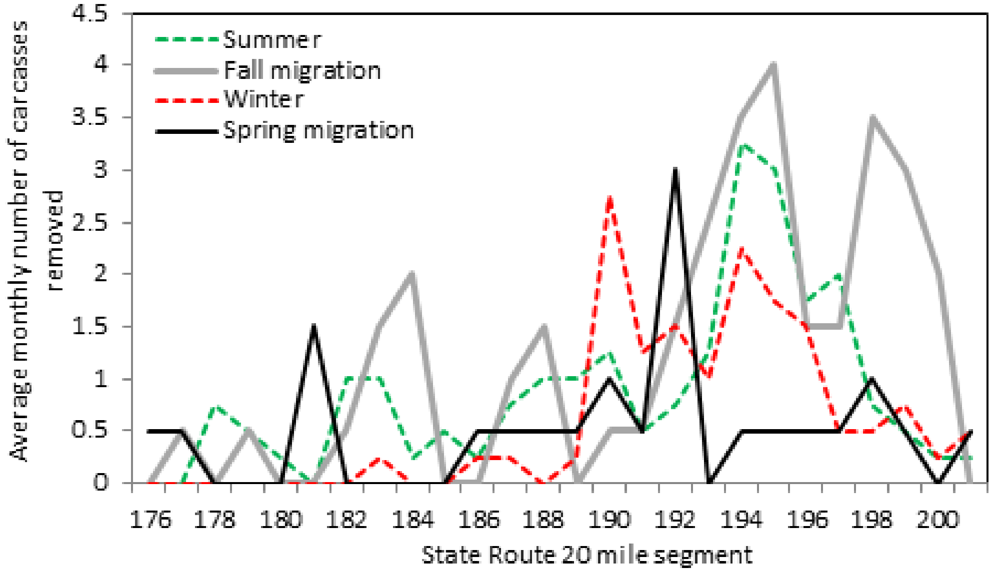

Figure 6. Average monthly number of deer carcasses (mule deer (n=191) and white-tailed deer combined (n=51)) removed from 1-mile segments of State Route 20 in the Methow Valley, Washington by WSDOT personnel from 2009-2015 according to season: summer (Jun, Jul, Aug, Sept), fall migration (Oct, Nov), winter (Dec, Jan, Feb, Mar), spring migration (Apr, May).

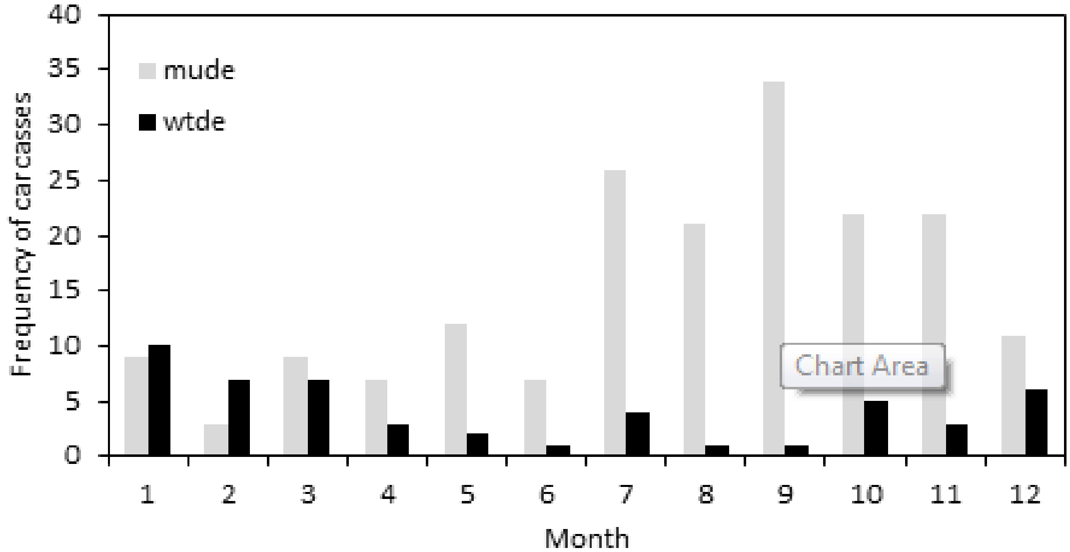

Figure 7. Frequency of deer carcasses (mule deer (n=191) and white-tailed deer combined (n=51)) removed from State Route 20 between mile posts 176-201 in the Methow Valley, Washington by WSDOT personnel from 2009-2015

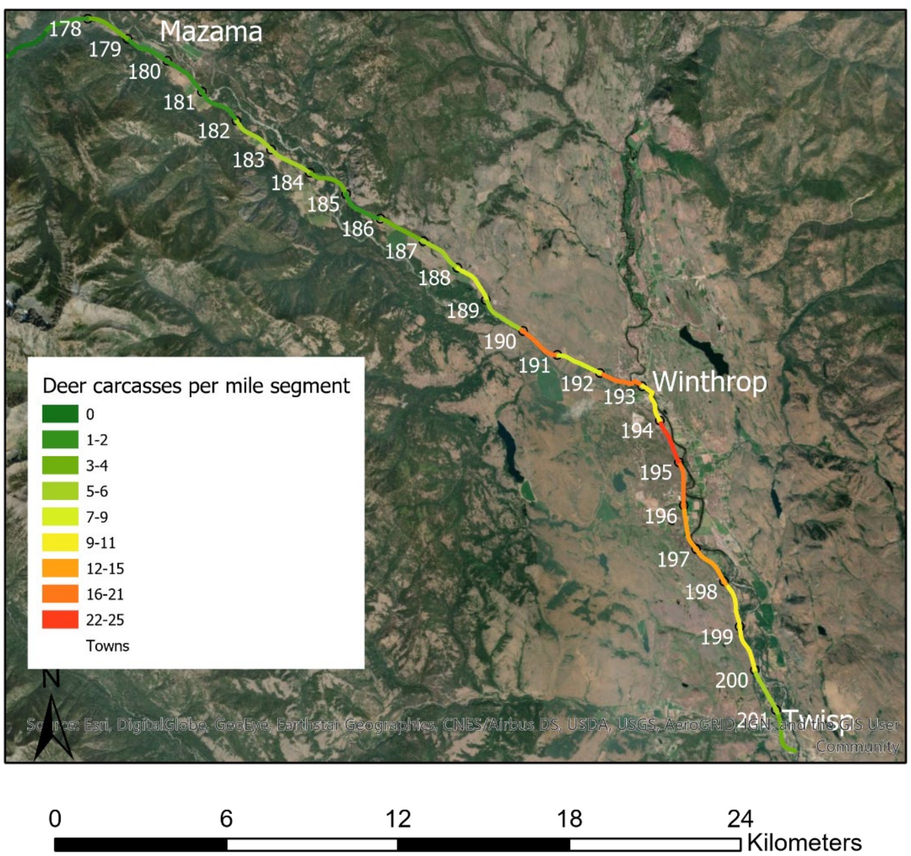

Figure 8. Cumulative counts of deer carcasses removed from SR 20 in the Methow Valley by WSDOT between 2009-2015. Mile posts are shown. See Figure 5 for graphical representation of average annual counts.

Previously Identified Mule Deer Migration Corridors

The WDFW studied the seasonal movements of radio-collared mule deer in the Methow Valley and surrounding region in the 1980s, and mapped out summer ranges, winter ranges, and migration corridors (Figure 9; Myers et al. 1989). Summer ranges typically were distributed in higher elevation areas, although there was one summer range just southwest of Winthrop, immediately west of SR 20 between mile posts 195 and 197 (Figure 9). Winter ranges typically occurred in the valley bottom and surrounding low foothill areas from approximately 12 km north of Winthrop in the Methow Valley and Big Valley confluence to approximately 12 km south of Twisp. Based only on the sample of radio-collared deer available, the WDFW identified migration paths between summer and winter ranges that effectively traversed much of this landscape, indicating that this valley is a major and significant migratory corridor for the region's mule deer population. From the numerous migration paths identified by WDFW, 10 crossed SR 20 between Mazama and Twisp. However, given the high number and widespread distribution of migration paths in the valley, it is reasonable to expect that entire population of mule deer that overwinter in the valley and surrounding region move throughout much of the valley bottom and surrounding foothills to meet resource requirements (e.g., forage, water, thermal protection, avoid predation risk) during winter. This may also be the case in summer due to the presence of summer range in the valley.

Pilot Study

We conducted a pilot study during summer 2017 to investigate the extent to which deer-vehicle collisions were related to the frequency of live deer occurring along the SR 20 right-of-way. For this, we conducted simultaneous, foot-based visual surveys for live and dead deer weekly from May through August 2017. This time of year was chosen because preliminary findings from the existing databases referenced above revealed a peak in mule deer carcass removals between July and November. A single observer recorded standardized data for 1 hour / week in each 1-mile section, and reported the species, status (live or dead), number, status of road crossing (crossing or not crossing SR 20), and coordinates of each encounter. These data were then combined into their corresponding 1-mile SR 20 segments, and used to compare the frequency and cumulative counts between the two species, the probability of deer crossing the road and the average number of live deer, and number of carcasses and number of road crossings in each 1-mile section.

Between May and August 2017, a total of 835 animal observations were recorded (Figure 10a), with 29 of these documented as carcasses attributed to wildlife-vehicle collisions (Figure 10b). Of these, 537 mule deer and 229 white-tailed deer were observed. Numbers of live deer varied spatially, with peak counts centered around the town of Winthrop (Figure 11).

The frequency and cumulative counts of mule deer and white-tailed deer were negatively correlated (Figure 12). The probability of deer crossing was correlated to the average number of live deer (Figure 13a), and the number of crossings was predicted by number of live deer (Figure 13b). However, number of deer carcasses was unrelated to the frequency of road crossings after accounting for WSDOT carcass removal and WDFW citizen salvage (Figure 14).

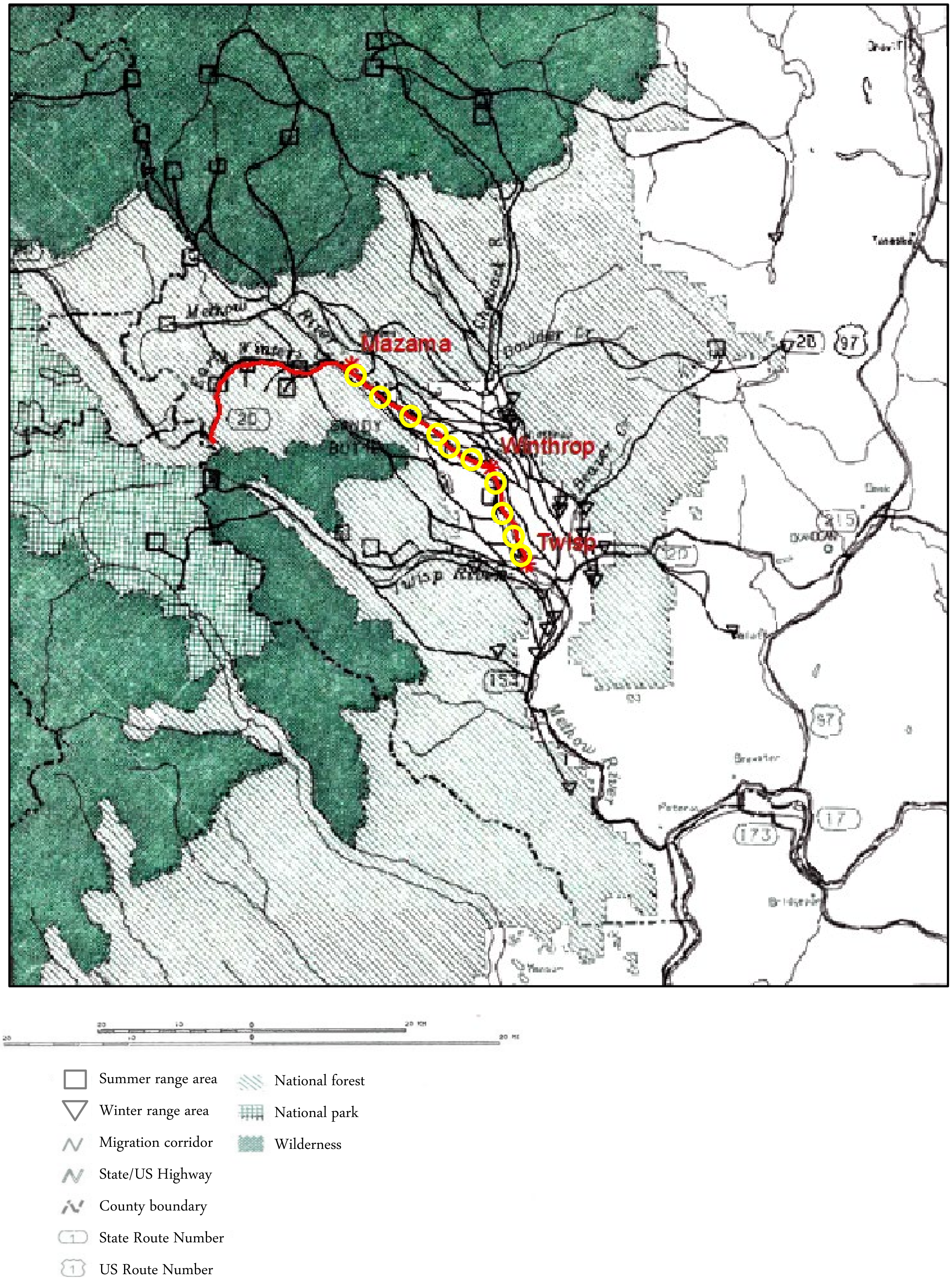

Figure 9. Mule deer migration paths in the 1980s (source: WDFW; Myers et al. 1989). Red line is SR 20; yellow circles depict locations where a migration path intersects SR 20.

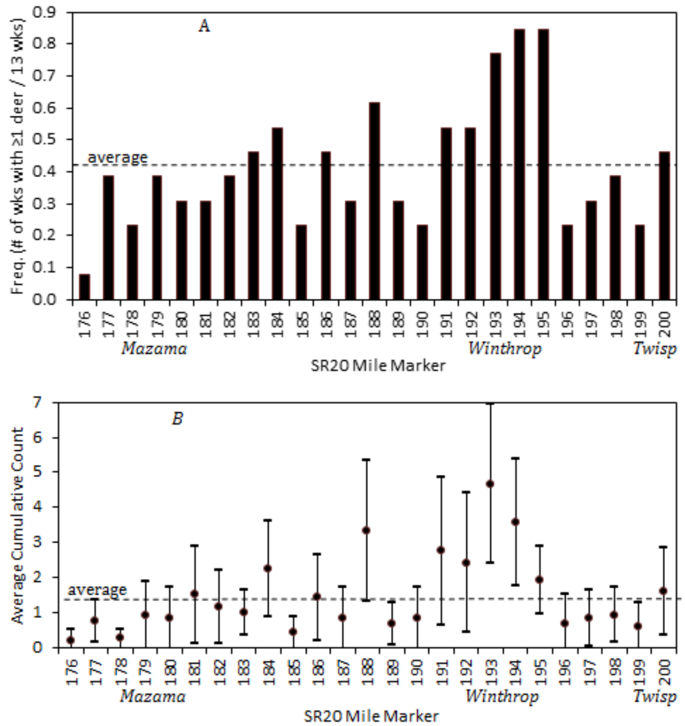

Figure 10. Counts of (A) animals by species and (B) carcasses related to wildlife-vehicle collisions along SR 20 between mile posts 176-201 in the Methow Valley, Washington, May-August 2017.

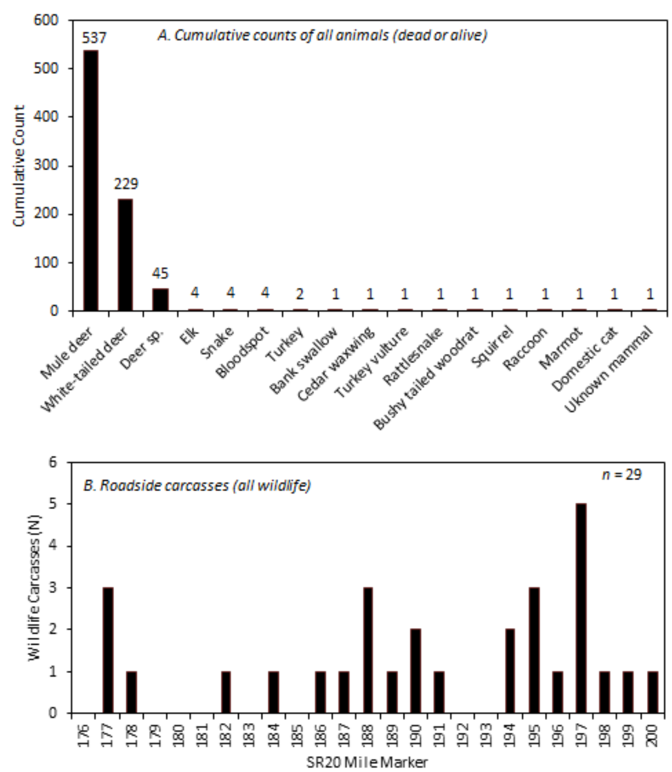

Figure 11. Frequency of live deer (A) and cumulative deer counts (B) along SR 20 between mile posts 176-201 in the Methow Valley, Washington, May-August 2017.

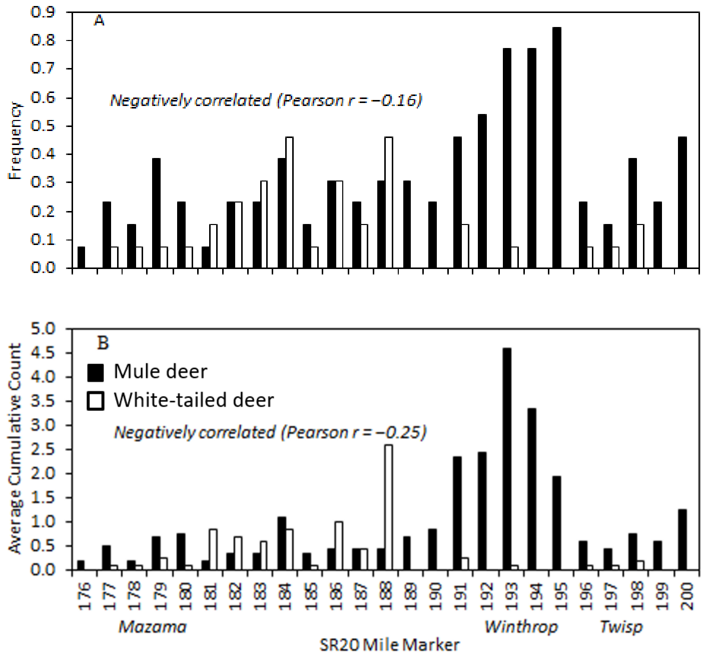

Figure 12. Frequency (A) and cumulative counts (B) of live mule deer and white-tailed deer along SR 20 between mile posts 176-201 in the Methow Valley, Washington, May-August 2017.

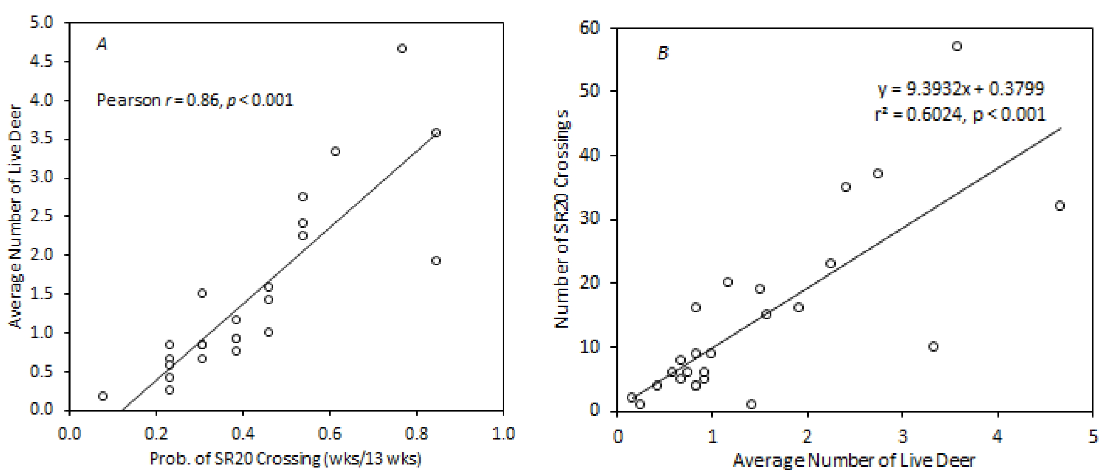

Figure 13. Relationships between (A) number of deer and probability of a deer crossing the road and (B) number of deer crossings and number of deer along SR 20 between mile posts 176-201 in the Methow Valley, Washington, May-August 2017.

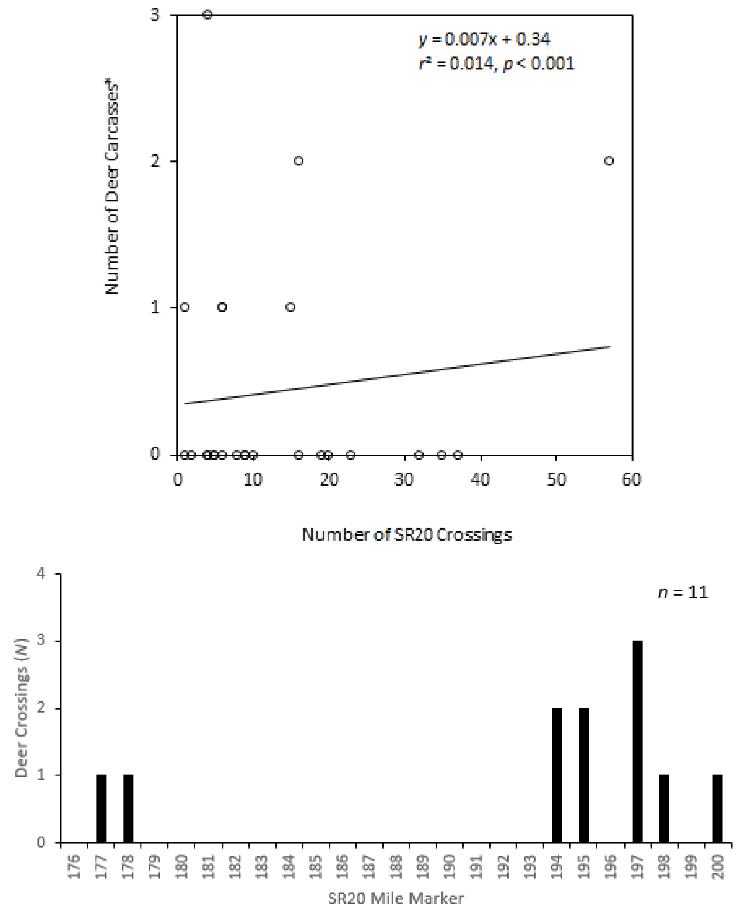

Figure 14. Relationship between live deer crossings and deer carcasses after accounting for carcasses that were removed by WSDOT and WDFW citizen salvage permits along SR 20 between mile posts 176-201 in the Methow Valley, Washington, May-August 2017.

MODELING ENVIRONMENTAL DRIVERS OF DEER-VEHICLE COLLISIONS

Field Sampling and Predictor Datasets

Frequency of deer-vehicle collisions (standardized carcass surveys)

Spring and fall carcass surveys -- Information on the distribution of carcasses along the highway was gathered to calculate empirical estimates of carcass abundance. This sampling design included repeat surveys that allowed for correcting unintentional bias that can emerge from imperfect detection of carcasses during surveys or incidental carcass removal efforts (e.g., detection <100% because some carcasses may go undetected by some observers due to being obstructed by vegetation, topography, degree of decomposition, distance from asphalt, etc.).

Carcass surveys were conducted following standardized survey methods in mid-spring (April 15 and 22) and mid-fall (October 21 and 28), 2017 by WSU Pullman Campus' SOE 446 Wildlife Habitat Ecology students. Surveys entailed walking both sides of the highway in pairs across the entire study area between 0900 and 1400 h to detect and record the condition and location of each detected deer carcass. Fresh carcasses and skeletal remains confirmed to be deer (i.e. the presence of skin, teeth, antler, or a skull) were recorded as carcasses and identified to species when possible (white-tailed deer, mule deer, or deer sp.). The mid-spring survey included recording deer tracks and scat, and the fall survey included assigning the state of decomposition into 1 of 3 categories: 1) old carcass, which were carcasses that consisted only of bones or bones and dried skin and fur (these were assumed present during the April survey), 2) possibly recent carcass, with aged and dried flesh and skin (possibly deposited since the April survey), and 3) recent carcass, which were freshly killed deer with un-desiccated flesh (deposited since the April survey). Thus, the spring survey represented the baseline of all carcasses present in the study area at that time, including those from past years that remained in a skeletal state and bone piles. The raw count was 177 in April and 233 in October (Figure 15).

We used these April and October 2017 carcass data to determine how many and where new carcasses emerged (as a proxy for deer-vehicle collisions that resulted in deer mortality) in the study area during this period. For this, we first identified and removed repeat detections of April carcasses (i.e., those October carcasses <5 m from an April carcass). We considered October carcasses that were classified as recent as a new carcass regardless of being <5 m from an April carcass, and retained these recent records in the data. If >1 October carcass was <5 m from an April carcass, we only removed the closest October location, producing a raw count of 192 new carcasses.

To ensure that the 2017 summer data captured the general spatial patterns in carcass abundances and were suitable for subsequent modeling, we compared our raw counts of new carcasses from summer 2017 to the cumulative WSDOT counts between 2009-2015. A general pattern of higher raw counts corresponding with higher carcass counts recorded by WSDOT between 2009-2015 did emerge, albeit with the 2017 summer survey detecting an average of 25% less carcasses as expected (Figure 16). This lower number of carcasses compared to that recorded by WSDOT was expected because WSDOT removes recorded carcasses from the highway. It is reasonable to expect an even lower percentage to have been detected in a single summer survey compared to the 6 years of WSDOT data, but we attribute the absence of this to the 2017 summer survey extending outward from the center line across to include the entire width of the right-of-way width where many deer likely moved to before dying after a deer-vehicle collision and not recorded by WSDOT.

Correcting for carcass detection bias -- To construct models and test hypotheses regarding factors that influence deer-vehicle collisions, reliable estimates of carcasses were needed for use as a proxy for the number of deer-vehicle collisions that resulted in deer mortality. Since estimated abundances of carcasses along SR 20 can be influenced by the observer's ability to detect (see) carcasses, we estimated and corrected for imperfect detection of carcasses during visual surveys. During the 2017 spring carcass survey, a set of consecutive 1-mile segments was randomly selected for mark-resight sampling (McClintock et al. 2009) during two separate carcass survey occasions on the same day, such that two groups of observers surveyed the same randomly selected sample of three 1-mile-segments of SR 20 independent of each other. From these data, a carcass detection rate (d) was calculated for the spring survey effort as $d = k/(c \text{ x } t)$, where k is the number of times the number of carcasses (c) were detected over $t = 2$ surveys; here, the detection rate can range from 0 (no detection of carcasses) to 1 (100% of carcasses detected on both mark-resight surveys).

