MONTANA
Department of Transportation
Research

# EFFECTIVE WILDLIFE FENCES THROUGH BETTER FUNCTIONING BARRIERS AT ACCESS ROADS AND JUMP-OUTS

*FHWA/MT-23-004/9923-808*

## Effective Jump-Outs for White-tailed Deer and Mule Deer - Interim Report

September 2023

*prepared for*

THE STATE OF MONTANA DEPARTMENT OF TRANSPORTATION

*in cooperation with*

THE U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

September 2023

*prepared by*

Marcel P. Huijser
Samantha C. Getty

Montana State University
Bozeman, MT

# Effective Jump-outs for White-tailed Deer and Mule Deer

Prepared by:

Marcel P. Huijser, PhD
Samantha C. Getty, BSc

Western Transportation Institute
Montana State University

Prepared for the

MONTANA DEPARTMENT OF TRANSPORTATION

in cooperation with the

U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL HIGHWAY ADMINISTRATION

September 2023

# TECHNICAL REPORT DOCUMENTATION PAGE

| 1. Report No. | 2. Government Accession No. | 3. Recipient's Catalog No. |
|---|---|---|
| FHWA/MT-23-004/9923-808 | | |

| | |
|---|---|
| **4. Title and Subtitle**<br>Effective Jump-Outs for White-tailed Deer and Mule Deer | **5. Report Date**<br>September 2023<br>**6. Performing Organization Code** |
| **7. Author(s)**<br>Huijser, M.P. (https://orcid.org/0000-0002-4355-4631)<br>Getty, S.C. (https://orcid.org/0000-0002-5610-0241) | **8. Performing Organization Report No.** |
| **9. Performing Organization Name and Address**<br>Western Transportation Institute – Montana State University<br>PO Box 174250<br>Bozeman, MT 59717 | **10. Work Unit No.**<br>**11. Contract or Grant No.**<br>MSU Project Number 4W8863 (MDT)<br>MSU Project Number 4W8408 (SURTCOM)<br>MDT Project Number 9923-808 |
| **12. Sponsoring Agency Name and Address**<br>Research Programs<br>Montana Department of Transportation (SPR)<br>2701 Prospect Avenue<br>PO Box 201001<br>Helena MT 59620-1001 | **13. Type of Report and Period Covered**<br>Interim Report<br>October 2018 - September 2023<br>**14. Sponsoring Agency Code**<br>5401 |

**15. Supplementary Notes**

Conducted in cooperation with the U.S. Department of Transportation, Federal Highway Administration. This report can be found at https://www.mdt.mt.gov/research/projects/admin/wildlife-jumpouts.aspx DOI: https://doi.org/10.21949/1518327

Recommended Citation: Huijser, M.P., and S.C. Getty. 2023. *Effective Jump-Outs for White-tailed Deer and Mule Deer*. Helena, MT: Montana Department of Transportation. DOI: https://doi.org/10.21949/1518327

**16. Abstract**

The height of jump-outs along a fenced road corridor should be low enough for the target species to readily jump down from the fenced road corridor to the safe side, or the habitat side, of the fence. At the same time, the jump-outs should be high enough to discourage animals from jumping from the habitat side of the fence up into the fenced road corridor. Previous research along US Hwy 93 North in Montana showed that only about 32% of the mule deer and about 7% of the white-tailed deer that appeared on top of 10 monitored jump-outs, jumped down to safety. For this project, these same 10 jump-outs along US Hwy 93 North were lowered in height to 152 cm (5 ft) and provided with a bar on top. The height of the bars (made from rebar) and their setback from the vertical face of the jump-outs were adjustable and the researchers applied 4 different treatments: 2 different heights (46 and 38 cm (18 and 15 inches)) and 3 different setbacks (10, 30, and 38 cm (4, 12, and 15 inches)). The overall effectiveness of the lowered jump-outs in allowing white-tailed deer to jump down, regardless of the height and setback of the bar, was only about 5% (no improvement). For mule deer the effectiveness of the lowered jump-out height in allowing them to jump down, regardless of the height and setback of the bar, was about 64% (this was about double the effectiveness of non-modified jump-outs). One of the treatments even resulted in about 80% effectiveness for mule deer. With the lowered jump-outs some mule deer jumped up into the fenced road corridor. However, there was still a net benefit as far more mule deer escaped the fenced road corridor.

| 17. Key Words | 18. Distribution Statement |
|---|---|
| Animals, Barriers (Roads), Road kill, Crashes, Connectivity, Wildlife crossings, Deer, Ecology, Fences, Gates, Habitat (Ecology, Infrastructure, Jump-outs, Mammals, Hazard mitigation, Mortality, Ramps, Mule deer, Safety, Traffic, Transportation, Ungulates, Vehicles, White-tailed deer, Wildlife | No restrictions. This document is available through the: National Technical Information Service. Springfield, VA 22161 |

| 19. Security Classif. (of this report) | 20. Security Classif. (of this page) | 21. No. of Pages | 22. Price |
|---|---|---|---|
| Unclassified | Unclassified | 46 | |

## DISCLAIMER STATEMENT

This document is disseminated under the sponsorship of the Montana Department of Transportation (MDT) and the United States Department of Transportation (USDOT) in the interest of information exchange. The State of Montana and the United States assume no liability for the use or misuse of its contents.

The contents of this document reflect the views of the authors, who are solely responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the views or official policies of MDT or the USDOT.

The State of Montana and the United States do not endorse products of manufacturers.

This document does not constitute a standard, specification, policy or regulation.

## ALTERNATIVE FORMAT STATEMENT

Alternative accessible formats of this document will be provided on request. Persons who need an alternative format should contact the Office of Civil Rights, Department of Transportation, 2701 Prospect Avenue, PO Box 201001, Helena, MT 59620. Telephone 406-444-5416 or Montana Relay Service at 711.

## ACKNOWLEDGEMENTS

The authors would like to thank the panel members for this project: Jason Allen, Heidy Bruner, Robert Heiser, Aaron Mason, Whisper Means, Larry Sickerson, Sue Sillick, Ivan Ulberg, Nathaniel Walters, Joe Weigand and Darrell Williams. In addition, the authors thank the Research Project Managers: Vaneza Callejas and Bobbi deMontigny. Finally, the authors thank the following organizations that were members of the Animal Vehicle Collision (WVC) Reduction and Habitat Connectivity Transportation Pooled-Fund Project, TPF-5(358) for their support: Alaska Department of Transportation and Public Facilities, ARC Solutions, Arizona Department of Transportation, California Department of Transportation, Federal Highway Administration, Iowa Department of Transportation, Michigan Department of Transportation, Minnesota Department of Transportation, Nevada Department of Transportation, New Mexico Department of Transportation, Ontario Ministry of Transportation, Oregon Department of Transportation, Parks Canada, and Washington Department of Transportation. Additional thanks to the road maintenance crews of the Montana Department of Transportation in Evaro and Ravalli for their help in lowering the jump-outs, including providing the personnel, a bobcat, and a backhoe. Finally, we thank the Confederated Salish and Kootenai Tribes for their permission to conduct the research on the Flathead Indian Reservation.

# TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

| STANDARD CONVERSION TABLE – ENGLISH TO METRIC | | | | |
|---|---|---|---|---|
| Symbol | To convert from | Multiply by | To determine | Symbol |
| | | **LENGTH** | | |
| IN | inch | 25.4 | millimeters | mm |
| FT | feet | 0.3048 | meters | m |
| YD | yards | 0.9144 | meters | m |
| MI | miles | 1.609344 | kilometers | km |
| | | **AREA** | | |
| SI | square inches | 645.16 | square millimeters | $mm^2$ |
| SF | square feet | 0.09290304 | square meters | $m^2$ |
| SY | square yards | 0.83612736 | square meters | $m^2$ |
| A | acres | 0.4046856 | hectares | ha |
| $MI^2$ | square miles | 2.59 | square kilometers | $km^2$ |
| | | **VOLUME** | | |
| CI | cubic inches | 16.387064 | cubic centimeters | $cm^3$ |
| CF | cubic feet | 0.0283168 | cubic meters | $m^3$ |
| CY | cubic yards | 0.764555 | cubic meters | $m^3$ |
| GAL | gallons | 3.78541 | liters | L |
| OZ | fluid ounces | 0.0295735 | liters | L |
| MBM | thousand feet board | 2.35974 | cubic meters | $m^3$ |
| | | **MASS** | | |
| LB | pounds | 0.4535924 | kilograms | kg |
| TON | short tons (2000 lbs) | 0.9071848 | metric tons | t |
| | | ***PRESSURE AND STRESS*** | | |
| PSF | pounds per square foot | 47.8803 | pascals | Pa |
| PSI | pounds per square inch | 6.89476 | kilopascals | kPa |
| PSI | pounds per square inch | 0.00689476 | megapascals | Mpa |
| | | **DISCHARGE** | | |
| CFS | cubic feet per second | 0.02831 | cubic meters per second | $m^3/_s$ |
| | | **VELOCITY** | | |
| FT/SEC | feet per second | 0.3048 | meters per second | m/s |
| | | **INTENSITY** | | |
| IN/HR | inch per hour | 25.4 | millimeters per hour | mm/hr |
| | | **FORCE** | | |
| LB | pound (force) | 4.448222 | newtons | N |
| | | **POWER** | | |
| HP | horsepower | 746.0 | watts | W |
| | | **TEMPERATURE** | | |
| ˚F | degrees Fahrenheit | 5 X (˚F – 32)/9 | degrees Celsius | ˚C |
| | | **DENSITY** | | |
| $lb/ft^3$ | pounds per cubic foot | 16.01846 | kilograms per cubic meter | $kg/m^3$ |
| | | **ACCELERATION** | | |
| g | freefall, standard | 9.807 | meters per second squared | $m/s^2$ |

TO CONVERT FROM METRIC TO ENGLISH, DIVIDE BY THE ABOVE CONVERSION FACTORS.

