Preliminary Data on Wildlife Use of Existing Structures along I-25,

Kaycee, Wyoming, USA

INTERIM REPORT 1

by

Marcel P. Huijser, PhD

Amanda Warren, BSc

&

Elizabeth R. Fairbank, MSc

Western Transportation Institute
College of Engineering, Montana State University,
P.O. Box 174250. Bozeman, MT 59717-4250

A report prepared for the
Wyoming Game and Fish Department
5400 Bishop Blvd
Cheyenne, WY 82006

August, 2019

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official policies of the Western Transportation Institute (WTI) or Montana State University (MSU). This report does not constitute a standard, specification, or regulation.

ACKNOWLEDGEMENTS

The authors of this report would like to thank the Wyoming Game and Fish Department and the Buffalo Field Office of the Bureau of Land Management for funding this project. We also thank the Wyoming Department of Transportation for their help. Special thanks are due to the following individuals. Their contributions have been critical to the project.

- Todd Caltrider (Wyoming Game and Fish Department)
- Christopher Sheets (Bureau of Land Management)

TECHNICAL DOCUMENTATION

1. Report No. 4W7020	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A	
4. Title and Subtitle Preliminary Data on Wildlife Use of Existing Structures along I-25, Kaycee, Wyoming, USA. Interim report 1.		**5. Report Date** 1 August 2019 **6. Performing Organization Code**	
7. Author(s) M.P. Huijser, A. Warren & E.R. Fairbank		**8. Performing Organization Report No.**	
9. Performing Organization Name and Address Western Transportation Institute P.O. Box 174250 Montana State University Bozeman, MT 59717-4250		**10. Work Unit No. (TRAIS)** **11. Contract or Grant No.** 4W7020	
12. Sponsoring Agency Name and Address Wyoming Game and Fish Department 5400 Bishop Blvd Cheyenne, WY 82006		**13. Type of Report and Period Covered** Research report April 2018 – August 2019 **14. Sponsoring Agency Code**	
15. Supplementary Notes A PDF version of this report is available from WTI's website at www.westerntransportationinstitute.org			
16. Abstract This is an interim report with the preliminary data on wildlife use of existing structures under I-25 which were not originally designed for wildlife. There were 15 wildlife species observed at the structures, and 13 of these species passed through a structure at least once. However, the structures are predominantly used by mule deer (2,491 successful crossings) and to a lesser extent by white-tailed deer (772 successful crossings). Both deer species usually accepted the structures; most deer that were recorded at a structure ended up passing through the structure (74% for mule deer, 95% for white-tailed deer). However, the pronghorn that were recorded at the structures almost never passed through the structures. The structure that was used by pronghorn three times was relatively wide: 227 ft / 69 m from the animal's perspective. The number of successful passages for mule deer was highest from June through November, with lower numbers in the winter (December) and spring (April and May). The patterns for white-tailed deer and pronghorn are not as clear, probably because of their relatively low sample size. Mule deer and white-tailed deer crossed at every hour of the day, but mostly around dusk and dawn. While in lower numbers, mule deer continued to cross throughout the night, and they crossed substantially less during the middle of the day. Pronghorn were predominantly active near the structures between 5-8 am and 2-8 pm. Pronghorn were barely active near the structures during the dark hours, suggesting they cannot take advantage of low traffic volume during the night for at grade crossings. Pronghorn may be relatively vulnerable to the barrier effect of roads and traffic, at least when compared to mule deer and white-tailed deer. The preliminary conclusion is that the existing structures without wildlife fences appear to be accepted by mule deer and white-tailed deer, but not or barely by pronghorn.			
17. Key Words agriculture, bridges, collisions, connectivity, corridors, crashes, crossing structures, culverts, deer, equipment, existing structures, fences, habitat, highway, hotspot, livestock, machinery, mitigation, mortality, measures, mule deer, plan, population, procedures, prioritization, pronghorn, ranking, river, road, roadkill, safety, strategy, strategies, stream, tools, tunnels, underpasses, ungulates, viability, vehicle, wildlife, Wyoming		**18. Distribution Statement** Unrestricted. This document is available through WTI-MSU.	
19. Security Classification (of this report) Unclassified	**20. Security Classification. (of this page)** Unclassified	**21. No. of Pages** 24	**22. Price**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

SUMMARY

This is an interim report with the preliminary data on wildlife use of existing structures under I-25 which were not originally designed for wildlife. There were 15 wildlife species observed at the structures, and 13 of these species passed through a structure at least once. However, the structures are predominantly used by mule deer (2,491 successful crossings) and to a lesser extent by white-tailed deer (772 successful crossings). Both deer species usually accepted the structures; most deer that were recorded at a structure ended up passing through the structure (74% for mule deer, 95% for white-tailed deer). However, the pronghorn that were recorded at the structures almost never passed through the structures. The structure that was used by pronghorn three times was relatively wide: 227 ft / 69 m from the animal's perspective. The preliminary conclusion is that the existing structures without wildlife fences appear to be accepted by mule deer and white-tailed deer, but not or barely by pronghorn.

The number of successful passages for mule deer was highest from June through November, with lower numbers in the winter (December) and spring (April and May). Interestingly, the number of unsuccessful passages by mule deer was highest from June through September, presumably because the mule deer were grazing in the immediate vicinity of the structures, within detection range of the cameras. The patterns for white-tailed deer and pronghorn are not as clear, probably because of their relatively low sample size.

