CULVERT, BRIDGE, AND FENCING RECOMMENDATIONS FOR BIG GAME WILDLIFE CROSSINGS IN WESTERN UNITED STATES BASED ON UTAH DATA

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ABSTRACT

Long term monitoring of culverts and bridges with and without wildlife exclusion fencing is helping to determine the best designs for wildlife crossings for mule deer and other species. In this study 35 bridges and culverts across Utah were monitored with remote cameras to determine: if wildlife exclusion fencing (8 feet, 2.4 m high) was necessary to convince wildlife to use structures to move beneath roads; if mule deer and other wildlife use increased at these structures with the placement of wildlife exclusion fencing; what structure dimensions were most important to mule deer success rates in using structures; and to determine recommendations for structure designs that encourage the greatest wildlife use, especially by mule deer (*Odocoileus hemionus*), and elk (*Cervus canadensis*). The study was conducted from 2007 through 2013 using 44 remote cameras (camera traps) placed at 15 structures made explicitly for wildlife (wildlife crossing structures), and 20 multiple use culverts and bridges built for other purposes. Wildlife exclusion fencing was present at all wildlife crossing structures for a minimum of one mile in each direction. The multiple purpose structures did not have wildlife exclusion fencing initially. Two fencing projects were completed during the study and four culverts in those stretches were monitored pre and post fencing to help determine wildlife use. Cameras were placed at culvert and bridge entrances to examine animals that used the structures and those that approached and then repelled away. There were a total of 20 culverts, 13 bridges, and two overpasses monitored along seven highways. 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 (87%) compared to wildlife crossing culverts average success rate (74%). 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. Moose were most often photographed using a single corrugated steel culvert. Recommendations for the design of future wildlife crossing structures include open bridges with spans that approach or exceed 100 feet (31m), that are under 100 feet in length as the animals traverse under the road, culverts well under 150 feet (46m) long as the animals traverse under the road, and the installation of wildlife exclusion fencing. Wildlife exclusion fencing does not always ensure mule deer and elk use of existing multi-purpose culverts and bridges. Future research in specific geographic regions with local animal populations is necessary to determine local and regional species' preferences.

INTRODUCTION

Research is necessary to help determine the wildlife crossing structure designs and wildlife exclusion fencing requirements that work best at keeping wildlife off roads and using the wildlife crossing structures to pass beneath or above roads, thus helping to prevent wildlife vehicle collisions. A wildlife crossing structure is a culvert or bridge built specifically to accommodate wildlife under or over the roadway (*1*). While the U.S. and Canada have over 1,000 terrestrial wildlife crossing bridges and culverts (*1*, 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, and to understand the importance of wildlife exclusion fencing (8 feet, 2.4m) in motivating these animals to use wildlife crossing structures. 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

This research project used 44 motion-sensitive cameras (Reconxy 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 multi-purpose 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. 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, (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, *2*). 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 multi-purpose 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 (9m) 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. 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. Statistical analyses were performed by M. Schwender of Utah State University, who developed the database and statistical analyses in conjunction with her graduate degree. Computer code was written in the SAS statistical package, and data was analyzed with the Aike information criteria for the best fitting model that matched structure dimensions with mule deer success rate.

RESULTS

The study generated over two million pictures. Over six years (2007-2013), the study documented mule deer successfully moving under or over wildlife crossing structures on over 31,000 occasions. Of the 20 existing multi-purpose structures, mule deer used 11 of 12 culverts, 3 of 7 bridges, and did not use the overpass created for vehicular use. Success rates for mule deer passage were calculated for structures with the most data and used as the basis of evaluating the efficacy of the different structures in passing mule deer under and above the road (Table 1). The data was organized by structure types, bridges and culverts, and then whether they were created specifically for wildlife, or were existing multi-purpose bridges and culverts without wildlife fencing. Those existing multi-purpose culverts that had or received wildlife exclusion fencing are presented as the final category. This data grouping helps to evaluate bridges versus culverts, wildlife crossings versus existing structures, and fencing to existing structures versus no fencing at those structures.

The success rate for mule deer use of structures was used as the comparison index to evaluate different structures and their efficacy in allowing mule deer to cross beneath or above the road surface. Overall the wildlife crossing bridges had the highest average success rate for mule deer use, they averaged 87%. Wildlife crossing culverts had the second highest average success rate for mule deer, 74%. Multi-purpose bridges with no fencing had the next highest mule deer average success rate, 57%. Multi-purpose culverts with wildlife exclusion fencing placed had the second lowest average success rate, 46%. Finally, multi-purpose culverts with no wildlife exclusion fencing had the lowest average mule deer success rate of any category of structure and fence combination, 37%.

Wildlife crossing bridges and culvert lengths were plotted with corresponding mule deer success rates (Figure 2) to demonstrate the decrease in mule deer success in passing through structures as length increased. The dimensions of the culverts were statistically analyzed for correlations with mule deer success rates. Schwender (*3*) analyzed the culvert heights, widths, and lengths with respect to mule deer success rates and 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. Culvert width was the second most important culvert dimension in predicting mule deer success, with wider culverts having greater success. Culvert height was the least important dimension in predicting mule deer success.