## SUMMARY

Wildlife “jump-outs” or “escape ramps” are widely used to allow large wild mammals, especially ungulates, to escape fenced road corridors. Most wildlife jump-outs or escape ramps are earthen mounds that are positioned in the fenced road corridor to allow animals to walk up the slope to an opening in the fence. The height of the jump-outs needs to be low enough for the target species to readily jump down to the safe side, or the habitat side, of the fence. At the same time, the height of the jump-outs needs to be high enough to discourage animals that are on the habitat side of the fence from jumping up into the fenced road corridor. This implies that finding an optimum height for the target species is important. However, there is very little information available on the appropriate height of jump-outs for different species. A further complication occurs when there are multiple target species in an area, each with their own jumping or climbing capabilities.

The US Hwy 93 North reconstruction project (2004-2010) on the Flathead Indian Reservation in northwest Montana included wildlife crossing structures, wildlife fences, and wildlife jump-outs. Previous research on 10 of these wildlife jump-outs (between 1.75-2.04 m (5.7-6.7 ft) high) showed that only about 32% of the mule deer and about 7% of the white-tailed deer that appeared on top of the jump-outs, jumped down to safety. No mule deer or white-tailed deer was observed jumping up. In the spring of 2021, these same 10 jump-outs were lowered in height and provided with a bar on top. These jump-outs were in areas frequented by predominantly white-tailed deer (6 jump-outs in the Evaro area) and mule deer (4 jump-outs in the Ravalli Hill area). For this research project, the 10 selected jump-outs received the following modifications:

- Height lowered to exactly 152 cm (5 ft).
- The soil that was removed from the top was deposited at the bottom of the jump-outs to level the landing area.
- Removal of tall vegetation on top and on the road-facing slopes of jump-outs, and the landing area.
- Adding a bar on top of the jump-out above the ground level. Most of the “bars” were made from rebar, but the prototype with 4 inches setback was made from wood. The height of the bars and setback from the vertical face of the jump-outs was adjustable and the researchers applied 4 different treatments:
    - 46 cm (18 inches) high, 10 cm (4 inches) setback.
    - 46 cm (18 inches) high, 30 cm (12 inches) setback
    - 46 cm (18 inches) high, 38 cm (15 inches) setback
    - 38 cm (15 inches) high, 30 cm (12 inches) setback

The overall effectiveness of the lowered jump-outs in allowing white-tailed deer to jump down, regardless of the height and setback of the bar, was just above 5% (no improvement). No white-tailed deer jumped up into the fenced road corridor. For mule deer the effectiveness of the lowered jump-outs in allowing them to jump down, regardless of the height and setback of the bar, was about 64% (this was double the effectiveness of non-modified jump-outs). Of the mule deer that were present at the bottom of the jump-outs, just under 7% jumped up into the fenced road corridor. While one of the treatments for the modified jump-outs allowed some mule deer to

jump up into the fenced road corridor, there were still far more mule deer jumping down than up. In other words, for all 4 treatments combined, the lowered jump-outs still resulted in fewer mule deer in the fenced road corridor.

Regardless of how close white-tailed deer came to the face of the jump-out, and regardless of the treatment, only few jumped down to the habitat side of the fence. No white-tailed deer jumped up into the fenced road corridor for any of the treatments. Regardless of how close mule deer came to the face of the jump-out, and regardless of the treatment, they jumped down much more readily than white-tailed deer, and they jumped down much more readily than at the non-modified jump-outs. The treatment with a height of 46 cm (18 inches) and a setback of 38 cm (15 inches) had 80.36% of all mule deer that were observed within the right-of-way jump down to the habitat side of the jump-outs. While this specific treatment allowed some mule deer to jump up into the fenced road corridor, there were still far more mule deer jumping down than up. In other words, this specific treatment still resulted in fewer mule deer in the fenced road corridor.

While the modified jump-outs about doubled the effectiveness in allowing mule deer to escape the fenced road corridor, there was no improvement for white-tailed deer. For jump-outs to become more effective for white-tailed deer, a lower height of the bar, or a greater setback of the bar, may be required. It may also be that a jump-out height of 152 cm (5 ft) is still too high for white-tailed deer, regardless of the presence, height, and setback of a bar.

# 1 INTRODUCTION

## 1.1 Background

Historically, one-way escape gates have been implemented to allow large wild mammals, especially ungulates, to escape fenced road corridors (see review in Huijser et al. 2015). However, one-way gates are now rarely implemented because of low effectiveness in allowing animals to escape the fenced road corridor, allowing animal intrusions into the fenced road corridor, and resulting in injuries and death of animals using the one-way gates (see review in Huijser et al. 2015). Wildlife "jump-outs" or "escape ramps" are now widely used instead. Most wildlife jump-outs or escape ramps are man-made earthen mounds that are positioned in the fenced road corridor and allow animals to walk up the slope to an opening in the fence. The mound can be constructed out of soil or rocks, and in some cases the rocks are placed in gabion baskets with soil on top. The height of the jump-outs should be low enough for the target species to readily jump down to the safe side, or the habitat side, of the fence. At the same time, the jump-outs should be high enough to discourage animals that are on the habitat side of the fence from jumping up into the fenced road corridor. This implies that finding an optimum height for the target species is important. However, there is very little information available on the appropriate height of jump-outs for different species. A further complication occurs when there are multiple target species in an area, each with their own jumping or climbing capabilities (e.g., Gagnon et al. 2020).

Faces for wildlife-jump-outs have been made out of wooden planks, concrete walls, gabion baskets, or stacked interlocking concrete blocks. In some cases, metal sheeting has been attached to the face to reduce the likelihood of bears climbing up the wall into the fenced road corridor (Huijser et al. 2008). A flat and clear landing area, free of branches and debris, is recommended. Loose sand, rather than compacted soil or rocks at the bottom of jump-outs may also facilitate use and safe landings for the animals. The opening in the fence on top of the jump-out, should also be clear of branches and vegetation (Gagnon et al. 2020). The slope of a jump-out may affect jump-out use and investigating the effectiveness of a slope flatter than 3:1 is recommended (Kintsch et al. 2021). Others also recommended a more gradual approach (4:1) to the top of the jump-out (Gagnon et al. 2020). Jump-outs can also be integrated into the existing roadbed, especially near underpasses where there may be a drop-off. In those situations, no earthen mounds are required. The wildlife fence can also be lowered to 1.2-1.5 m (4-5 ft) if the fence is positioned on a steep slope angling down away from the road AZDOT 2013a, b). This construction is referred to as a "slope-jump" (AZDOT 2013a, b). It is unclear whether short sections of fence on top of the jump-outs, perpendicular to the fence line, increase use of jump-outs.

In North America, the height for wildlife jump-outs that have been constructed for large mammals, particularly ungulates, varies between 1.5-3.0 m (5-10 ft) (Huijser et al. 2015). Wildlife jump-outs that were about 1.5 m (5 ft) high appear to be used much more readily (about 7.9-11.0 times more) by mule deer (*Odocoileus hemionus*) than one-way gates (Bissonette & Hammer 2000). Wildlife jump-outs that were between 1.75-2.04 m (5.7-6.7 ft) high were used by about 32% of the mule deer that appeared on top of the jump-outs but very few (7%) of white-tailed deer (*O. virginianus*) that appeared on top of the jump-outs jumped down to safety (Huijser et al. 2016). Jump-out heights between 1.65-2.24 m (5.4-7.3 ft) were only used by 10% of the mule deer and 23% of the elk (*Cervus canadensis*) that had walked up the jump-outs (Kintsch et al. 2021). Others have set the height at 2.0 m (6.6 ft) in combination with a horizontal plank that stuck out from the edge (Siepel et al. 2013). However, these jump-outs did not function well for mule deer, and it was suggested to remove either the horizontal plank or reduce the height of the jump-outs (Siepel et al. 2013). A height of 2.0 m (6.6 ft) resulted in very low use by mule deer; only 6% of the animals on top of the jump-outs jumped down to the safe side of the fence (Jensen et al. 2018). A height of about 1.50-1.68 m (5-5.5 ft) seems advisable for white-tailed deer and mule deer (review in Huijser et al. 2015). Recommended wildlife jump-out height for elk is 1.83 m (6 ft) (Gagnon et al. 2020).