Mule deer and white-tailed deer crossed at every hour of the day, but mostly around dusk and dawn. While in lower numbers, mule deer continued to cross throughout the night, and they crossed substantially less during the middle of the day. Pronghorn were predominantly active near the structures between 5-8 am and 2-8 pm. Pronghorn were barely active near the structures during the dark hours. The latter is particularly interesting; pronghorn seem only potentially interested in crossing the road during the day light when traffic volume tends to be higher than during the middle of the night. This suggests that pronghorn cannot take advantage of low traffic volume during the night for at grade crossings, and that they may be relatively vulnerable to the barrier effect of roads and traffic, at least when compared to mule deer and white-tailed deer.

1. INTRODUCTION

1.1. Background

A general decline in mule deer population size and an increase in unnatural mortality is associated with residential and energy development, highways, fences, and severe weather (Sawyer et al., 2016; Johnson et al., 2017). The decline of mule deer populations is a concern to the Wyoming Game and Fish Department (WGFD) (Pers. Com. Todd Caltrider, Terrestrial Habitat Biologist, WGFD). In addition, mule deer hunters in Wyoming have expressed concern about the decline in mule deer populations and hunting opportunities (Pers. Com. Todd Caltrider, Terrestrial Habitat Biologist, WGFD). Hunters are particularly concerned with the negative effects of predation, harvest management, climate and drought, habitat loss, and highways and other transportation infrastructure on mule deer hunting opportunities (Pers. Com. Todd Caltrider, Terrestrial Habitat Biologist, WGFD). WGFD is responsible for the management and conservation of wildlife in Wyoming. WGFD is sensitive to the concerns of hunters, especially issues related to hunting opportunities for game species, including mule deer. Therefore, WGFD is coordinating with Wyoming Department of Transportation (WYDOT) to reduce direct wildlife mortality along highways while maintaining or improving habitat connectivity.

1.2. The Project

A section of I-25 near Kaycee (mile reference posts 253-268) has been identified as having high direct road mortality for mule deer (Pers. Com. Todd Caltrider, Terrestrial Habitat Biologist, WGFD) (Figure 1). Between 1 January 2006 and 31 December 2014 there were 1,111 large wild mammals removed (123.4 per year) along 60 miles of I-25 (between mile reference posts 240 and 300). Most of the carcasses related to mule deer (n=806, 72.55%) (Huijser, 2017). The remaining carcasses related to white-tailed deer (n=240, 21.60%), pronghorn (n=55, 4.95%), elk (n=5, 0.45%), and moose (n=5, 0.45%) (Huijser, 2017). The road section has an average annual daily traffic volume of about 1,500-1,800 vehicles per day with about 18-20% truck traffic (Pers. Com. Mark Williams, WYDOT). This section of I-25 has right-of-way fences and it has existing underpasses for streams, roads, livestock, and farm equipment (see images in Huijser, 2017). WYDOT and WGFD would like to explore the possibility of funneling large mammals, particularly mule deer and pronghorn, through the existing underpasses rather than building new underpasses specifically designed for wildlife. A cost-benefit analyses showed that the thresholds for wildlife fences (i.e. replacing right-of-way fences with 8 ft high standard ungulate proof fence, no new dedicated wildlife crossing structures) are easily met along substantial sections of I-25 (Huijser et al., 2009; 2017). In some areas, new dedicated wildlife underpasses and overpasses may even be attractive based on financial considerations alone (Huijser, 2017). Both WGF and WYDOT would also like to learn about the actual effectiveness of this wildlife mitigation approach that uses the existing underpasses (i.e. existing underpasses not built for wildlife) in combination with potential future wildlife fences to reduce wildlife-vehicle collisions and provide wildlife safe crossing opportunities. The benefits of a mitigation approach that is based on existing underpasses are:

- No travel delays and other issues associated with building new underpasses. The road surface and roadbed can remain intact as the mitigation approach does not include new underpasses that are specifically designed for wildlife. Instead, the mitigation approach aims to funnel wildlife to existing underpasses built for other purposes (streams, roads, livestock, and farm equipment). This reduces the impact to travelers and adjacent landowners.
- No funds required for designated wildlife underpasses. Instead, the mitigation approach aims to funnel wildlife to existing underpasses built for other purposes (streams, roads, livestock, and farm equipment).
- Wildlife-vehicle collisions can be "immediately" addressed as soon as wildlife fences are constructed. A mitigation approach based on existing underpasses lends itself to a relatively swift implementation of mitigation measures aimed at reducing wildlife-vehicle collisions while maintaining habitat connectivity for wildlife. Constructing new crossing structures that are specifically designed for wildlife requires not only more time for construction. New crossing structures that would be specifically designed for wildlife are typically only implemented when the highway requires major reconstruction. This means that such a "traditional" mitigation approach may not be implemented for multiple decades. Therefore, wildlife-vehicle collisions may not be addressed for decades as well. Instead, a mitigation approach based on existing underpasses can be implemented within a relatively short timeframe.

