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Department of Transportation Federal Highway Administration

EVALUATION OF MULE DEER CROSSING STRUCTURES IN NUGGET CANYON, WYOMING

By:

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Abstract: Wildlife-vehicle collisions pose a major safety concern to motorists and can be a significant source of mortality for wildlife. A 13-mile section of Highway 30 in southwest Wyoming has been especially problematic with an average of 130 mule deer killed each year

WYDOT installed at total of seven underpasses along this area. Through three years of monitoring the study documented 49,146 mule deer moving through the underpasses. Overall, the construction of seven underpasses and game-proof fencing reduced deer-vehicle collisions by 81 percent.

The results suggest that underpasses, combined with game-proof fencing, can provide safe and effective movement corridors for mule deer and other wildlife species while improving highway safety for motorists.

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SI* (Modern Metric) Conversion Factors

Approximate Conversions from SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
Volume				
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3

Approximate Conversions to SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
Area				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
Volume				
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3

m^3	cubic meters	1.307	cubic yards	yd^3
Mass				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
Temperature (exact)				
°C	Centigrade temperature	1.8 C + 32	Fahrenheit temperature	°F
Illumination				
lx	lux	0.0929	foot-candles	fc
cd/m^2	$candela/m^2$	0.2919	foot-Lamberts	fl
Force and Pressure or Stress				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

yd^3	cubic yards	0.765	cubic meters	m^3
Mass				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
Temperature (exact)				
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
Illumination				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	$candela/m^2$	cd/m^2
Force and Pressure or Stress				
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

ABSTRACT

Wildlife-vehicle collisions pose a major safety concern to motorists and can be a significant source of mortality for wildlife. A 13-mile section of U.S. Highway 30 in southwest Wyoming that passes through Nugget Canyon has been especially problematic because it bisects the winter range and migration route of a large mule deer herd. Through the 1990's, an average of 130 deer were killed each year. Accordingly, the Wyoming Department of Transportation (WYDOT) installed a series of 20' (w) x 10-11' (h) x 60' (l) concrete box culvert underpasses and game-proof fencing to funnel deer to the underpasses. The purpose of this study was to quantify the number of mule deer that used the underpasses, identify their seasonal and temporal movement patterns, and evaluate how effective the underpasses were at reducing deer-vehicle collisions. Through three years of monitoring, we documented 49,146 mule deer move through the underpasses. Peak movements during the fall migration occurred in mid-December, while peak spring movements were in mid-March and early-May. Most mule deer moved through underpasses during morning (0600-0800 hrs) and evening (1800-2000 hrs) periods. Deer-vehicle collisions were effectively reduced 81%, from 0.75 per month at each milepost to 0.14 per/month. Provided that fence gates remained closed and cattle guards remain clear of snow, deer-vehicle collisions should be eliminated from Nugget Canyon in the near future. Importantly, other wildlife species such as elk, pronghorn, and moose benefited from underpass construction. Our results suggest that underpasses, combined with game-proof fencing, can provide safe and effective movement corridors for mule deer and other wildlife species and improve highway safety for motorists.

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INTRODUCTION

Wildlife-vehicle collisions are a serious safety concern to motorists and can be a significant source of mortality for affected wildlife (Romin and Bissonette 1996, Putman 1997, Forman et al. 2003). Roadway conflicts are especially problematic for ungulates when roads coincide with winter range or migration routes, where animal densities are high during certain times of the year. For example, U.S. Highway 30 west of Kemmerer, Wyoming is a two-lane highway that extends 13 miles through Nugget Canyon – an area that provides crucial winter range for thousands of mule deer and bisects an important migration route. Mule deer-vehicle collisions have historically been high along this roadway, with an average of 130 deer killed per year since 1990 (Plumb et al. 2003). Despite a variety of mitigation measures implemented during the 1990's aimed at slowing traffic and warning motorists of potential collisions with wildlife (e.g., signs, reflectors, flashing lights), dozens of deer-vehicle collisions continued to occur each year in this 13-mile segment (milepost 28-41) of highway. The high rates of deer-vehicle collisions created safety concerns for both motorists and mule deer. In an effort to move deer underneath the highway and reduce deer-vehicle collisions, the Wyoming Department of Transportation (WYDOT) installed seven miles of game fence (milepost 28-35) and a concrete box culvert at milepost 30.5 in 2001. This crossing structure was monitored for two years following construction and was used by hundreds of deer, particularly during spring (March-April) and fall (November-December) migrations (Gordon and Anderson 2003). Structure dimensions (20' w x 10-11' h x 60' l) had an openness ratio of approximately 1.10 and were determined to be adequate for mule deer use (Gordon and Anderson 2003). Although the underpass and associated fencing was successful at reducing deer-vehicle collisions around milepost 30, remaining portions of the project area (i.e., mileposts 35-41) continued to have high levels of collisions and it was apparent that additional crossing structures were needed. Accordingly, WYDOT approved construction of six new underpasses and seven additional miles of game fence to be completed in October 2008. The location of these underpasses generally corresponded with road segments that had high levels of deer-vehicle collisions and were installed at mileposts 35.25, 35.96, 37.44, 38.23, 39.00, and 40.62 (Fig.1).

