

DESIGN RECOMMENDATIONS FROM FIVE YEARS OF WILDLIFE CROSSING RESEARCH ACROSS UTAH

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ABSTRACT

A state-wide camera trap study of how wildlife used 35 bridges and culverts to move under and above roads provided data that can greatly assist in the design of future wildlife crossing structures and the retrofit of existing multiple-use structures to facilitate the passage of mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), moose (*Alces alces*), and other wildlife. The objectives of the study were to: 1. Evaluate how successful different types of bridges and culverts were in passing mule deer, elk, and moose; and 2. Evaluate other wildlife species' use of different types of structures to detect preferences in structure types and in relation to water conveyed in structures. Using 44 cameras over five years, 15 wildlife crossing structures, 20 multiple-use structures, and five pre-construction sites were monitored. Wildlife exclusion fencing (8 feet, 2.4 meters high) was present at all wildlife crossing structures for a minimum of one mile in each direction. There were a total of 20 culverts, 13 bridges, and two overpasses monitored along seven highways. Cameras were placed at culvert and bridge entrances to examine both animals that used the structures and those that approached and then repelled away. Camera traps produced over 2 million pictures over 40,000 plus camera days. All designated wildlife crossing bridges and culverts were used by mule deer, the target species of these structures. Individual mule deer were recorded moving successfully through these structures on over 31,000 occasions. Success rate at each structure was defined as the number of successful individual animal movements through divided by the total number of animals photographed at the entrances. Bridged wildlife crossings had a higher average success rates for mule deer (86.5%) compared to wildlife crossing culverts average success rate (74.3%). Statistical analyses found culvert length was the most important dimension relative to mule deer crossing success rates; the shorter the length, the greater the success rate. The width of the crossing was the second most important dimension, and the height was the least important. Elk were reluctant to use any structures, on just 73 occasions elk used structures. All but seven elk passages were by bull elk. All ages and both genders of moose used a corrugated steel culvert in northern Utah, but were seldom recorded at other structures. Carnivores successfully moved through culverts under bridges and over a wildlife crossing overpass throughout the state, but were not photographed in all structures. Meso-mammals were more often photographed in culverts. Recommendations for the design of future wildlife crossing structures include open bridges with spans that approach or exceed 100 feet (30.5m), culverts well under 200 feet (61m) long, structures in conjunction with streams and water features to help increase the diversity of species present, and the installation of wildlife exclusion fencing. Future research in specific areas with specific populations of different species is necessary to determine local and regional species' preferences.

INTRODUCTION

Wildlife crossing structure designs and wildlife exclusion fencing are important components of mitigation systems that allow wildlife to pass under and above the road while keeping them away from vehicular traffic and potentially becoming involved wildlife-vehicle collisions (wvc). Wildlife crossing structures are culverts and bridges built to accommodate wildlife under or over the roadway (*Bissonette and Cramer 2008*). While the U.S. and Canada have over 1,000 terrestrial wildlife crossing bridges and culverts (*Bissonette and Cramer 2008*, and updated information), scientists and practitioners are still developing the body of knowledge on how different species of wildlife in different places react to a variety of structures. If the wildlife crossing structural designs and dimensions and concurrent wildlife exclusion fencing are researched for their efficacy in promoting wildlife movement while reducing wvc, then departments of transportation can better evaluate their cost-effectiveness and design the most efficient crossing structures. The Utah Department of Transportation (UDOT) constructed 40 wildlife crossing structures along highways in an effort to help prevent wildlife-vehicle collisions across the state. This research project was designed to evaluate how different culvert and bridge designs functioned at passing mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis*), and other wildlife. The overall goal was to help wildlife professionals and transportation professionals understand the effects of structure variables such as height, length, width, and structure type on wildlife use.