The probability of detecting a carcass was estimated to be 0.69, and the probability of not detecting a carcass that was present was estimated to be 0.31 (1-0.69). Applying these probability statements, we corrected for false positive detections (carcasses present but missed in April and detected in October; (1-0.69)*0.69 = 0.21) and overall detection rate (0.69) in the raw count of new carcasses ($n = 192$), producing a mark-resight detection bias corrected estimate of 219 new carcasses along the SR 20 right-of-way attributed to deer-vehicle collisions that resulted in deer mortality. From this, we produced spatially explicit estimates of detection bias corrected estimates of new carcass abundance, which also showed a comparable pattern in carcass abundances documented across the study area between 2009-2015 by WSDOT (Figures 16 and 17), indicating that the 2017 summer data were suitable for modeling the deer-vehicle collision process in this area of SR 20.

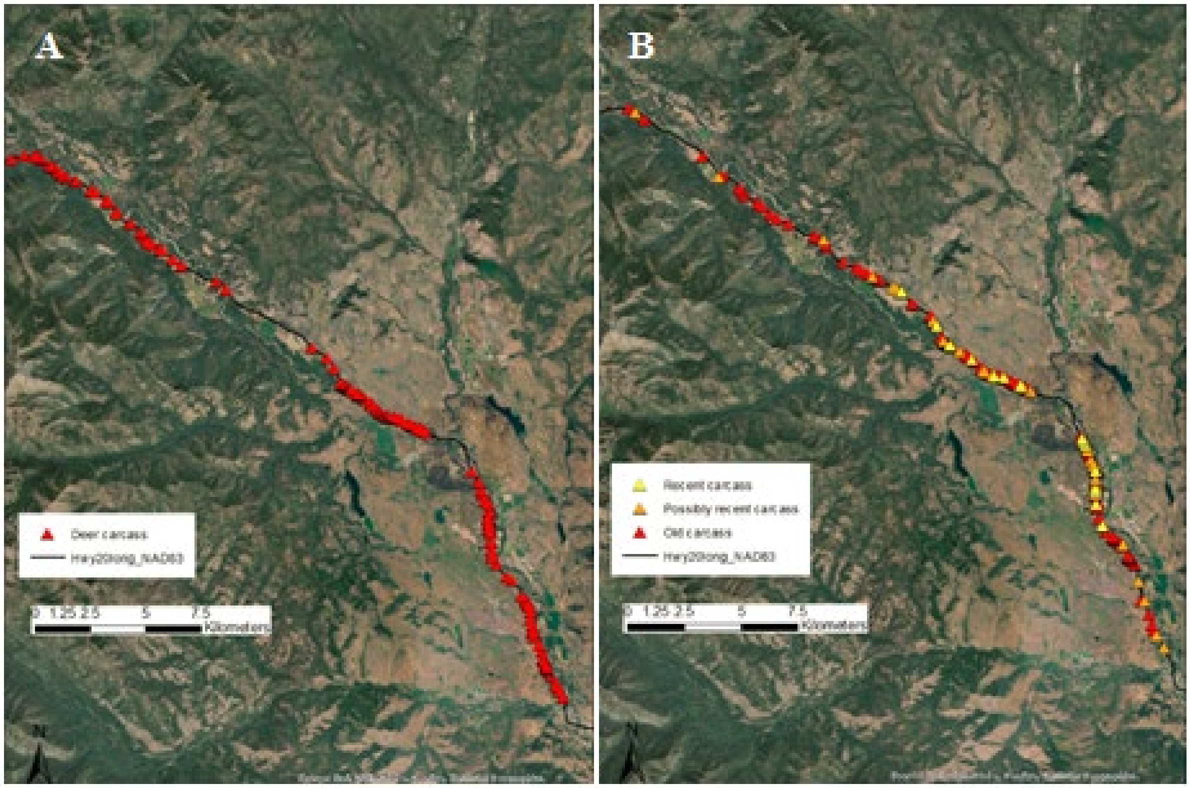

Figure 15. Results from deer carcass surveys between mile posts 176-201 in the Methow Valley, Washington in A) mid-spring (April) 2017 and B) fall (October) 2017.

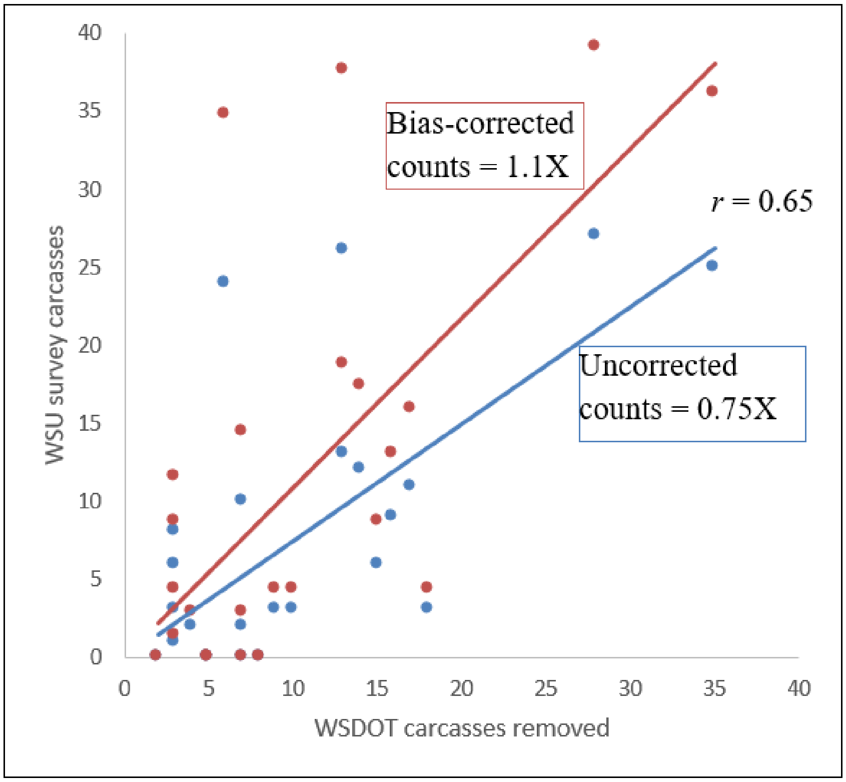

Figure 16. Counts of new deer carcasses detected between April and October 2017 compared with counts of carcasses removed by WSDOT 2009 – 2015 between mile posts 176-201 of SR 20, Washington. Carcasses counted in 1-mile segments (sampling units here) centered around mile posts. Uncorrected counts are raw counts; bias-corrected are raw counts corrected for detection bias (0.69).

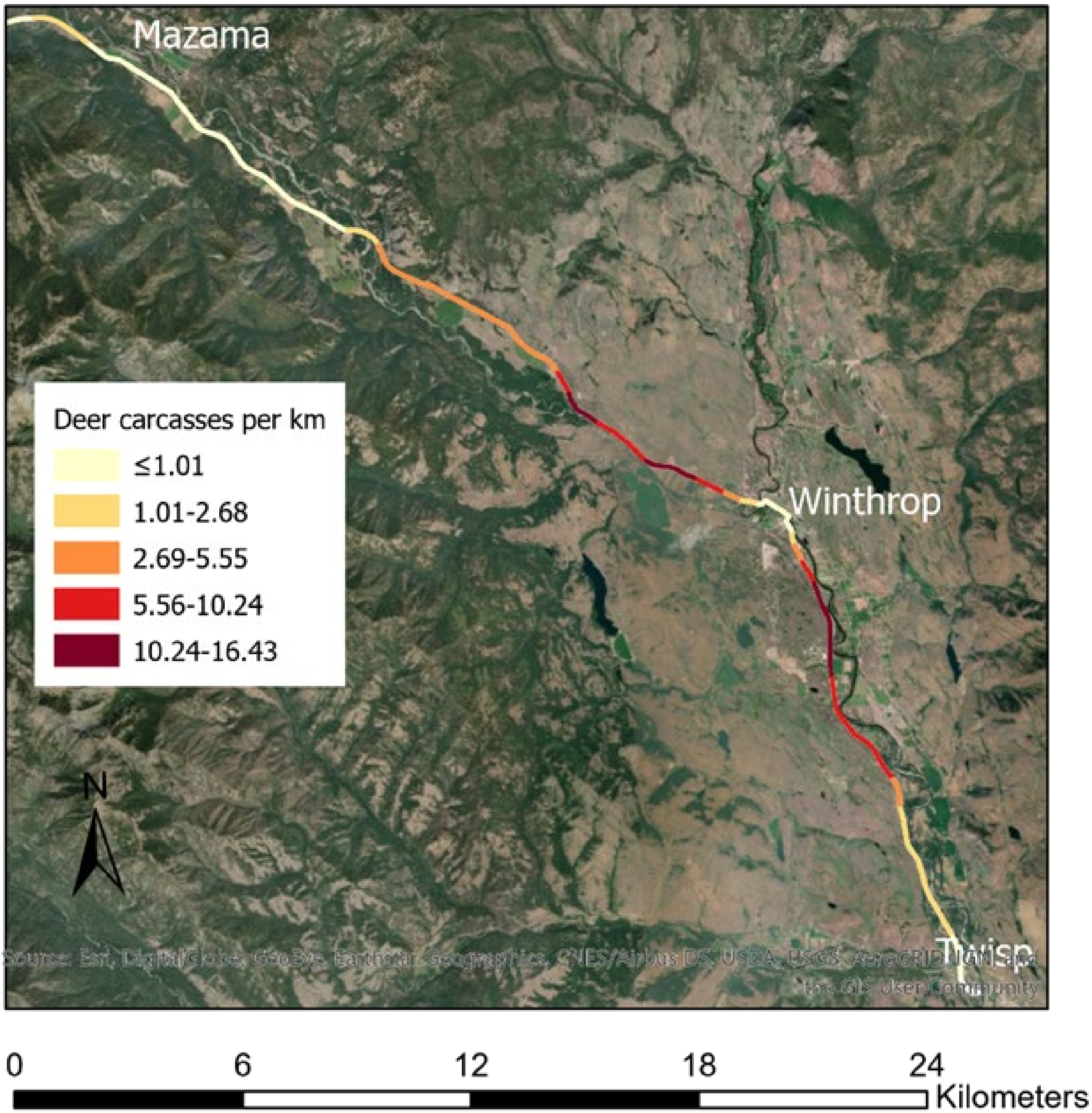

Figure 17. Detection bias-corrected estimates of deer carcass abundance (or frequency of deer-vehicle collisions that resulted in a deer fatality) between mid-Apr through Oct 2017 between mile posts 176-201 of SR 20, Washington. Observer detection bias (d) = 0.69.

Frequency of SR 20 crossings by deer (game cameras)

Browning Dark Ops Elite BTC-6HDE game cameras (n = 60) were deployed along SR 20 (3/mile) in a stratified random sample of 1-mile road segments according to the frequency of deer carcasses to examine the presence/absence of deer along the right-of-way within study area.

Cameras were installed in April 2017 and removed in October 21, spanning the peak months when previous deer-vehicle collisions have occurred. Cameras were set to record a single photograph when triggered by an animal's movement or heat signature. Photo processing included the assignment of each photo to species and count of individuals. Photo processing was completed by students enrolled in the WSU Pullman Campus' SOE 446 Wildlife Habitat Ecology course in Fall 2017 and 2018.

Of the 60 cameras deployed, one malfunctioned and did not record data. A total of 519,284 georeferenced, time-stamped photographs were recorded by the 59 game cameras from April – October 2017. Photos were processed/sorted into 18 species groupings (Appendix A; Figure 18). The species with the highest frequency of photographs was mule deer (*n* = 4,855), followed by unknown deer species (i.e., deer species not distinguishable) (*n* = 1,467), and white-tailed deer (*n* = 1,118).

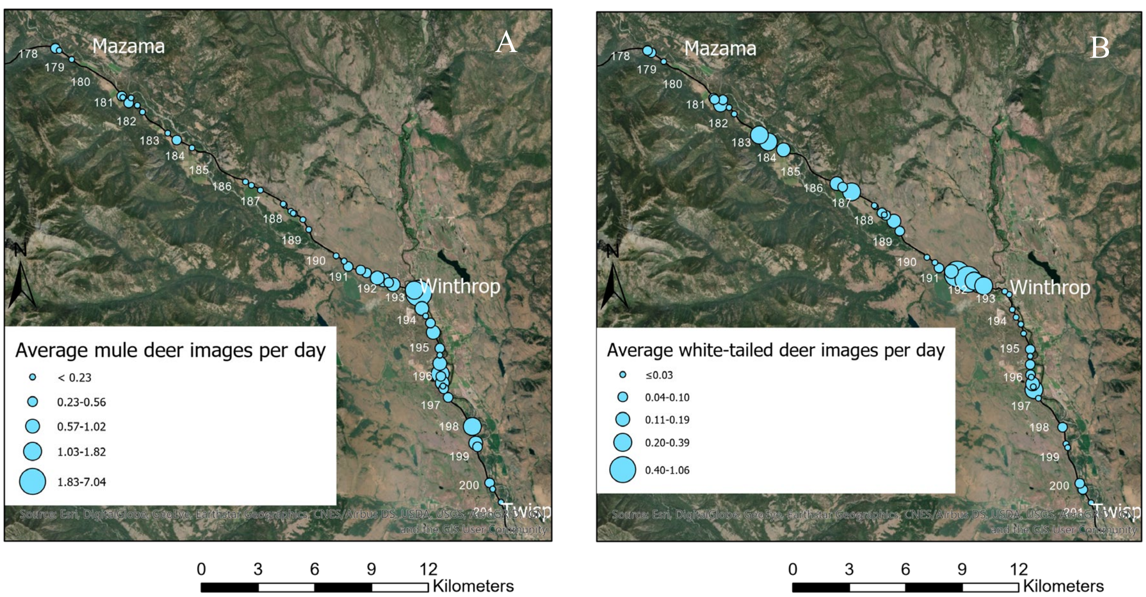

Figure 18. Number of photos of A) mule deer and B) white-tailed deer recorded by game cameras per day along SR 20 in the Methow Valley, Washington from April - October 2017. Mile posts are shown.

Movements and frequency of SR 20 crossings by individual deer (radio-tracking and data loggers)

Deer capture and radio-collaring -- To convert frequency of deer crossings (from game cameras described in the section above) to estimates of deer abundance, we captured and radio-collared deer to quantify movements and the number of SR 20 crossings by individual deer. Deer were captured in baited Clover traps (Clover 1954, 1956, Thompson et al. 1989, VerCauteren et al. 1999) from January 1 through March 31, 2018 in close proximity to the SR 20 right-of-way

(Figures 19 and 20). We constrained our capture effort to this winter period to minimize risk of deer experiencing hyperthermia and negative effects on pregnant females during spring (Casady and Allen 2013), and because the WDFW required this time period for these reasons. Capture areas were selected based on a combination of topography, vegetation, winter range designation and presence of deer during our trapping effort, access, and distance to SR 20. To increase independence of samples, we initially distributed our capture efforts throughout the study area and applied trapping effort in proportion to observed abundances prior to this period, where areas with higher numbers of deer were targeted for greater numbers trap nights. We also distributed traps in several areas where white-tailed deer were more abundant to account for the proportion of white-tailed deer vs. mule deer involved in collision from 2009-2015 (18% white-tailed deer). An observed absence of deer in the northern half of the study area as early as mid-January (due to increased snow accumulations in the Mazama area) led to adjusting our capture efforts to the southern half of our study area (Figure 20), which supported primarily mule deer.

Clover traps were baited with apples soaked in a brine solution. Traps were checked 3 times per day, and males and fawns were immediately released without handling or collaring in order to minimize health risk associated with placing a collar on an animal that may experience a changing or growing neck circumference. Adult female deer were physically restrained, hobbled, and blindfolded without immobilization drugs, and released immediately after receiving a radio-collar and health assessment. Once an animal was released, we monitored the recovery process. All animal handling was conducted in accordance with guidelines and requirements from the WSU Institutional Animal Use and Care Committee Animal Subjects Approval Form 04968, Washington Department of Fish and Wildlife (WDFW) Scientific Collecting Permit 17-339, and WDFW Right-of-Entry permit 110381,110366,110309, dated January 22, 2018.

A total of 22 adult female deer (20 mule deer and 2 white-tailed deer) were fitted with a lightweight Vertex Plus radio-collar (Vectronic Aerospace GmbH). Collars were equipped with very-high frequency (VHF) transmitters, ultra-high frequency (UHF) transmitters, and morality sensors. All collars contained a decomposable cotton connector designed to allow collars to automatically drop off, except in cases where a deer died before that time. In cases where the mortality sensor was activated, the carcass was located, collar retrieved, and cause of death determined (where possible).

Radio-tracking -- All collared deer were radio-tracked using handheld R1000 VHF receivers (Communications Specialists, Inc.), directional RA-23 antennas (Telonics), and compasses (Silva) during regular intervals throughout the remainder of the trapping period (April 2018). From May through mid-August 2018, we continued to radio-track collared deer that remained in the valley during summer (i.e., non-migratory residents). We focused on summer tracking to target the period of peak mule deer-vehicle collisions (mid-summer) identified in the existing WSDOT deer carcass and collision data. Additionally, we used a combination of homing and triangulation for tracking (repeatedly relocating collared deer) during one day in October 2018 and 2019. Over the course of the study, >5,000 compass bearings to collars were recorded. Three bearings (each from a different location) recorded <1 hour apart (2,624 bearings) were used to generate triangulated locations of collared deer using Location Of A Signal (LOAS) software (Ecological Software Solutions LLC). A total of 2,624 bearings were included to estimate triangulation locations, with bearings with low precision (e.g., in opposite direction from and not crossing the other two bearings attributed to 'bounce') excluded.

Migratory status of radio-collared deer -- Thirty-two percent (*n* = 7) of the 22 collared deer were not detected in the Methow Valley after May 2018 and presumed to have migrated to distant summer ranges. The remaining 68% (*n* = 15) were classified as "non-migratory;" these animals stayed in the study area after May 2018 (considered to be summer residents). This pattern, where approximately three quarters of sampled female deer exhibit a non-migratory life strategy, is not commonly reported in ungulate populations elsewhere in the north because elevational migration to lower-elevations are necessary for animals to survive deep snows associated with northern winters (Hebblewhite and Merrill 2009, Manning 2010, Anderson et al. 2012, Manning and Garton 2012, Middleton et al. 2013, WDFW 2016).

Radio-tracking of these remaining 15 resident deer took place from May through August 2018, with a total of 807 triangulation locations estimated (Figure 20). In October 2018 and 2019, triangulation was attempted in the study area for all 22 deer, with five (4 mule deer and 1 white-tailed deer) of those not detected in summer 2018 being detected. The other two collared deer that left the study area in May 2018 were not detected again, indicating that up to 32% (7) of the 22 collared animals were migratory.

Mortality status of radio-collared deer -- Five of the 22 collared deer died during the study; discovered by mortality signals and incidental sightings by local community members (Figure 21):

- White-tailed deer 6995 (radio frequency 264) died alongside SR 20 in May 2018, but extreme radio signal bounce prevented locating the carcass. This animal was captured and collared on March 27, 2018 in good body condition, albeit with a heavy lice load. Based on the strongest signals, it appeared that the animal died alongside SR 20 where the river abutted a turnout, indicating that it may have been involved in a deer-vehicle collision. However, it is unknown whether the heavy lice load or a collision with a vehicle was the ultimate cause of death.
- Mule deer 6996 (radio frequency 275) died next to Liberty Bell High School / Methow Valley Elementary School around January 10, 2019. Photos and general location provided by local resident. Cause of death unknown; much of carcass consumed by scavengers. But, its close proximity to SR 20 may indicate deer-vehicle collision.
- Mule deer 6962 (radio frequency 589) died south of Winthrop approximately 600 feet east of Twisp-Winthrop Eastside Rd on December 27, 2019. Residents detected the carcass after seeing avian scavengers, and WDFW biologist Scott Fitkin conducted a site visit and determined cause of death to likely be deer-vehicle collision due to proximity to road.
- Mule deer 6966 (radio frequency 815) died on SR 20 as a result of a deer-vehicle collision on August 13, 2019. University of Washington graduate student Lauren Satterfield observed and reported the mortality.
- Mule deer 6970 (radio frequency 014) died on SR 20 on or before November 4, 2019. Radio-collar dropped off at the WDFW office in Winthrop with site coordinates provided by local resident. Cause of death unknown, but location on SR 20 may indicate deer-vehicle collision. This deer was seen in the area on October 19, 2019 with two fawns.

Ultra-high frequency data logging system -- To convert the frequencies of deer crossings (from game cameras) to estimates of deer abundance, we established an automated UHF data logging system (*n* = 49 data loggers) within the SR 20 right-of-way to detect radio-collared deer and quantify the number of SR 20 crossings by individual deer. This system received the UHF frequency signals from radio collars and operated from January - October 2018. Each data logger automatically recorded information on radio-collared deer 24/7 when they entered <130m from a data logger (130m radius circle = 6 data loggers for complete coverage along highway in a 1-mile segment). Each data logger was set to record the ID, date, time, and location of individually radio-collared deer (see below) every 30 seconds while a deer was within the detectable range. In combination with the mortality of white-tailed deer ID 6995 in May 2018 and the migratory status of 7 deer, 14 collared animals were present in the study area from May – October 2018 and used for these analyses. Of the 49 data loggers deployed, 39 detected radio-collared deer during the study, ranging from 2 to 1,047 total detections per data logger (Figure 22).

Figure 19. Erecting a Clover trap and releasing a recaptured radio-collared adult female deer in the Methow Valley, winter 2018.

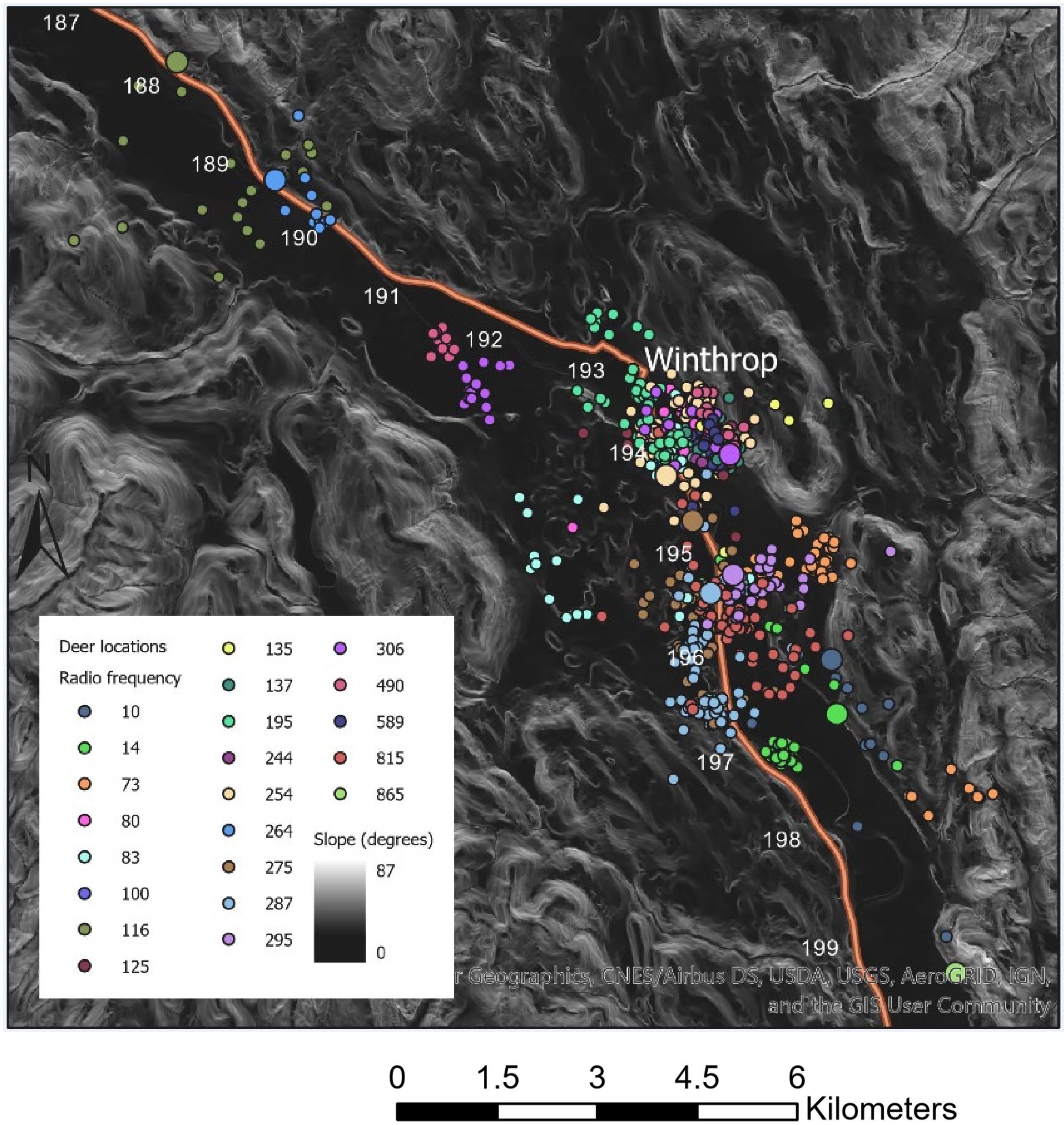

Figure 20. Radio-tracking Point locations (small circles) of radio-collared adult female deer estimated from VHF triangulation in the Methow Valley, January – August 2018. Larger circles are capture locations. Some capture locations represent multiple individuals. Additional trapping locations occurred, but without capture success.