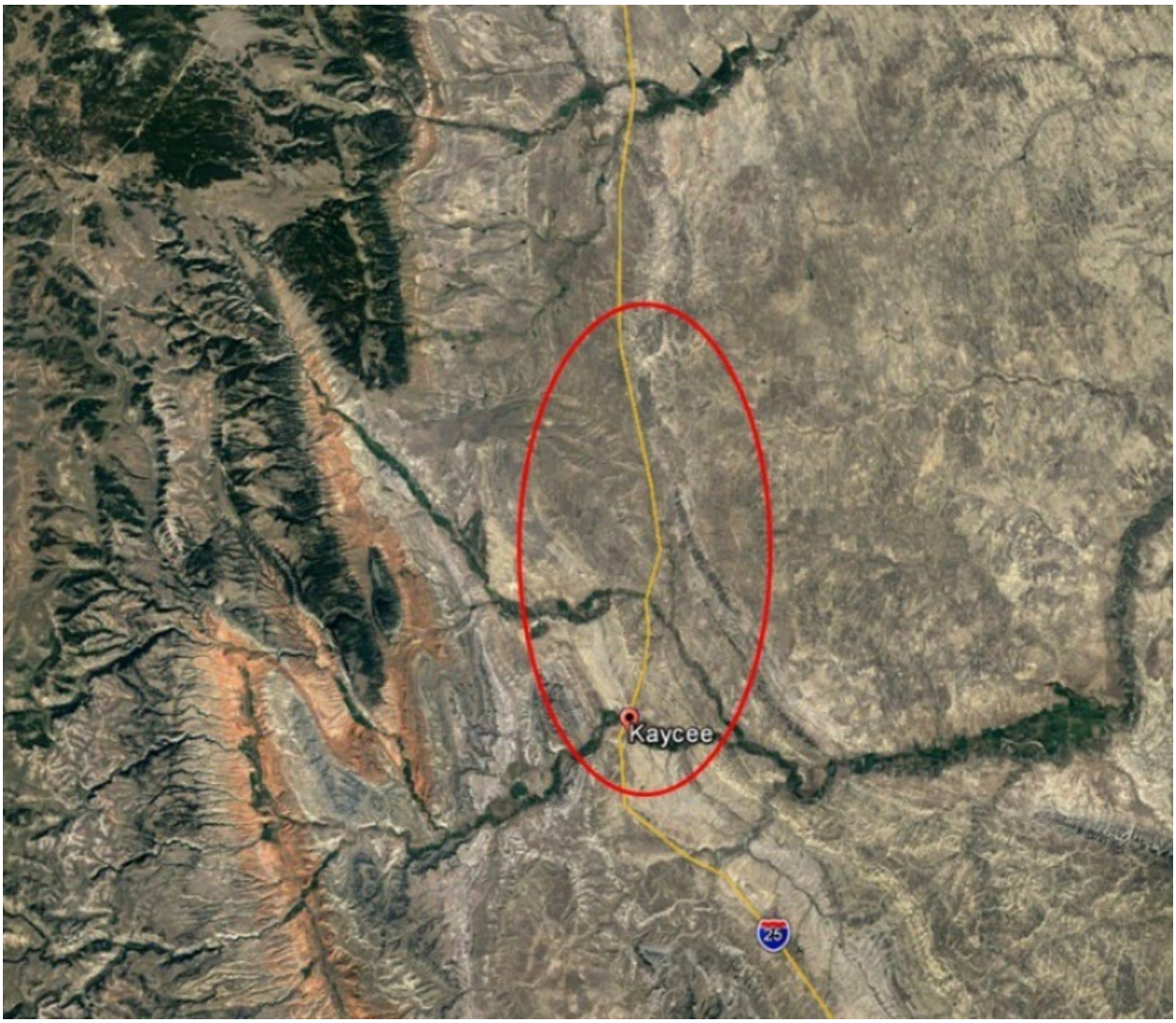

Figure 1: The section of I-25 (around mile reference posts 253-268) near Kaycee that has a concentration of mule deer-vehicle collisions (red oval).

1.3. This Report

This report is a preliminary summary of the wildlife use of the structures that were monitored. The data relate to the period 16 April 2018 until 15 January 2019. The data include all species observed, regardless of the certainty of species identification.

2. PRELIMINARY DATA ON WILDLIFE USE OF THE STRUCTURES

2.1. Structures Monitored

The researchers monitored 9 structures with wildlife cameras (Reconyx PC900 HyperFire); 7 structures that were centrally located in designated (future) control or fenced road sections, and 2 additional structures that were not part of the principal study design. See Huijser (2017) for details on locations of the structures and study design.

Table 1: The structures that were monitored for wildlife use.

Structure Name	(Future) Control/Fenced	Mile Reference Post	Structure Description	Width structure from animal's perspective	Cameras (n)
MP 259	Fenced 1	258.98	Bridge-North Fork Powder River	139ft/42.4m	4
MP 261	Control 1	261.43	Bridge- Old Highway 87	158ft/48m	4
MP 265	Fenced 2	265.48	Bridge- Reno Rd Interchange	83ft/25m	2
MP 269	Control 2	269.22	Bridge farm vehicles	75ft/23m	2
MP 276	Fenced 3	276.22	Underpass farm equipment	75ft/23m	2
MP 272	Control 3	271.88	Bridge farm vehicles	75ft/23m	1
MP 279	Control 4	279.56	Bridge-Middle Fork Crazy Woman	227ft/69m	6
MP 264	Additional culvert	264.01	Double round corrugated metal culvert at Antelope Creek	~10 ft diameter on each side	1
MP 270	Additional culvert	270.5	Concrete box culvert for livestock	~10x10ft	1
Total					23

2.2. Species Use of the Structures and Acceptance

There were 15 wildlife species observed at the structures, and 13 of these species passed through a structure at least once (Table 1). The most frequently observed wildlife species at the structures were mule deer (68.74% of all wildlife observations), white-tailed deer (16.59%), and unidentified deer (5.14%), and raccoon (5.14%) (Table 2). Most deer that were recorded at a structure ended up passing through the structure (74% for mule deer, 95% for white-tailed deer). Of the 138 pronghorn observed at the structures, only 3 (2.17%) ended up passing through the structures. “Other” included swift foxes (n=11), unidentified fox species (n=1) and a ground squirrel species (n=1).

Table 2: The wildlife species, and humans and domesticated species recorded at the structures (total), whether the individuals passed through the structures (yes, mixed (some in group did, others did not), no, unknown), and the acceptance of the structure (yes/total).