METHODS

The research involved the use of 44 motion-sensitive cameras (Reconyx model PC 85 and PC 800 Hyperfire Professional InfraRed) placed across the state at 15 wildlife crossing sites, future wildlife crossing sites, and 20 existing bridges and culverts to help determine mule deer, elk, moose, and other wildlife reactions to and use of the structures, and use of sites of future structures (Figure 1). The roads monitored included: US Highway 6, Interstate 70 (I-70), US Highway 89/91, US Highway 191, Interstate 15 (I-15), Interstate 80 (I-80), and US Highway 189, see Figure 1. Each road consisted of two to six lanes of traffic with traffic volumes ranging from 2,400 vehicles to 44,500 vehicles per day (Annual Average Daily Traffic – AADT, *Utah Department of Transportation 2010*). All 15 wildlife crossing structures had from one to many miles (kilometers) of wildlife exclusion fencing placed along the road and connected to the structures. Cameras were placed at the entrances of each structure, creating what is commonly known as a camera trap. Two camera traps were placed at the entrances of each wildlife crossing structure. Existing structures had between one and two cameras at the entrances, with wider structures such as bridges requiring the two camera trap set up. Cameras were placed approximately 30 feet (9.1m) from the entrances and turned toward the structure. This was the longest distance the cameras' infrared flash could cover at night. The cameras were mounted in utility boxes and locked to cables set in 60 to 100 pounds (27-45 kilos) of concrete in the base of the locked utility boxes. Memory cards from 2 to 8 gigabytes were placed in the cameras, along with either C or AA batteries, depending on the camera model. Cameras were checked every 6 to 8 weeks, when information was downloaded to a laptop computer, batteries changed out, and the photographic data was briefly analyzed to examine for equipment failures or blowing vegetation in front of the cameras. Photographic data was analyzed in the office and information from each event captured on the cameras was input into an Access database. An event was based on both

the activities photographed, and a time limit of 15 minutes. If an event lasted longer than 15 minutes, it was recorded for each 15 minute block of time. Each event was translated into: date, time, time of day, what species of animal was photographed, the number of animals in each gender and age class, and whether each animal successfully moved through the structure, approached but then repelled away, or moved in a parallel motion that typically involved grazing past the entrance of the structure. Data was tallied for each structure.