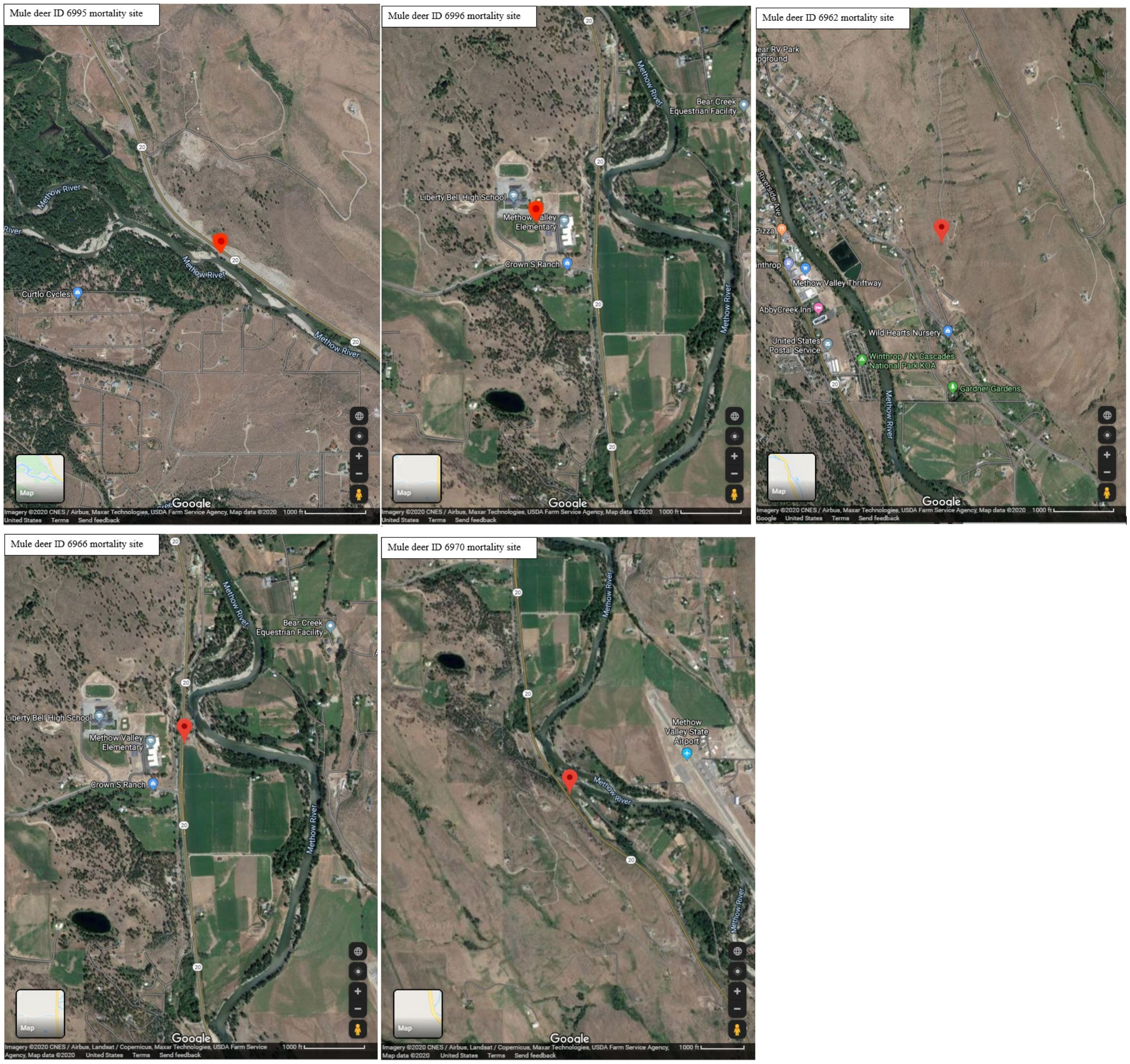

Figure 21. Mortality sites of radio-collared mule deer (n = 4) and white-tailed deer (*n* = 1), Methow Valley, Washington, 2018-2019. The 5 deer were white-tailed deer ID 6995 (radio frequency 264), mule deer ID 6996 (radio frequency 275), mule deer ID 6962 (radio frequency 589), mule deer ID 6966 (radio frequency 815), mule deer ID 6970 (radio frequency 014).

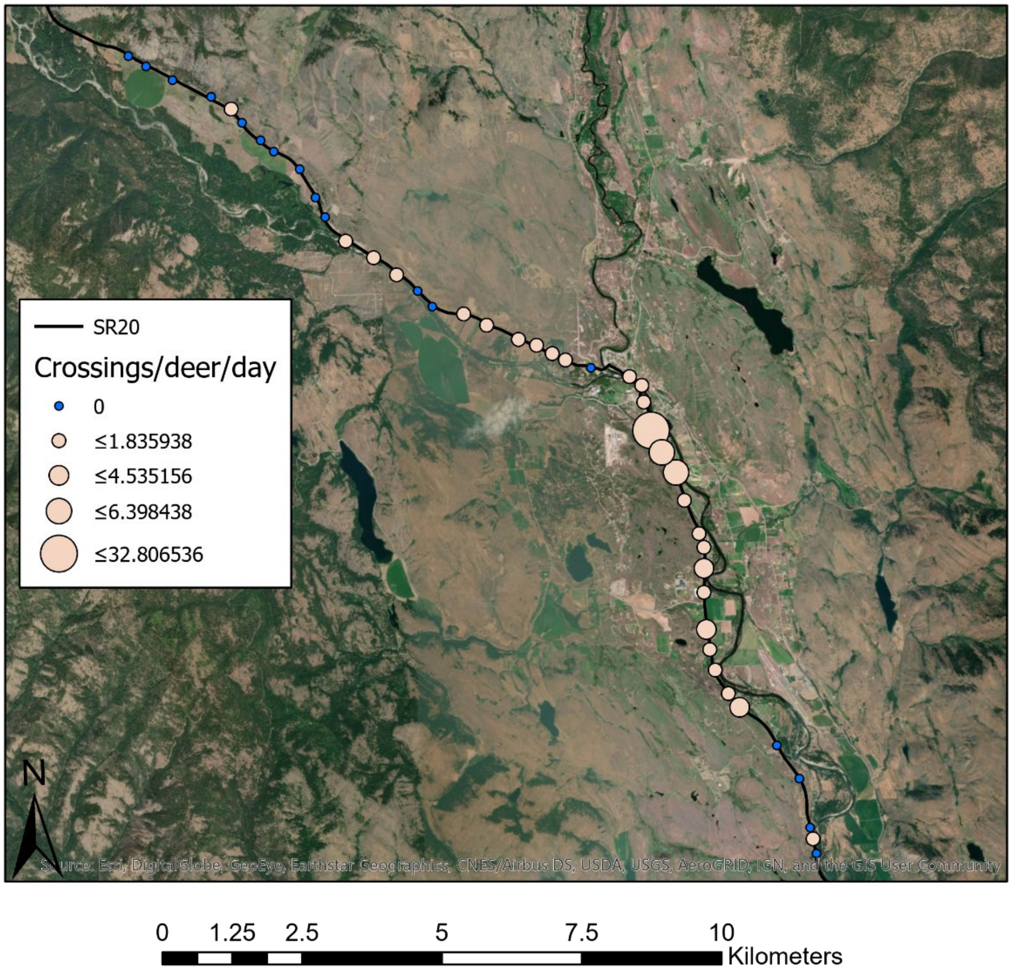

Figure 22. Average number of times per day individual white-tailed and mule deer crossed SR 20 in the Methow Valley, January 2018-October 2018. Data from 22 radio-collared adult, female deer.

Environmental variables

A series of landscape and habitat variables were considered as potential contributing factors of the deer-vehicle collision process and predictors in subsequent modeling. Two existing sources of land cover data were examined for accuracy in predicting vegetation that could be used to quantify environmental features in the study area. These two freely available datasets are the GAP Land Cover database and the National Land Cover Map (Homer et al. 2015, USGS 2011). This assessment was necessary because these maps were developed across broad regions at scales that may not yield the level of detail desired when linking local vegetation characteristics to individual wildlife movements and locations. To assess the accuracy of these two land cover maps, vegetation characteristics were recorded at 446 ground-truth locations across the study area and compared to that predicted by the maps. Of these, 320 locations were collected near the highway in April 2017 by students enrolled in the WSU Pullman Campus' SOE 446 Wildlife

Habitat Ecology course, and the remaining 126 were collected away from the highway during subsequent summer months by a WSU student intern.

Comparison of the vegetation recorded at ground-truth points with that predicted by the GAP and National Land Cover maps indicated that these two existing maps had a high level of error in classifying vegetation at local sites in the study area. Therefore, we used the more accurate map (National Land Cover) to create a baseline forest layer as a shapefile, then edited this layer within 5 km of the highway for accuracy, as well as hand-digitizing buildings, water features, and agricultural fields based on World Imagery (0.3m resolution) in ArcGIS Pro 2.4.1 (ESRI, Inc.) as of July 2019 (Figure 23). We considered three water categories: linear (canals and rivers), standing water (ponds and lakes), and all water features combined. We assumed that these all functioned as drinking sources for deer, but accessibility by deer differed. For example, canals and rivers both provided fresh water typically parallel SR 20, whereas standing water offered more remote sources of unknown quality (e.g., sewage or runoff) and accessibility (e.g., fencing, livestock competition, higher elevations, or farther from the highway). We considered all water features combined in order to account for the closest source of water regardless of type.

We created raster surfaces (10 m pixel size) of distance to different resources anticipated to influence deer space use (and possibly frequency of highway crossings in order to obtain required resources) using the Euclidean Distance tool in ArcGIS Pro 2.4.1. From the land cover map, these resources included forest patches >1500 m^2 to represent those that would provide thermal protection for deer during warm summer periods and severe winter conditions, buildings where lawns may attract deer to forage or humans and dogs may deter deer but also afford protection from large predators, agriculture as a source of food, and water resources as described above. We also measured distance from south-facing slopes without forest cover in patches >1000 m^2 (open south-facing slopes) as an important forage and thermoregulatory resource (direct solar radiation in winter reduces snow depth and aids in thermal requirements). We classified areas of the road that were juxtaposed between the nearest water, agriculture, and open south-facing slopes because hypothesized that this landscape position may increase the frequency of crossings, and hence deer-vehicle collisions.

We also created a raster surface of maximum slope at a fine-scale resolution along SR 20. For this, we characterized the slope along SR 20 at a 10-m resolution in degrees, based on a Digital Elevation Model (DEM; 1/3 arc-second, approximately 10 m pixels, USGS) and using the Slope tool in ArcGIS Pro 2.4.1. We then found the maximum slope within 60 m of each pixel using the Focal Statistics tool, which uses a moving neighborhood to characterize cells across the landscape. This surface was used to test the hypothesis that deer movements (e.g., a deer heading down a steep hill toward SR 20 may be less able to be seen and also less able to stop upon entering the road, whereas deer heading up steep slopes to the road may not be seen by a driver or be able to see oncoming traffic) may influence the frequency of deer-vehicle collisions. We used a large spatial window to reduce the influence of flat road surface on estimating slope.

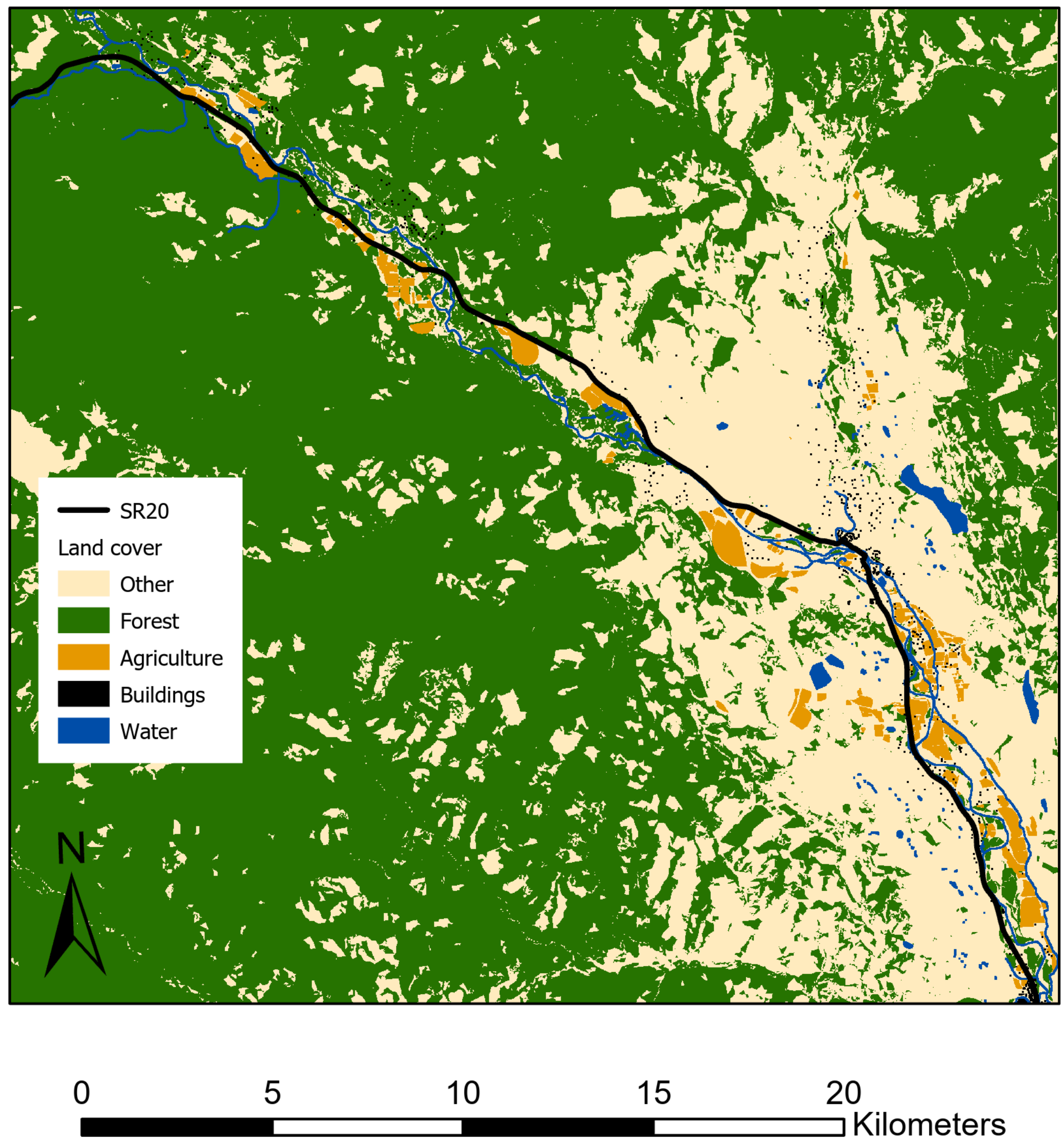

Figure 23. Land cover types in the Methow Valley, 2016-2019.

Road geometry variables

To investigate the role of road geometry in the deer-vehicle collision process, we used sight distance measured and provided by WSDOT. For each segment of road, we assigned the minimum sight distance included in the assessed area as provided by WSDOT, both directions of horizontal as well as vertical (Figure 24). Horizontal sight distance was not provided for areas with 35 mph speed limits and below, these are excluded from this analysis. Areas outside of ARMs where sight distance was measured were given a sight distance of 10000 ft.

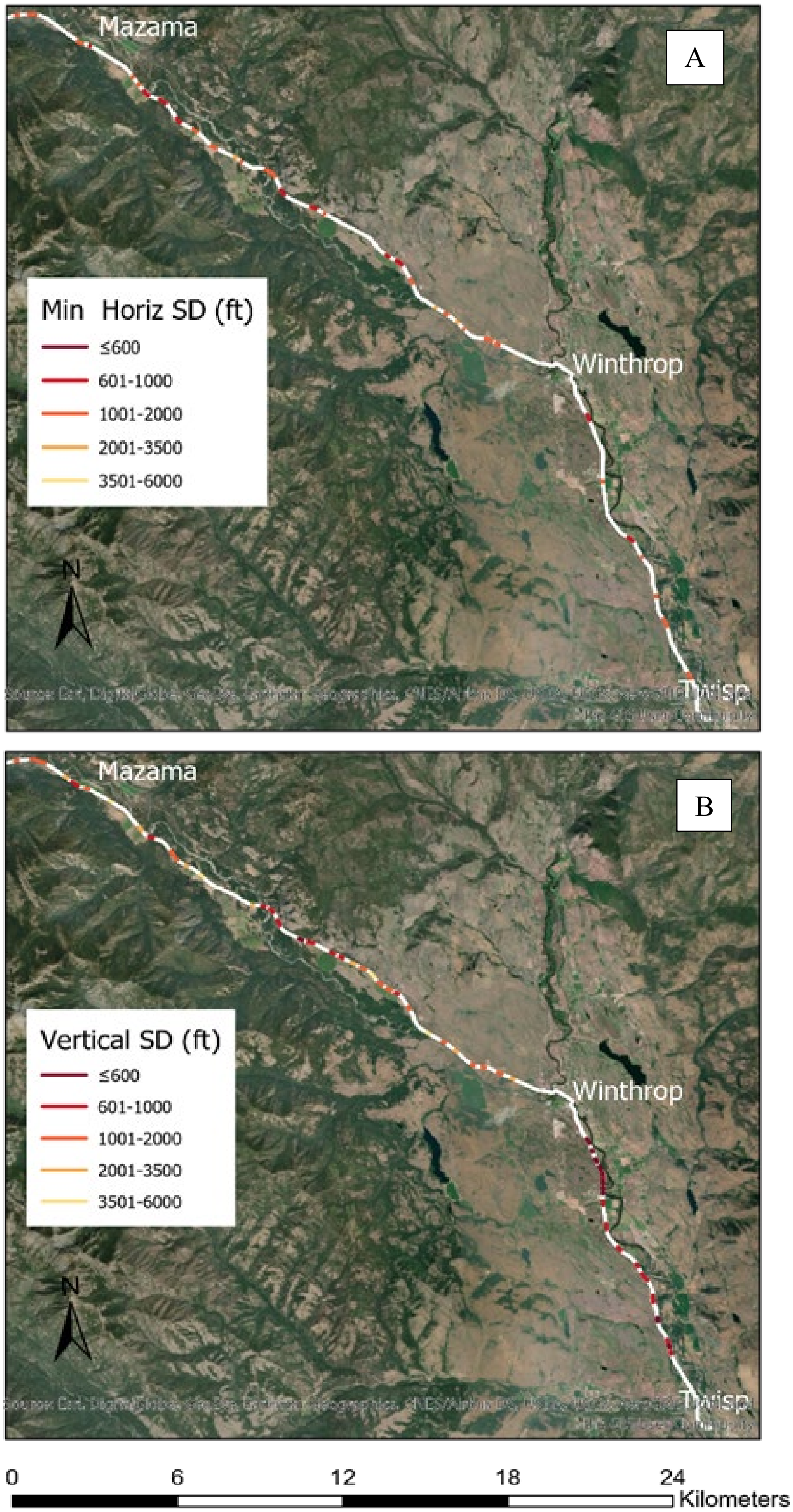

Figure 24. Sight distances along SR 20 in the Methow Valley, Washington, A) Minimum horizontal sight distance, B) Vertical sight distance. White indicates highway segment without measured sight distance limitation.

Modeling Methods

Environmental factors that predict spatially variable frequencies of crossings

We modeled the frequency of deer crossings at each data logger that contained ≥1 deer detections (*n* = 39) to assess what landscape variables were related to frequency of crossings. We standardized the number of detections at each data logger per day by the number of collared deer detected at the logger that day. We note that these data primarily reflect the behavior of mule deer, as the majority of collared animals were resident mule deer.

Models included distance to forest patch, distance to open south facing slope, distance to linear water feature (canal or river, which was correlated with distance to any water feature (r = 0.87) and excluded from further analyses), distance to building, distance to agriculture, whether the nearest agriculture and nearest water were on different sides of the road (0/1), whether the nearest water and nearest open south-facing slope were on different sides of the road (0/1), and whether the nearest open south-facing slope and agriculture were on different sides of the road (0/1). These were analyzed for a set of 18 *a priori* models (Table 1). Frequency of road crossings was natural log-transformed to meet normality assumptions. We used the most parsimonious model with the highest evidence weight to predict the frequency of crossing per deer per day at cameras. We used Akaike's Information Criterion (AIC; Akaike 1973) corrected for small sample size (AICc) and AICc weights for selecting the most parsimonious model (Burnham and Anderson 2002).

Road geometry features that predict frequency of deer-vehicle collisions

To understand whether road geometry features further explained the abundance of deer-vehicle collisions beyond that attributed to deer abundance alone, we modeled the detection-bias corrected estimates of carcass abundance at our camera locations as a proxy for deer-vehicle collisions. We used the camera locations because this is where we could estimate deer abundance. We used a kernel density estimator (ArcGIS Pro 2.4.1, ESRI, Inc.) to create a 10 m resolution raster surface of new carcass density based on carcasses within 1 km (Figure 17). For each camera, this produced an unbiased estimate of abundance, which was log + 0.1 transformed to meet assumptions of normality. We focused on mule deer for these data and associated models because our estimates of abundance were based on frequencies of observed crossings by mule deer, which dominated our sample of radio-collared deer.

We constructed an *a priori* set of 9 linear regression models, each representing various additive and interactive effects of features hypothesized to influence the deer-vehicle collision process. Our null model included deer abundance obtained from the results of the previous modeling (of frequency of crossings). Deer abundance was estimated at each camera associated with its corresponding data logger by dividing the number of images of mule deer or all deer per day by the predicted frequency of deer crossings per day. We used AICc and AICc weights to select the most parsimonious model and determine if and how deer abundance, minimum sight distance (horizontal and vertical), maximum slope within 60 m, and distance to building influenced the abundance of deer-vehicle collisions (Table 2). We used these results to identify linear lengths of highway where high numbers of deer-vehicle collisions were predicted to occur and refer to these linear lengths as "deer-vehicle collision zones."

Integration of independent carcass and deer-vehicle collision datasets with modeling results

While our linear models were designed to assess environmental and road geometry drivers of the deer-vehicle collision process across the entire study area, finer-scale site-specific application of such models can sometimes lead to spatial scale mismatches and inconsistencies in the reliability of site-specific predictions (Morrison et al. 2006). To improve the utility of our models for site-specific engineering solutions, we heuristically assessed our model predictions against WSDOT's independent carcass and deer collision datasets; this approach was intended to assess site-specificity of our results. For this, we overlaid the deer-vehicle collision zones identified in the previous section onto WSDOT carcass and deer collision data to examine overlap and proximity.

Status of previously identified mule deer migration corridors

To evaluate the status of previously identified mule deer migration corridors, we overlaid current estimates of mule deer abundance and crossings (frequency of photographed encounters) at camera stations onto a georeferenced map of mule deer migration corridors identified by WDFW in the 1980s (Myers et al. 1989). We limited this assessment to the portion of the study area south of mile post 185 (where we identified 7 migration routes documented in the 1980s by Myers et al. (1989)) because our camera data north of mile post 185 were adjusted with movement data from resident deer in the lower elevations south of mile post 185, which limits our most reliable estimates of abundance and associated ability to assess the status of previous migration routes crossing SR 20 to south of mile post 185. We then visually compared where high abundances of mule deer were determined along SR 20 in this study with the migratory routes identified to cross SR 20 in the 1980s and quantified the proportion of previous migration corridors that were active during this study.

Modeling Results

Environmental factors that predict spatially variable frequencies of crossings

The global model fit the dataset of deer crossings reasonably well (Q-Q residual plots), and there was strong evidence that higher frequencies of crossings per deer were positively associated with distance from open south-facing slopes (more crossings farther from these slopes) and negatively associated with distance to linear water feature (canal or river) (more crossings closer to these features; Table 1). The most parsimonious linear model was

$$ln(average\ detections\ per\ deer\ per\ day) = -1.36 + 0.0122 \times distance\ to\ nearest\ south\ facing\ slope\ (m) - 0.00196 \times distance\ to\ nearest\ river\ or\ canal\ (m).$$

Table 1. Linear models of deer crossing frequencies between mile posts 176-201 of SR 20 in the Methow Valley, Washington, January 2018 – October 2018. See text for descriptions of predictors listed under model column. *k* = number of parameters, AICc = small sample corrected Akaike's Information Criterion, ΔAICc = difference in AICc between model and most parsimonious model, AICc weight = relative model weight according to AICc.

Model (predictors)	*k*	AICc	ΔAICc	AICc weight
Distance to open south-facing slope + distance to linear water feature	3	156.5	0	0.54
Distance to open south-facing slope + distance to water + located between nearest open south-facing slope and water (0/1)	4	158.3	1.79	0.22
Distance to open south-facing slope	2	159.7	3.15	0.11
Distance to linear water feature	2	162.5	5.97	0.03
Distance to forest + distance to building + distance to agriculture + distance to linear water feature + distance to open south-facing slope	6	162.6	6.06	0.03
Distance to agriculture + distance to linear water feature	3	163.7	7.21	0.01
Distance to nearest building + distance to linear water feature	3	164.9	7.40	0.01
Distance to open south-facing slope + distance to agriculture + located between nearest open south-facing slope and agriculture (0/1)	4	164.0	7.51	0.01
Distance to agriculture + distance to linear water feature + located between nearest agriculture and water (0/1)	4	164.1	7.53	0.01
Distance to nearest forest patch + distance to linear water feature	3	164.7	8.19	0.01
Distance to forest + distance to building + distance to agriculture + distance to linear water feature + distance to open south-facing slope + located between nearest agriculture and water (0/1) + located between nearest open south-facing slope and water (0/1) + located between nearest open south-facing slope and agriculture (0/1)	9	167.0	10.51	0.00
Located between nearest agriculture and water (0/1)	2	168.2	11.70	0.00
Distance to building	2	169.7	13.14	0.00
Located between nearest agriculture and water (0/1) + located between nearest open south-facing slope and water (0/1) + located between nearest open south-facing slope and agriculture (0/1)	4	170.2	13.64	0.00
Located between nearest open south-facing slope and agriculture (0/1)	2	170.6	14.09	0.00
Distance to forest	2	171.2	14.71	0.00
Distance to agriculture	2	172.4	15.92	0.00
Located between nearest open south-facing slope and water (0/1)	2	172.5	16.02	0.00

Road geometry features that predict frequency of deer-vehicle collisions

Our global model of road geometry effects on frequency of deer-vehicle collision fit the new deer carcass abundance data reasonably well (Q-Q residual plots). The frequency of new deer carcasses (as a proxy for deer vehicle collisions) between April 2017 and October 2017 was best explained by an interaction of the abundance of mule deer in the area during that time and the minimum sight distance (vertical or horizontal) at the point in the road, plus the maximum slope within a 60 m buffer (Table 2). The most parsimonious linear model predicted

> *ln(frequency of deer-vehicle collisions)* = 0.09642 + 0.3183 x *predicted mule deer abundance* + 0.0001094 x *minimum sight distance (ft)* – 0.00004199 x *minimum sight distance (ft)* x *predicted mule deer abundance* + 0.05748 x *max slope within 60 m (degrees)*

(Figures 25-27). This same model was also the most parsimonious (highest model weight) in a parallel analysis using all deer (mule and white-tailed deer) combined (Appendix B). A spatially explicit representation of this model revealed nine deer-vehicle collision zones, characterized by linear lengths of highway containing ≥1 0.16-km-segments where relatively high numbers (≥7) of deer-vehicle collisions were predicted to occur during the study period (Figure 27).

Table 2. Linear models of deer-vehicle collision abundances (as represented by new carcasses on the road April 2017 – October 2017) between mile posts 176-201 of SR 20 in the Methow Valley, Washington, April – October 2017. See text for descriptions of predictors listed under model column. *k* = number of parameters, AICc = small sample corrected Akaike's Information Criterion, ΔAICc = difference in AICc between model and the most parsimonious model, AICc weight = relative model weight according to AICc (Burnham and Anderson 2002). Also see Appendix D.