A jump-out can be made to appear higher for animals that may be interested in jumping up into the fenced road corridor and lower for animals that may be interested in jumping down to the safe side of the wildlife fence. The area in front of the "vertical face," on the safe side or habitat side of the fence, may be dug out in an area up to 1.5-1.8 m (5-6 ft) from the face (AZDOT 2013a, b), but pits may fill with snow in areas with heavy snow fall. Naturally the pit should extend along the entire vertical face of the jump-out, plus an additional buffer zone of perhaps 0.91 m (3 ft). The soil may be deposited on the "landing pad" which may start 1.5-1.8 m (5-6 ft) from the vertical face. Similarly, the top of the jump-out can be made to appear higher by adding soil on top of the jump-out starting about 2.4 m (8 ft) away from the edge of the top of the jump-out (AZDOT 2013a, b). Alternatively, a metal bar or wooden plank may be attached about 46 cm (18 inches) on the top of the jump-out, setback from the face (Siemers et al. 2013, Gagnon et al. 2020). This still allows animals that are on top of the jump-out to step over or crawl under the barrier before jumping down. Animals wanting to jump up would also have to clear the bar or plank as there is insufficient space to land in front of the barrier.

For this study we investigate the effectiveness of modifications to existing jump-outs along US Hwy 93 North on the Flathead Indian Reservation in northwest Montana. Previous research on 10 of these wildlife jump-outs (between 1.75-2.04 m (5.7-6.7 ft) high) showed that only about 32% of the mule deer and about 7% of the white-tailed deer that appeared on top of the jump-outs, jumped down to safety. No mule deer or white-tailed deer was ever observed jumping up. The 10 existing jump-outs were lowered to 1.52 m (5 ft) and provided with a bar on top that varied in height and setback (i.e., distance to the face of the jump-out). We investigated potential increase in desired use (i.e., jumping down) and undesired use (i.e., jumping up) for white-tailed deer and mule deer with different configurations of the bar.

## 1.2 The Problem Definition in Perspective

The problem of having large wild mammals inside a fenced road corridor can be addressed through different strategies, or a combination of different strategies:

1. Reduce the likelihood that animals enter the fenced road corridor to begin with. This can be achieved by carefully designing, implementing and maintaining a wildlife fence for the target species. Design includes the physical characteristics of a fence in relation to the jumping, climbing, and digging capabilities of the target species, as well as the strength

of the target species. Wildlife fences should have a tight connection to wildlife crossing structures or other features such as gates or wildlife guards at access roads. The length of the fenced road section, and where the fence starts and ends, also affects the number of animals that can enter the fenced road corridor. Additional measures at fence-ends (e.g., bringing the fence end close to the edge of the pavement, wildlife guards or electrified barriers embedded in the travel lanes), gaps in the fence at access roads (e.g., gates, wildlife guards or electrified barriers embedded in the travel lanes) also classify as "preventative measures" to that aim to reduce the number of large wild animals that are able to gain access into the fenced road corridor to begin with.

2. Allow animals that do end up in the fenced road corridor easy access to a wildlife jump-out. This relates to the number, spacing, slope of the mound, and other design characteristics that influence whether animals that are present in the fenced road corridor make it to the edge of the jump-out. Animals that do not experience the edge of a jump-out can never be served by that jump-out, regardless of how tall the face of the jump-out is, and the presence, height, and setback of a bar on top of the jump-out.
3. Design the jump-outs in such a way that animals that make it to the edge of the jump-out readily jump down to the safe side of the fence. At the same time, the design should minimize the number of animals that jump up into the fenced road corridor. This is about seeking a balance, and a bar on top of the jump-out can influence that balance by still allowing animals to readily jump down but making it more difficult for animals to jump up into the fenced road corridor. The balance of a design should always be net positive; it should allow more animals to escape from the fenced road corridor than it allows animals to access the fenced road corridor. The result is fewer animals that are present in the fenced road corridor.

It is best to implement all three strategies above from the earliest design stages onward. However, the focus of this report is solely with the third strategy; designing jump-outs in such a way that animals that make it to the edge of the jump-out readily jump down to the safe side of the fence and that no animals, or relatively few animals, jump up into the fenced road corridor.

# 2 METHODS

## 2.1 Study Area

US Highway 93 North (hereafter referred to as "US Hwy 93 North") is located between Evaro and Polson on the Flathead Indian Reservation in northwest Montana, USA. The study area is a mixed-use landscape, including forested hills, upland natural grasslands, riparian zones along rivers, wetlands, pastures, cropland and mixed housing densities. County and local roads cross through the landscape in the areas adjacent to US Hwy 93 North. Major mountain ranges include the Mission Mountains to the east and the Rattlesnake Mountains to the south-east. US Hwy 93 North is a major highway that connects Interstate-90 and Missoula to the Flathead Valley with Kalispell and Glacier National Park as major destinations. Average Annual Daily Traffic was 6,700-7,600 vehicles between 2010-2015 (Huijser et al. 2016) and 7,672-9,196 vehicles on different road sections in 2021 and 2023 (Adams et al. 2023).

The US Hwy 93 North reconstruction project (2004-2010) on the Flathead Indian Reservation in northwest Montana represents one of the most extensive wildlife-sensitive highway design efforts to date in North America. The reconstruction of the 56 mile (90 km) long road section included the installation of wildlife crossing structures at 39 locations and approximately 8.7 miles (14 km) of road with wildlife exclusion fences (8 ft (2.4 m) tall) on both sides of the highway (Huijser et al. 2016). Long fenced road sections also had jump-outs or escape ramps installed. The longest sections with contiguous mitigation measures are in the Evaro, Ravalli Curves, and Ravalli Hill areas (Figure 1).

## 2.2 Effectiveness of Existing, Non-Modified, Jump-Outs

Between 2008-2015, 52 jump-outs or escape ramps were monitored using tracking beds on top and on the bottom of the jump-outs (Huijser et al. 2016) (Figure 2 and 3). Most of these jump-outs were about 1.83-2.13 m (6-7 ft) high and had a width (i.e., gap in the fence) of about 5 m (15 ft). Only 13.84% of the deer that were tracked on top (white-tailed deer and mule deer combined) were estimated to have jumped down. None of the deer that passed by on the habitat side of the jump-out were estimated to have jumped up into the fenced road corridor (Huijser et al. 2016). More detailed monitoring with wildlife cameras (2014-2016) of 10 of these 52 jump-outs (varying in height 1.75-2.04 m (5.7-6.7 ft)) showed that only 6.88% of the white-tailed deer and 32.35% of the mule deer detected on the top of the jump-outs jumped down to the safe side of the fence (Huijser et al. 2016). None of the deer that passed by on the habitat side of the jump-outs were observed jumping up into the fenced road corridor (Huijser et al. 2016).