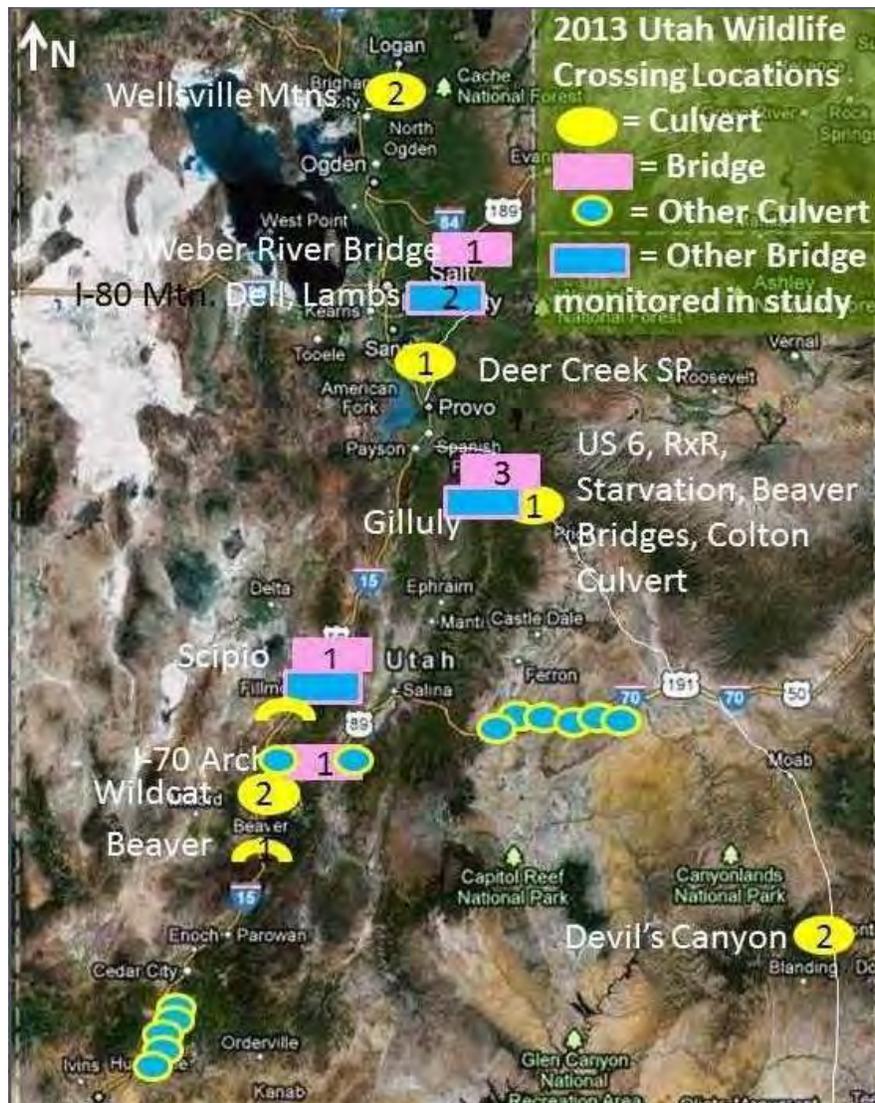


FIGURE 1. Wildlife crossing bridges, culvert, and overpass and existing structures monitored in this study.

Success rates were defined as the total number of occasions an animal of a species went through a structure divided by the total number of occasions animals of that species were photographed in front of the structure. Repel rate was defined as the number of animals that approached the structure and turned away divided by the total number of animals of that species that were photographed in front of the structure. Parallel rate was defined as the total number of animals of

a species that walked past the structure and showed no signs of an intention to walk toward the structure and use it (typically they were grazing on vegetation nearby), divided by the total number of animals of that species that were photographed in front of the camera at that structure. Statistical analyses were performed by Megan Schwender of Utah State University, who developed the database and statistical analyses in conjunction with her Masters of Science degree.

RESULTS

The study generated over two million pictures. Over five years (2008-2013), the study documented mule deer successfully moving under or over wildlife passages on over 31,000 occasions. During that time there were 73 occasions when elk passed under or on wildlife crossings, and 228 successful moose passages through culverts and under bridges. Other species of wildlife also photographed using existing structures and wildlife crossing bridges, culverts and overpass, included: mountain lion (puma, *Puma concolor*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), grey fox (*Urocyon cinereoargenteus*), red fox (*Vulpes vulpes*), badger (*Taxidea taxus*), black bear (*Ursus americanus*), porcupine (*Erethizon dorsatum*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), ground squirrel (*Spermophilus armatus*), marmot (*Marmota flaviventris*), white-tailed jackrabbit (*Lepus townsendi*), and wild turkey (*Meleagris gallopavo*). Results are presented below according to the three main objectives.

Mule Deer, Elk, and Moose Use of Culverts and Bridges

Mule Deer

Mule deer were photographed using all 15 of the designated wildlife crossing structures, 11 of the 12 culverts, three of the 7 bridges created for other purposes, and did not use the overpass created for vehicular use. Mule deer were recorded on over 31,000 occasions using the designated wildlife crossing bridges, culverts, and overpass. Success rates for mule deer passage were calculated for each structure and used as the basis of evaluating the efficacy of the different structures in passing mule deer under and above the road (Table 1).

Overall bridged wildlife crossing structures averaged an 86.5% success rate in passing mule deer. Culverts had an average success rate of 74.3% in passing mule deer. The dimensions of the culverts were statistically analyzed for correlations with mule deer success rates along with two multi-use culverts where wildlife exclusion fencing was placed in 2010. Schwender (2013) took a subset of this data along with the data on the two above mentioned culverts and analyzed the culvert heights, widths, and lengths with respect to mule deer success rates. Schwender (2013) found that in the single variable regression models, mule deer structure use was positively correlated with shorter culverts and that culvert length was the best predictor variable of structure dimensions in correlating higher mule deer success rates. In her research, Schwender (2013) also created a measure of the openness of the culverts based on the dimensions, called the window ratio. Statistical analyses of this window ratio also found a significant relationship of the success rate of mule deer passage with the window ratio, which is largely a measure of the length of a structure.