Model (predictors)	*k*	AICc	ΔAICc	AICc weight
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance + maximum slope within 60 m	5	155.7	0.00	0.63
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance + maximum slope within 60 m + distance to building	6	158.0	2.3	0.20
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance	4	159.7	3.91	0.09
Predicted mule deer abundance + maximum slope within 60 m	3	161.1	5.33	0.04
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance + distance to building	4	161.6	5.88	0.03
Predicted mule deer abundance + minimum sight distance	3	165.4	9.64	0.01
Predicted mule deer abundance	2	165.5	9.78	0.00
Minimum sight distance	2	165.9	10.21	0.00

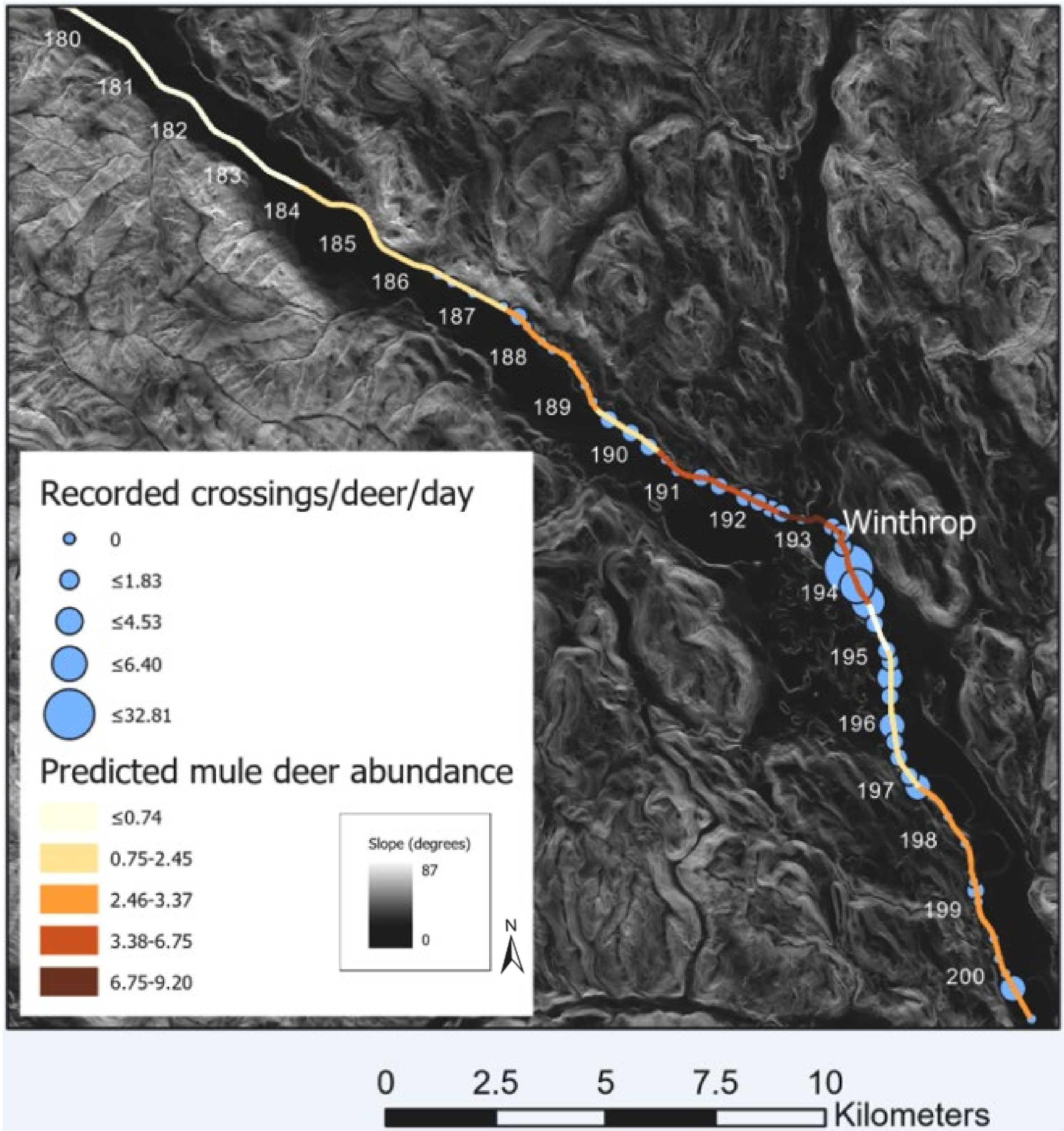

Figure 25. Predicted daily abundance of mule deer that crossed the road (averaged between camera locations by kriging) and the number of times individual (radio-collared) deer crossed the road (based on 49 data loggers) between mile posts 185 – 201 along SR 20 in the Methow Valley, Washington. For example, the abundance of deer crossing SR 20 and the number of times per day they crossed jointly peaked (i.e., high abundance of frequently crossing deer) just south of Winthrop. See text for method used to predict daily mule deer abundance.

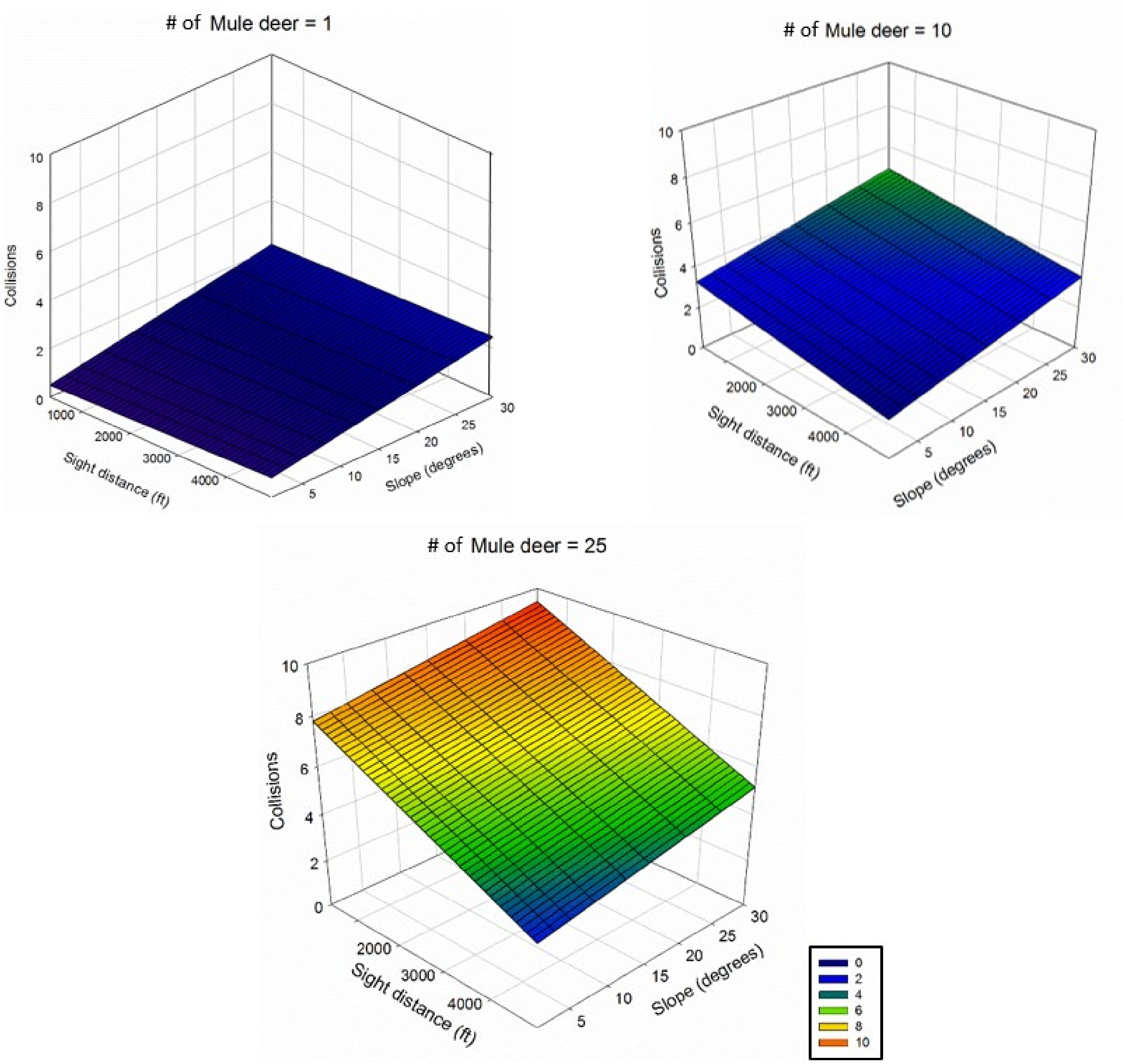

Figure 26. Predicted number of deer carcasses (as a proxy for deer-vehicle collisions resulting in deer mortality) as a multiplicative function of number of deer and minimum sight distance, plus maximum slope within 60 m of the road between mile posts 176-201 along SR 20 in the Methow Valley, Washington for 1 – 25 mule deer crossing the road per day. Results from the most parsimonious linear regression model (see Table 2 and text for details).

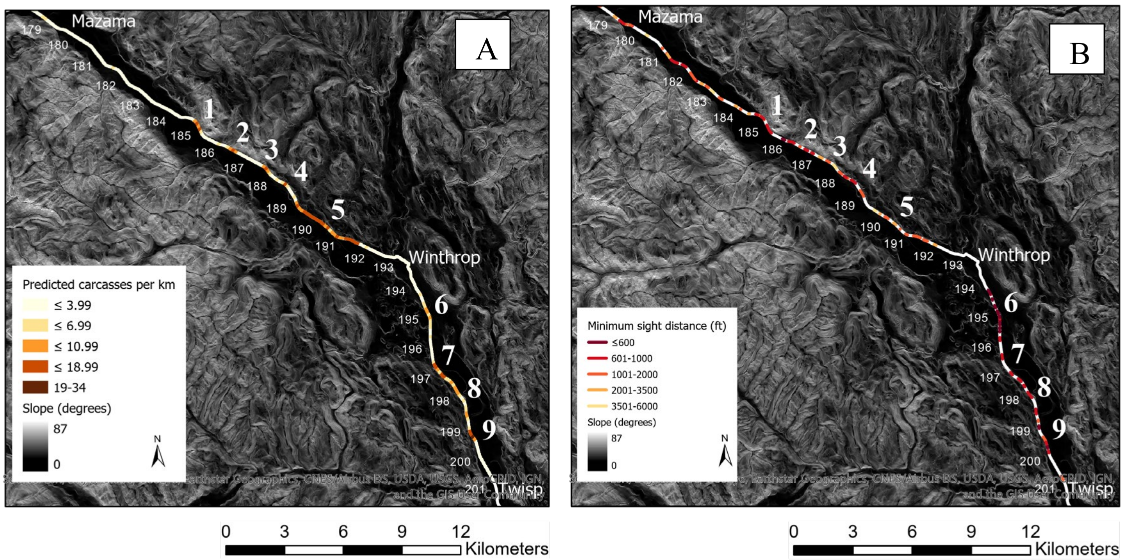

Figure 27. A) Spatial representation of the most parsimonious (top) road geometry model of deer carcass frequency (as a proxy for deer-vehicle collisions) (from Table 2 and Figure 26) along SR 20 in the Methow Valley, Washington. B) Minimum sight distance along SR 20 in the Methow Valley, Washington. Numbers 1-9 depict linear lengths of highway (deer-vehicle collision zones) containing ≥1 0.16-km-segments where high numbers (≥7) of deer-vehicle collisions were predicted to occur during the study. Mile posts included.

Integration of independent carcass and deer-vehicle collision datasets with modeling results

The assessment of model predictions against the independent WSDOT carcass and deer collision datasets indicated a high level of agreement between them. Additionally, it revealed several areas of SR 20 where deer carcass and collision data were clustered adjacent to 0.16-km-segments of the highway where carcass numbers were predicted to be high (Figure 28).

Status of previously identified mule deer migration corridors

Mule deer in the Methow Valley have been characterized generally as migratory (Myers et al. 1989, Myers et al. 2008, WDFW 2016). Our study focused on the peak period of mule deer-vehicle collisions and carcass removals (May-October). Based on winter trapping, radio-tracking

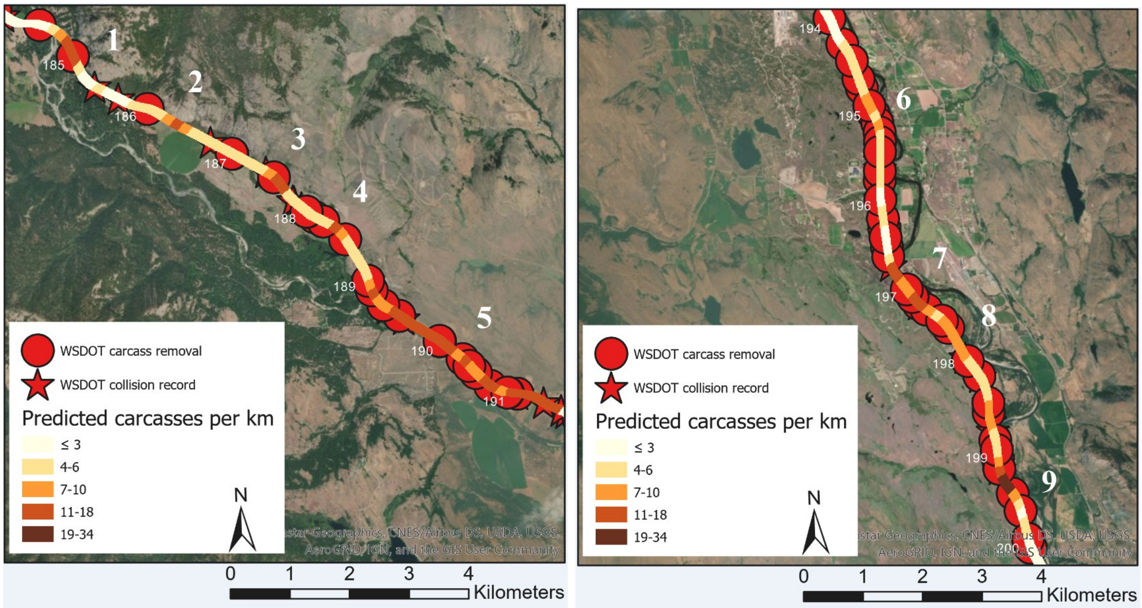

Figure 28. Linear segments of SR 20 where deer-vehicle collision risk was predicted to be high (from Figure 27) in the Methow Valley, Washington overlaid onto WSDOT's independent deer carcass removal and collision datasets (2009-2015). Numbers 1-9 are from Figure 27, depicting deer-vehicle collision zones where high numbers (≥7) of deer-vehicle collisions were predicted to occur. Mile posts are shown.

during the peak period of deer-vehicle collisions (May-October), and data loggers, we classified 68% (n = 15) of the 22 does radio-collared along SR 20 as non-migratory, year-round residents with home ranges that straddled SR 20. Despite using recorded numbers of deer photos in combination with the frequency of crossings by individual collared deer to estimate spatially explicit estimates of deer abundance, deep snows north of mile post 185 during winter trapping led to an absence of deer to capture and collar in that northern region of the study area. Additionally, we also did not detect any of our collared deer north of mile post 185 the following summer, further indicating that our sample of collared deer exhibited strong year-round site fidelity and space use patterns that may diverge from those of deer that migrate through the area. Despite our pilot study revealing that increased abundance corresponds with increased numbers of crossings (Figure 13), our camera data north of mile post 185 were adjusted with movement data from resident deer in the lower elevations south of mile post 185, which limits our most reliable estimates of abundance and associated ability to assess the status of previous migration routes crossing SR 20 to south of mile post 185. Focusing on the region between mile posts 185-201, we found that 100% (n = 7) of the locations in this region where deer migration routes crossed SR 20 in the 1980s were active during this study (Figure 29A and B).

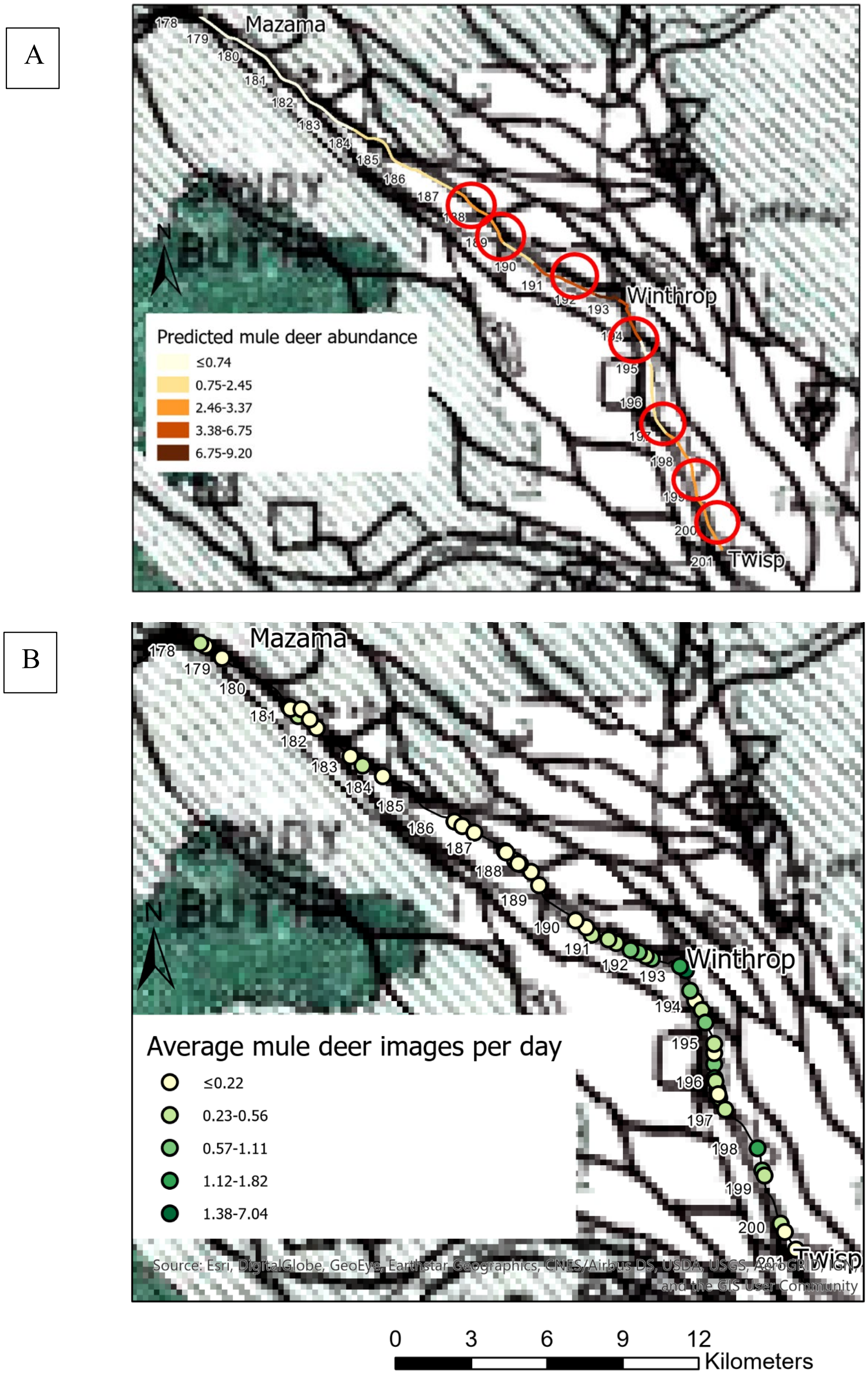

Figure 29. Status of past mule deer migratory corridors; (A) predicted mule deer abundance and (B) average number of mule deer photos overlaid onto mule deer movement corridors (bold lines) identified in the 1980s (Meyers et al. 1989). Mile posts are shown.

DISCUSSION

The majority (68%) of collared deer sampled during this study were non-migratory, year-round residents with home ranges that straddled SR 20. This finding differs from what others previously found in the valley—that mule deer were primarily migratory (Myers et al. 1989, Myers et al. 2008, WDFW 2016); this life history strategy is more common in areas where variable precipitation and snow cover occurs (e.g., southern California; Nicholson et al. 1997). This pattern, where approximately three quarters of sampled female deer exhibited a non-migratory life strategy, is not commonly reported in northern ungulate populations because migration to lower elevations during winter is necessary for animals to survive deep snow associated with northern winters (Sawyer et al. 2005, Hebblewhite and Merrill 2009, Manning 2010, Anderson et al. 2012, Manning and Garton 2012, Middleton et al. 2013, WDFW 2016). Migration also enables northern ungulates to access highly nutritious forage in high-elevation spring and summer ranges and minimize energy expenditure in shallow snow depths within winter ranges, which are linked to fecundity and survival (Cook et al. 2004, Pettorelli et al. 2007, Tollefson et al. 2010). The high proportion of non-migratory resident mule deer we found is in line with descriptions from local residents who reported an increase in the number of deer in the valley over the past 50 years, and that deer were essentially non-existent prior to that time except for small isolated areas like the area southwest of Winthrop identified by Myers et al. (1989). In combination with these reports, our findings suggest a growing population segment of non-migratory mule deer around and south of the town of Winthrop.

The positive correlation between probability of crossings and number of live deer and the significant effect of deer numbers on frequency of crossings (Figure 12-14) were expected, and indicate that the frequency of highway crossings by deer is a meaningful metric to investigate the deer-vehicle collision process. Mule deer abundance and frequency of road crossings were particularly concentrated around the town of Winthrop (Figures 20 and 25), indicating that the juxtaposition of this location within the regional migratory pathways may play an important role, among other factors, in the abundance of deer in this area. The confluence of the Methow and Big Valleys is characterized by open, low-elevation flats and hillsides, access to forage and water (river and canals), and south-southwest facing slopes, consistent with winter habitat preferences of mule deer elsewhere in the northwest (Manning 2010, WDFW 2016). The elevation of this area is lower than the surrounding summer range and at the upper elevation range of suitable mule deer winter habitat, providing shallower snow depths in winter for deer to navigate. High incidence of solar radiation on open south-facing slopes, coupled with prevailing winds from the northwest, provide deer with reduced snow depths compared to neighboring forested slopes or flat land aids, and offer thermal protection and more easily accessible forage. Deer also exhibited an increase in road crossing in areas closer to rivers and canals—potentially because flowing waters present in these linear water features freezes later and thaws earlier than water impoundments. Although not important in our models, the presence of agriculture close to towns in the study area may also contribute to the prevalence of year-round, resident deer present near Winthrop because highly nutritious agricultural crops (e.g., winter wheat) have been linked to increased deer body condition, survival, and spatial shifts (WDFW 2016) – potentially changing space use and/or altering migration behavior.

After accounting for deer abundance in our models, we found that the number of deer-vehicle collisions was directly related to minimum sight distance by vehicle drivers and the maximum slope occurring within 60 m from the road. Sight distance corresponds to a vehicle's driver's ability to detect a deer. Our best model predicted that deer-vehicle collisions decreased with increasing sight distance. We also found that deer-vehicle collisions increased with increasing slope and abundance of deer crossing the road. When deer numbers were low, we found a smaller influence of sight distance on deer-vehicle collisions, with steep slopes near the road having a greater negative impact. This may be due to the speed and momentum of deer entering the roadway as they came down from above, reducing the reaction time of deer and drivers in those situations. The effect of sight distance on collisions increased with increasing deer numbers, with a strong effect at locations where high numbers of mule deer per day occurred (e.g., near the town of Winthrop). However, speed limit likely attenuated the relationship between deer numbers and deer-vehicle collisions in and around the town of Winthrop (between mile posts 192 and 195), which resulted in the absence of a deer-vehicle collision zone in this area despite high deer numbers.

Because resident deer, which navigate traffic daily, may behave and interact differently with highways compared to migratory deer, a more thorough understanding of the migratory status is needed. Mule deer in the Methow Valley continue to use previously recorded migration routes (Figure 29). We detected this despite using crossing data largely from resident deer to adjust the numbers of deer photos – this was the case probably because the number of photos increased in areas where the number of deer crossing the road included migrants. This finding was not surprising given that mule deer exhibit strong fidelity to migratory routes throughout their range (e.g., Sawyer et al. 2013). In addition to documenting the continued use of traditional migration routes, this study revealed additional locations along the highway where high abundances and frequencies of crossings occur, depicting a combination of migration routes for migratory animals and local movement routes used by resident deer. Future studies could involve sampling both migrant and resident deer to determine the contributions of each segment within this deer population in deer-vehicle collisions. Efforts to reduce deer-vehicle collisions may differ depending on which segment of the population is targeted for engineering solutions.

RECOMMENDATIONS

As most of the radio-collared deer during this study were year-round resident mule deer, the following recommendations are based primarily on the movements of resident deer in the Methow Valley. These resident mule deer appear to constitute the majority of deer in areas where most collisions and carcass removals occurred (i.e., from mile 190 to 198). We note that the recommended solutions below may not take into account specific management goals established by resource agencies for migratory deer populations in the region or those focused on white-tailed deer.

To identify and recommend zones along SR 20 where engineering solutions can be applied to reduce deer-vehicle collisions, we began by improving the specificity of our model results. To accomplish this, we extended deer-vehicle collision zones (from Figures 27 and 28) out by 0.16-km increments in both directions to encompass contiguous highway increments that contained a WSDOT-documented carcass or collision. We excluded carcasses on mile posts because

WSDOT's records were linked to the nearest mile post in some cases (Figure 30). This resulted in nine zones for recommending engineering solutions (between mile posts 184-200; Figure 30). Despite a high abundance of likely resident deer in and around the town of Winthrop (between mile posts 192 and 194), low numbers of carcasses and deer-vehicle collisions led to this area not being identified as a recommended zone for engineering solutions.

Lengths of recommended engineering zones ranged from 0.48-4.32 km (Table 3); the lengths of three zones (1-3) were comprised entirely of deer-vehicle collision zones, and the remaining six were comprised of both deer-vehicle collision zones and extensions. Engineering solutions carried out in the more northern zones (1-4) would benefit white-tailed deer, which dominate deer numbers in this area of the study area. Zones 5-7 would benefit both white-tailed and mule deer, with increasing benefits to mule deer in zones 6 and 7. Zones 8 and 9 would primarily benefit mule deer, which dominate deer numbers there.

Because the implementation of engineering solutions would likely take place over time, we developed two methods to prioritize the implementation of engineering solutions among these nine zones according. These include: 1) the percent reduction in overall deer-vehicle collision numbers along this stretch of highway (Figure 31) and 2) a biological benefit to local deer herds based on the proportion of mule deer mortality (or loss of animals) due to deer-vehicle collisions relative to the corresponding local herd size (Figure 32). This latter ranking metric is grounded in the recognition that high mortality in local deer groups could lead to reductions in local deer abundance and familial (genetic) lineages, and that the conservation of local deer groups scales up to improved health of regional deer herds. It is provided here to provide a biological context for prioritizing zones for engineering solutions.