Our study was designed to evaluate the effectiveness of the newly constructed underpasses and associated fencing. Specifically, we aimed to: 1) quantify the number of mule deer (and other wildlife) that used the underpasses; 2) identify temporal patterns of mule deer movements through underpasses; 3) estimate the success rates of underpasses through time, and 4) evaluate deer-vehicle collisions before underpass construction (1990-2000), after construction of one underpass (2002-2007), and after construction of six additional underpasses (2009-2011). This information was intended to improve the ability of wildlife and transportation agencies to sustain migratory ungulate populations while maintaining public safety on roadways.

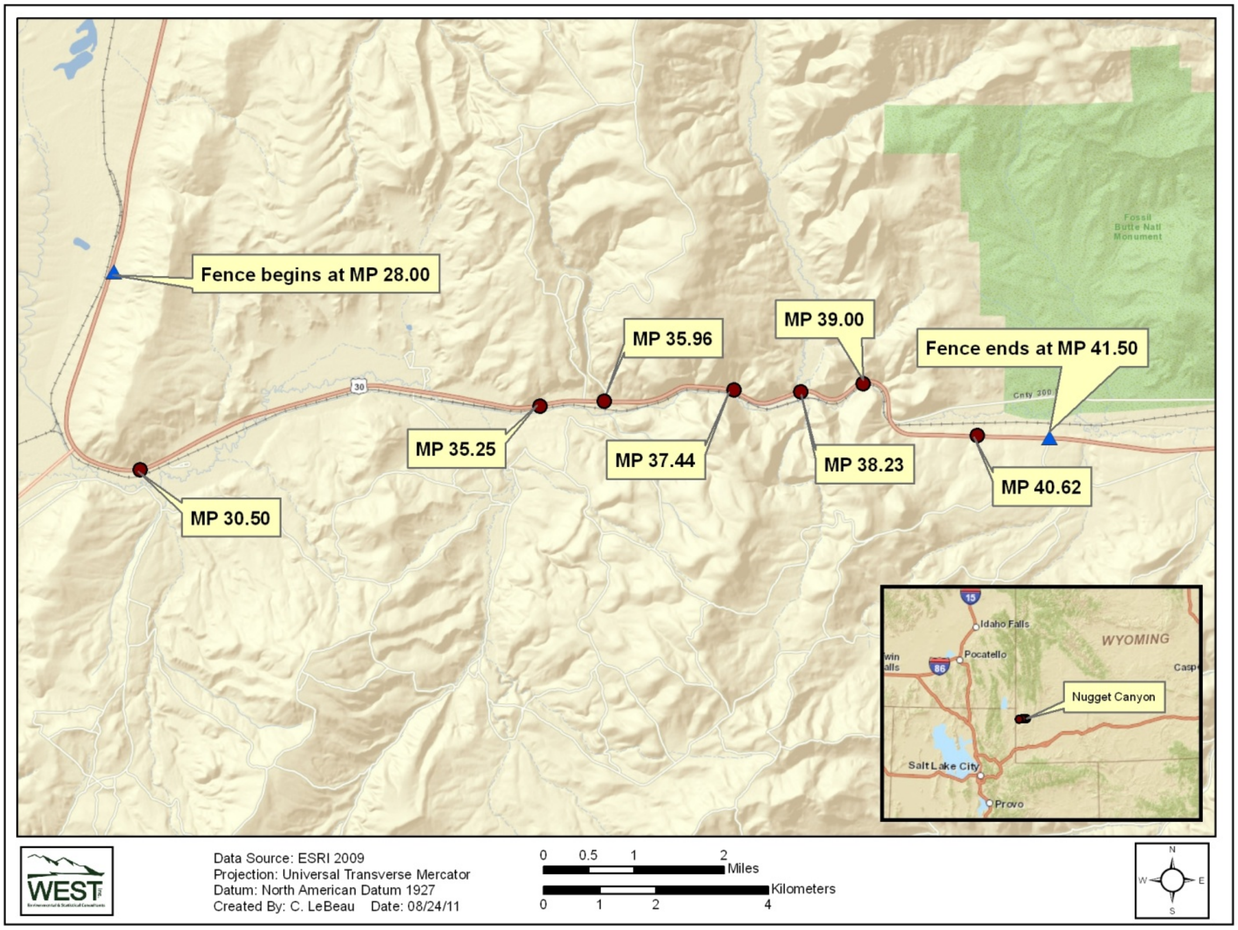

Figure 1. Approximate location of game-proof fencing and underpasses (MP = milepost) along U.S. Highway 30 in Nugget Canyon, Wyoming.