TABLE 1. Wildlife Crossing Structures Monitored, Dimensions, Date Constructed, and Mule Deer Successful Passages and Repel Rates.

Structure	Type	Height	Width/ Span	Length	Date placed	Number of Mule Deer Passages/ Occasions Through	Mule Deer Success Rate	Mule Deer Repel Rate
Bridges								
US 6 RxR Bridge	Bridge	16'	93'	86'	2009	2,406	98%	2%
US 6 Starvation Bridge	Bridge	16'	108'	82'	2010	818	77%	13%
US 6 Beaver Bridge	Bridge	15.5'	108'	98'	2009	1,387	90%	8%
I-70 MP 5 Bridge pair w/ open median	Bridge	16'	48'	39'	2010	895	93%	7%
I-15 Scipio Bridges pair w/ open median	Bridge	15'	80'	38'	1975	722	*	*
I-80 Weber River Bridge	Bridge	~20'	~130'	~102'	2012	103	68%	14%
I-15 Overpass	Over- pass	na	22'	210' each	1975	1,722	93%	7%
							Bridge average 86.5%	
Culverts								
I-15 Wildcat North culvert pair w/ open median, corrugated steel	Culvert	16-20'	27'	62-68'	2004	7,529	89%	8%
I-15 Wildcat south culvert pair w/ open median, corrugated steel	Culvert	13-15'	25-27'	63-76'	2004	10,062	86%	11%
US 6 Colton Culvert, concrete box	Culvert	16'	26.5'	98'	2008	1,134	95%	1%
US 191 Devil's North corrugated steel	Culvert	10'	14'	110'	2005	567	72%	16%
US 191 Devil's South corrugated steel	Culvert	9.7'	13.5'	121'	2005	179	58%	21%
US 189 Deer Crk. SP corrugated steel	Culvert	21.7'	17-22'	150'	2011	166	83%	6%
US 91 MP 8 Culvert corrugated steel	Culvert	10'	17'	160'	1995	1,284	44%	49%
US 91 MP 14 Culvert corrugated steel	Culvert	13'	17'	165'	1995	2,075	67%	28%
						Total: 31,049	Culvert average 74.3%	

*This bridge was the first monitored in the study and the camera was placed in the center of the median, thus repel events were not recorded, and success rate could not be calculated.

In this study wildlife crossing bridges and culvert lengths were plotted with corresponding success rates (Figure 2). While no statistical analyses was conducted at this time, a trend toward decreasing success rates with increasing lengths regardless of type of structure can be viewed. This plotting of the data allows the viewer to compare mule deer success rates with both lengths and types of structures.