Zone 5 just north of Winthrop was the top ranked zone, containing the highest percentage of deer carcasses and collisions (Table 3). Implementation of engineering solutions that prevent deer-vehicle collisions in this zone would reduce the total annual number of deer-vehicle collisions between the towns of Mazama and Twisp by 18.6%. This zone is also ranked as a high priority for biological importance for white-tailed and mule deer. As such, we recommend zone 5 as a top priority for implementing engineering solutions.

Our second recommended priority for engineering solutions is zone 6 due to the high percentage of deer-vehicle collisions (11.9%) combined with the highest ranking for biological importance (Table 3), with an estimated 14% loss of local deer abundance attributed to deer-vehicle collisions. Engineering solution in this zone would benefit both species. This is closely followed by our third recommended zone (zone 9), which would primarily benefit mule deer and has 12.6% of deer-vehicle collisions but ranked only 6^{th} in biological importance. Our fourth recommended zone for engineering solutions is zone 7, with benefits to both species and 8.7% of deer-vehicle collisions, with the 3^{rd} highest ranking for biological importance. Engineering solutions implemented in these four zones (5, 6, 7, and 9) would result in a 51.9% cumulative reduction in deer-vehicle collisions annually between the towns of Mazama and Twisp. Engineering solutions implemented in all 9 zones would result in a 57.8% reduction in deer-vehicle collisions between Mazama and Twisp.

Recognizing that recommendations of site-specific engineering solutions is beyond our expertise and the project scope, we provide the following general description of potential technologies and engineering solutions. Various technologies have been developed to reduce wildlife-vehicle collisions across North America. Laser detection systems and roadside animal activated detection systems (e.g., Grace et al. 2017) continue to be developed and tested. Laser detection systems that can activate warning signs could prove helpful. Reduced speed limits and deer reflectors are common, but each has its own strength and drawback (e.g., https://www.wsdot.wa.gov/environment/protecting/wildlife-collisions). For example, reduced speed limits may help reduce wildlife-vehicle collisions, but passing, tailgating, and speeding may arise where drivers perceive unreasonably low speed limits, and enforcement can be difficult. However, we deduce that the reduced speed limit (≤35mph) in and around the town of Winthrop (between mile posts 192 and 195) likely contributed to a low number of deer-vehicle collisions despite high deer numbers, indicating that reduced speed limits may provide a functional solution in some areas of SR 20. Our models indicate that increasing sight distance reduces deer-vehicle collisions, and increasing the minimum vertical sight distance in areas like zone 6 (currently 220 ft; Table 3) would help reduce collisions.

Highway crossing structures (wildlife over- and under-passes) constructed in British Columbia's National Parks, Montana highways, and along Interstate 90 in Washington State by WSDOT have shown marked success at reducing wildlife-vehicle collisions and contributing to local and regional wildlife populations. Interlinking multiple wildlife crossing structures with wildlife-proof fencing on both sides of a highway can reduce wildlife-vehicle collisions along stretches of highways. At 4.32 km long, zone 5 contains various sites along its length where over- and under-passes could be engineered and linked by deer-proof fencing on both sides of the highway. To reduce deer from walking around the ends of fencing, cattle guards extending across the road at each end of the zone could be considered.

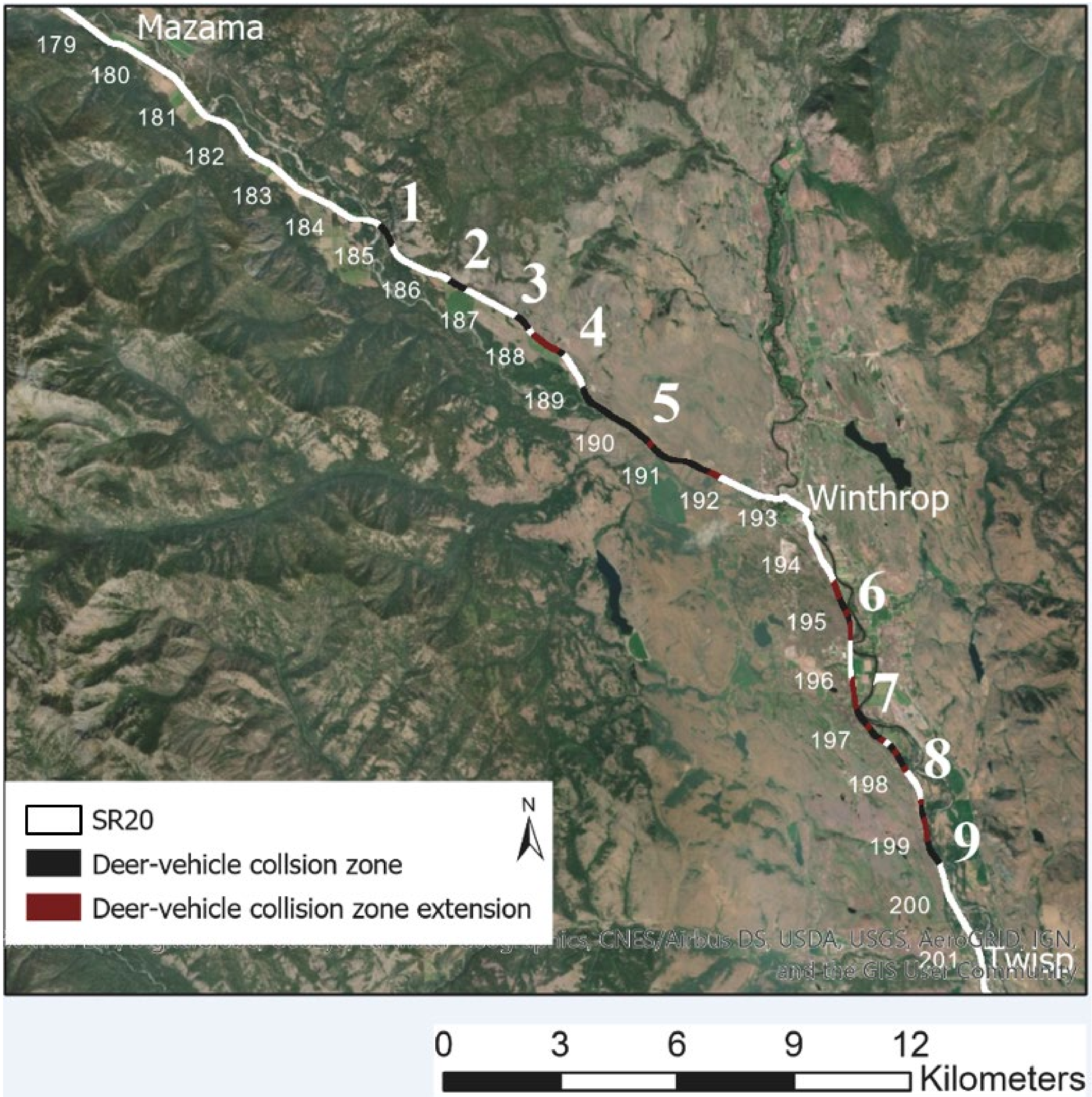

Figure 30. Recommended zones for engineering solutions (comprised of both deer-vehicle collision zones and zone extensions) between SR 20 mile posts 176-201 in the Methow Valley, Washington. Numbers 1-9 correspond to deer-vehicle collision zones presented in Figure 27; zones were not identified north of mile post 184. Zone extensions derived from extending existing zones into adjacent clusters of independent WSDOT carcasses and deer-vehicle collision records. Mile posts included.

Table 3. Characteristics and ranking of recommended zones for engineering solutions between mile posts 178-201in the Methow Valley, Washington. Zones are labeled 1-9 from north to south.

	Coordinates at north-end[1]			Percent of length					
Zone	Northing	Easting	Linear length (km)	Model output[2]	Carcass/ collision data[3]	Minimum sight distance[4] (ft)	Target species[5]	Ranking by deer-vehicle collisions[6]	Ranking by biological importance[7]
1	5380199	697612	0.64	100	0	650 V	WTDE	8 (0.3)	8
2	5378775	699398	0.48	100	0	875 V	WTDE	9 (0.0)	7
3	5377855	701116	0.48	100	0	4,491 V	WTDE	7 (0.4)	9
4	5377403	701544	0.96	16	84	799 V	WTDE	5 (4.6)	5
5	5376044	702834	4.32	89	11	1,058 H	BOTH	1 (18.6)	2
6	5371052	709279	1.60	30	70	220 V	BOTH	3 (11.9)	1
7	5368570	709750	1.92	42	58	668 V	BOTH	4 (8.7)	3
8	5366839	710720	0.80	60	40	739 H	MUDE	6 (0.6)	4
9	5365464	711521	1.76	55	45	902 V	MUDE	2 (12.6)	6

[1] NAD83, Zone 10.
[2] From road geometry model; see Figures 26 and 27 and Table 2.
[3] From WSDOT carcass data from 2009 to 2015 independent of the road geometry model.
[4] V = vertical sight distance, H = horizontal sight distance (whichever was shorter).
[5] WTDE = white-tailed deer, MUDE = mule deer, BOTH = both deer species.
[6] Determined from the percentage of deer-vehicle collisions (number of carcasses and deer-vehicle collisions during a given year / total number between SR 20 mile posts 178-201 during that year) averaged over 7 years (2009-2015). Average percentages in parentheses. Ranking ranges from 1-9, with 1 being highest. Carcass and collision data from WSDOT.
[7] Determined from the proportion of deer mortality (number of carcasses relative to local abundance of mule deer) predicted along SR 20 between April and October during the study period (see text for details). Ranking ranges from 1-9, with 1 being most biologically important (i.e., engineering solutions in this zone would reduce the greatest proportional loss (attributed to deer-vehicle collisions) to the local deer herd).

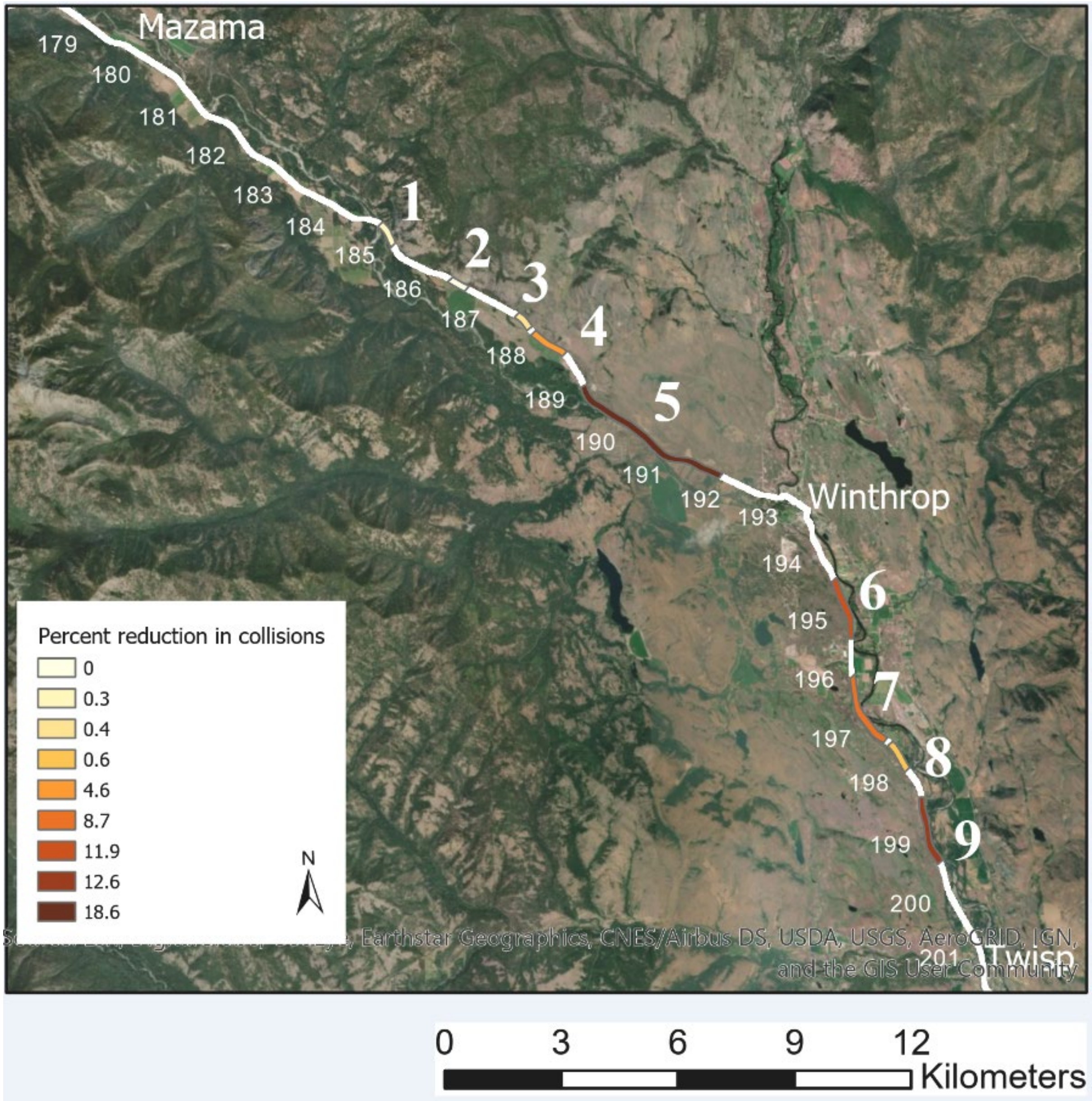

Figure 31. Pertentage of deer-vehicle collisions in each of 9 recommended zones for engineering solutions between SR 20 mile posts 178-201 in the Methow Valley, Washington. Percentage calculated as the number of carcasses and deer-vehicle collisions during a given year / total number across the study area during that year) averaged over 7 years (2009-2015). Carcass and collision data from WSDOT. Numbers 1-9 are from Figure 27, depicting predicted deer-vehicle collision zones. Mile posts included.

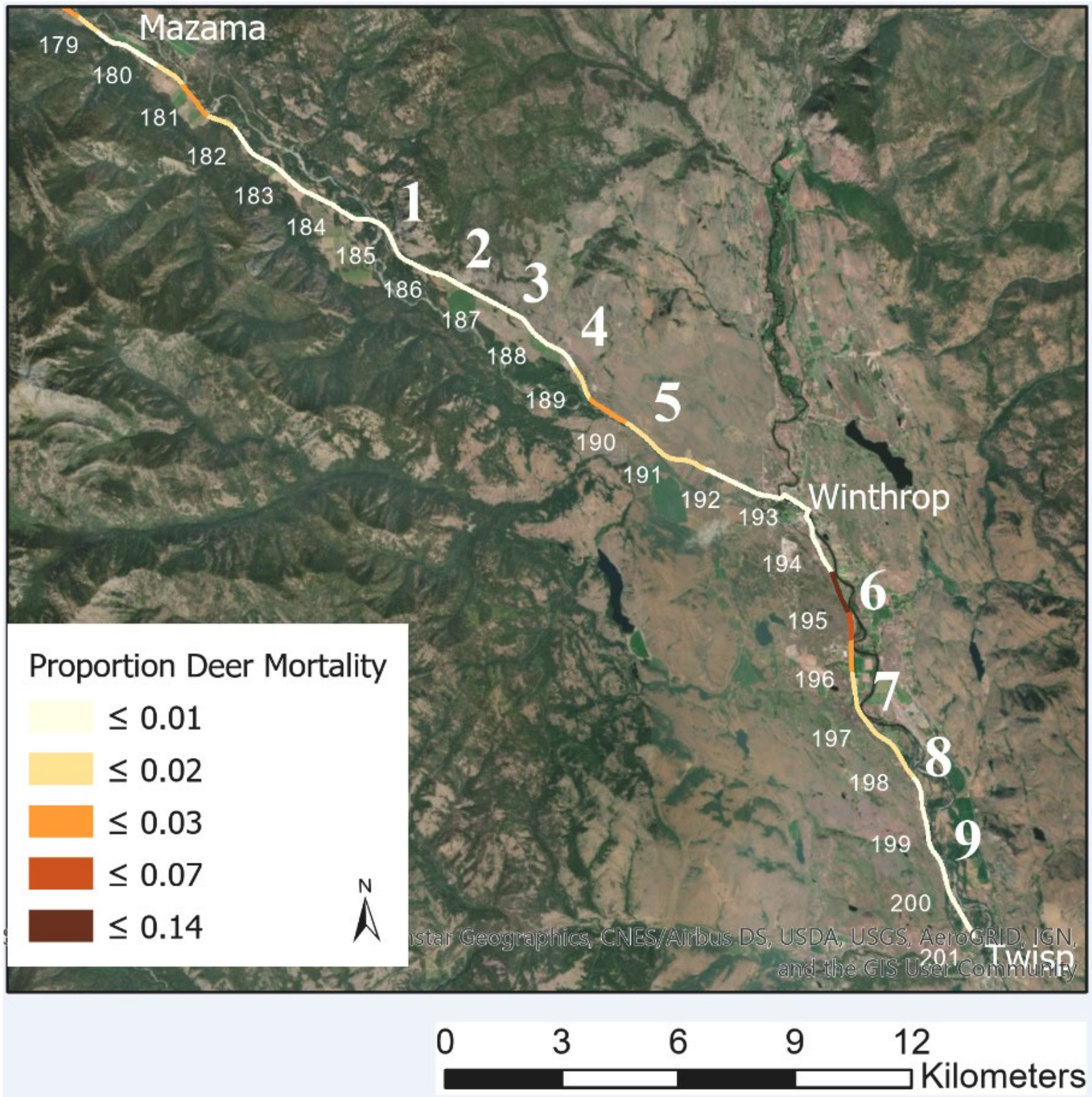

Figure 32. Proportion of mule deer mortality (number of carcasses relative to local mule deer abundance) predicted along SR 20 between April and October (i.e., detection bias-corrected estimate of carcass abundance / estimated mule deer abundance x 180 days) between mile posts 178-201 along SR 20 in the Methow Valley, Washington. Numbers 1-9 are from Figure 27, depicting deer-vehicle collision zones where high numbers (≥7) of deer-vehicle collisions were predicted to occur. Mile posts included.

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Appendix A. Photographs recorded by 59 game cameras along State Route 20 between mile posts 176-201 in the Methow Valley, Washington, April-October 2017.

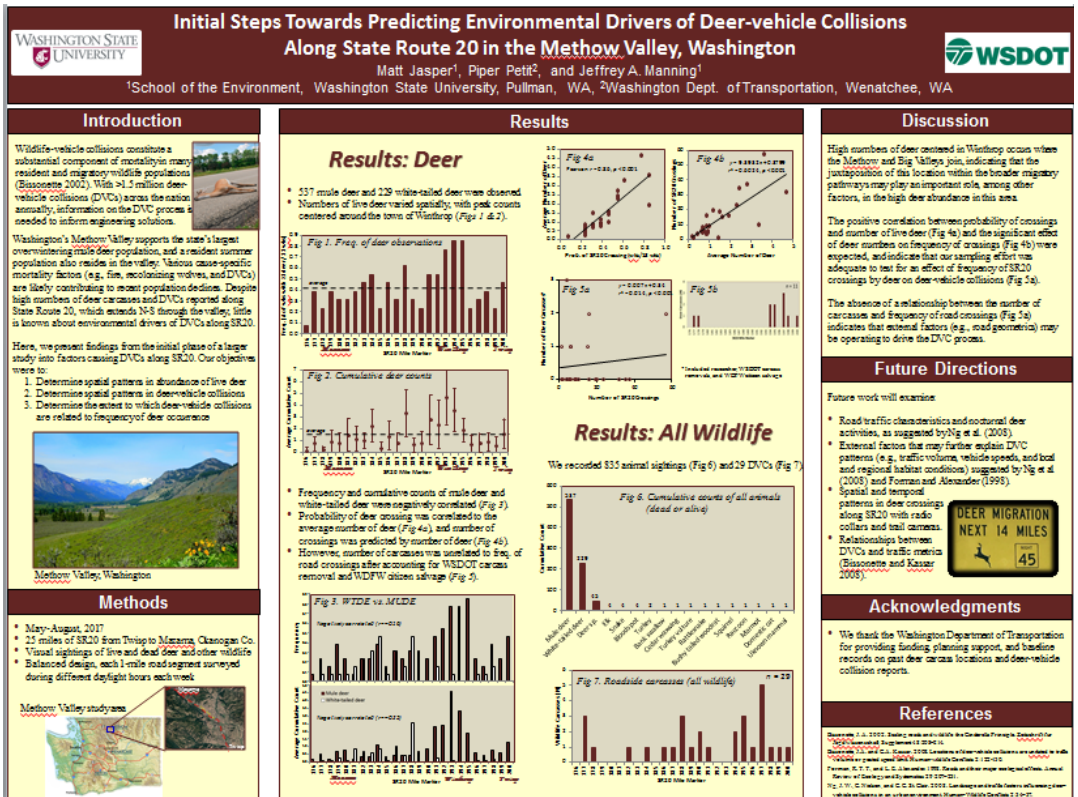
Camera	Mule deer	Unk deer	White-tailed deer	Both deer	Bird	Black bear	Cougar	Coyote	Chipmunk	Domestics	Human	Marmot	Moose	Mouse	Raccoon	Squirrel
BTC DOE 01	35	18	0	0	0	0	0	19	0	23	40	0	0	0	0	0
BTC DOE 02	47	4	8	0	0	0	0	0	0	0	5	0	0	0	0	0
BTC DOE 03	34	18	17	0	0	0	0	0	0	0	21	0	0	0	0	0
BTC DOE 04	22	3	0	0	2	0	0	0	0	0	15	0	0	0	1	0
BTC DOE 05	78	19	0	0	2	0	0	1	0	1	8	0	0	0	0	0
BTC DOE 06	206	23	0	0	1	0	0	9	0	14	4	0	0	0	0	0
BTC DOE 07	33	24	2	0	42	0	0	0	0	0	9	0	0	0	0	0
BTC DOE 08	26	14	0	0	2	0	0	0	0	3	6	0	0	1	0	0
BTC DOE 09	31	1	4	0	34	0	0	0	0	0	10	0	0	0	0	1
BTC DOE 10	163	22	0	0	14	0	0	0	0	0	41	0	0	0	1	0
BTC DOE 11	1310	10	0	0	17	0	0	0	0	11	15	0	0	0	32	3
BTC DOE 13	278	96	0	0	59	0	0	0	0	31	14	0	0	0	0	0
BTC DOE 14	124	5	59	1	6	0	0	0	0	1	4	0	0	0	0	1
BTC DOE 15	77	37	60	0	1	0	0	0	0	227	3	0	0	0	0	0
BTC DOE 16	199	57	59	0	1	0	0	1	0	0	6	0	0	0	0	0
BTC DOE 17	168	139	189	1	68	0	0	0	0	0	902	0	2	0	0	0
BTC DOE 18	94	86	196	0	0	0	0	2	0	2	6	0	0	0	0	0
BTC DOE 19	91	110	29	0	0	3	0	1	0	1	92	0	0	0	0	0
BTC DOE 20	51	31	10	0	1	0	0	1	0	1	49	0	0	0	0	0
BTC DOE 21	6	4	0	0	11	0	0	0	0	1	5	0	0	0	0	0
BTC DOE 22	23	6	2	0	0	0	0	0	0	0	11	0	0	0	0	0
BTC DOE 23	31	23	7	0	182	0	0	0	0	0	6	0	0	0	0	0
BTC DOE 24	41	15	16	0	1	0	0	1	0	0	26	0	0	0	0	0
BTC DOE 25	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0
BTC DOE 26	4	0	25	0	0	1	0	1	0	0	8	0	0	0	0	0
BTC DOE 27	29	28	6	0	1	1	0	0	0	0	9	0	0	5	0	0
BTC DOE 28	40	52	72	0	8	0	0	0	0	17	5	0	0	0	0	0
BTC DOE 29	25	4	20	0	7	0	0	0	0	0	1	0	0	0	0	0
BTC DOE 30	9	2	6	0	1	0	0	2	0	0	6	0	0	0	0	0
WSDOT 01	340	6	15	0	37	0	0	117	1	0	8	2	0	0	1	0
WSDOT 02	128	19	31	0	1	0	0	8	0	0	2	2	0	0	2	0
WSDOT 03	71	99	59	0	1	1	0	30	0	3	1054	0	0	0	0	0
WSDOT 04	260	15	19	0	0	0	0	0	0	0	5	0	0	0	0	0
WSDOT 05	127	87	1	0	3	0	0	5	0	0	12	0	0	0	0	0
WSDOT 06	70	9	1	0	0	0	0	0	0	63	5	0	0	0	0	0

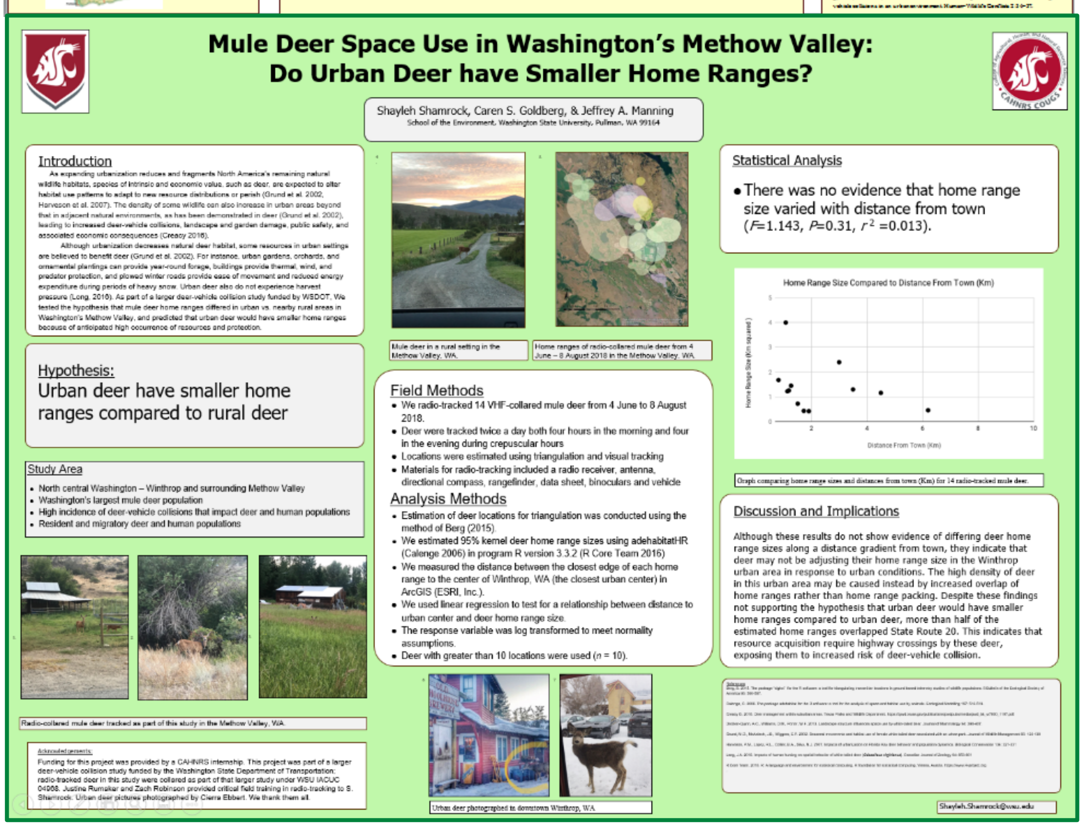
WSDOT 07	21	29	30	0	1	0	0	1	0	0	36	0	0	0	0	1
WSDOT 08	43	15	56	0	0	0	0	0	2	4	8	0	0	0	0	2
WSDOT 09	24	54	51	0	0	1	0	0	0	0	4	0	0	0	0	0
WSDOT 10	2	6	0	0	1	0	0	0	0	1	43	3	0	0	0	3
WSDOT 11	8	5	10	0	1	0	0	0	0	0	1	0	0	0	0	0
WSDOT 12	43	43	9	0	1	0	0	0	0	0	5	0	0	0	0	0
WSDOT 14	6	5	0	0	8	1	0	4	0	1	3	0	0	14	0	1
WSDOT 15	14	7	1	0	2	2	0	0	0	0	7	0	0	0	0	0
WSDOT 16	63	20	1	0	3	1	0	1	0	0	55	0	0	0	0	0
WSDOT 17	133	23	12	0	1	2	1	3	0	0	4	0	1	0	0	0
WSDOT 18	58	13	0	0	3	0	0	0	0	0	8	0	0	0	0	0
WSDOT 19	3	0	2	0	0	0	0	1	0	3	12	0	0	0	0	1
WSDOT 20	10	19	2	0	1	0	0	0	0	0	7	0	0	0	0	0
WSDOT 21	24	41	6	0	0	2	0	3	0	0	5	0	0	0	0	0
WSDOT 22	24	32	6	0	18	0	0	0	0	1	13	0	0	0	0	0
WSDOT 23	2	2	0	0	8	0	0	0	45	0	86	0	0	61	0	0
WSDOT 24	4	0	4	0	0	0	0	0	0	0	3	0	0	0	0	0
WSDOT 25	1	4	2	0	36	0	0	0	0	0	8	0	0	0	0	0
WSDOT 26	1	6	3	0	0	0	0	0	0	0	61	0	0	0	0	0
WSDOT 27	8	10	3	0	1	0	0	0	0	1	6	0	0	0	0	0
WSDOT 28	45	7	4	0	36	0	0	3	0	0	3	0	0	0	0	3
WSDOT 29	10	17	1	0	1	0	0	0	0	0	127	0	0	0	0	0
WSDOT 30	37	23	2	0	6	0	0	4	0	0	2	0	0	0	0	0

Appendix B. Linear models using all deer (white-tailed and mule deer) combined to evaluate factors that influence abundance of deer-vehicle collisions (as represented by new carcasses on the road April 2017 – October 2017). The most parsimonious model provided evidence that abundance of deer-vehicle collisions was predicted best by $e^{(0.02397 + 0.09338 \text{*predicted deer abundance} + 0.00008011 \text{*minimum sight distance(ft)} - 0.00001301 \text{*minimum sight distance(ft)*predicted deer abundance} + 0.05816 \text{*max slope within 60 m (degrees)})}$. *k* = number of parameters, AICc = Akaike's Information Criterion, ΔAICc = difference in AICc between model and the most parsimonious model, AICc weight = relative model weight according to AICc (Burnham and Andeson 2002).