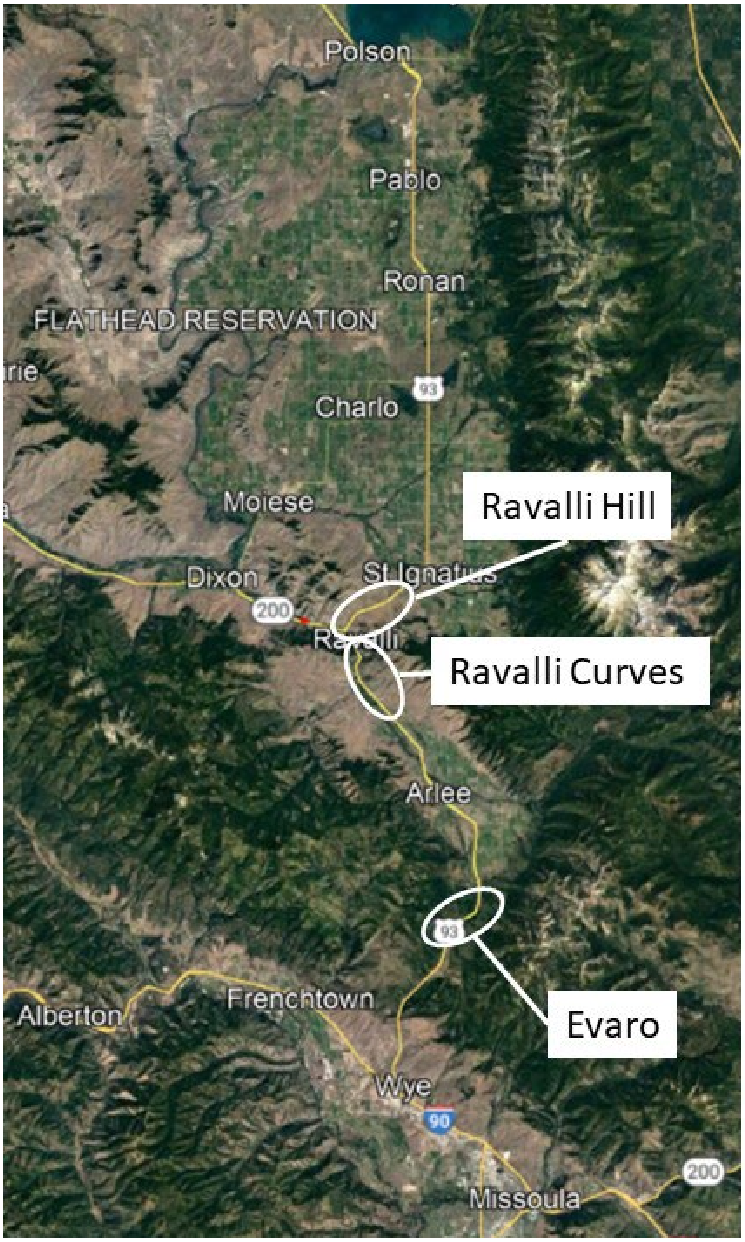


**Figure 1: US Hwy 93 North between Evaro and Polson, with the longest sections of mitigated road (Evaro, Ravalli Curves, and Ravalli Hill).**


**Figure 2: An unmodified jump-out in the Evaro area. The mound allows the animals to walk up to an opening in the fence, with a drop of around 1.83 m (6 ft) to the habitat side of the jump-out.**


**Figure 3: Some of the unmodified jump-outs are extremely high.**

## 2.3 Modifications to the Jump-Outs

The same 10 jump-outs that were monitored with trail cameras between 2014-2016 were lowered in height and provided with a bar on top in the spring of 2021 (Table 1). These jump-outs were in areas frequented by predominantly white-tailed deer (6 jump-outs in the Evaro area) and mule deer (4 jump-outs in the Ravalli Hill area) (Figures 2 and 3, Appendix A). The 10 jump-outs received the following modifications:

- The face was lowered to exactly 1.52 m (5 ft). This was accomplished by removing soil from the top and removing one or multiple rows of the concrete blocks from the face (the wall) (Figure 4). The top blocks are 7.6 cm (3 inches) tall, and the standard blocks are 17.8 cm (7 inches) tall. The jump-outs in the Ravalli Hill area were lowered on 21 April 2021. The jump-outs in the Evaro area were lowered on 4 May 2021.
- The soil that was removed from the top was deposited at the bottom of the jump-outs to level the landing area up to about 2 m (6-7 ft) out from the vertical face of the jump-outs. This resulted in a consistent height of 1.52 m (5 ft) for the vertical face of the jump-outs.
- Tall vegetation was removed from the top and road-facing slopes of jump-outs, and the landing area.
- An adjustable bar was added on top of the jump-out above the ground level.

A prototype of the "bar" was made from treated lumber; "5x5" cm ("2x2" inch) and "10x10" cm ("4x4" inch) (Figure 5). The "10x10" cm ("4x4" inch) posts sat on the top of the concrete blocks allowing an initial setback of 4 inches from the face. More permanent "bars" were made from rebar (grade 60, 1.25 cm (1/2-inch) diameter) (Figure 6). The rebar was bent into giant "staples" that measured 152 cm (60 inches) horizontal with 107 cm (42 inch) legs. The 107 cm (42 inch) legs allowed the "staples" to go deep into the soil of the mound for stability, and also allowed for height adjustments (higher or lower above the ground on top of the mound). However, the setback for the rebar was 12 inches (30.5 cm) from the face at a minimum. This is because the legs could not go through the 12 inch (30.5 cm) wide concrete blocks that formed the face. L-shaped 91 cm (36 inch) swing arms (with 107 cm (42 inch) legs) were used to connect the bar to the fence posts at each side of the jump-out (Figures 7-9). The legs of the "staples" and L-shape corner elements were wrapped with metal wire twisted around both legs to increase rigidity.

**Table 1: The "original" height of the ten jump-outs selected for this project. EV=Evaro, RH= Ravalli Hill.**

| | | Dominant deer species in the area | Original Height | | Modified Height | |
|---|---|---|---|---|---|---|
| Area | ID# | | ft | cm | ft | cm |
| EV | 14 | White-tailed deer | 6' 8.5" | 204 | 5' 0" | 152 |
| EV | 17 | White-tailed deer | 6' 0" | 183 | 5' 0" | 152 |
| EV | 19 | White-tailed deer | 6' 8" | 203 | 5' 0" | 152 |
| EV | 20 | White-tailed deer | 6' 0" | 183 | 5' 0" | 152 |
| EV | 21 | White-tailed deer | 6' 1.5" | 187 | 5' 0" | 152 |
| EV | 23 | White-tailed deer | 5' 6" | 168 | 5' 0" | 152 |
| RH | 26 | Mule deer | 5' 11" | 180 | 5' 0" | 152 |
| RH | 27 | Mule deer | 6' 0" | 183 | 5' 0" | 152 |
| RH | 28 | Mule deer | 5' 9" | 175 | 5' 0" | 152 |
| RH | 29 | Mule deer | 5' 11" | 180 | 5' 0" | 152 |


**Figure 4: The Montana Department of Transportation assisted with the lowering of 10 jump-outs. After removing concrete blocks of the face, soil from the top was deposited at the bottom for the landing area.**

**Figure 5: The prototype for the "bar" made from "5x5" cm ("2x2" inch) and "10x10" ("4x4" inch) treated lumber.**

**Figure 6: Several of the "staples" (60-inch horizontal, 107 cm (42 inch) legs) the L-shaped corner elements (91 cm (36 inch) swing arms, 107 cm (42 inch) legs).**

**Figure 7: The rebar installed with the L-shaped corner elements connected to the fence post.**

**Figure 8: The L-shaped corner elements were connected to the fence posts with brackets and screws.**


**Figure 9: The legs of the "staples" and L-shaped corner elements were connected with metal wire.**

## 2.4 Experimental Treatment of Bar Height and Setback

The top of the wooden prototype of the bar was 46 cm (18 inches) above the top or surface of the jump-out and had 10 cm (4 inches) setback from the wall (Figure 10). The bars made from rebar were initially also 46 cm (18 inches) above the top or surface of the jump-out. However, they had to be positioned behind the concrete blocks that formed the wall and therefore they had an initial setback of 30 cm (12 inches) (Figure 11). Based on the initial results with the prototype, 10 cm (4 inches) setback appeared to be insufficient to allow the deer to step over the bar with their front legs and take advantage of the low height of the jump-out (Figure 12). Because the deer jumped the bar going down, the effective height for the animals jumping down was 152 cm (5 ft) plus an additional 46 cm (18 inches): 1.98 cm (6½ ft) total height. Additional data from the rebar design (height 46 cm (18 inches), setback 30 cm (12 inches)) showed an increase in mule deer jumping down compared to the wooden prototype, but the performance was still marginal and similar to the use of the non-modified jump-outs; 10% or less of the white-tailed deer and only 30-40% of the mule deer that were recorded on top of the jump outs jumped down. Therefore, further modifications of the height and setback of the bars were initiated. The height was reduced, and the setback was increased in 7.5 cm (3 inch) increments (Figure 13, Table 2).

**Figure 10: The wooden prototype had a setback of 10 cm (4 inches).**


**Figure 11: The rebar had a minimum setback of 30 cm (12 inches) as the legs had to be positioned behind the concrete blocks of the face of the jump-out.**


**Figure 12: A mule deer jumps down the jump-out with the prototype (height 46 cm (18 inches), setback 10 cm (4 inches)). The animal starts the jump from behind the bar and does not step over the bar first before jumping down.**