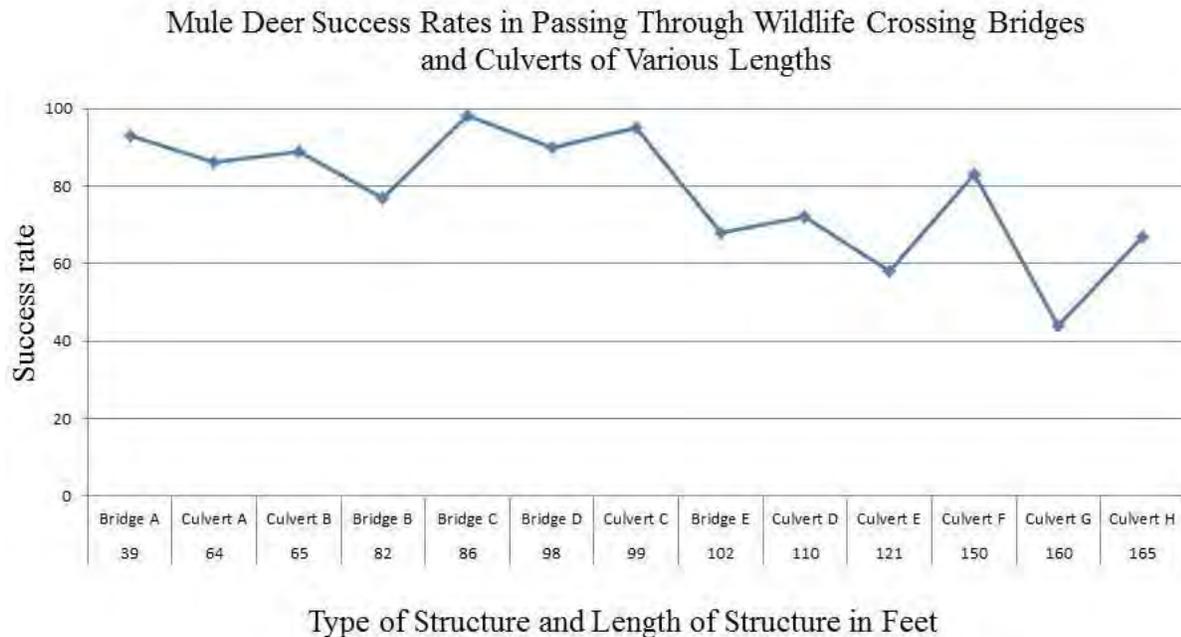


FIGURE 2. Mule deer success rates as a function of length of bridges and culverts. Structures assigned generic names for ease of comparison.

Elk

Elk were photographed approaching 13 different structures a total of 207 individual times. On 73 occasions elk went through culverts and bridges and over an overpass, for an overall success rate of 35%. Bull elk were much more likely to use structures; 57 of elk passages were by bulls, for a success rate of 54%. Cow elk were much less likely to use any structures. Cow elk approached culverts, bridges and an overpass a total of 70 occasions, but used structures just 7 times, for a success rate of 10%. There were 32 occasions where the gender of the animals could not be determined, and 28% of those approaches resulted in an animal using the structure.

The wildlife overpass along I-15 had the greatest number of elk passages, 28 times elk moved over, all of them bulls. The wildlife overpass has been in place since 1975. It is a series of two bridges over the opposing lanes of traffic, with a natural vegetated area above the highway. The overpass bridges are just 22 feet (6.7m) wide, and each approximately 200 feet long (61m). It was built along a major mule deer and elk migration route from the east to west, along the Bureau of Land Management (BLM) lands and to the Dixie National Forest on the east. A recently constructed wildlife underpass bridge along I-70 (built fall of 2010) had the second highest number of elk passages, 25. Again, all of these were bulls. Within two miles of this

recently constructed wildlife passage, there is an existing 230 feet (70m) long box culvert and a pair of box culverts with an open median. These three structures along I-70 were in an area where elk must migrate to lower elevations in winter and move to the mountains in warmer months. The area is within the Fish Lake National Forest. These three structures taken together had the majority of elk movements through structures in the study, 41 successful passages (six of the cow elk successful passages, all occurred in the 230 feet long box culvert). The remaining elk passages through structures (4) occurred under another bridge in the Fish Lake National Forest, and a bridge in the Uinta National Forest.

Moose

Moose were photographed on 284 occasions at six structures. Of the total 284 occasions, 278 of these approaches were to a single corrugated steel culvert in the Wellsville Mountains outside of Logan in northern Utah. The culvert was 10 feet high x 17 feet wide by 160 feet long (3x5x49m). Fifty-one of the approaches to this culvert resulted in animals being repelled (18%), on 4 occasions moose were recorded moving parallel to the culvert (1%), and there was an 80% success rate for moose passage (223 occasions where animals went through). The species was also recorded passing under 2 bridges (n=2), two other culverts (n=3), and repelling from a third existing bridge (n=1).

Wildlife Diversity at Different Structures

This study monitored a total of 15 wildlife crossings: 8 wildlife crossing culverts, 6 wildlife crossing bridges, and one wildlife overpass. Twenty structures that were not created for wildlife were monitored: 7 bridges, one overpass, and 12 culverts. There were 20 culverts in the study, which was 57% of the total structures. The 13 bridges monitored in the study comprised 37% of the total structures. The two overpasses (one for wildlife, one for vehicles) comprised 5.7% of the total structures.