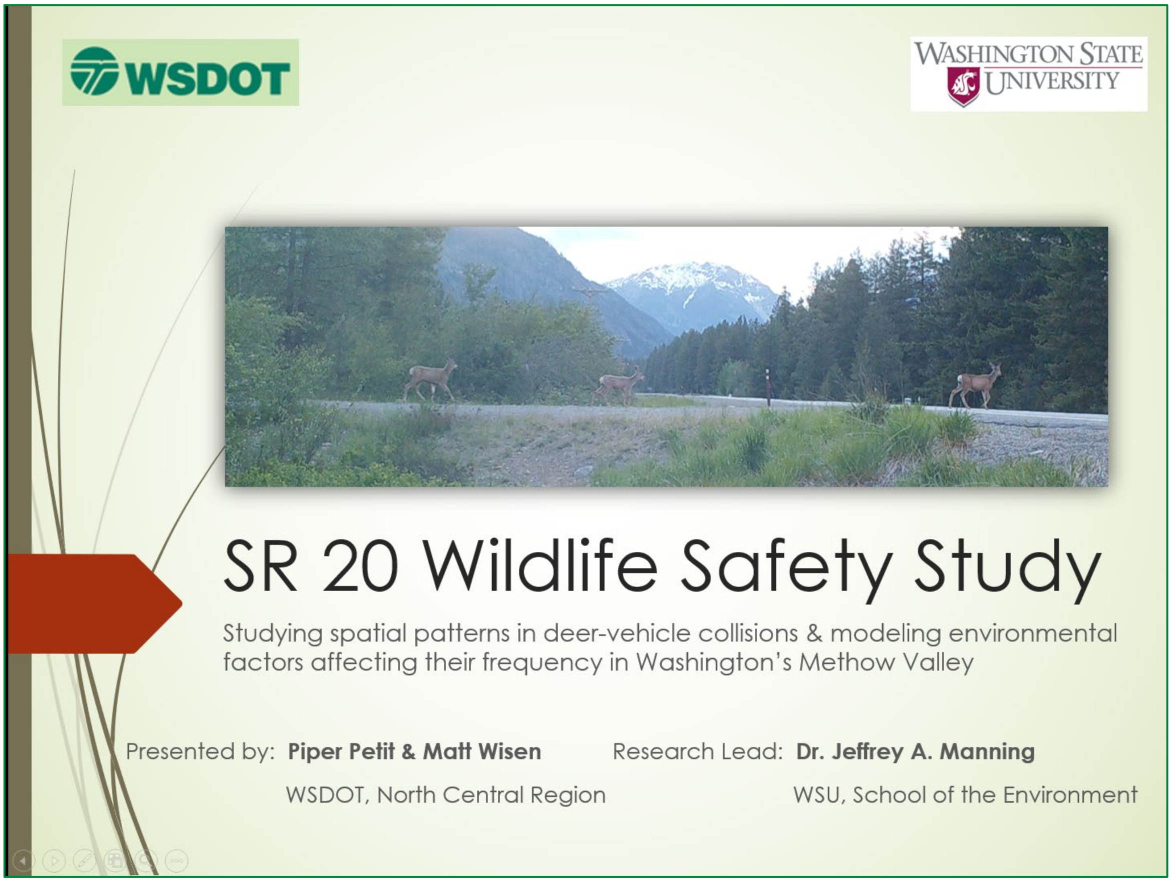
Model (predictors)	*k*	AICc	ΔAICc	AICc weight
Predicted deer abundance + minimum sight distance + predicted deer abundance*minimum sight distance + maximum slope within 60 m	5	162.7	0.00	0.33
Predicted deer abundance + maximum slope within 60 m	3	162.9	0.18	0.30
Predicted deer abundance + minimum sight distance + predicted deer abundance*minimum sight distance + maximum slope within 60 m + distance to building	6	164.5	1.77	0.13
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance	4	165.8	3.14	0.07
Minimum sight distance	2	165.9	3.27	0.06
Predicted deer abundance + minimum sight distance + predicted deer abundance*minimum sight distance + distance to building	4	167.4	4.47	0.03
Predicted deer abundance	2	167.4	4.71	0.03
Predicted deer abundance + minimum sight distance	3	168.2	5.54	0.02
Predicted deer abundance + distance to building	3	168.2	5.56	0.02

Appendix C. Posters and presentations presented at the Washington/Oregon Chapters of The Wildlife Society, Undergraduate Research Symposium at WSU Pullman Campus, and Mule Deer Summit at the Okanogan Trails Chapter of the Mule Deer Foundation.





Appendix C (continued)



Appendix D. This appendix was added to address post-report inquiries by Kaitlyn Maise, WSDOT. It summarizes a post hoc analysis to assess (1) the importance of deer abundance on deer-vehicle collisions and (2) the relative importance of various landscape factors as predictors of deer abundance. We included deer abundance in our original models of deer-vehicle collisions in Table 2 of the report because we presumed that the deer-vehicle collision process was a deer density-dependent process.

To assess the importance of deer abundance on deer-vehicle collisions, we expanded on the existing linear models and model selection procedures used in Table 2 of the report by adding 4 models to test for the importance of deer abundance on deer-vehicle collisions (Table D.1). In doing so, we tested for singular, additive, and interactive effects of deer abundance relative to the other factors listed. As in the original analysis, we found reasonable support (most parsimonious model with ΔAICc = 0 and AICc weight = 0.59, with next best model having ΔAICc > 2.0) for an interactive effect of deer abundance and minimum sight distance with an additive effect of maximum slope (Table D.1). The inclusion of the additional 4 models helped verify the importance of abundance, which had been included in our original analyses (Table 2).

To assess the relative importance of various landscape factors on deer abundance, we considered the same landscape metrics used in our initial analysis of frequency of deer crossings (Table 1) as predictors of deer abundance (Table D.2). We used the same linear modeling and model selection procedures used in the report. Two nested models emerged as competing, one with distance to open south-facing slope and the other with additive effects of distance to open south facing slope and distance to linear water feature (Table D.2). Based on the principle of parsimony and weight of evidence, we considered the simpler model with the effect of distance to open south facing slope as the most parsimonious of the two models (ΔAICc = 0.65). In other words, there was little evidence that the addition of distance to linear water feature to this model helped improve the fit of the model to the data. The lack of importance of agriculture was surprising, but may be explained by the fact that the preponderance of data obtained and used here were from mule deer, which are generally considered browsers that forage on herbaceous and woody shrub vegetation relatively more than white-tailed deer, which are viewed more as grazers (Lyons et al. 2012). This may be further explained by habitat segregation between these two species, with mule deer being more typically distributed on surrounding slopes where they are more effective at evading predators compared to white-tailed deer in more gentle terrain (Lingle 2001, Lingle and Wilson 2001, Lingle 2002) where agriculture typically occurs.

Literature Cited

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Lingle, S. 2002. Coyote predation and habitat segregation of white-tailed and mule deer. Ecology 2037-2048.

Lyons, R.K., T.D.A. Forbs, and R. Machen. 2012. What range herbivores eat – and why. Texas Agricultural Extension Service, Texas A&M University System, College Station. Report B-

6037. Available at: http://animalscience.tamu.edu/wp-content/uploads/sites/14/2012/04/B6037-rangeherbivores.pdf.

Table D.1. Linear models of deer-vehicle collision abundances (as represented by new carcasses on the road April 2017 – October 2017) between mile posts 176-201 of SR 20 in the Methow Valley, Washington, April – October 2017. This adds 4 models to Table 2 in the main report, to perform a post hoc analysis of the importance of deer abundance on the abundance of deer-vehicle collisions. See text for descriptions of predictors listed under model column. *k* = number of parameters, AICc = small sample corrected Akaike's Information Criterion, ΔAICc = difference in AICc between model and the most parsimonious model, AICc weight = relative model weight according to AICc.

Model (predictors)	*k*	AICc	ΔAICc	AICc weight
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance + maximum slope within 60 m	5	155.7	0.00	0.59
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance + maximum slope within 60 m + distance to building	6	158.0	2.3	0.19
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance	4	159.7	3.91	0.08
Predicted mule deer abundance + maximum slope within 60 m	3	161.1	5.33	0.04
Predicted mule deer abundance + minimum sight distance + predicted mule deer abundance*minimum sight distance + distance to building	4	161.6	5.88	0.03
Minimum sight distance + maximum slope within 60 m	3	162.8	7.01	0.02
Minimum sight distance + maximum slope within 60 m + distance to building	4	163.2	7.43	0.01
Predicted mule deer abundance + minimum sight distance + maximum slope within 60 m + distance to building	5	163.7	7.92	0.01
Predicted mule deer abundance + minimum sight distance	3	165.4	9.64	0.01
Predicted mule deer abundance	2	165.5	9.78	0.00
Minimum sight distance + distance to building	3	165.9	10.14	0.00
Minimum sight distance	2	165.9	10.21	0.00
Predicted mule deer abundance + distance to building	3	166.9	11.11	0.00

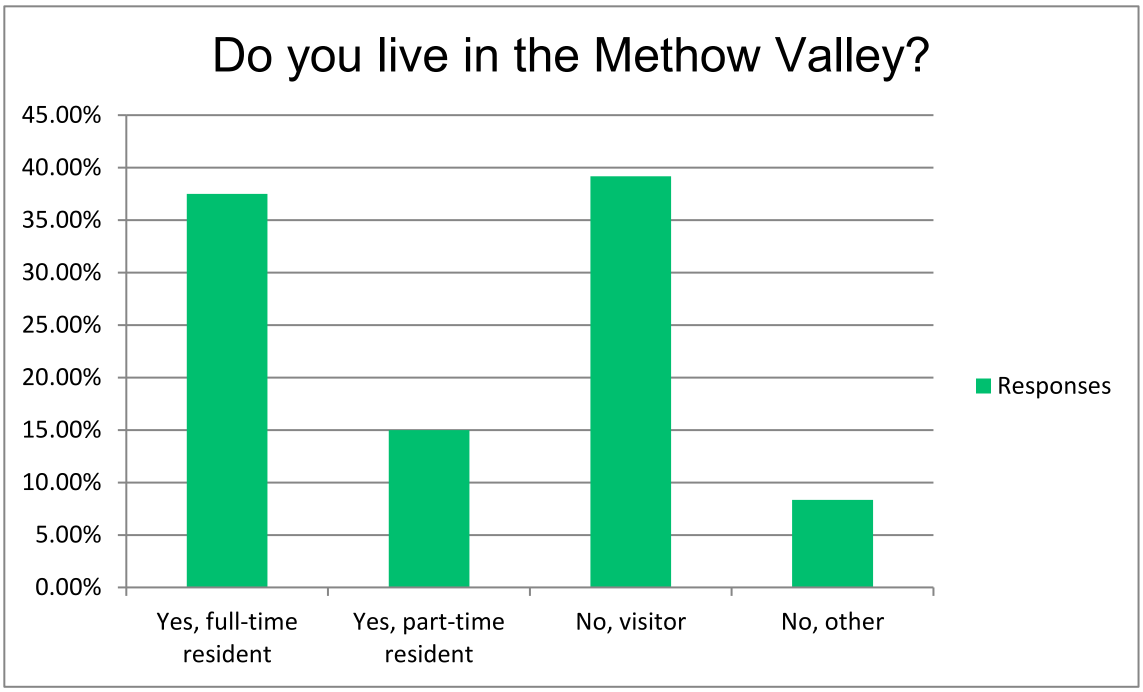
Table D.2. Linear models of estimated deer abundance between mile posts 176-201 of SR 20 in the Methow Valley, Washington, April-October 2017 and 2018. See text for details and descriptions of predictors listed under model column. *k* = number of parameters, AICc = small sample corrected Akaike's Information Criterion, ΔAICc = difference in AICc between model and the most parsimonious model, AICc weight = relative model weight according to AICc.

Model (predictors)	*k*	AICc	ΔAICc	AICc weight
Distance to open south-facing slope	2	174.5	0	0.65
Distance to open south-facing slope + distance to linear water feature	3	176.2	1.66	0.29
Distance to forest + distance to building + distance to agriculture + distance to linear water feature + distance to open south-facing slope	6	179.9	5.38	0.05
Distance to linear water feature	2	206.3	31.77	0.00
Distance to nearest building + distance to linear water feature	3	206.8	32.53	0.00
Distance to agriculture + distance to linear water feature	3	207.0	32.53	0.00
Distance to nearest forest patch + distance to linear water feature	3	208.4	33.89	0.00
Distance to agriculture	2	209.6	35.07	0.00
Distance to forest	2	211.4	36.91	0.00
Distance to building	2	212.3	37.77	0.00

Appendix C. WSDOT Community Outreach 2019 Survey Questions & Results

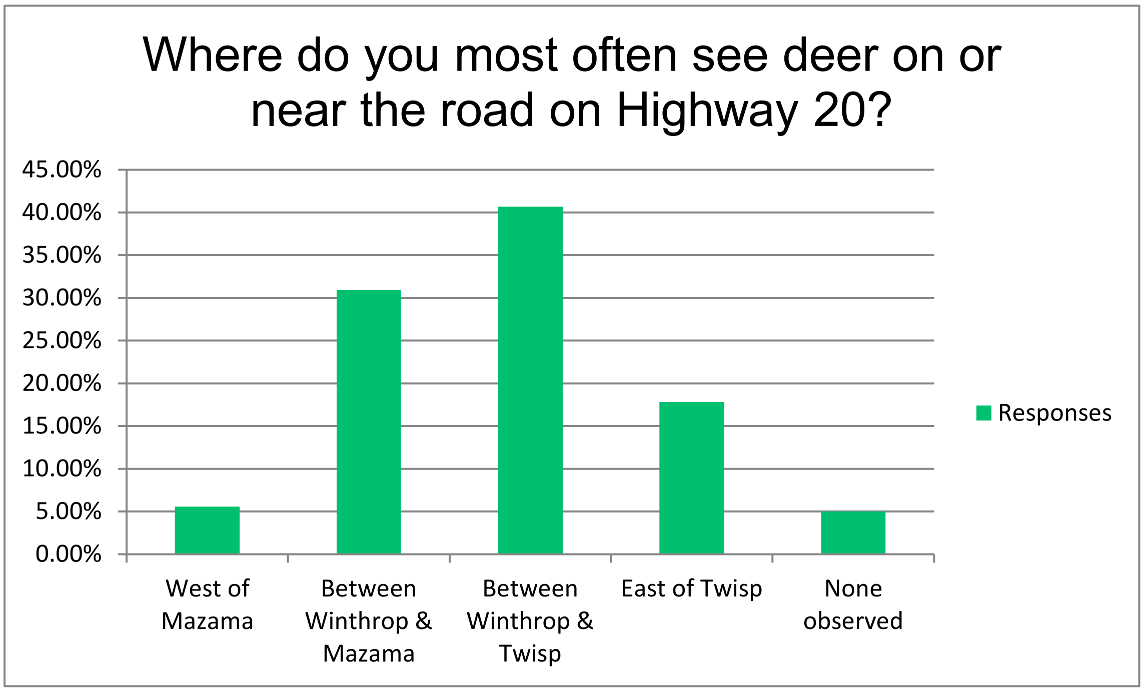
1.) Do you live in the Methow Valley?

Answer Choices	Responses	
Yes, full-time resident	37.50%	135
Yes, part-time resident	15.00%	54
No, visitor	39.17%	141
No, other	8.33%	30
	Answered	**360**
	Skipped	**2**



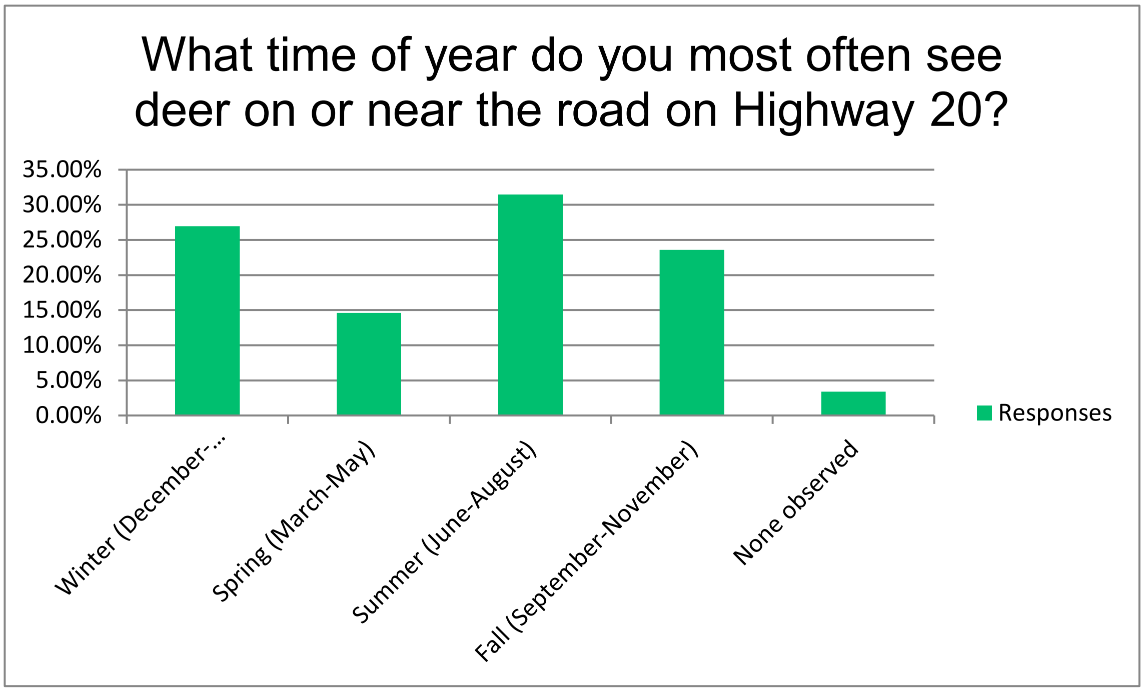
2.) Where do you most often see deer on or near the road on Highway 20?

Answer Choices	Responses	
West of Mazama	5.57%	20
Between Winthrop & Mazam	30.92%	111
Between Winthrop & Twisp	40.67%	146
East of Twisp	17.83%	64
None observed	5.01%	18
	Answered	**359**
	Skipped	**3**



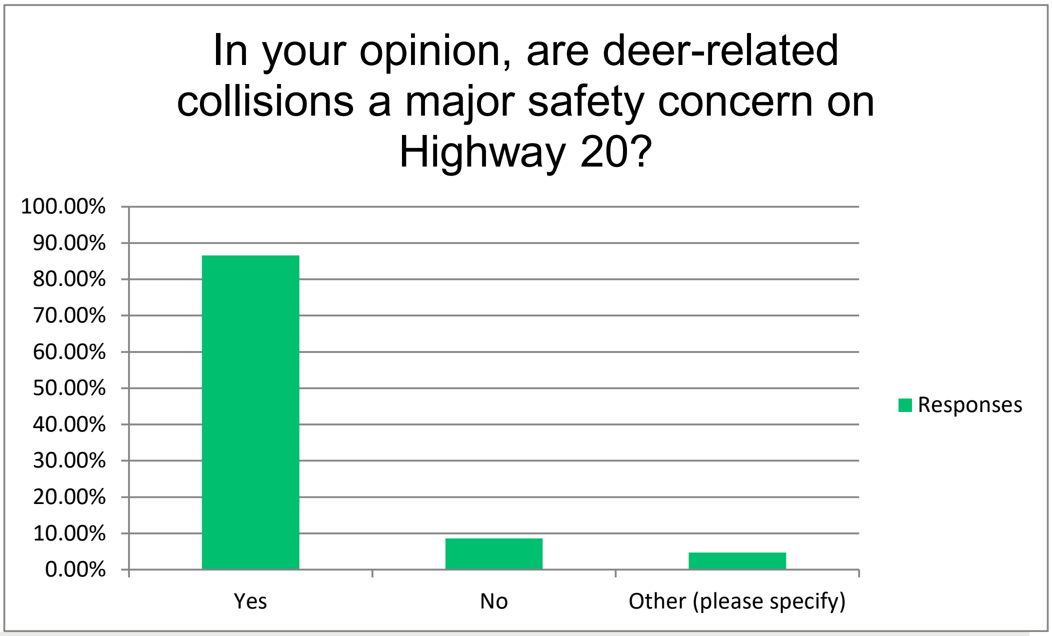
3.) What time of year do you most often see deer on or near the road on Highway 20?

Answer Choices	Responses	
Winter (December-February)	26.97%	96
Spring (March-May)	14.61%	52
Summer (June-August)	31.46%	112
Fall (September-November)	23.60%	84
None observed	3.37%	12
	Answered	**356**
	Skipped	**6**



4.) In your opinion, are deer-related collisions a major safety concern on Highway 20?

Answer Choices	Responses	
Yes	86.63%	311
No	8.64%	31
Other (please specify)	4.74%	17
	Answered	**359**
	Skipped	**3**



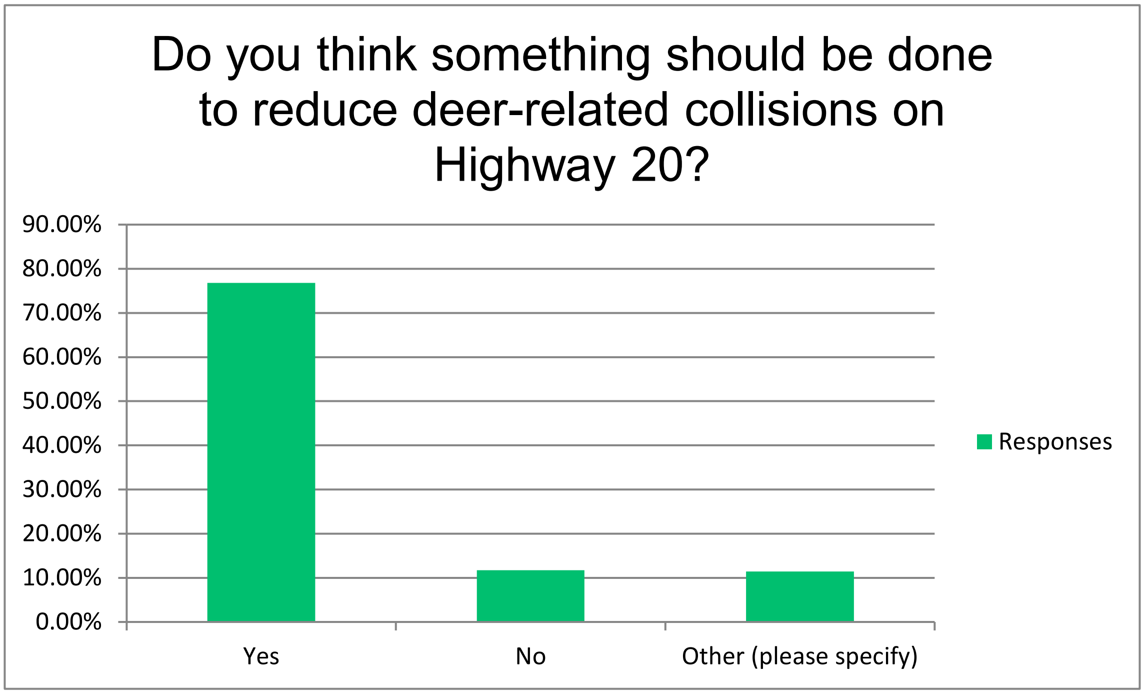
Respondents	Response Date	Other (please specify)
1	Mar 01 2019 06:38 AM	In question 3 I chose a season only because all year round wasn't an option.
2	Feb 27 2019 08:10 PM	Only when I drive e too fast. When deer are active, I know it and must remind myself to abide by the recommended 45mph.
3	Feb 27 2019 03:06 PM	Everyone tells me they are, but I haven't personally witnessed it.
4	Feb 27 2019 01:49 PM	Used to be but with decline of deer herd in Methow valley no longer a great concern
5	Feb 27 2019 11:48 AM	For me it is not a safety concern because all my vehicals would handle a deer strike with out damage but for most people I can see it being a issue
6	Feb 10 2019 03:02 PM	Not sure, only drove through the valley once

	7	Feb 09 2019 07:43 AM	I've lived full time in the Methow Valley for 46 years. The lower valley, Hwy 153 seems to see more deer than Hwy 20. Your survey model is flawed for not consider this.
	8	Feb 07 2019 08:55 AM	These questions already don't accurately show where the deer population is. Must be a stupid uneducated hack at WSU that wrote this survey. Question 2 I observe deer between mostly between pateros and mazama. Also between Twisp and Okanogan. Also up Twisp river up the chewuch and every access road we have available in the Methow. Question three. I see a deer almost every morning when I walk out my house. Really WSU....???? Wow this university is fucking stupid. Number 4 no stupid college hacks from WSU are more of a consent to me and I should know I went to WSU biggest regrets of my life WSU is a peice of federal shit
	9	Feb 07 2019 07:50 AM	Yes a concern, maybe not “major”.
	10	Feb 06 2019 11:45 PM	Yes if you ride a motorcycle
	11	Feb 06 2019 07:22 PM	The problem area is Highway 97 near Crumbacher, fix that problem.
	12	Feb 06 2019 07:16 PM	i don't live anywhere near there.. i live in Seattle.. and it asked me to take this survey.. why does this survey talk so much about highway 20?? I-90 i go every week to spokane and never encountered any deer.
	13	Feb 06 2019 01:35 PM	Undecided, any collision is a safety concern but aside from motorcycles most vehicles do a great job of protecting passengers in a deer collision. Also after most deer collisions the vehicle can still drive.
	14	Feb 06 2019 09:08 AM	Yes, it's a concern for the area. It's especially an issue for motorcyclists. People tend not to obey the 45 mph at night cuation signs from the top of the pass through Winthrop.
	15	Feb 06 2019 08:33 AM	Depends on your attentiveness to the surroundings.