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

Structure	Height	Width/ Span	Length	Date Con-structed	No. Days Moni-tored	No. of Mule Deer Passages/ Occasions Through	Mule Deer Success Rate	Mule Deer Repel Rate
Wildlife Crossing Bridges with Wildlife Exclusion Fencing								
US 6 RxR Bridge	16’	93’	86’	2009	1,014	2,406	98%	2%
US 6 Starvation Bridge	16’	108’	82’	2010	1,060	818	77%	13%
US 6 Beaver Bridge	15.5’	108’	98’	2009	952	1,387	90%	10%
I-70 MP 5 Bridge pair w/ open median	16’	48’	39’	2010	775	895	93%	7%
I-15 Scipio Bridges pair w/ open median	15’	80’	38’	1975	174	722	*	*
I-80 Weber River Bridge	~20’	~130’	~102	2012	111	103	68%	32%
I-15 Overpass	na	22’	210’ each	1975	1,103	1,722	93%	7%
						Wildlife Crossing Bridge Average Success Rate 87%		
Existing Bridges without Wildlife Exclusion Fencing								
I-70 Ivy Creek Bridge					375	4	40%	60%
I-80 Weber River Bridge –Pre Replacement					475	361	73%	27%
						Existing Bridges No Fence Average Success Rate 57%		
Wildlife Crossing Culverts with Fencing								
I-15 Wildcat North culvert pair w/ open median, corrugated steel	16-20’	27’	62-68’	2004	1,050	7,529	89%	11%
I-15 Wildcat south culvert pair w/ open median, corrugated steel	13-15’	25-27’	63-76’	2004	1,095	10,062	86%	14%
US 6 Colton Culvert, concrete box	16’	26.5’	98’	2008	871	1,134	95%	5%
US 191 Devil’s North corrugated steel	10’	14’	110’	2005	671	567	72%	28%
US 191 Devil’s South corrugated steel	10’	13.5’	121’	2005	739	179	58%	42%
US 189 Deer Crk. SP corrugated steel	22’	17-22’	150’	2011	123	166	83%	17%
US 91 MP 8 Culvert corrugated steel	10’	17’	160’	1995	1,221	1,284	44%	56%

US 91 MP 14 Culvert corrugated steel	13’	17’	165’	1995	917	2,075	67%	33%
						Wildlife Crossing Culvert Average Success Rate 74%		
Multi-Purpose Culverts No Fencing								
I-70 MP 6 Concrete Box Culvert	17’	17’	231’	~1975	706	9	31%	69%
I-70 MP 3 Split Concrete Box Culvert – open median between two box culverts of equal dimensions	16’	18’	40’	~1975	277	0	0%	100
I-15 Ash Creek Concrete Box Culvert	26’	26’	135’	~1975	444	11	100%	0%
I-15 Camp Creek North Concrete Box Culvert	9’	11’	210’	~1975	371	12	61%	39%
I-70 Woman Plateau Concrete Box Culvert	11’	12’	210’	~1975	328	1	5%	95%
I-70 Culvert Hollow Concrete Box Culvert	10’	11’	220’	~1975	351	2	25%	75%
						Multi-Purpose Culverts No Fencing Average Success Rate 37%		
Multi-Purpose Culverts With Fencing				Date of Fencing				
I-70 MP 6 Concrete Box Culvert	17’	17’	231’	2010	899	191	47%	53%
I-70 MP 3 Split Concrete Box Culvert– open median between two box culverts of equal dimensions	16’	18’	40’	2010	828	1,627	60%	40%
I-15 Ash Creek Concrete Box Culvert	26’	26’	135’	2011	360	13	29%	71%
I-15 Camp Creek North Concrete Box Culvert	9’	11’	210’	2011	360	87	85%	15%
I-15 Shirts Concrete Box Culvert	13’	13’	207’	2012	360	2	6%	94%
I-15 Westview Box Culvert	9’	9’	220’	2012	360	0	0%	100%
I-70 Rattlesnake Concrete Box Culvert	12’	12’	200’	1985	678	98	63%	37%
I-70 Gooseberry Concrete Box Culvert	12’	12’	98’	1985	662	19	76%	24%
						Multi-Purpose Culverts With Fencing Average Success Rate 46 %		

*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.