	Passage						
Species	**Total (n)**	**Total (%)**	**Yes**	**Mixed**	**No**	**Unknown**	**Acceptance (%)**
Wildlife species							
Deer mule	3369	68.74	2491	116	591	171	73.94
Deer white-tailed	813	16.59	772	11	28	2	94.96
Deer spp	252	5.14	175	4	54	19	69.44
Raccoon	252	5.14	224		8	20	88.89
Pronghorn	138	2.82	3		127	8	2.17
Fox red	15	0.31	9		3	3	60.00
Hare	13	0.27	4		7	2	30.77
Other	13	0.27	9		3	1	69.23
Skunk w striped	13	0.27	11			2	84.62
Coyote	7	0.14	5			2	71.43
Rabbit	7	0.14	1		1	5	14.29
Elk	3	0.06			3		0.00
Badger	2	0.04				2	0.00
Bobcat	2	0.04	2				100.00
Moose	1	0.02			1		0.00
Unknown	1	0.02				1	0.00
Subtotal	4901	100	3706	131	826	238	
Humans and domesticated species							
Human and car	5347	40.53	5330		17		
Sheep domestic	3844	29.14	2800		1044		
Cow domestic	3292	24.95	2468	147	611	66	
Cat domestic	193	1.46	165		8	20	
Human and ATV	171	1.30	167		4		
Horse	159	1.21	143	2	12	2	
Human data collector	76	0.58	76				
Human and horse	53	0.40	49		4		
Dog	25	0.19	18	2	2	3	
Human	22	0.17	12		9	1	
Human and dog	7	0.05	6		1		
Human and bicycle	4	0.03	4				
Subtotal	13193	100	11238	151	1712	92	
Total	18094	200	14944	282	2538	330	

2.3. Species Use per Structure

Species use per structure is summarized in Table 3.

Table 3: The species observed at each structure.

Structure	Species	Passage				
		Total	Yes	Mixed	No	Unknown
MP 259	Bobcat	1	1			
MP 259	Cat domestic	15	14		1	
MP 259	Deer mule	395	362	4	15	14
MP 259	Deer spp	22	16		3	3
MP 259	Deer white-tailed	63	59		3	1
MP 259	Horse	153	137	2	12	2
MP 259	Human	1				1
MP 259	Human data collector	10	10			
MP 259	Other	4	3		1	
MP 259	Raccoon	229	216		5	8
MP 261	Badger	2				2
MP 261	Cat domestic	115	103		1	11
MP 261	Cow domestic	7	7			
MP 261	Deer mule	371	335		23	13
MP 261	Deer spp	12	11			1
MP 261	Deer white-tailed	2	2			
MP 261	Dog	4	2			2
MP 261	Fox red	7	6			1
MP 261	Horse	6	6			
MP 261	Human	2	2			
MP 261	Human and ATV	9	9			
MP 261	Human and bicycle	3	3			
MP 261	Human and car	2521	2516		5	
MP 261	Human and dog	5	4		1	
MP 261	Human and horse	28	25		3	
MP 261	Human data collector	10	10			
MP 261	Other	2	2			
MP 261	Raccoon	3			1	2
MP 261	Sheep domestic	1650	1650			
MP 261	Skunk w striped	8	8			
MP 261	Unknown	1				1
MP 264	Cat domestic	16	13		1	2
MP 264	Cow domestic	422	320	82	20	

Structure	Species	Passage				
		Total	Yes	Mixed	No	Unknown
MP 264	Coyote	2				2
MP 264	Deer mule	757	310	53	308	86
MP 264	Deer spp	29	9		15	5
MP 264	Dog	2	2			
MP 264	Fox red	3	1		1	1
MP 264	Hare	11	4		6	1
MP 264	Human	2	2			
MP 264	Human and ATV	15	15			
MP 264	Human and car	25	25			
MP 264	Human and horse	15	15			
MP 264	Human data collector	8	8			
MP 264	Other	1	1			
MP 264	Pronghorn	11			11	
MP 264	Rabbit	6	1		1	4
MP 264	Raccoon	3	1		1	1
MP 264	Skunk w striped	1				1
MP 265	Cat domestic	14	9		2	3
MP 265	Cow domestic	600	600			
MP 265	Deer mule	134	102		27	5
MP 265	Deer spp	8	7		1	
MP 265	Dog	8	6	2		
MP 265	Human	7	5		2	
MP 265	Human and ATV	13	11		2	
MP 265	Human and bicycle	1	1			
MP 265	Human and car	2642	2635		7	
MP 265	Human and dog	2	2			
MP 265	Human and horse	6	6			
MP 265	Human data collector	9	9			
MP 265	Moose	1			1	
MP 265	Other	1	1			
MP 265	Skunk w striped	1	1			
MP 269	Deer mule	217	158	19	29	11
MP 269	Deer spp	57	24	4	29	
MP 269	Deer white-tailed	3	3			
MP 269	Dog	6	3		2	1
MP 269	Human and ATV	5	5			
MP 269	Human and car	11	9		2	

Structure	Species	Passage				
		Total	Yes	Mixed	No	Unknown
MP 269	Human data collector	9	9			
MP 269	Pronghorn	11			10	1
MP 269	Sheep domestic	2194	1150		1044	
MP 270	Cow domestic	161		4	157	
MP 270	Deer mule	253	133	23	92	5
MP 270	Deer spp	8	1		2	5
MP 270	Deer white-tailed	2	2			
MP 270	Elk	3			3	
MP 270	Fox red	5	2		2	1
MP 270	Hare	1				1
MP 270	Human and ATV	3	3			
MP 270	Human and car	2	2			
MP 270	Human data collector	8	8			
MP 270	Other	4	1		2	1
MP 270	Pronghorn	96			94	2
MP 270	Skunk w striped	1	1			
MP 272	Cat domestic	1			1	
MP 272	Cow domestic	584	445		139	
MP 272	Deer mule	11			8	3
MP 272	Deer spp	2			2	
MP 272	Human and ATV	67	67			
MP 272	Human and car	110	110			
MP 272	Human and horse	4	3		1	
MP 272	Human data collector	4	4			
MP 272	Pronghorn	1			1	
MP 272	Rabbit	1				1
MP 272	Raccoon	2				2
MP 276	Deer mule	537	477	7	34	19
MP 276	Deer spp	56	53		1	2
MP 276	Deer white-tailed	14	12		1	1
MP 276	Human	5	3		2	
MP 276	Human and ATV	55	55			
MP 276	Human and car	34	33		1	
MP 276	Human data collector	8	8			
MP 276	Pronghorn	3				3
MP 276	Raccoon	8	2		1	5