16	Feb 06 2019 12:16 AM	Opinion means nothing, statements about safety concerns should be based on measurable factors that can be tracked over time.
17	Feb 04 2019 09:09 AM	not sure

5.) Do you think something should be done to reduce deer-related collisions on Highway 20?

Answer Choices	Responses	
Yes	76.82%	275
No	11.73%	42
Other (please specify)	11.45%	41
	Answered	**358**
	Skipped	**4**



Respondents	Response Date	Other (please specify)
1	Mar 01 2019 06:38 AM	If possible.
2	Feb 28 2019 08:10 PM	Any way of discouraging deer from the highway would be good, but driver attention most significant element.
3	Feb 27 2019 03:06 PM	I appreciate the signage on Hwy 20 warning people to slow down
4	Feb 27 2019 11:48 AM	I don't think there is much you could do other then high fence the road sides and do animal over passes
5	Feb 27 2019 08:50 AM	You can’t train deer to use a crosswalk and you can’t rely on drivers to pay attention and use caution
6	Feb 21 2019 07:01 AM	Not sure. It definitely is a water path.

7	Feb 17 2019 09:41 PM	Kepp well intentioned people like those in Twisp that have large feeding sites for deer in town next to the highway to stop feeding as this causes multiple deer with no fear of humans to move back and forth across the highway at low light times near the grocery store on the soith side of town. Possible solition is the game dept re-establishing winter feeding as they did after the 95 winter esp with concerns over winter deer mortality
8	Feb 12 2019 03:39 PM	tell folks toslow down, no cure for dumb.
9	Feb 11 2019 07:38 PM	Have people drive slower
10	Feb 11 2019 06:47 PM	Not sure what could be done.
11	Feb 10 2019 03:02 PM	Not sure, only drove through the valley once
12	Feb 09 2019 07:43 AM	This issue is mostly night time related. More reflective warning signs need to be placed. Better yet, a night time speed limit of 45 MPH would really reduce collisions. That's the speed I've been driving for decades in the evening and has resulted in no collisions.
13	Feb 08 2019 11:16 AM	This is Traditional Territory of the Colville Tribes and they should be hunting them and removing them
14	Feb 07 2019 01:14 PM	Not sure much can be done. The deer were there first and the herd has been dramatically reduced since modern settlement
15	Feb 07 2019 11:20 AM	Not sure. Depends on what the solution might be
16	Feb 07 2019 08:55 AM	Don’t drive like an idiot from wsu
17	Feb 07 2019 08:43 AM	People should drive slower
18	Feb 07 2019 07:41 AM	Yes, but I don't want large scale fencing everywhere.

	19	Feb 07 2019 07:35 AM	Initially I said yes until I saw your suggestions below. Most are unrealistic for our very rural area. We don't want high fences along the road or over/under passes. The issue should not be about allow or not allowing deer to move - the issue is about educating people, mostly people who don't live here, to slow the F down, especially during certain times of the day, and at certain places that are known "deer areas." Deer are on the valley floor more in the winter, but there are more cars on the road in the summer and a lot of them are visitors that aren't thinking about deer at all. There are numerous public education things that could be done before you do something expensive and invasive such as several of the items listed below.
	20	Feb 07 2019 07:27 AM	Train the deer to use the deer crossing signs
	21	Feb 07 2019 06:16 AM	Depends on the cost of intervention
	22	Feb 06 2019 11:34 PM	Constructing wildlife crossing areas (overpasses or underpasses) designed specifically for wildlife and in conjunction with their migration patters would be safer for everyone!
	23	Feb 06 2019 08:50 PM	Drivers exercise more caution would be more effective
	24	Feb 06 2019 08:32 PM	It's hard to manage wild animals without tall fences
	25	Feb 06 2019 08:27 PM	Slow down in some areas
	26	Feb 06 2019 07:22 PM	Sure, if you are talking about the problem area near Wauconda.
	27	Feb 06 2019 07:16 PM	no idea
	28	Feb 06 2019 06:50 PM	How about using studded tires when it is icy? Oh wait, those are going to be illegal. Unsafe, but classic Washington hypocrisy.
	29	Feb 06 2019 06:48 PM	Yes, by increasing the deer hunting season, increasing bag limits and doe tags, overall reducing the deer population through legal hunting.
	30	Feb 06 2019 06:39 PM	Repair deer fences

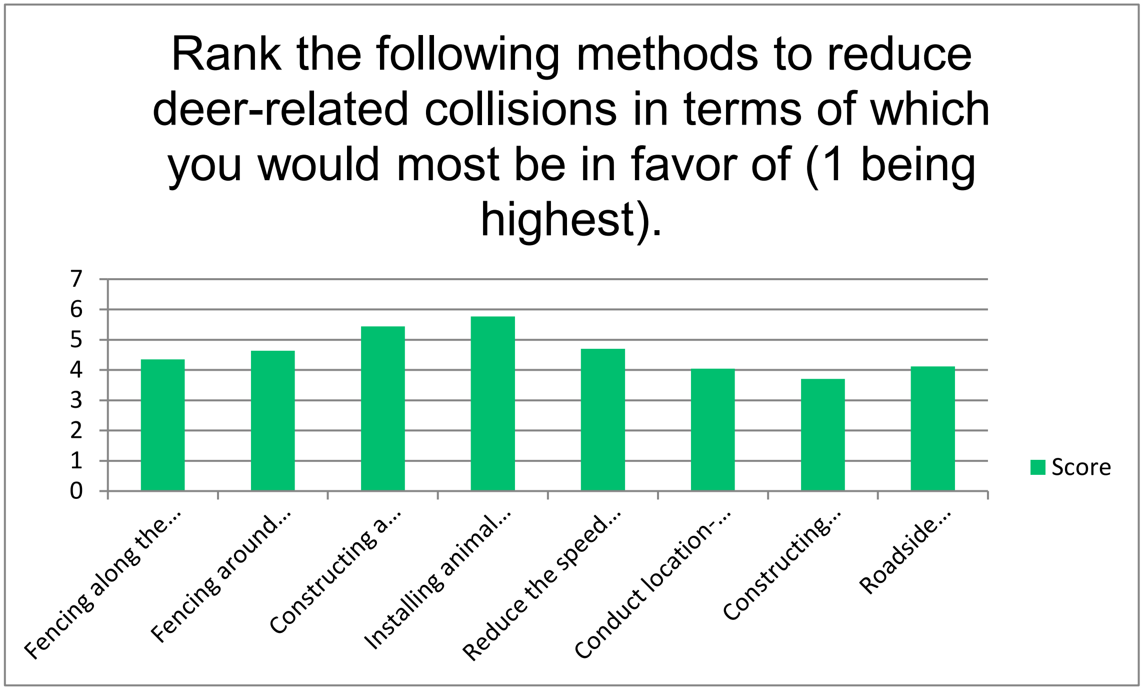
31	Feb 06 2019 05:15 PM	It seems most of the time it is possible to avoid hitting the deer if you remain observant and patient. Most of the collisions seem to be driver error
32	Feb 06 2019 04:48 PM	Not sure what can be done. I slow down at night
33	Feb 06 2019 02:20 PM	Predator control cause the deer get pushed down
34	Feb 06 2019 12:31 PM	if possible
35	Feb 06 2019 09:08 AM	Potentially, but I'm not sure how you could do this year-round. There is too much snow in the winter to make culvert crossings effective, and bridges would hurt the landscape. I think education would he the next option. Locals are aware of the dangers, but tourists passing through aren't as aware.
36	Feb 06 2019 08:53 AM	People simply need to slow down and be watchful
37	Feb 06 2019 08:52 AM	We live in the country, so drivers need to slow down
38	Feb 06 2019 08:33 AM	I would believe those that respond who live there should have their input count more than mine
39	Feb 06 2019 08:32 AM	Not sure
40	Feb 06 2019 12:16 AM	This is a subjective and uninformative question. Did you have any help from an professional human dimensions specialist when this survey was created?
41	Feb 05 2019 08:02 PM	deer whistles work !

6.) Rank the following methods to reduce deer-related collisions in terms of which you would most be in favor of (1 being highest).

	1		2		3		4		5		6		7		8		Total	Score
Fencing along the highway to exclude deer from the road	15.1%	44	11.30%	33	15.4%	45	7.2%	21	8.6%	25	8.9%	26	12.3%	36	21.2%	62	292	4.35
Fencing around specific crops that may attract deer across the highway	8.5%	25	14.24%	42	12.2%	36	17.6%	52	15.3%	45	14.9%	44	11.9%	35	5.4%	16	295	4.64
Constructing a wildlife overcrossing/ undercrossing	33.6%	105	10.22%	32	16.0%	50	6.7%	21	5.8%	18	8.6%	27	6.4%	20	12.8%	40	313	5.44
Installing animal detection/warnin g system (flashing beacons when animals are near the road)	18.7%	58	26.37%	82	13.2%	41	19.6%	61	10.6%	33	4.2%	13	3.5%	11	3.9%	12	311	5.77

Reduce the speed limit during the hours around dusk & dawn	14.8%	46	15.43%	48	11.9%	37	5.8%	18	20.3%	63	10.3%	32	10.0%	31	11.6%	36	311	4.7
Conduct location-specific deer population monitoring and/or control	3.6%	11	9.18%	28	12.1%	37	16.7%	51	11.5%	35	26.2%	80	9.5%	29	11.2%	34	305	4.04
Constructing alternative water sources on the side opposite the river	4.9%	15	9.54%	29	8.9%	27	10.9%	33	12.2%	37	10.9%	33	32.2%	98	10.5%	32	304	3.7
Roadside vegetation management	11.4%	36	7.91%	25	12.3%	39	13.6%	43	12.7%	40	11.1%	35	8.9%	28	22.2%	70	316	4.12

Answered	**352**
Skipped	**10**


Rank the following methods to reduce deer-related collisions in terms of which you would most be in favor of (1 being highest).
7
6
5
4
3
2
1
0
Fencing along the...
Fencing around...
Constructing a...
Installing animal...
Reduce the speed...
Conduct location-...
Constructing...
Roadside...
Score

7.) General comments:

Answered **165**
Skipped **197**

Respondents	Response Date	Responses
1	Mar 02 2019 05:47 PM	Reduce the speed limit and patrol for speeders. Its cheap and drivers will be paying attention because they are more scared of getting a ticket than wrecking their vehicles.
2	Mar 02 2019 08:28 AM	Most deer/car crashes are preventable through safer driving. I realize there are exceptions. Deer/car collisions should cost insurance points. (I just heard from a guy who hit his 4th deer in 4 years. One might be unavoidable, but four should have insurance and driving penalties. Meanwhile - if you hit one you aren't driving to the conditions.
3	Mar 01 2019 07:21 PM	You don’t have to spend $millions to begin getting results
4	Mar 01 2019 06:38 AM	Deer are often along the side of the road without crossing, so flashing lights would be like crying wolf. The speed limit is reduced enough, and people often drive 45-50 mph in the daylight on the 60 mph highway. Don’t make it worse! Over or underpasses cost too much money, and there are more important things. Plus, there are Hot Spots: a 2 mile stretch just west of Winthrop going towards Mazama; between Carlton and Twisp by Benson Creek; between Lower Beaver Creek and Hwy. 153 on the Loup, and the town limits of Winthrop and Twisp. I live in Mazama, work in Okanogan.
5	Feb 28 2019 09:15 PM	We have hit a deer on this highway. We have family that resides in Twisp, so we travel this highway 10+ times per year. I would suggest simply placing more LIGHT UP and FLASHING signs warning about deer crossing, and to slow down in the area.

6	Feb 28 2019 08:10 PM	There is no replacing driver attentiveness in this issue.
7	Feb 28 2019 07:57 PM	We usually fawns separated from mothers.
8	Feb 28 2019 02:35 PM	none
9	Feb 27 2019 11:37 PM	Go cougs
10	Feb 27 2019 08:10 PM	Keep the road free range. Warning lights, when used properly, are very effective. Fences will adversely affect asthetics and deer migration. Cattle should be fenced before deer!
11	Feb 27 2019 07:21 PM	.
12	Feb 27 2019 06:29 PM	Heavy spots for deer- field across from twin lakes road turn off...it's also the turn to the schools....the straight stretch of road by the river as you're leaving Winthrop to go to Mazama..
13	Feb 27 2019 05:51 PM	Wildlife crossings
14	Feb 27 2019 04:49 PM	Please do something to help deer.
15	Feb 27 2019 03:39 PM	The major area is by the sheep ranch and the steep south facing hillside
16	Feb 27 2019 03:06 PM	I ride my bicycle over Hwy 20 much more than I drive a car. I've seen a few dead animals so I know the threat is real. I've just never seen them moving...
17	Feb 27 2019 02:12 PM	Thank you for studying this!!
18	Feb 27 2019 01:49 PM	None
19	Feb 27 2019 01:27 PM	Thanks for working to keep us safer!
20	Feb 27 2019 11:48 AM	I don't think reducing the deer population would be a good thing, it is a big hunting area in this state and hunting brings in revenue.
21	Feb 27 2019 11:37 AM	In Alaska, fencing has reduced moose and motor vehicle collisions pretty dramatically. Fencing must be accompanied by passages under the roadway to allow wildlife to cross.
22	Feb 27 2019 11:00 AM	High deer population, thankful that WSDOT is taking time to find a solution for a growing problem.
23	Feb 27 2019 10:34 AM	I hit a mule deer many years back outside Winthrop, they can get in front you and come out of no where
24	Feb 27 2019 10:11 AM	We should study and probably implement animal habitat bridges

25	Feb 27 2019 09:11 AM	I visit the methow valley for a least week every summer and think that the beauty of the area is how humans and nature are connected in the area. I would like to reduce the amount of fatal accidents to both people and the deer, with the least amount of environmental impact. I think large fences would be unnecessary and ugly to the highway. Incentivizing the deer to congregate elsewhere with other water and food sources is an interesting idea I feel could work.
26	Feb 27 2019 08:43 AM	Put in a wildlife crossing instead of miles of fence and more signs
27	Feb 27 2019 08:29 AM	Dont change the scenery
28	Feb 27 2019 08:18 AM	People driving way above the speed limits would be the biggest problem
29	Feb 27 2019 07:42 AM	What ever is going to cost the least!!
30	Feb 27 2019 07:28 AM	Have seen most deer/car collisions right outside of Winthrop
31	Feb 25 2019 07:50 PM	It's important to keep in mind that many deer use the fields as forage due to the lack of winter range available in the Methow Valley. Fencing crops may not deter deer using smell and sight to find sources of food, until they reach the fence and begin to look for other nearby sources of forage.
32	Feb 23 2019 12:39 PM	I hit a deer between Twisp and Carlton 12 years ago and totaled my SUV on a dark October night.
33	Feb 21 2019 11:04 AM	This is such a broad issue I don't think any one solutions exists. The question of where do I see the most deer and when is too specific. I see deer everywhere and at al times of year. Mule deer migrate and addressing only one area will not be enough. Speed limits help but I've hit deer at 25 and 65 mph, and everywhere in between. Resident herds in the Twin Lakes and rendezvous areas could and should be addressed as they are the biggest issue I see.

34	Feb 21 2019 07:01 AM	I am answering this without educated knowledge or facts to make the right decisions. I hate to see the deer stopped from making their migration to water just because we want to drive fast on the HWY. I also don't know whether farmers would rather have fencing around their crops or if that affects how they have to cut their hay, etc. too many factors to make an educated answer for the ordinary person. I live full time here and drive that road all the time and know that I should go slow to avoid deer. I suppose its visitors that need education on how to pass through wildlife corridors.
35	Feb 20 2019 09:03 PM	The straw bales for the sheep just west of Winthrop definitely attract a lot of deer and there are a lot of collisions there. Even where the road isn’t next to the river, deer cross back and forth.
36	Feb 18 2019 04:31 PM	Deer feeding by residents (intentionally or unintentionally) is also a contributor
37	Feb 18 2019 08:59 AM	make deer whistles mandatory accessories
38	Feb 17 2019 09:41 PM	My #s 4 through 7 are totally unrealistic and a waste of taxpayer money. Winter range management to pull deer away from populations, winter feeding and educating people esp in towns like twisp that feeding in town on the Hwy just creates more proplems
39	Feb 15 2019 03:36 PM	Question #3...all year long it is the same...no specific time. And they will go to the river no matter what..
40	Feb 14 2019 01:35 PM	reducing the speed limit is a no brainer, and least costly
41	Feb 12 2019 09:42 PM	I think people need to slow done and pay attention. If you travel the area frequently you generally know the high deer areas.
42	Feb 12 2019 03:39 PM	Bad survey, multiple answers for most questions
43	Feb 12 2019 01:26 PM	Something needs to be done with flexibility for long term effectiveness
44	Feb 12 2019 12:33 PM	Speeding is aproblem
45	Feb 12 2019 12:08 PM	People need to slow down/drive defensively
46	Feb 12 2019 07:28 AM	I’m not going to rank the options as I have no way to assess effectiveness vs costs

47	Feb 12 2019 06:50 AM	This is a joke, right? If not, it's the most ridiculous study I have ever heard of. Controlling deer migration??? Akin to traffic lanes in the ocean for fish. What a total waste of time and tax payer money. Someone should loose their job over this. Yes, you may call me mad as hell in the Methow Valley!
48	Feb 12 2019 05:07 AM	Slow down the speeders!!!!!!!!!!!!!!!!!!!!!!
49	Feb 11 2019 10:13 PM	reduce night time speeds in the whole valley, clean barrow ditches of vegitation
50	Feb 11 2019 10:01 PM	The deer are a major problem! In fact they are almost MORE of a problem on highway 153 between Carlton and Twisp.
51	Feb 11 2019 08:38 PM	Usually the simplest solution is the most effective and the most cost efficient.
52	Feb 11 2019 08:37 PM	The problem is less about the deer grazing next to the road, they're crossing it to get from one forage area to another.
53	Feb 11 2019 07:47 PM	I don't know what the best solution is but I'm sure there are examples that have worked well elsewhere.
54	Feb 11 2019 07:38 PM	I think most of those ideas are ridiculous, given the length of the highway, the number of deer and that they just live & wander around here. Clearing roadsides so the deer can be noticed further away seems the most reasonable.
55	Feb 11 2019 07:35 PM	Any of your reasons that we had to rank are not the cause of the problem. Example many homes right near the hwy south of Twisp feed the deer. This causes mass deer during winter to group on roads.
56	Feb 11 2019 07:04 PM	Need mandatory 45 miles per hour between Dusk and Dawn. Not the recommended 45 mile per hour yellow speed limit signs that we currently have.
57	Feb 11 2019 06:32 PM	I see more deer on east side road
58	Feb 11 2019 06:01 PM	There’s already slower speed signs posted, perhaps tickets to drivers who ignore slower signs? Many times, as we are slowed down according to the signs we have other drivers passing us at much faster than the daytime speeds.
59	Feb 11 2019 05:59 PM	N/a

60	Feb 11 2019 05:53 PM	This is the wilderness, people need to drive more slowly especially at times of the year and day when deer are on the move. Constructing barriers to their movement is potentially devastating to their survival and our ecosystem. I am not in favor of anything that impedes their natural movement. I am possibly in favor of something that facilitates their access to water by an under or overpass.
61	Feb 10 2019 03:02 PM	I had a deer collision, not in this valley, not in WA. This should be taken seriously.
62	Feb 10 2019 11:15 AM	Fencing would limit the migration patterns of wildlife and should not be considered an option
63	Feb 09 2019 07:52 PM	no easy way. there does not seem to be an obvious single migration route
64	Feb 09 2019 07:50 PM	Widening roads might help for vision too
65	Feb 09 2019 07:10 PM	Most deer I see are in the middle of the day, not dusk/dawn.
66	Feb 09 2019 04:01 PM	Clearing vegetation and trees that are within 30 feet of the road
67	Feb 09 2019 07:43 AM	Few people will voluntarily slow down for night time driving. I know because they fly by me at night while I'm driving 45mph. To be successful, you need to make the evening speed limit mandatory.
68	Feb 08 2019 11:16 AM	The Colville Confederated Tribes should be consulted on this matter.
69	Feb 07 2019 10:55 PM	the multiple choice was buggy and wouldn't let me answer all the questions
70	Feb 07 2019 10:34 PM	Control coyotes and other predators that cause the deer to dash across the road to escape, only to run into oncoming traffic. Fencing is in place already and it doesn't help much.
71	Feb 07 2019 10:13 PM	Na
72	Feb 07 2019 09:37 PM	When the irrigation ditches were changed to piping and the ditches filled with dirt, then the deer had to go to the river for water and of course the hiway is beside the river.
73	Feb 07 2019 09:04 PM	People drive too fast and ignore the warning signs no matter what. The piping of the irrigation ditches has caused a significant increase in vehicle/deer collisions

74	Feb 07 2019 08:48 PM	I think the question asking where we see the most deer kill should not be limited to one area/answer as there are multiple “bad deer kill areas” which would vary according to specific travel route frequencies, as well as dependent on high tourism times in and out of the valley and routes availability/hwy closures.
75	Feb 07 2019 08:36 PM	Signs
76	Feb 07 2019 06:55 PM	Post a maximum speed of 45 between sunset and sunrise, and enforce it.
77	Feb 07 2019 02:53 PM	Have encountered deer many times.
78	Feb 07 2019 01:21 PM	I think dead deer are an important food source for wildlife especially in the winter. Deer are not the problem. Drivers are. Speed limit on SR 20 should be lowered to 50-55 from 60. More signage warning of deer, livestock and pedestrians/bycylists. Locals tend to drive slower \`cause they know\`.
79	Feb 07 2019 01:14 PM	I dont think any of those options will have any significant effect and most likely a huge waste of money. I also believe the options given will be detrimental to the herd and environment. People need to just not drive like idiots.
80	Feb 07 2019 12:02 PM	I feel like this survey isn't specific enough to be of much use in informing any management decisions.
81	Feb 07 2019 10:42 AM	More signs so out of towners are more aware
82	Feb 07 2019 10:09 AM	The best solutions will not probably require drivers to pay more attention. The current 45 mph evening speeds are ignored.
83	Feb 07 2019 09:48 AM	we know pretty well where deer crossings are as there are crossing signs and warnings put up by DOT, just need to establish safe and viable under/over passes. Expensive but so is repair work and medical bills

84	Feb 07 2019 09:00 AM	I am not in favor of deer fences in the Methow due to astetic reasons. I feel there are other options that can be taken to help the situation without negatively affecting the scenic quality of the Methow Valley. Deer are predictable in certain locations in the winter time, and measures could be taken in specific areas to hopefully reduce deer collisions.
85	Feb 07 2019 08:55 AM	Dumbest survey ever. Who ever wrote this should be ashamed. Best way to not hit a deer is to pay attention while driving. WSU is so stupid. Why is this piece of shot school trying to put restrictions in my valley? I wouldn't be so negative if the university would help with real problems like figuring out blight in the area which the school wouldn't even give me information on because I own a pot farm. Fuck wsu
86	Feb 07 2019 08:43 AM	No big projects that change the look of the Methow. Mostly people need to slow down and hope for the best.
87	Feb 07 2019 08:42 AM	Looking forward to the talk at the Mule Deer Summit!
88	Feb 07 2019 08:17 AM	I have hit 4 deer in 4 years of living in the Methow Valley. I put lower the speed limit as last because I already drive 45 at night on the highway. Regardless, I have still hit deer and it's still a problem not with the drivers, but with the plentiful amount of deer we have in the valley. I think installing fencing is the most plausible, budget friendly, and quickest way to manage the issue. Other things can be done as well, during and after.
89	Feb 07 2019 08:15 AM	I think the best solutions would involve managing human behavior. The deer population, particularly mule deer, suffer enough without being fenced out of food and water resources. Please don't do anything that would negatively impact our deer anymore than they already are.
90	Feb 07 2019 07:55 AM	Something has to be done.

91	Feb 07 2019 07:52 AM	Raising driver awareness vegetation management on the roadside as well as in town may help
92	Feb 07 2019 07:50 AM	I'm not sure anything can really be done, considering the length of road and quantity of deer.
93	Feb 07 2019 07:41 AM	I'm opposed to large scale fencing and population control as methods of control. The Methow is a rural area that's home to a ton of deer. Controls that are put into affect should focus on human behavior rather than changing deer behavior. Some fencing in farmers fields would be ok with me, but I don't want to see 10 foot tall fences all over the place from Pateros to Mazama. Plus I'm concerned that fencing would negatively impact deer migration patterns.
94	Feb 07 2019 07:35 AM	See my comments in #5. Thank you for trying to reduce the number of deer collisions.
95	Feb 07 2019 07:30 AM	Hunting laws need to be addressed as well. They do not seem to be in the best interest of the deer population but more for non-local residents to come spend money. The deer are starving and so are some of the locals.
96	Feb 07 2019 06:51 AM	I only visit in the summer and winter, so I'm not sure what spring and fall are like.
97	Feb 07 2019 06:16 AM	Additional signage might help as many drivers on SR20 are unfamiliar with the danger
98	Feb 07 2019 05:25 AM	What about including Heyv153 from Twisp to Pateros? I see a lot of deer in the lower Methow.
99	Feb 07 2019 04:33 AM	The 2 biggest factors are speed and the vegetation on the sides of the road.
100	Feb 07 2019 12:25 AM	I live in the okanogan valley. Deer always worry me.
101	Feb 07 2019 12:04 AM	Supporting a natural, native predator could help control deer populations. Wolf? Grizzly bear?