METHODS

We used digital photos from infrared Reconyx® cameras to calculate the number of deer that used each underpass. Three cameras were mounted in each of the seven underpasses, including one at the entrance, one in the middle, and one at the exit (Fig. 2). This camera configuration allowed us to count the number of deer that approached and/or passed through the underpass from either direction. The underpasses were equipped with cameras from December 16, 2008 through May 31, 2011. This time period included the later part of fall 2008 migration, and the entire migration period for spring 2009, 2010, 2011 and fall 2009, 2010. We examined seasonal temporal patterns by plotting the number of deer that passed through each structure each day, across the entire monitoring period. We examined the daily temporal patterns by calculating the number of deer that moved through structures each hour of the day, for a 10-day sampling period that corresponded with the peak levels of use during fall and spring migrations.

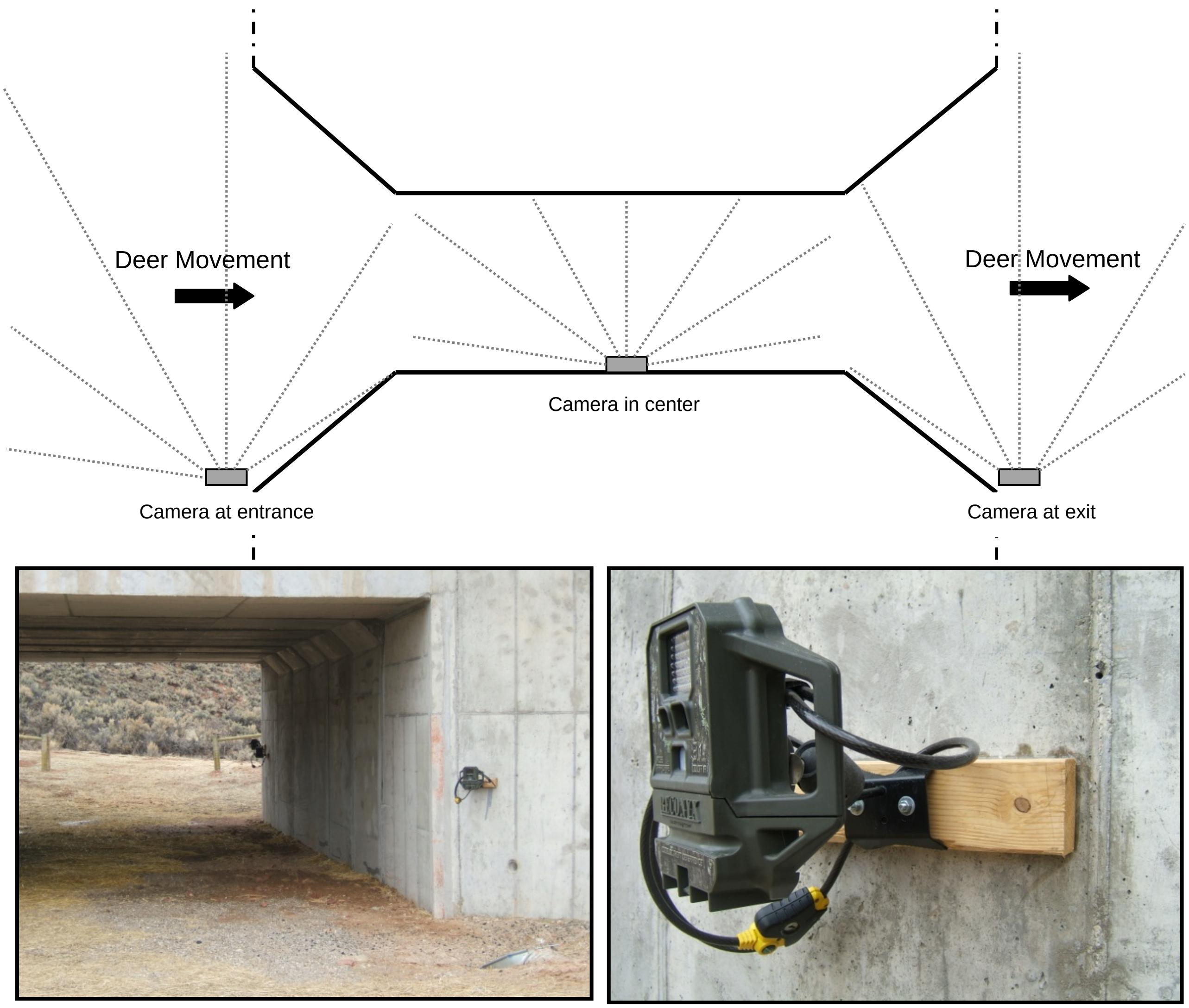

Figure 2. Placement and configuration of three cameras on each of the seven underpasses located at Nugget Canyon, Wyoming.