Structure	Species	Passage				
		Total	Yes	Mixed	No	Unknown
MP 276	Skunk w striped	2	1			1
MP 279	Bobcat	1	1			
MP 279	Cat domestic	32	26		2	4
MP 279	Cow domestic	1518	1096	61	295	66
MP 279	Coyote	5	5			
MP 279	Deer mule	694	614	10	55	15
MP 279	Deer spp	58	54		1	3
MP 279	Deer white-tailed	729	694	11	24	
MP 279	Dog	5	5			
MP 279	Hare	1			1	
MP 279	Human	5			5	
MP 279	Human and ATV	4	2		2	
MP 279	Human and car	2			2	
MP 279	Human data collector	10	10			
MP 279	Other	1	1			
MP 279	Pronghorn	16	3		11	2
MP 279	Raccoon	7	5			2

2.4. Mule Deer, White-tailed Deer, and Pronghorn Crossings by Month

The researchers tallied the number of successful passages and unsuccessful passages per month for mule deer, white-tailed deer, and pronghorn (Figures 2, 3 and 4). Unsuccessful passages included observations of animals that were not necessarily interested in using the crossing structure; many observations of "unsuccessful passages" related to animals that were grazing near the crossing structures.

The number of successful passages for mule deer was highest from June through November, with lower numbers in the winter (December) and spring (April and May) (Figure 2). However, monitoring in April did not start until 16 April; the data from April do not relate to the entire month. Interestingly, the number of unsuccessful passages by mule deer was highest from June through September, presumably because the mule deer were grazing in the immediate vicinity of the structures, within detection range of the cameras. The patterns for white-tailed deer and pronghorn are not as clear, probably because of their relatively low sample size.

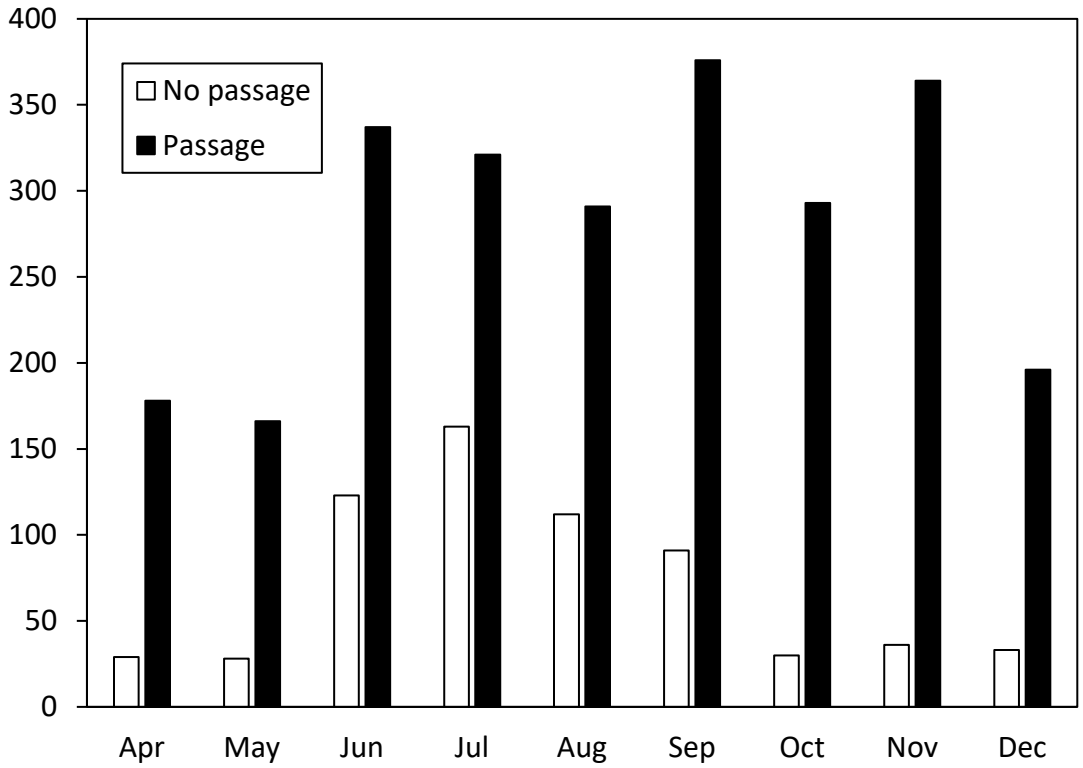

Figure 2: The number of successful passages and unsuccessful passages per month for mule deer.