Of the 35 structures studied, six conveyed water for most or all of the year (17% of all structures). Two existing bridges, and four wildlife crossing bridges conveyed water year round or most of the year, and none of the 20 culverts in the study conveyed water for any prolonged period of time annually. In Table 2, species of carnivores, rodents, lagomorphs, and wild turkey photographed at the structures are tallied for the entire study. Because all but the puma, black bear, and coyote were meso-mammals or smaller, most of the animals' recorded passage through the structure was unknown due to their inability to trigger cameras at both ends of a culvert or bridge. Wild turkey were photographed going through several of the structures. No statistical analyses were performed on this data at this time. Several generalizations are made below.

-Puma were photographed at all types of crossings, culverts, bridges and the wildlife crossing overpass, supporting the statement that the species will use all types of structures, with perhaps a slight preference for culverts. There was not a strong attraction to water, as only one of the 13 structures puma were photographed using had a year round water source.

- While bobcat appear to favor bridges based on total occasions photographed at bridges, this could be the results of just one or two bobcats repeatedly using one or two bridges, so results should be taken with caution. Overall bobcat used bridges and culverts with perhaps a preference for bridged structures with water.

TABLE 2. Carnivore, Rabbit, Rodent and Bird Species Most Often Photographed at All Structures and Percentage Use in Culverts, Bridges, and Overpass and In Structures That Conveyed Water.

Species	Total Occasions Photographed at Structures	Total structures where species was photographed	Percentage of Used Structures That were Culverts	Percentage of occasions photographed at culverts	Percentage of occasions photographed at Bridges	Percentage of occasions photographed on Overpass	Percentage of Structures used w/ water
Puma (<i>Puma concolor</i>)	33	13	62%	73%	11%	16%	8% (n=1)
Bobcat (<i>Lynx rufus</i>)	61	12	50%	38%	62%	0	33% (n=4)
Coyote (<i>Canis latrans</i>)	229	17	70%	84%	7%	9%	17% (n=2)
Red fox (<i>Vulpes vulpes</i>)	30	8	88%	97%	3%	0	13% (n=1)
Gray fox (<i>Urocyon cinereoargenteus</i>)	40	3	100%	100%	0	0	0
Black Bear (<i>Urus americanus</i>)	1	1	100%	100%	0	0	0
American Badger (<i>Taxidea taxus</i>)	7	6	83%	83%	14%	0	14% (n=1)
Striped skunk (<i>Mephitis mephitis</i>)	140	6	67%	98%	2%	0	33% (n=2)
Raccoon (<i>Procyon lotor</i>)	302	15	60%	75%	25%	0	27% (n=4)
Ground Squirrel (<i>Spermophilus armatus</i>)	69	13	62%	90%	10%	0	15% (n=2)
Jack rabbit (<i>Lepus spp.</i>)	30	5	80%	70%	30%	0	0
Marmot (<i>Marmota flaviventris</i>)	64	4	50%	60%	40%	0	50% (n=2)
Porcupine (<i>Erethizon dorsatum</i>)	9	2	0	0	100%	0	50% (n=1)
Wild Turkey (<i>Meleagris gallopavo</i>)	56	5	80%	79%	21%	0	0

-Coyote were the most photographed animal after the top three ungulates of the study. On 229 occasions coyotes were photographed at 17 different structures, making for a strong statistical sample. While coyote were photographed on all three structure types, it appears that they used culverts in greater proportion (70%) than the culverts were represented in the study (57%). They used structures with water passing through in proportions identical to the proportion of structures with water, 17% of the total.

-Red fox and gray fox were photographed on 70 occasions. Both species had a strong preference for culverts, with the gray fox photographed solely at culverts and the red fox photographed at culverts on 97% of the occasions they were documented at structures. There did not appear to be an attraction to water carrying structures.

-Striped skunks and raccoons were photographed on hundreds of occasions. Both species were photographed at culverts, and at structures bearing water in greater proportion than those types of structures were present in the study. It appears striped skunks were more closely tied to using culverts than raccoons were.

-Ground squirrels were photographed on 69 occasions, and had a heavy tendency toward using culverts.

-Marmots were photographed on 64 occasions and did not appear to prefer using culverts or bridges, but may prefer structures with water bodies.