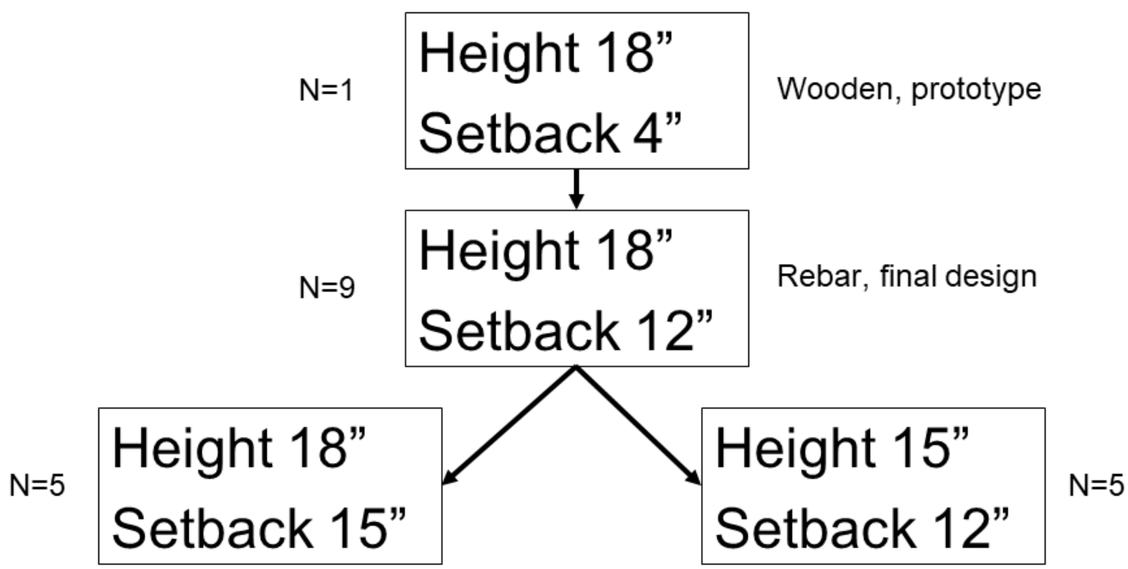



**Figure 13: The treatments (height, setback) and the sample sizes (N) distributed over the 10 jump-outs that were lowered.**

**Table 2: The height and setbacks of the bar for ten jump-outs. EV=Evaro, RH= Ravalli Hill.**

| Area | ID# | Material | Period | | Dimensions (inches) | |
|---|---|---|---|---|---|---|
| | | | Start | End | Height | Setback |
| EV | 14 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 15 | 12 |
| EV | 17 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 18 | 15 |
| EV | 19 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 15 | 12 |
| EV | 20 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 15 | 12 |
| EV | 21 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 18 | 15 |
| EV | 23 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 18 | 15 |
| RH | 26 | Wood | 26 Apr 21 | 26 Aug 21 | 18 | 4 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 18 | 15 |
| RH | 27 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 15 | 12 |
| RH | 28 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 15 | 12 |
| RH | 29 | Rebar | 18 May 21 | 26 Aug 21 | 18 | 12 |
| | | Rebar | 26 Aug 21 | 24 Apr 22 | 18 | 15 |

## 2.5 Research Cameras and Data Analyses

All 10 jump-outs had research cameras (Reconyx PC900 HyperFire) installed on 28 May 2021. The cameras were typically positioned on the habitat (safe) side of the fence, looking at the face of the jump-outs. This allowed the researchers to observe animals that appeared on the top of the jump-out and also see animals that passed by on the safe side of the jump-out (Figures 14 and 15). In some cases, a camera needed to be installed on one of the fence posts at the edges of the jump-out because of the topography, vegetation, or land ownership. In all cases, a clear view of potential animals on top of the jump-outs was prioritized over a clear view of potential animals on the habitat side of the jump-out. The researchers analyzed the images from the cameras. The researchers identified the species, evaluated whether the animals came within 2 m (6.6 ft) of the face of the jump-out (on top and at the bottom of the jump-outs), noted if they showed interest in jumping up or down, and evaluated whether the animals ultimately jumped up or down. The researchers observed and counted the behavior of individual animals, regardless of whether they occurred in a group. Of the deer that jumped down to the habitat side of the jump-outs, the researchers also noted if the deer first stepped over the bar, and if so, with how many legs.

The effectiveness of jump-outs was calculated as a percentage based on the number of animals that appeared on top of the jump-outs and how many of them jumped down. If an animal did not jump, but if it reappeared on top of the same jump-out within 5 minutes of the last sighting, it was regarded as 1 event. If more than 5 minutes had passed between appearances, it was counted as two separate events.


**Figure 14: The typical view of the cameras allowing the researchers to see animals both on top and at the bottom of the jump-outs. Mule deer contemplates jumping down to the habitat side of the fence.**


**Figure 15: The typical view of the cameras allowing the researchers to see animals both on top and at the bottom of the jump-outs. Mule deer contemplates jumping up into the fenced road corridor.**

# 3 RESULTS

## 3.1 Overall Jumping-Out Use, Regardless of Bar Treatment, for all Species

White-tailed deer (N=341) and mule deer (N=153) were the most frequently observed wild large mammal species at the jump-outs (Table 3, Appendix B). These numbers include all observations, regardless of whether the animals jumped up or down the jump outs.

The overall effectiveness of the lowered jump-outs in allowing white-tailed deer to jump down, regardless of the height and setback of the bar, was only just above 5% (Table 3). On the other hand, no white-tailed deer were recorded jumping up into the fenced road corridor. For mule deer the effectiveness of the lowered jump-outs in allowing them to jump down, regardless of the height and setback of the bar, was about 64% (Table 3). Of the mule deer that were present at the bottom of the jump-outs, just under 7% were recorded jumping up into the fenced road corridor.

Other mammal species greater or equal in size or weight to a raccoon were also evaluated for their behavior at the jump-outs (Table 3, Figures 16-20). However, due to small sample sizes no distinction was made between the different treatments for the bar. Black bear, bobcat, elk, mountain lion and wolf usually jump down to the safe side of the jump-out (>50%), whereas coyote and red fox occasionally jump down (≤50%). Bobcat and mountain lion always jumped up (100%), whereas black bear occasionally climbed up the face into the fenced right-of-way (12.5%), and coyote, elk, and moose were never observed jumping up.

**Table 3: The overall effectiveness of the lowered jump-outs in allowing species to jump down (desired behavior) and jump up (undesired behavior).**

| Species | Total | Jump down (N) | Jump up (N) | In r-o-w[*1] (N) | In Habitat (N) | Jump down (%) | Jump up (%) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| White-tailed deer | 341 | 4 | 0 | 73 | 268 | 5.48 | 0.00 |
| Mule deer | 153 | 52 | 5 | 81 | 72 | 64.20 | 6.94 |
| Bear black | 37 | 14 | 2 | 21 | 16 | 66.67 | 12.50 |
| Coyote | 23 | 4 | 0 | 19 | 4 | 21.05 | 0.00 |
| Bobcat | 21 | 10 | 5 | 16 | 5 | 62.50 | 100.00 |
| Elk | 7 | 1 | 0 | 1 | 6 | 100.00 | 0.00 |
| Mountain lion | 6 | 3 | 3 | 3 | 3 | 100.00 | 100.00 |
| Red fox | 2 | 1 | 0 | 2 | 0 | 50.00 | N/A |
| Moose | 1 | 0 | 0 | 0 | 1 | N/A | 0.00 |
| Raccoon | 1 | 0 | 0 | 1 | 0 | 0.00 | N/A |
| Wolf | 1 | 1 | 0 | 1 | 0 | 100.00 | N/A |

[*1] Right-of-way

**Figure 16: Some black bears first stepped over the bar; others crawled under.**

**Figure 17: Black bears typically jumped down (desired behavior) headfirst.**

**Figure 18: A bobcat jumps down to the habitat side of the jump-out (desired behavior).**

**Figure 19: An elk contemplates jumping up into the fenced road corridor.**

**Figure 20: A mountain lion jumps down to the habitat side of the jump-out (desired behavior).**

## 3.2 Effectiveness of Jump-Outs for Deer for the 4 Different Treatments

Regardless of how close the animals came to the face of the jump-out, and regardless of the treatment, white-tailed deer rarely jumped down to the habitat side of the fence (10.00% or less for each of the 4 different treatments) (Figure 21). No white-tailed deer jumped up into the fenced road corridor for any of the treatments (Figure 21). Regardless of how close the animals came to the face of the jump-out, and regardless of the treatment, mule deer jumped down much more readily (range 17.7-100.00% for the 4 different treatments, Figure 22) than white-tailed deer. The treatment with a height of 46 cm (18 inches) and a setback of 38 cm (15 inches) had 80.36% of all mule deer that were observed within the fenced right-of-way jump down to the habitat side of the jump-outs (Figure 22). Jumping down (Figure 23) is the desired behavior. At the same time, this treatment allowed 14.7% of the mule deer that were observed on the habitat side of the jump-out to jump up into the fenced road corridor (Figure 22). Jumping up (Figure 24) is the undesired behavior. While the treatment with a height of 38 cm (15 inches) and a setback of 30 cm (12 inches) also seemed to perform well, it suffered from low sample size.