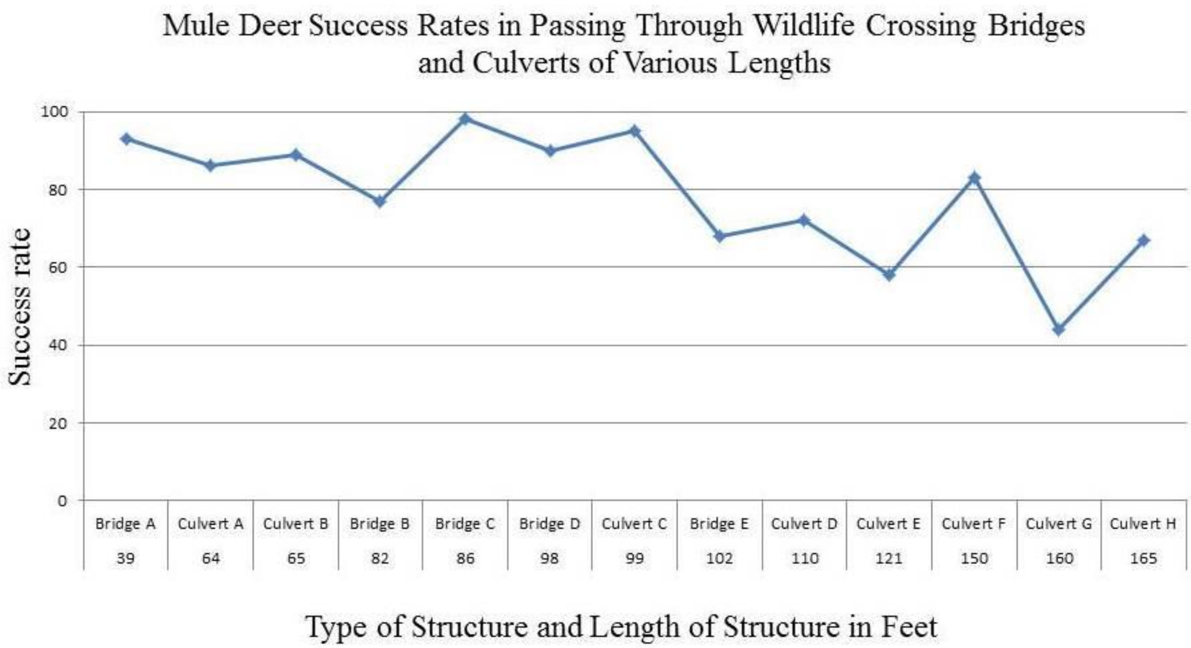

FIGURE 2. Mule deer success rates as a function of length of bridges and culverts. Structures assigned generic names for ease of comparison.

Elk were much more adverse to using any kind of structure than mule deer. 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%. The structure with the greatest number successful elk movement through was the overpass, which had 28 occasions where bull elk moved across the overpass to cross above I-15. This 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 (7m) wide, and each approximately 200 feet long (61m). Culverts were the least useable type of structure, with just 10 total occasions where elk used them to pass beneath the road.

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 that was 10 feet high x 17 feet wide by 160 feet long (3x5x49m). There was an 80% success rate for moose at this culvert.

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 will use a multitude of structure types, with a preference for open bridges. They are least likely to use culverts longer than 150 feet (46m) under the road, without wildlife exclusion fencing. Success rates used as a form of comparison are the most important indicator of animal preferences once they have approached a structure. This is not the only measure. If the number of mule deer occasions through a structure was divided by the number of days a structure was monitored, the mule deer per day would give a more complete picture of how many animals were using the structure and how successful it was overall to the population of animals in the area. For example, a culvert that passed 2 mule deer that approached it would have a success rate of 100% but only passed close to 0 mule deer per day. Data presented in Table 1 allow the reader to make these calculations for themselves from the columns for each structure.

Elk are very adverse to using any kind of structure. Bull elk are more willing to use a variety of structures compared to cow elk, and most heavily used a wildlife overpass. Cow elk are very cautious about using any of the structures studied and may eventually use large open bridges. At this time they can be considered one of the most difficult animals to encourage using any kind of structure to pass beneath or above roads. Moose appear to locally use specific structures, and regularly used a culvert 160 feet (49m) long.

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 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 successfully move through culverts, through bridge underpasses, and over wildlife overpasses. All three types of structures can be used to past 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 (37m) 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. Wildlife exclusion fencing should not be placed to existing multi-purpose culverts and bridges and assumed to be successful in convincing local populations to use these structures to cross beneath roads. The mixed results of this study support the theory that local populations and local situations need to be studied for the efficacy of such actions.

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. When fencing projects placed wildlife exclusion fencing to existing culverts, there were less than one dozen occasions where elk used those structures. This was the case along three highways with 6 culverts, and two bridges. Elk in Utah may not necessarily be motivated to use existing culverts and bridges with wildlife exclusion fencing.

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 (5m) wide are recommended for moose. On just one occasion was a moose photographed using an existing multi-purpose structure with recently place wildlife exclusion fencing. It was a bridge at a local street interchange under an interstate. Moose were not distributed across the state, so there are limited populations of this species. Nonetheless, moose may not adapt to using existing multi-purpose structures, especially culverts, once wildlife exclusion fencing is placed.

In closing, the study helped clarify mule deer, elk, and to some degree moose preferences for wildlife crossing structure types in Utah. The success of this study was dependent on the 6 year time frame, which helped capture wildlife adapting to new structures, and the geographic range of the study, which was across multiple ecosystems in 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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