-Most birds did not pass through structures but were photographed at entrances or fishing or hunting for prey within structures. The one exception was wild turkey, which was photographed at the entrances of and using structures on 54 occasions. The turkeys were photographed more often in culverts than bridges, and showed no preference for water in structures.

DISCUSSION

This study's length of time and geographic range within the state of Utah gave this research a breadth and depth of data that can assist researchers and practitioners in better understanding different species' preferences for using culverts and bridges of different dimensions and types to pass under and above roads.

Mule Deer

Mule deer was the species that most heavily used the structures and the target species for the development of all the wildlife crossings. With over 31,000 documented mule deer crossing occasions, generalizations can be made about the species' use of structures in Utah. It is apparent that mule deer will use culverts as well as bridges, and a wildlife bridged overpass. The structure averages support the idea that mule deer will more successfully move under bridges than through culverts, in general. When mule deer success rates are plotted against the length of the structures, which is the length the animals have to traverse under the road, a general trend of decreasing success rates with length is apparent, for both bridges and culverts, with some one exception, a 160 feet (48.8m) long culvert, which had a success rate comparable to bridges. This paper did not address success as defined by total numbers of mule deer using structures. The

total numbers of mule deer using a structure is a function of the structure and also the location of the structure in relation to where and how mule deer need to move. The most highly used structures in the study were pairs of culverts with open medians under I-15. They were placed in a migration area that mule deer must move through in order to survive winter and summer seasons. This has allowed an astounding 17,591 mule deer occasions through these structures in the first four years of monitoring. While design recommendations were derived from the data, the importance of location can also be seen from the numbers of animals using certain structures. It is also important to include wildlife exclusion fencing 8 feet (2.4m) with all wildlife crossings for extended (at least 1 mile, 1.6 km) in length on both sides of the road.

Elk

Elk are the most difficult wildlife species to move through any type of wildlife crossing structure. Cow elk have been proven to be the most difficult animal to motivate to move under bridges, over overpasses, and through culverts. Another aspect of this difficulty is the herd nature of elk. When bull elk have approached structures as lone animals or in groups up to three animals, there are greater success rates (over 60%) than when those bull approach a structure in the presence of cow elk. Matriarchal cow elk are the animals making the decisions whether to use structures, and when a herd of up to 20 animals approach a structure, their decision is based on her actions, even the bulls rely on her decision (*see Hamlin 2011 a,b*). In the spring of 2012 UDOT personnel placed a salt/mineral block at the entrance to the bridge wildlife crossing on I-70. In the winter of 2013 a herd of cow elk were photographed eating the salt. Within 2 weeks the herd of about nine cow elk passed under the bridge crossing twice. This was the first herd of elk to use a structure in the entire study. That data was not included in this paper because all photos to that point were not analyzed and incorporated into the data sets. Future publications will include these data. This development may help practitioners and researchers understand how to motivate elk to use crossings, and to appreciate the length of time it takes for elk to learn to use a new wildlife crossing structure.

Moose

Moose are at the southern end of their range in Utah. The northern half of the state has moose populations, southward to approximately I-70. There were fewer occasions for moose to be photographed than elk and mule deer. Nonetheless, they were present in areas and did not use most bridges and culverts monitored. It is not known why they did not use most structures. It is encouraging to see the full range of moose age classes and the two genders using the one culvert in the study they were most often photographed in. This culvert is the US 91 MP 14 culvert, which is 13x 17x 165 feet (4x5.2x50m). The short height of the culvert in relation to the size of a moose and the length of the culvert would seem to preclude the animal's use of the structure. Since this culvert has been in place since 1995, perhaps the animals in the area have adapted to the culvert over time. It is striking to see that this culvert had one of the lowest mule deer success rates (67%) of all wildlife crossing structures. Moose use of the culvert can be viewed in film at the YouTube channel (*see Hamlin 2011c, d*).

Species Diversity

Fourteen species of mammals and birds in addition to mule deer, elk, and moose were photographed in this study in numbers high enough to warrant reporting. At least six other

species were photographed but not included in this paper. While these species' needs were not included in the development of wildlife crossings and existing structures, it is useful to understand that they do use these structures as well.