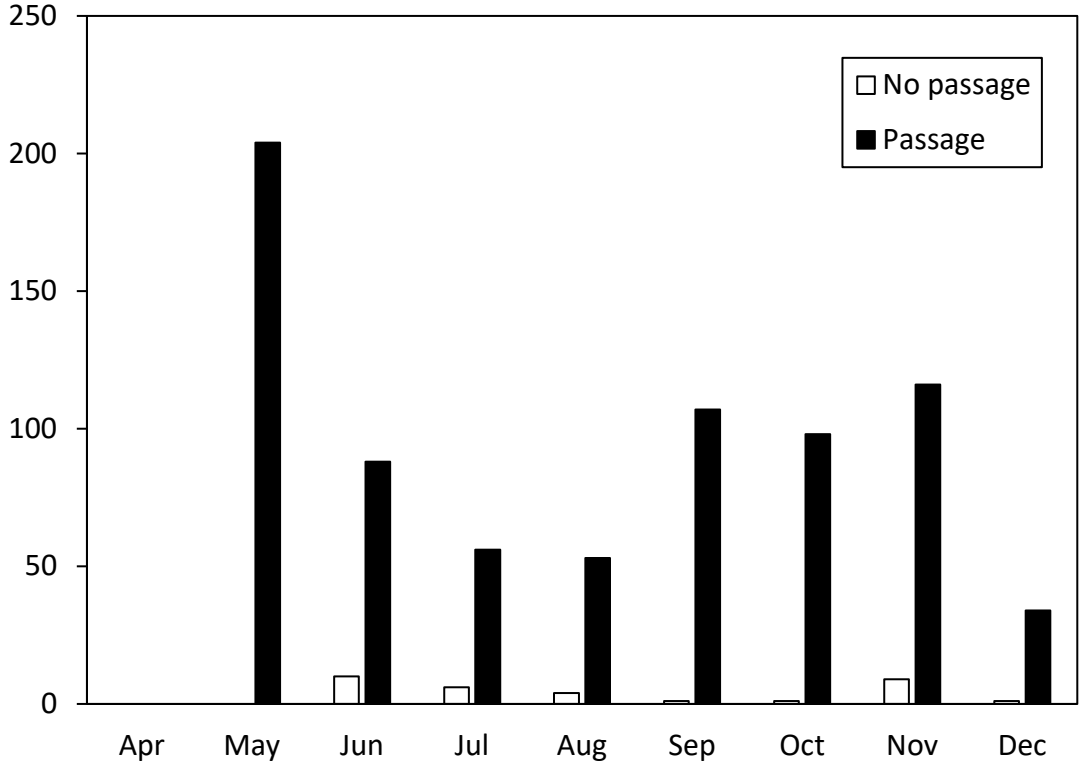

Figure 3: The number of successful passages and unsuccessful passages per month for white-tailed deer.

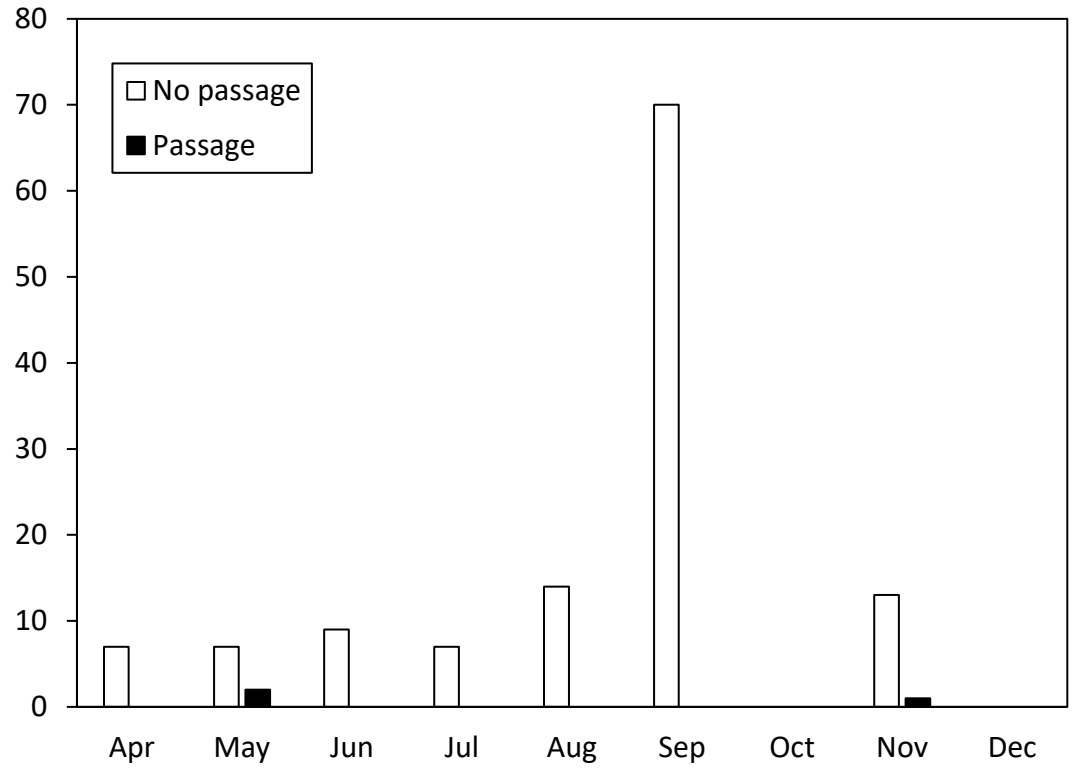

Figure 4: The number of successful passages and unsuccessful passages per month for pronghorn.

2.5. Mule Deer, White-tailed Deer, and Pronghorn Crossings by Hour of Day

The researchers tallied the number of successful passages and unsuccessful passages per hour of day for mule deer, white-tailed deer, and pronghorn (Figures 5, 6 and 7). Unsuccessful passages included observations of animals that were not necessarily interested in using the crossing structure; many observations of "unsuccessful passages" related to animals that were grazing near the crossing structures.

Mule deer and white-tailed deer crossed at every hour of the day, but mostly around dusk and dawn. While in lower numbers, mule deer continued to cross throughout the night, and they crossed substantially less during the middle of the day. Pronghorn were predominantly active between 5-8 am and 2-8 pm. Pronghorn were barely active during the dark hours.