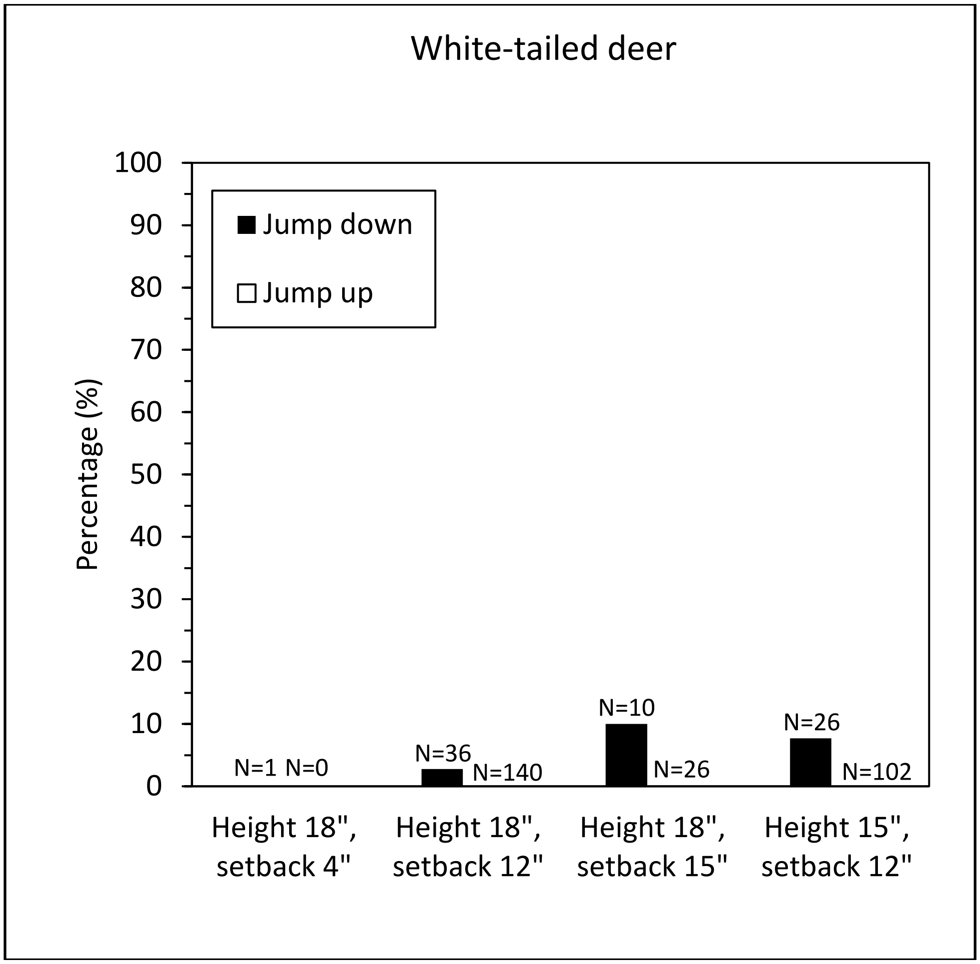



**Figure 21: The percentage of white-tailed deer that jumped down (desired behavior) and that jumped up (undesired behavior) for the different treatments. N is the sample size for each treatment.**

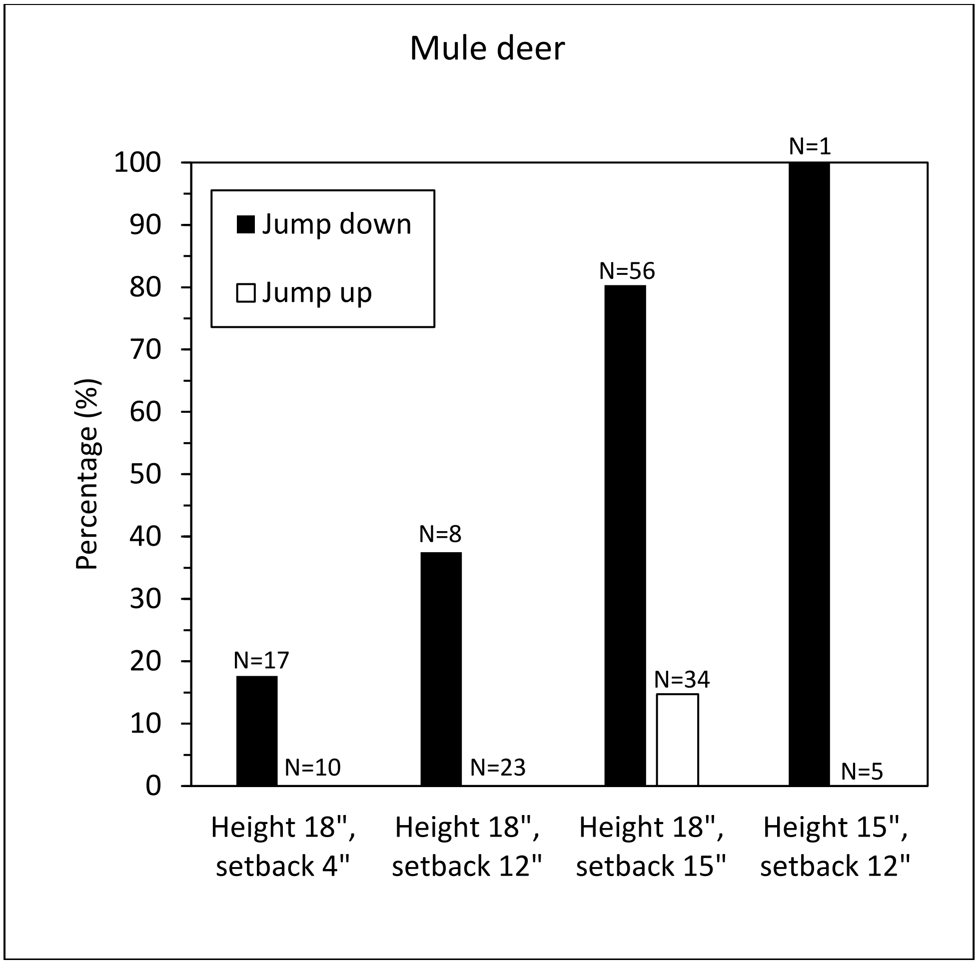



**Figure 22: The percentage of mule deer that jumped down (desired behavior) and that jumped up (undesired behavior) for the different treatments. N is the sample size for each treatment.**

**Figure 23: A mule deer jumps down to the habitat side of the jump-out (desired behavior).**

**Figure 24: A mule deer jumps up into the fenced road corridor, clearing the bar (undesired behavior).**

## 3.3 Effectiveness Jump-Outs for Deer that Came within 2 m of the Face

There were only 24 white-tailed deer observed within the fenced right-of-way that did not come within 2 m of the face of the jump-out; 10 in the treatment “height 18 inches and setback 12 inches”, 4 in the treatment “height 18 inches, setback 15 inches”, and 10 in the treatment “height 15 inches, setback 12 inches”. This changed the respective results for these treatments in Figure 21 for jumping down to 3.85% (N=26), 16.67% (N=6), and 12.50% (N=16). There were 16 white-tailed deer observed on the habitat side of the jump-outs that did not come within 2 m of the face of the jump-out; 9 in the treatment “height 18 inches and setback 12 inches”, 3 in the treatment “height 18 inches, setback 15 inches”, and 4 in the treatment “height 15 inches, setback 12 inches”. This changed the respective results for these treatments in Figure 21 for jumping up to 0.00% (N=131), 0.00% (N=23) and 0.00% (N=98).

There were only 3 mule deer observed within the fenced right-of-way that did not come within 2 m of the face of the jump-out; 1 in the treatment “height 18 inches and setback 4 inches”, and 2 in the treatment “height 18 inches, setback 15 inches”. This changed the respective results for these treatments in Figure 22 for jumping down to 18.75% (N=16) and 83.33% (N=54). There were 9 mule deer observed on the habitat side of the jump-outs that did not come within 2 m of the face of the jump-out; 1 in the treatment “height 18 inches and setback 4 inches”, 5 in the treatment “height 18 inches and setback 12 inches”, and 3 in the treatment “height 18 inches, setback 15 inches”. This changed the respective results for these treatments in Figure 22 for jumping up to 0.00% (N=9), 0.00% (N=18) and 16.13% (N=31).

## 3.4 Net Benefit Jumping Down vs. Jumping Up for Mule Deer

For all 4 treatments combined, the percentage mule deer that jumped down to the safe side of the fence was 64.20% (Figure 22). Compared to the 32.35% effectiveness of the non-modified jump-outs this was an improvement by a factor of 1.98. However, with the lower jump-outs, the percentage mule deer that jumped up into the fenced road corridor increased (unmodified jump-outs 0.00% vs. lowered jump-outs for all 4 treatments combined 14.71%). Nonetheless the balance of the modified jump-outs (all 4 treatments combined) was positive; 52 mule deer jumped down (desired behavior) and 5 mule deer jumped up (undesired behavior). In other words, by increasing the effectiveness for mule deer jumping down by a factor 1.98 compared to non-modified jump-outs, 25.74 (1-(52/1.98)) more mule deer escaped from the fenced road corridor, while “only” 5 more mule deer entered the fenced road corridor. The result is a “net benefit” of 20.74 fewer mule deer in the fenced road corridor. This means that, despite some mule deer jumping up, lowering the jump outs to a height of 5 ft, regardless of the bar height and a bar setback, still resulted in a marked performance improvement, with related benefits for human safety and fewer dead and injured mule deer.