102	Feb 06 2019 11:46 PM	An over/undercross would be a waste of money. Deer cross anywhere and everywhere. The worst area is approx two miles west of Winthrop, I have almost hit deer every morning commuting to work. They cross at residents driveways. My opinion would be the worst area for deer is between Carlton and Twisp. I can't count how many of my family and friends have hit deer in that stretch. Please do not consider an under or over crossing. Our valley is fine the way it is, it would be a huge waste of taxpayers money. Proper roadside vegetation management would the best as it would allow us see the deer ahead of time instead of flying through thick tall grasses at the last minute.
103	Feb 06 2019 11:45 PM	None
104	Feb 06 2019 11:34 PM	I grew up in the Methow Valley and highly recommend that people drive slower and remain vigilant in areas where deer populations are high.
105	Feb 06 2019 11:04 PM	Corridors are the best option
106	Feb 06 2019 11:00 PM	Allow another hunting season for does
107	Feb 06 2019 10:49 PM	Speed limit too fast for such a winding 2 lane road.
108	Feb 06 2019 09:36 PM	Other countries construct wildlife underpasses and overpasses and they work remarkable well. Better for the deer, and better for the cars. It's a win-win.
109	Feb 06 2019 09:30 PM	Fencing, monitoring, alternative water sources are not effective methods for removing the animals from the road. Under/overpasses remove animals from the road.
110	Feb 06 2019 09:01 PM	None
111	Feb 06 2019 08:17 PM	None. People should slow down at night
112	Feb 06 2019 08:12 PM	The idea of putting up fencing tall enough to keep out deer along the road would certainly be a detriment to the Methow's main attraction of scenery in a tourist driven economy.

113	Feb 06 2019 08:04 PM	I travel over loup loup multiple times a week and see many deer near or on the road between tice ranch and upper beaver creek
114	Feb 06 2019 08:03 PM	not many deer now because of wolves and fires. I have not picked up road kill in 2 years now.
115	Feb 06 2019 07:55 PM	A dear hit my car while I was driving at 35mph in front of River Run Resort just outside of Winthrop.
116	Feb 06 2019 07:52 PM	Slow down and pay attention
117	Feb 06 2019 07:51 PM	Reducing speeds, educating drivers and a massive cull would all be great ideas
118	Feb 06 2019 07:25 PM	It would be beneficial to do this survey along hwy 395 in Spokane county between Colbert and Deer Pk. Deer and Moose are killed on this section of the hwy weekly
119	Feb 06 2019 07:23 PM	This is a rural community. Deer are part of our lives. Deer populations are struggling, and my perception is that deer collisions have decreased.
120	Feb 06 2019 07:22 PM	Fix the problem area on Highway 97, a year round transportation corridor, near Crumbacher and Riverside.
121	Feb 06 2019 07:07 PM	Reducing the speed of vehicles is key. Visitors unfamiliar with the area drive too fast for conditions.
122	Feb 06 2019 06:50 PM	I am excited for about 10 years from now when whatever you do will be fought by PETA as an unethical encroachment upon wildlife.
123	Feb 06 2019 06:48 PM	Deer are attracted to salt on the highway in the winter. Possibly providing farmers a financial incentive to place salt blocks away from the highway would help. Fish and wildlife has created an adverse environment for hunters by charging too much for permits and overregulating deer hunting to the point that many local hunters no longer hunt. Overpopulation is such a problem that hundreds of deer starve to death that could otherwise be humanely harvested by legal hunting.

124	Feb 06 2019 06:21 PM	I think the speed limit between Twisp & Winthrop should be 45. 60 is entirely too fast for as many deer as I have seen on that stretch of highway.
125	Feb 06 2019 05:58 PM	WSDOT should look at roadside reflector technology that helps to identify deer, or moose crossing at night on the Highway corridor.
126	Feb 06 2019 05:35 PM	Better to do this on 20 in the Okanogan Valley
127	Feb 06 2019 05:15 PM	I see deer in my travels year round but generally in the same areas. I've avoided several collisions just by paying attention.
128	Feb 06 2019 04:48 PM	In 13 yrs my family has hit at least 7 deer, totaled 2 cars
129	Feb 06 2019 04:44 PM	there are deer crossing hey 20 at all times of year and in all areas put forth in the survey
130	Feb 06 2019 04:39 PM	Make tourists more aware of the migration patterns or deer in the valley.
131	Feb 06 2019 04:37 PM	Deer and other wildlife are a major concern on HWY 20. The animal hazard combined with the road and the typical weather makes HWY 20 one of the most dangerous roads in the area.
132	Feb 06 2019 04:12 PM	The methods for control that I prefer are whichever methods have the best evidence of working well for road safety with minimal impacts for other wildlife.
133	Feb 06 2019 03:13 PM	No
134	Feb 06 2019 03:02 PM	Thank you for caring!
135	Feb 06 2019 02:43 PM	Really mazama to methow are where the deer are located
136	Feb 06 2019 02:20 PM	Predator control! The deer feel safer around highways and people
137	Feb 06 2019 01:52 PM	I live at 29.5 mile marker of hwy 153. There have been over 20 deer hit at my driveway in 2018 alone. In one spot!

138	Feb 06 2019 01:35 PM	The largest issue in this area is driver awareness and distractions. One of the magical draws to this area is the lack of fences and abundance of wildlife. Fences and flashing lights will kill the wild feeling of this area where so many of us go to experience nature. Signage showing cost of damage or days since deer kill to raise awareness could prove to be most productive. An observable method of keeping deer out of the way may raise speeds and do little to reduce collisions.
139	Feb 06 2019 01:15 PM	Human populations dictate animal populations
140	Feb 06 2019 01:05 PM	Wildlife crossings way above all the others.
141	Feb 06 2019 12:32 PM	A lot of deer collisions happen from speeding and not paying attention to surroundings while driving.
142	Feb 06 2019 12:31 PM	Cost benefit data needed for decisions
143	Feb 06 2019 11:52 AM	Over or under, many cities do this, why don't we care?
144	Feb 06 2019 11:51 AM	I have none.
145	Feb 06 2019 11:04 AM	Drivers need to be more educated as well. Locals aren't invincible, as we have all hit deer, but most of us are aware of usual crossing spots, and the diurnal/seasonal movement patterns. People not local to the area don't know these things and don't take the current warnings in place seriously. More than a few times I have slowed down for deer or was driving slow during "deer o'clock" only to have a driver pass me and either hit a deer or have a near miss. So I think maybe more of an education campaign based on being defensive and anticipating deer could be helpful too.
146	Feb 06 2019 10:39 AM	Thanks for the concern. Speeding is the main cause of deer collisions.
147	Feb 06 2019 10:39 AM	Put flashing lights on the deer collars
148	Feb 06 2019 10:39 AM	As my wife and I drive between Winthrop and Mazama, one of us is always the spotter and we always slow down along the river-edge area.
149	Feb 06 2019 10:06 AM	Continue with your good work
150	Feb 06 2019 09:47 AM	Really, the whole hwy from Lone Fir to Twisp is terrible

151	Feb 06 2019 09:21 AM	I’ve lived in Winthrop for my entire life. I Loup Loup daily for 27 years. The biggest problem I’ve observed is cars traveling too fast. In addition piping of irrigation ditches, specifically the Chewuch from Winthrop to Twisp on the East County Road has increased the number of deer crossing the high to reach the river. Fencing was tried many years ago. You can see the remains south Of Carlton along Hwy 20. As with the sheep fence between Wenatchee and Entiat, the sheep go around the fence and have been push down to Ohme Gardens and Stemilt Growers to cross for water. Nighttime speed limit should be 45 mph throughout the valley. Even then, vehicles won’t slow down. The increased number of tourists has negatively impacted the deer population. Try an ad campaign targeted to west-siders in addition to locals.
152	Feb 06 2019 09:21 AM	As you are no doubt aware, there's some flaw to your methodology. The areas where deer are most seen likely correspond to where the person lives. Also, I was unable to indicate that I see the most deer in Winter and Fall (tho there are PLENTY the rest of the year). Deer fencing is expensive and problematic, I sure hope you don't go that direction. But thank you overall for stopping to ask our opinion and I hope something can be done!
153	Feb 06 2019 09:14 AM	Question 3 should allow more answers.
154	Feb 06 2019 09:11 AM	Though I've hit a deer, they are a party of the wildlife if the methow valley, reduction in speed is probably the number one thing that will reduce car-deer incidents.
155	Feb 06 2019 09:08 AM	It's a complex issue in the area, but the moajority of the time I see deer crossing the road, it is for food, water, their night time bedding areas, or they are being chased by a predator. Some instances could be prevented, and other simply can't. I see more deer killed on side roads in the Methow than on 20.

156	Feb 06 2019 09:02 AM	As a motorcycle rider, deer are a major concern. I won't ride at dusk or after in mountainous areas.
157	Feb 06 2019 09:01 AM	Too many deer collisions in this area
158	Feb 06 2019 08:53 AM	I know what sections of road to slow down and watch for deer. The more infrequent visitor will need clues, plus a reduced speed in those sections.
159	Feb 06 2019 08:52 AM	Thank you.
160	Feb 06 2019 08:50 AM	Many close calls! I've actuall seen deer on roadway everywhere north of Carlton.
161	Feb 06 2019 08:31 AM	While I chose the area between Mazama and Winthrop as the area where I see the most deer, the area from Lone Fir Campground to Mazama is pretty terrible too.
162	Feb 06 2019 07:22 AM	Highest deer populations are along Highway 20 where there is private property. Trained response for animals is to stay where there is protection. Like it or not year round these animals stay in their protection zone, private property. Landowners love them, want to see them, have them around to watch. Problem is these animals stay very close to private safety nets. They become unmanaged by Washington Department Of Wildlife. They can't be harvested. Landowners need to be educated on importance of WDFW and harvest of some of these local animals. If animals were pushed off of the private property they would be less likely to remain year round in a comfort zone of private land and disburse into the thousands of public land available to them. Again trained response.
163	Feb 06 2019 12:16 AM	Does anyone at WSDOT or WDFW know this survey is being passed around or havre any opportunity to review and provide comment of the content and use of any information collected?

164	Feb 05 2019 08:02 PM	I've been struck by two deer in my years of driving. I have never had a collision since using deer whistles. Just by observation, they definitely get the deer's attention. They'll stop & listen thereby avoiding any collision.
165	Feb 05 2019 12:27 PM	None at this time

8.) How did you hear about this survey?

Answered **242**
Skipped **120**

Respondents	Response Date	Responses
1	Mar 02 2019 05:47 PM	Facebook
2	Mar 02 2019 08:28 AM	online
3	Mar 02 2019 07:56 AM	My son
4	Mar 01 2019 07:21 PM	Emailed to me
5	Mar 01 2019 06:38 AM	Friend
6	Feb 28 2019 09:15 PM	Facebook
7	Feb 28 2019 08:10 PM	Facebook
8	Feb 28 2019 07:57 PM	Facebook
9	Feb 28 2019 02:35 PM	wsdot website
10	Feb 28 2019 11:32 AM	Facebook
11	Feb 28 2019 07:30 AM	Facebook
12	Feb 28 2019 07:15 AM	Facebook
13	Feb 28 2019 06:23 AM	Facebook
14	Feb 28 2019 12:37 AM	Facebook
15	Feb 27 2019 11:37 PM	WSDOT Facebook
16	Feb 27 2019 11:33 PM	Facebook
17	Feb 27 2019 08:44 PM	Twitter
18	Feb 27 2019 08:10 PM	Facebook feed
19	Feb 27 2019 07:31 PM	Facebook
20	Feb 27 2019 07:21 PM	internet.
21	Feb 27 2019 06:29 PM	WSDOT facebok page
22	Feb 27 2019 05:51 PM	Facebook
23	Feb 27 2019 04:49 PM	WSDOT Facebook
24	Feb 27 2019 03:39 PM	WSDOT Facebook page
25	Feb 27 2019 03:06 PM	facebook
26	Feb 27 2019 02:12 PM	Facebook WDOT site.
27	Feb 27 2019 01:49 PM	Friend
28	Feb 27 2019 01:27 PM	Facebook
29	Feb 27 2019 12:13 PM	Facebook
30	Feb 27 2019 11:48 AM	I saw it on Facebook
31	Feb 27 2019 11:37 AM	Facebook
32	Feb 27 2019 11:06 AM	WSDOT twitter
33	Feb 27 2019 11:00 AM	Facebook
34	Feb 27 2019 10:55 AM	Facebook
35	Feb 27 2019 10:52 AM	Tweet from State Patrol
36	Feb 27 2019 10:34 AM	Twitter
37	Feb 27 2019 10:32 AM	Twitter

38	Feb 27 2019 10:26 AM	Facebook
39	Feb 27 2019 10:11 AM	Twitter
40	Feb 27 2019 10:08 AM	Twitter
41	Feb 27 2019 10:00 AM	Facebook
42	Feb 27 2019 09:11 AM	I saw it through the WSDOT facebook page.
43	Feb 27 2019 08:43 AM	Email
44	Feb 27 2019 08:43 AM	Facebook
45	Feb 27 2019 08:29 AM	facebook
46	Feb 27 2019 08:25 AM	Facebook wsdot
47	Feb 27 2019 08:20 AM	Facebook
48	Feb 27 2019 08:18 AM	Wsdot Facebook page
49	Feb 27 2019 07:43 AM	Facebook
50	Feb 27 2019 07:42 AM	FB
51	Feb 27 2019 07:28 AM	facebook
52	Feb 25 2019 07:50 PM	Omak Mule Deer Summit. I live in the Okanogan and I am very pleased to see our state's DOT taking on issues of wildlife connectivity and reducing vehicle collisions with wildlife in both the Methow and Okanogan Valleys.
53	Feb 23 2019 12:39 PM	Facebook
54	Feb 21 2019 11:04 AM	My wife!
55	Feb 21 2019 07:01 AM	From a friend
56	Feb 20 2019 09:03 PM	Wsdot east twitter
57	Feb 18 2019 04:31 PM	Methow Valley news
58	Feb 18 2019 12:12 PM	Facebook
59	Feb 18 2019 08:59 AM	Facebook-
60	Feb 17 2019 09:41 PM	FB forward
61	Feb 17 2019 04:32 PM	Facebook
62	Feb 17 2019 08:51 AM	okanogan county and methow valley topics of interest facebook
63	Feb 15 2019 03:36 PM	David Betts Loup Loup Ski Bowl GM facebook page.
64	Feb 14 2019 01:35 PM	facebook
65	Feb 13 2019 07:21 PM	Instagram
66	Feb 12 2019 09:42 PM	Saw it on Facebook
67	Feb 12 2019 03:39 PM	FB
68	Feb 12 2019 01:26 PM	Everywhere (paper, email, social media, at the bar)

69	Feb 12 2019 12:33 PM	weather site
70	Feb 12 2019 12:08 PM	Facebook
71	Feb 12 2019 10:22 AM	Facebook
72	Feb 12 2019 09:10 AM	Facebook
73	Feb 12 2019 07:28 AM	Social media
74	Feb 12 2019 06:50 AM	Town of Twisp marketing
75	Feb 12 2019 05:07 AM	?
76	Feb 12 2019 01:18 AM	Facebook
77	Feb 11 2019 10:13 PM	from a family member
78	Feb 11 2019 10:01 PM	Twisp Instagram
79	Feb 11 2019 09:04 PM	Okanogan County webpage on Facebook
80	Feb 11 2019 08:38 PM	Winthrop/Twisp Facebook page
81	Feb 11 2019 08:37 PM	My wife found it on Facebook.
82	Feb 11 2019 07:47 PM	It was shared on Facebook.
83	Feb 11 2019 07:38 PM	Facebook
84	Feb 11 2019 07:20 PM	Twisp Twitter
85	Feb 11 2019 07:18 PM	Social media
86	Feb 11 2019 07:04 PM	Twisp Washington Facebook page
87	Feb 11 2019 06:44 PM	Facebook
88	Feb 11 2019 06:32 PM	Facebook
89	Feb 11 2019 06:19 PM	Facebook
90	Feb 11 2019 06:01 PM	Methow Valley news
91	Feb 11 2019 05:59 PM	My wife
92	Feb 11 2019 05:53 PM	Facebook
93	Feb 10 2019 03:02 PM	Facebook page. Originally was looking at WSDOT road condition, snow plowing posts.
94	Feb 10 2019 11:15 AM	Facebook
95	Feb 09 2019 07:52 PM	facebook
96	Feb 09 2019 07:50 PM	Facebook
97	Feb 09 2019 07:10 PM	Fb post
98	Feb 09 2019 04:16 PM	Okanogan County and Methow Valley interesting topics Facebook page
99	Feb 09 2019 04:01 PM	News
100	Feb 09 2019 11:23 AM	Facebook
101	Feb 09 2019 07:43 AM	digital media
102	Feb 08 2019 04:06 PM	Facebook

103	Feb 08 2019 11:16 AM	email
104	Feb 08 2019 07:56 AM	Saw it on facebook
105	Feb 07 2019 10:55 PM	FB
106	Feb 07 2019 10:34 PM	Wsdot sent it to me. In 9 years of living here, I've hit 3 deer. All of them were blindly trying to run away from something else.
107	Feb 07 2019 10:13 PM	Website
108	Feb 07 2019 09:47 PM	Facebook
109	Feb 07 2019 09:37 PM	Facebook
110	Feb 07 2019 09:04 PM	Facebook
111	Feb 07 2019 08:48 PM	Saw it on line
112	Feb 07 2019 08:36 PM	Twitter
113	Feb 07 2019 06:55 PM	Tripped over it on Facebook.
114	Feb 07 2019 02:53 PM	@wsdot twitter account
115	Feb 07 2019 02:42 PM	I have "Methow Valley" in my Google alerts.
116	Feb 07 2019 01:21 PM	Methow Valley News
117	Feb 07 2019 01:14 PM	A friend sent me a link on facebook
118	Feb 07 2019 12:21 PM	Facebook
119	Feb 07 2019 12:02 PM	WSDOT
120	Feb 07 2019 11:20 AM	Facebook
121	Feb 07 2019 10:42 AM	Facebook
122	Feb 07 2019 10:11 AM	Facebook
123	Feb 07 2019 10:09 AM	Facebook
124	Feb 07 2019 09:48 AM	fb
125	Feb 07 2019 09:00 AM	Facebook
126	Feb 07 2019 08:55 AM	Word of mouth travels fast here especially when it’s something as stupid as this
127	Feb 07 2019 08:43 AM	Facebook post
128	Feb 07 2019 08:28 AM	Facebook
129	Feb 07 2019 08:17 AM	Facebook
130	Feb 07 2019 08:15 AM	Facebook
131	Feb 07 2019 07:55 AM	internet
132	Feb 07 2019 07:52 AM	News break app
133	Feb 07 2019 07:50 AM	WSDOT Twitter feed.
134	Feb 07 2019 07:41 AM	A friend
135	Feb 07 2019 07:37 AM	Facebook
136	Feb 07 2019 07:35 AM	Friend posted on Facebook

137	Feb 07 2019 07:30 AM	saw on FB
138	Feb 07 2019 07:27 AM	the news
139	Feb 07 2019 06:51 AM	Instagram
140	Feb 07 2019 06:16 AM	WSDOT Facebook posting
141	Feb 07 2019 05:25 AM	Facebook post
142	Feb 07 2019 04:33 AM	Facebook
143	Feb 07 2019 12:25 AM	Came across it
144	Feb 07 2019 12:04 AM	Facebook group
145	Feb 06 2019 11:46 PM	A friend
146	Feb 06 2019 11:45 PM	Jake
147	Feb 06 2019 11:34 PM	A friend forwarded it to me via FaceBook.
148	Feb 06 2019 11:04 PM	Facebook
149	Feb 06 2019 11:00 PM	facebook
150	Feb 06 2019 10:49 PM	On WSDOT Facebook page
151	Feb 06 2019 09:51 PM	News
152	Feb 06 2019 09:44 PM	Facebook post from WSDOT
153	Feb 06 2019 09:36 PM	Internet-Facebook
154	Feb 06 2019 09:30 PM	Facebook
155	Feb 06 2019 09:11 PM	Facebook Share
156	Feb 06 2019 09:01 PM	Facebook
157	Feb 06 2019 08:50 PM	Facebook
158	Feb 06 2019 08:17 PM	Wsdot
159	Feb 06 2019 08:11 PM	Facebook
160	Feb 06 2019 08:04 PM	Facebook
161	Feb 06 2019 08:03 PM	Wenatchee World
162	Feb 06 2019 07:55 PM	Facebook
163	Feb 06 2019 07:52 PM	Facebook posting
164	Feb 06 2019 07:51 PM	Facebol
165	Feb 06 2019 07:47 PM	Facebook
166	Feb 06 2019 07:25 PM	Tv
167	Feb 06 2019 07:23 PM	Facebook
168	Feb 06 2019 07:22 PM	WSDOT FB
169	Feb 06 2019 06:50 PM	KXLY
170	Feb 06 2019 06:48 PM	Facebook
171	Feb 06 2019 06:39 PM	Okanogan county methow valley site
172	Feb 06 2019 06:21 PM	On Facebook
173	Feb 06 2019 06:21 PM	Facebook
174	Feb 06 2019 06:12 PM	Instagram
175	Feb 06 2019 06:07 PM	Facebook
176	Feb 06 2019 06:00 PM	Internet

177	Feb 06 2019 05:58 PM	Online News Report
178	Feb 06 2019 05:54 PM	Was on Facebook
179	Feb 06 2019 05:35 PM	facebook
180	Feb 06 2019 05:15 PM	Facebook
181	Feb 06 2019 04:48 PM	WSDOT Facebook page
182	Feb 06 2019 04:44 PM	came up on facebook
183	Feb 06 2019 04:39 PM	On the Okanagon County website Facebook page.
184	Feb 06 2019 04:37 PM	Facebook
185	Feb 06 2019 04:35 PM	Okanogan County website
186	Feb 06 2019 04:12 PM	Facebook
187	Feb 06 2019 03:56 PM	facebook from WSDOT
188	Feb 06 2019 03:49 PM	From a relative
189	Feb 06 2019 03:33 PM	Facebook
190	Feb 06 2019 03:24 PM	Okanogan County and Methow Valley Topics of Interest Facebook page
191	Feb 06 2019 03:18 PM	WSDOT facebook page.
192	Feb 06 2019 03:13 PM	Facebook
193	Feb 06 2019 03:02 PM	Email
194	Feb 06 2019 02:43 PM	Facebook
195	Feb 06 2019 02:37 PM	Facebook
196	Feb 06 2019 02:20 PM	Facebook
197	Feb 06 2019 02:20 PM	FB
198	Feb 06 2019 02:00 PM	Wenatchee World website
199	Feb 06 2019 01:52 PM	Freind
200	Feb 06 2019 01:35 PM	WSDOT Twitter
201	Feb 06 2019 01:15 PM	Interweb
202	Feb 06 2019 12:32 PM	Facebook
203	Feb 06 2019 12:31 PM	email
204	Feb 06 2019 12:22 PM	Online
205	Feb 06 2019 11:58 AM	Twitter
206	Feb 06 2019 11:51 AM	On the WSDOT website.
207	Feb 06 2019 11:31 AM	Facebook
208	Feb 06 2019 11:20 AM	Facebook
209	Feb 06 2019 11:04 AM	Wenatchee world
210	Feb 06 2019 10:59 AM	Facebook
211	Feb 06 2019 10:39 AM	Facebook
212	Feb 06 2019 10:39 AM	Facebook
213	Feb 06 2019 10:39 AM	Twitter @WSDOT_EAST
214	Feb 06 2019 10:30 AM	Facebook Wsdot's post
215	Feb 06 2019 10:06 AM	Son
216	Feb 06 2019 09:56 AM	Friend sent link
217	Feb 06 2019 09:55 AM	Facebook

218	Feb 06 2019 09:47 AM	My wife
219	Feb 06 2019 09:33 AM	friend who lives in area
220	Feb 06 2019 09:21 AM	Facebook
221	Feb 06 2019 09:21 AM	Facebook friend
222	Feb 06 2019 09:14 AM	Facebook
223	Feb 06 2019 09:11 AM	Wsdot
224	Feb 06 2019 09:08 AM	WSDOT Facebook.
225	Feb 06 2019 09:02 AM	Facebook
226	Feb 06 2019 09:01 AM	Facebook
227	Feb 06 2019 08:53 AM	It popped up on twitter
228	Feb 06 2019 08:52 AM	Facebook.
229	Feb 06 2019 08:50 AM	Facebook
230	Feb 06 2019 08:50 AM	WSDOT Twitter
231	Feb 06 2019 08:47 AM	Facebook
232	Feb 06 2019 08:46 AM	Facebook
233	Feb 06 2019 08:46 AM	WSDOT twitter
234	Feb 06 2019 08:37 AM	Twitter
235	Feb 06 2019 08:33 AM	Facebook
236	Feb 06 2019 08:32 AM	Facebook
237	Feb 06 2019 08:31 AM	Facebook
238	Feb 06 2019 07:22 AM	Happened upon it online.
239	Feb 06 2019 12:16 AM	Twitter.
240	Feb 05 2019 08:02 PM	DAILY WORLD
241	Feb 05 2019 12:52 PM	Twitter
242	Feb 05 2019 12:27 PM	Twitter

Appendix D. Zones 1-9 Digital Photographs from WSDOT SRview 3 Application

Zone 1

020 Inc 2018: SRMP 184.61 / ARM 184.11

020 Inc 2018: SRMP 185.15 / ARM 184.65

Zone 2

020 Inc 2018: SRMP 186.27 / ARM 185.77

020 Dec 2018: SRMP 186.41 / ARM 185.91

Zone 3

020 Inc 2018: SRMP 187.41 / ARM 186.91

020 Inc 2018: SRMP 187.66 / ARM 187.16

Zone 4

020 Inc 2018: SRMP 188.00 / ARM 187.50

020 Inc 2018: SRMP 188.45 / ARM 187.95

Zone 5

020 Inc 2018: SRMP 191.00 / ARM 190.50

020 Dec 2018: SRMP 190.67 / ARM 190.17

Zone 6

020 Inc 2018: SRMP 194.40 / ARM 193.79

020 Dec 2018: SRMP 194.85 / ARM 194.24

Zone 7

020 Inc 2018: SRMP 196.66 / ARM 196.05

020 Dec 2018: SRMP 196.86 / ARM 196.25

Zone 8

020 Inc 2018: SRMP 197.62 / ARM 197.01

020 Dec 2018: SRMP 198.09 / ARM 197.48

Zone 9

020 Inc 2018: SRMP 198.91 / ARM 198.30

020 Dec 2018: SRMP 198.25 / ARM 197.64