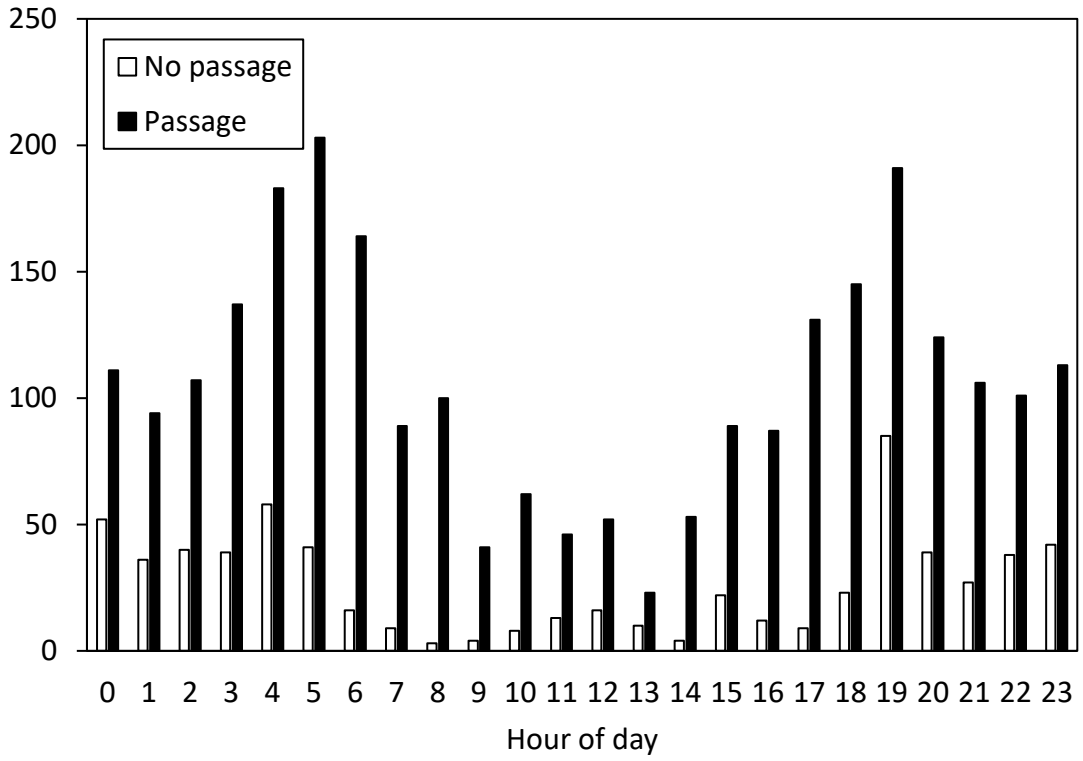

Figure 5: The number of successful passages and unsuccessful passages per hour of day for mule deer.

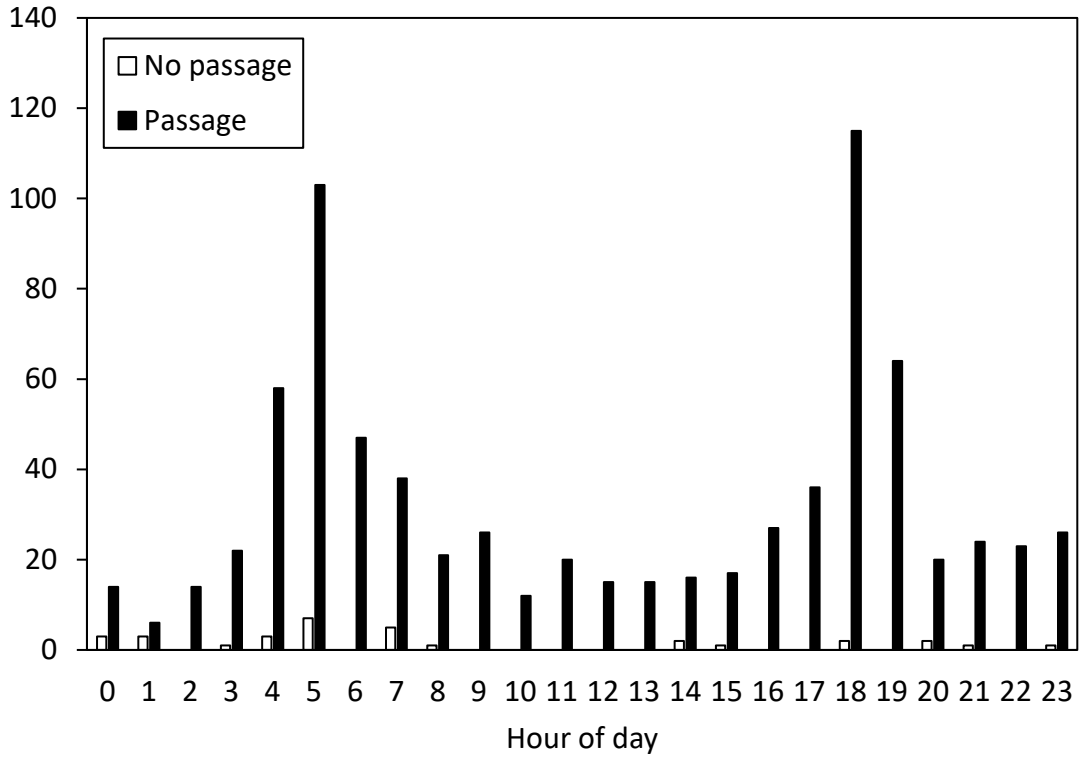

Figure 6: The number of successful passages and unsuccessful passages per hour of day for white-tailed deer.