For the treatment with a height of 46 cm (18 inches) and a setback of 38 cm (15 inches) the percentage mule deer that jumped down to the safe side of the fence was 80.36% (Figure 22). Compared to the 32.35% effectiveness of the non-modified jump-outs this was an improvement by a factor of 2.48. However, with the lower jump-out for this specific treatment, the percentage mule deer that jumped up into the fenced road corridor increased (unmodified jump-outs 0.00%

vs. lowered jump-outs with this treatment 14.71%) (Figure 22). Nonetheless the balance of the modified jump-outs with the treatment with a height of 46 cm (18 inches) and a setback of 38 cm (15 inches) was positive; 45 mule deer jumped down (desired behavior) and 5 mule deer jumped up (undesired behavior). In other words, by increasing the effectiveness for mule deer jumping down by a factor 2.48 compared to non-modified jump-outs, 26.85 (1-(45/2.48)) more mule deer escaped from the fenced road corridor, while “only” 5 more mule deer entered the fenced road corridor. The result is a “net benefit” of 21.85 fewer mule deer in the fenced road corridor. This means that, despite some mule deer jumping up, lowering the jump outs to a height of 5 ft and a bar height of 46 cm (18 inches) and a bar setback of 38 cm (15 inches) still resulted in a marked performance improvement, with related benefits for human safety and fewer dead and injured mule deer.

## 3.5 Deer Behavior when Jumping Down

There was only 1 white-tailed deer for which the images showed if and with how many legs the animal first stepped over the bar before jumping down (Table 4). This animal first stepped over the bar with 2 legs (the front legs). Mule deer jumped down by jumping over the bar (without first stepping over it), but also by first stepping over the bar with one or more legs (Table 4). Most of the mule deer that jumped down first stepped over the bar with at least 1 leg, most often 2 legs (front legs), before jumping down (Figure 25). One mule deer stepped over with all 4 legs before jumping down. The jump-outs with the greatest setback (38 cm (15 inches)) received most of the successful jump downs and most of the mule deer that jumped down stepped over the bar with their two front legs before jumping down.

**Table 4: The number of deer that successfully jumped down to the habitat side and with how many legs they first stepped over the bar, if any.**

| Species | Step over bar | Individuals observed per treatment (N) Height - Setback | | | |
|---|---|---|---|---|---|
| | | 18 - 4 | 18 - 12 | 18 - 15 | 15 -12 |
| | | | | | |
| White-tailed deer | no step over | | | | |
| | step over, 1 leg | | | | |
| | step over, 2 legs | | 1 | | |
| | step over, 3 legs | | | | |
| | step over, 4 legs | | | | |
| Mule deer | no step over | 3 | 1 | 12 | 1 |
| | step over, 1 leg | | | 4 | |
| | step over, 2 legs | | 2 | 26 | |
| | step over, 3 legs | | | | |
| | step over, 4 legs | | | 1 | |


**Figure 25: A mule deer steps over the bar with both its front legs before jumping down (desired behavior).**

# 4 DISCUSSION

Overall, the jump-outs that were lowered to a height of 152 cm (5 ft) did not improve the effectiveness for white-tailed deer jumping down (unmodified jump-outs 6.88% vs. lowered jump-outs 5.48%) (Huijser et al. 2016). However, the probability of collisions did not increase either as no white-tailed deer were observed jumping up into the fenced road corridor (unmodified jump-outs 0.00% vs. lowered jump-outs 0.00% (Huijser et al. 2016). Overall, the jump-outs that were lowered to a height of 152 cm (5 ft), regardless of the 4 different treatments, about doubled the effectiveness for mule deer jumping down (unmodified jump-outs 32.35% vs. lowered jump-outs 64.20%) (Huijser et al. 2016). However, with the lower jump-outs the percentage mule deer that jumped up into the fenced road corridor increased (unmodified jump-outs 0.00% vs. lowered jump-outs 6.94%) (Huijser et al. 2016). Nonetheless, the balance of the modified jump-outs compared to the non-modified jump-outs was still very positive; a "net benefit" of 25.74 fewer mule deer in the fenced road corridor for all 4 treatments combined.

The height and setback of the bar did influence the likelihood of mule deer jumping down to the habitat side of the fence. The treatment with a height of 46 cm (18 inches) and a setback of 38 cm (15 inches) had 80.36% of all mule deer that were observed in the fenced road corridor jump down. Further investigation showed that a setback of 38 cm (15 inches) had more of the mule deer place their front legs over the bar before jumping down. The data showed that a greater setback of the bar improved the performance of the jump-outs in allowing mule deer to escape the fenced road corridor. The treatment with a height of 46 cm (18 inches) and a setback of 38 cm (15 inches) did have some mule deer jump up into the fenced road corridor. Nonetheless, the balance of the modified jump-outs compared to the non-modified jump-outs was still very positive; a "net benefit" of 21.85 fewer mule deer in the fenced road corridor for the treatment with a bar height of 46 cm (18 inches) and a setback of 38 cm (15 inches).

# 5 CONCLUSION

The modified jump-outs, for the 4 different treatments combined, about doubled the effectiveness in allowing mule deer to escape the fenced road corridor unmodified jump-outs 32.35% vs. lowered jump-outs 64.20%). One specific treatment with a bar height of 46 cm (18 inches) and a bar setback of 38 cm (15 inches) even had 80.36% of all mule deer on top jump down. While some mule deer jumped up into the fenced road corridor, the balance of the modified jump-outs compared to the non-modified jump-outs was still very positive; there were 25.74 fewer mule deer in the fenced road corridor for all 4 treatments combined, and 21.85 fewer mule deer in the fenced road corridor for the treatment with a bar height of 46 cm (18 inches) and a setback of 38 cm (15 inches).

However, there was no improvement for any of the treatments of the lowered jump-outs for white-tailed deer. For jump-outs to become more effective for white-tailed deer, a lower height of the bar, or a greater setback of the bar, may be required. It may also be that a jump-out height of 152 cm (5 ft) is still too high for white-tailed deer, regardless of the presence, height, and setback of a bar.

# 6 REFERENCES

Adams, P.J., M.P. Huijser & S.C. Getty. 2023. An assessment of existing and potential future mitigation measures related to grizzly bears along US Highway 93, Flathead Indian Reservation, Montana, USA. Confederated Salish and Kootenai Tribes, Pablo, Montana, USA.

AZDOT. 2013a. Wildlife escape measures. Arizona Department of Transportation, Phoenix, Arizona, USA.

AZDOT. 2013b. Statewide wildlife features inventory program: feature descriptions and inventory protocol. Environmental Services, Phoenix, Arizona, USA.

Bissonette, J.A. & M. Hammer. 2000. Effectiveness or earthen return ramps in reducing big game highway mortality in Utah. UTCFWRU Report Series 2000 (1): 1-29.

Gagnon, J.W., C.D. Loberger, K.S. Ogren, C.A. Beach, H.P. Nelson & S.C. Sprague. 2020. Evaluation of the effectiveness of wildlife guards and right of way escape mechanisms for large ungulates in Arizona. Report no. FHWA-AZ-20-729. Arizona Game and Fish Department, Phoenix, Arizona, USA.

Huijser, M.P., P. McGowen, A. P. Clevenger, & R. Ament. 2008. Best practices manual, wildlife-vehicle collision reduction study, Report to U.S. Congress. Federal Highway Administration, McLean, VA, USA.

Huijser, M.P., A.V. Kociolek, T.D.H. Allen, P. McGowen, P.C. Cramer & M. Venner. 2015. Construction guidelines for wildlife fencing and associated escape and lateral access control measures. NCHRP Project 25-25, Task 84, National Cooperative Highway Research Program, Transportation Research Board of the National Academies, Washington D.C., USA.

Huijser, M.P., W. Camel-Means, E.R. Fairbank, J.P. Purdum, T.D.H. Allen, A.R. Hardy, J. Graham, J.S. Begley, P. Basting & D. Becker. 2016. US 93 North post-construction wildlife-vehicle collision and wildlife crossing monitoring on the Flathead Indian Reservation between Evaro and Polson, Montana. FHWA/MT-16-009/8208. Western Transportation Institute – Montana State University, Bozeman, Montana, USA.