Research results can help develop the most effective and efficient wildlife mitigation designs for Utah. In turn, these developments will help reduce wildlife-vehicle collisions and help preserve wildlife populations, especially mule deer and elk, across the western United States.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, the study documented the efficacy of wildlife crossing culverts, bridges, and an overpass in passing mule deer and other wildlife. It also documented the difficulty in moving mule deer through long culverts (greater than 120 feet, 37m), existing multi-use culverts and bridged interchanges, and the extreme difficulty in moving elk through structures of any kind. From the study results designs of future wildlife crossings that consider the species in this study could be informed by the following recommendations.

Mule Deer

Mule deer successfully move through culverts, through bridge underpasses, and over wildlife overpasses. All three types of structures can be used to pass this species. It is strongly recommended that culverts and bridges be kept well under 200 feet (61m) long as the animals traverse under the highway, and kept shorter than 120 feet (36.6m) long to ensure that 80% or more of the mule deer that approach the structures use them. Width is of second importance to mule deer and other ungulates; they need escape space in the event a predator is nearby. If the crossing structure could be made to be as wide as possible it would also help increase successful passage. Finally, structure height is the least important dimension and can be as low as 10 feet (3m) high and still have mule deer success rates above 80%. Wildlife exclusion fencing is also a critical part of wildlife crossing mitigation, along with escape ramps for animals to escape the road right of way.

Elk

Elk are extremely cautious, and not only in Utah. Only bridged wildlife crossings are recommended for elk. Bridged overpasses may perform the best in passing elk, even better than bridged underpass structures, depending on the area. If elk are reluctant to use a structure, it is recommended that the structure be baited with salt/mineral blocks near the entrances to acquaint the more cautious animals with the structure in hopes they will someday use it. Continued research will help the transportation ecology community better understand designs and time periods that work for elk.

Moose

Moose in this study were apt in using a corrugated steel culvert just 13 feet (4m) high. This is not the top recommended design for moose, but illustrates the adaptive nature of moose. It is worth noting the moose in Utah have no large predators other than puma. If wolf are in an area, or higher concentrations of predators are found in an area than are found in Utah, it is possible

moose will not be as willing to navigate such small, long structures. Bridges and culverts over 15 feet (4.6m) high and at least 17 feet (5.2m) wide are recommended for moose.

Carnivores and Other Species

The larger carnivores in this study, puma, coyote, and bobcat showed an ability to use all types of crossing structures, with puma and coyote even regularly using a wildlife overpass. Coyote appear to prefer culverts. Bobcat were most often photographed at bridges conveying water. These results may have implications for future designs that would encourage use by each of these species. Puma appear to adapt to any type of crossing. Black bear are heavily hunted in Utah and may perhaps avoid roads, thus the reason for the sole black bear recorded at a structure. Both red fox and gray fox heavily favored using culverts over bridges in the study, thus culverts are recommended for passing these species under roads. Striped skunk, raccoon and ground squirrel all appear to prefer culverts to move under roads. Wild turkeys are highly adaptable and regularly used specific bridges and culverts for movement under the road.

In closing, the study helped clarify mule deer, elk, and to some degree moose preferences for wildlife crossing structure types. Carnivores such as puma, coyote, bobcat and both species of fox were documented in large enough numbers to also make generalizations. The success of this study was dependent on the 5 year time frame, which helped capture wildlife adapting to new structures and to document rarely seen puma, and the geographic range of the study, which was across the state of Utah.

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BIOSKETCH

Patricia Cramer is a Research Assistant Professor at Utah State University. She has active research projects studying wildlife and roads in Utah, Montana, and Oregon, and has completed wildlife crossing studies for Washington State and Idaho. Dr. Cramer was co-author with John Bissonette on the National Academies' Research Project, 'Evaluation of the Use and Effectiveness of Wildlife Crossings.' This 4 year study helped us understand the state of the practice and science of mitigating roads for wildlife in North America. She is a member of the Transportation Research Board's Committee on Ecology and Transportation. She received the Denver Zoo's Conservationist Award for 2010. This study received the Federal Highway Administration 2013 Environmental Excellence Award for Research.

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