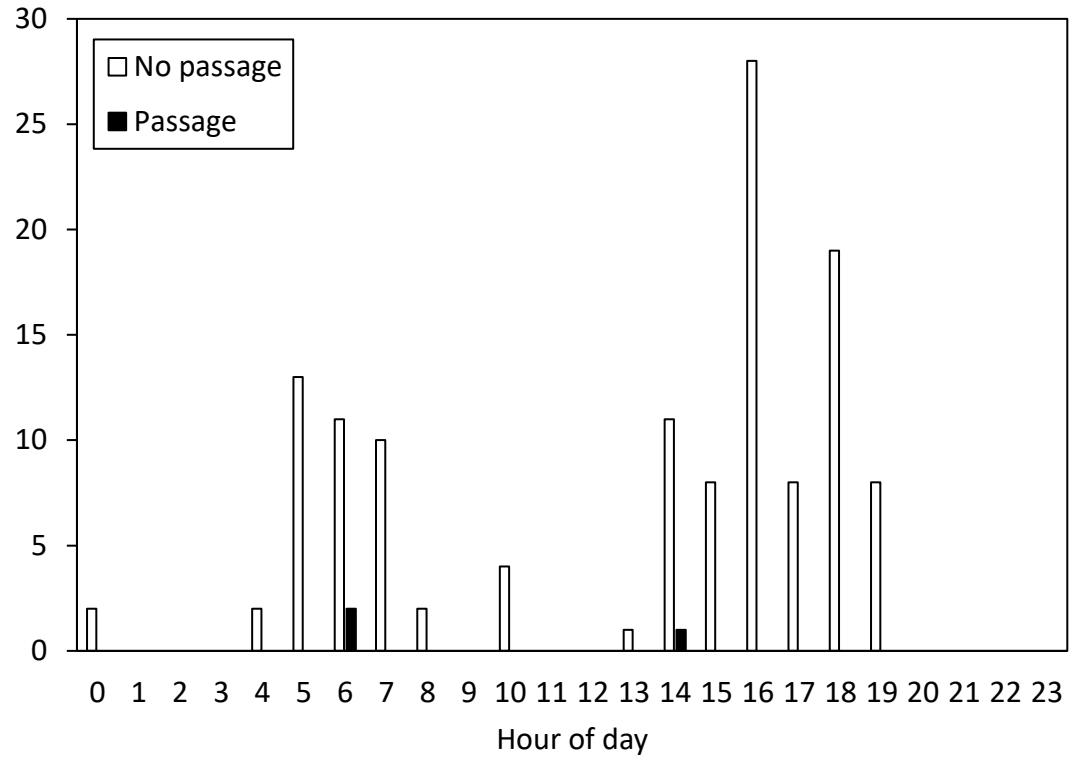

Figure 7: The number of successful passages and unsuccessful passages per hour of day for pronghorn.

2.6. Preliminary Conclusions

There were 15 wildlife species observed at the structures, and 13 of these species passed through a structure at least once. However, the structures are predominantly used by mule deer (2,491 successful crossings) and to a lesser extent by white-tailed deer (772 successful crossings). Both deer species usually accepted the structures; most deer that were recorded at a structure ended up passing through the structure (74% for mule deer, 95% for white-tailed deer). However, the pronghorn that were recorded at the structures almost never passed through the structures (2.1% acceptance). The structure that was used by pronghorn three times was relatively wide: 227 ft / 69m from the animal's perspective. The preliminary conclusion is that the existing structures without wildlife fences appear to be accepted by mule deer and white-tailed deer, but not or barely by pronghorn.

The number of successful passages for mule deer was highest from June through November, with lower numbers in the winter (December) and spring (April and May). Interestingly, the number of unsuccessful passages by mule deer was highest from June through September, presumably because the mule deer were grazing in the immediate vicinity of the structures, within detection range of the cameras. The patterns for white-tailed deer and pronghorn are not as clear, probably because of their relatively low sample size.

Mule deer and white-tailed deer crossed at every hour of the day, but mostly around dusk and dawn. While in lower numbers, mule deer continued to cross throughout the night, and they crossed substantially less during the middle of the day. Pronghorn were predominantly active near the structures between 5-8 am and 2-8 pm. Pronghorn were barely active near the structures during the dark hours. The latter is particularly interesting; pronghorn seem only potentially interested in crossing the road during the day light when traffic volume tends to be higher than during the middle of the night. This suggests that pronghorn cannot take advantage of low traffic volume during the night, and that they may be relatively vulnerable to the barrier effect of roads and traffic, at least when compared to mule deer and white-tailed deer.

3. REFERENCES

Huijser, M.P., J.W. Duffield, A.P. Clevenger, R.J. Ament & P.T. McGowen. 2009. Cost–benefit analyses of mitigation measures aimed at reducing collisions with large ungulates in the United States and Canada; a decision support tool. Ecology and Society 14(2): 15. [online] URL: http://www.ecologyandsociety.org/viewissue.php?sf=41

Huijser, M.P. 2017. Suggestions for the modification of existing right-of-way fences and bridges to reduce mule deer-vehicle collisions and maintain habitat connectivity for large ungulates along I-25, Kaycee, Wyoming. MPH:ETC report 2017-02, Missoula, Montana, USA.

Johnson, H.E., J.R. Sushinsky, A. Holland, E.J. Bergman, T. Balzer, J. Garner, S.E. Reed,. 2017. Increases in residential and energy development are associated with reductions in recruitment for a large ungulate. Global Change Biology 23 (2): 578-591.

Sawyer, H., A. D. Middleton, M. M. Hayes, M. J. Kauffman, and K. L. Monteith. 2016. The extra mile: Ungulate migration distance alters the use of seasonal range and exposure to anthropogenic risk. Ecosphere 7(10):e01534. 10.1002/ ecs2.1534