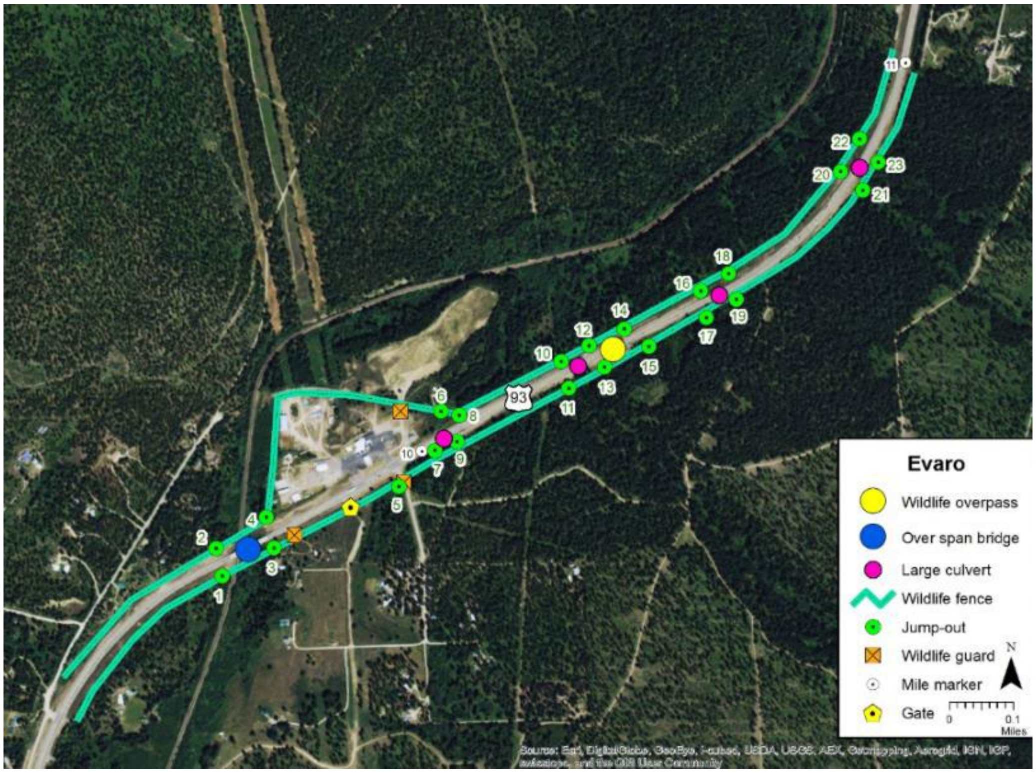
Jensen, A.J., J.D. Perrine, N. Siepel & M. Robertson. 2018. A proposed analysis of deer use of jumpout ramps and wildlife use of culverts along a highway with wildlife exclusion fencing. Pp.145-151. In: Woods, D.M. (Ed.). Proceedings of the Vertebrate Pest Conference, 2018, 28.

Kintsch, J., P. Cramer, P. Singer & M. Cowardin. 2021. State Highway 9 wildlife crossings monitoring. Report No. CDOT-2021-01. ECO-Resolutions, Golden, Colorado, USA.

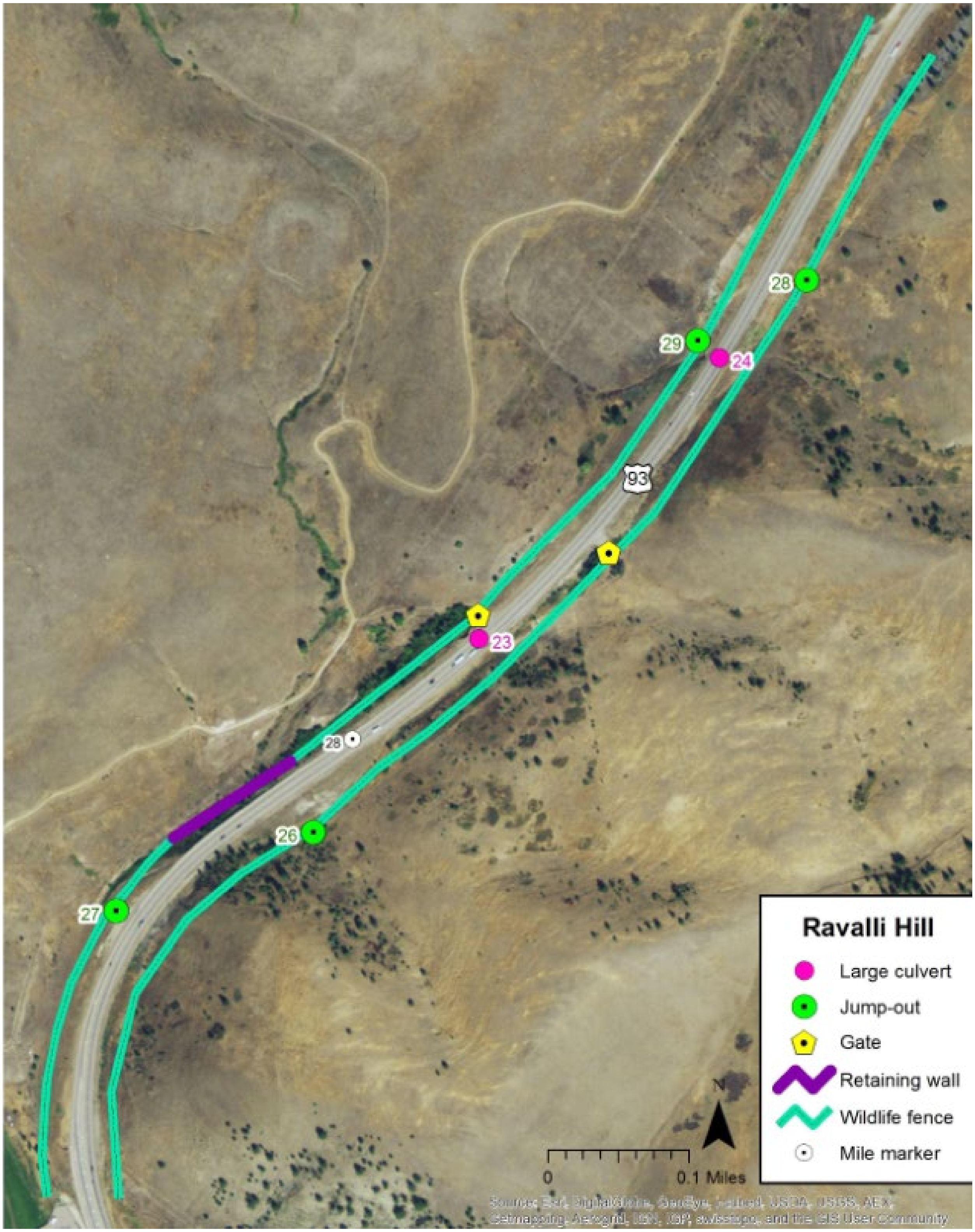
Siemers, J.L., K.R. Wilson & S. Baruch-Mordo. 2013. Wildlife fencing and escape ramp monitoring: Preliminary results for mule deer on southwest Colorado. Proceedings of the 2013 International Conference on Ecology and Transportation (ICOET 2013).

Siepel, N.R., J.D. Perrine, L.K. Schicker & M. Robertson. 2013. Saving lives and training the next generation: State Route 101 wildlife corridor safety project. Proceedings of the 2013 International Conference on Ecology and Transportation (ICOET 2013).

# 7 APPENDIX A



Location of the jump-outs in the Evaro area (green circles and associated ID#).




Location of the jump-outs in the Ravalli Hill area (green circles and associated ID#).

# 8 APPENDIX B

The abundance of individual species observed at the jump-outs, either on top or at the bottom, excluding human researchers, height, and setbacks of the bar for the jump-outs.

| Species | Total individuals observed (N) | Individuals observed per treatment (N) Height - Setback | | | |
|---|---|---|---|---|---|
| | | 18” - 4” | 18” - 12” | 18” - 15” | 15” - 12” |
| | | | | | |
| White-tailed deer | 341 | 1 | 176 | 36 | 128 |
| Cattle domesticated | 212 | 11 | 140 | 10 | 51 |
| Mule deer | 153 | 27 | 31 | 89 | 6 |
| Domesticated cat | 55 | | 32 | 13 | 10 |
| Bird spp. | 55 | | | 1 | 54 |
| Black bear | 37 | 4 | 8 | 18 | 7 |
| Coyote | 23 | | 7 | 10 | 6 |
| Bobcat | 22 | 2 | 1 | 18 | 1 |
| Human on foot | 20 | | | 1 | 19 |
| Red squirrel | 20 | | 3 | 2 | 15 |
| Western striped skunk | 16 | | 5 | 9 | 2 |
| Chipmunk spp. | 7 | | 2 | | 5 |
| Elk | 7 | | 5 | | 2 |
| Mountain lion | 6 | 1 | | 5 | |
| Snowshoe hare | 6 | | 1 | 1 | 4 |
| Deer unknown species | 5 | | 4 | | 1 |
| Domesticated dog | 4 | | 4 | | |
| Unknown species | 4 | | 2 | | 2 |
| Cottontail mountain | 2 | | 2 | | |
| Red fox | 2 | | | | 2 |
| Unknown ungulate | 2 | | | | 2 |
| Hare unknown | 1 | | | | 1 |
| Human with bicycle | 1 | | | | 1 |
| Moose | 1 | | 1 | | |
| Raccoon | 1 | | | 1 | |
| Wolf | 1 | | 1 | | |