We evaluated the success of deer crossings by comparing the number of deer that approached each underpass and moved through, versus the total number that approached. This metric was intended to quantify the effectiveness of each crossing structure and evaluate whether mule deer acclimate to the new underpasses over time. Using estimates of how many deer approached each structure and how many passed through, we calculated the success rate of each structure. For example, a structure that had 100 deer approach it and 75 actually move through, would result in a success rate of 75%. We calculated success rates during the 10-day peak migration period of each season (fall 2008 [Dec. 17-26], fall 2009 [Dec. 8-17], fall 2011 [Nov. 21-30], spring 2009 [April 23- May 02], spring 2010 [April 17-26], spring 2011 [May 1-10].

We used deer-vehicle collision data from WYDOT to assess how underpass and fence construction reduced deer-vehicle collisions. We compared the number of deer-vehicle collisions in three time periods: 1) January 1, 1990 – October 1, 2001, (141 months) prior to construction of the underpass at milepost 30.5, 2) October 1, 2001 – October 1, 2008, (82 months) following construction of the underpass at milepost 30.5, and 3) October 1, 2008 – May 1, 2011, (31 months) following construction of six additional underpasses. To make comparisons between the three periods that differed in temporal length, we standardized the number of deer-vehicle collisions by the number of months in each period.

RESULTS

Underpass Use by Mule Deer

We documented 49,146 mule deer move through the seven underpasses between December 2008 and May 2011 (Table 1), including 12,483 during the 2008-09 monitoring season (Dec. 16, 2008-May 20, 2009), 13,403 during the 2009-10 monitoring season (October 1, 2009 through May 31, 2010), and 23,260 during the 2010-11 season (October 1, 2010 through May 31, 2011). The increased levels of use during 2010-11 resulted from harsh winter conditions that pushed more deer than usual south of U.S. Highway 30. Overall, most deer movement occurred at mileposts 30.50 (47%; n=22,924) and 35.96 (28%; n=14,012; Table 1, Plates 1 & 2). However, use at the other five underpasses steadily increased through the three years of study and accounted for the remaining 12%, 28%, and 34% of deer use during the 2008-09, 2009-10, and 2010-11 monitoring seasons, respectively. Most underpass activity occurred during spring (37%; n=18,194) and fall (46%; n=22,569) migrations, but crossings (17%; n=8,383) also occurred on a regular basis throughout the winter period (January and February; Table 1).

Table 1. Number of mule deer that moved through underpasses during the fall migration (October –December), the winter period (January–February), and the spring migration (March–May), December 2008 through May 2011, Nugget Canyon, Wyoming.

	Underpass	2008-09	2009-10	2010-11	Total
Fall Migration	MP 30.50	1,552	3,308	5,553	10,413
	MP 35.25	83	274	855	1,212
	MP 35.96	638	885	4,242	5,765
	MP 37.44	149	1,062	1,529	2,740
	MP 38.23	18	151	298	467
	MP 39.00	3	199	943	1,145
	MP 40.62	47	374	406	827
	sub-total	***2,490***	***6,253***	***13,826***	***22,569***
Winter Period	MP 30.50	2,112	1,228	1,527	4,867
	MP 35.25	69	40	1,782	1,891
	MP 35.96	233	104	379	716
	MP 37.44	56	110	371	537
	MP 38.23	16	22	55	93
	MP 39.00	5	48	104	157
	MP 40.62	37	75	10	122
	sub-total	***2,528***	***1,627***	***4,228***	***8,383***
Spring Migration	MP 30.50	3,496	2,298	1,850	7,644
	MP 35.25	258	136	900	1,294
	MP 35.96	2,957	1,786	1,613	6,356
	MP 37.44	96	557	423	1,076
	MP 38.23	95	179	68	342
	MP 39.00	400	314	287	1,001
	MP 40.62	163	253	65	481
	sub-total	***7,465***	***5,523***	***5,206***	***18,194***
	Total	**12,483**	**13,403**	**23,260**	**49,146**

Plate 1. Of the seven underpasses, milepost 30.50 was used by the largest number of mule deer (*n*=22,294) and recorded 47% of all deer crossings.

Plate 2. The underpass at milepost 35.96 was used by 14,012 mule deer and recorded 28% of all deer crossings.

The amount of deer use varied between fall and spring migrations at some of the underpasses. For example, the proportion of deer use was higher at milepost 30.50 during the fall compared to the spring, whereas deer use at milepost 35.96 was higher during the spring compared to fall (Figs. 3A & B). Additionally, the proportion of use of the newly constructed structures generally increased throughout the study period, whereas use at milepost 30.50 and 35.96 tended to decrease (Figs. 3A & B).

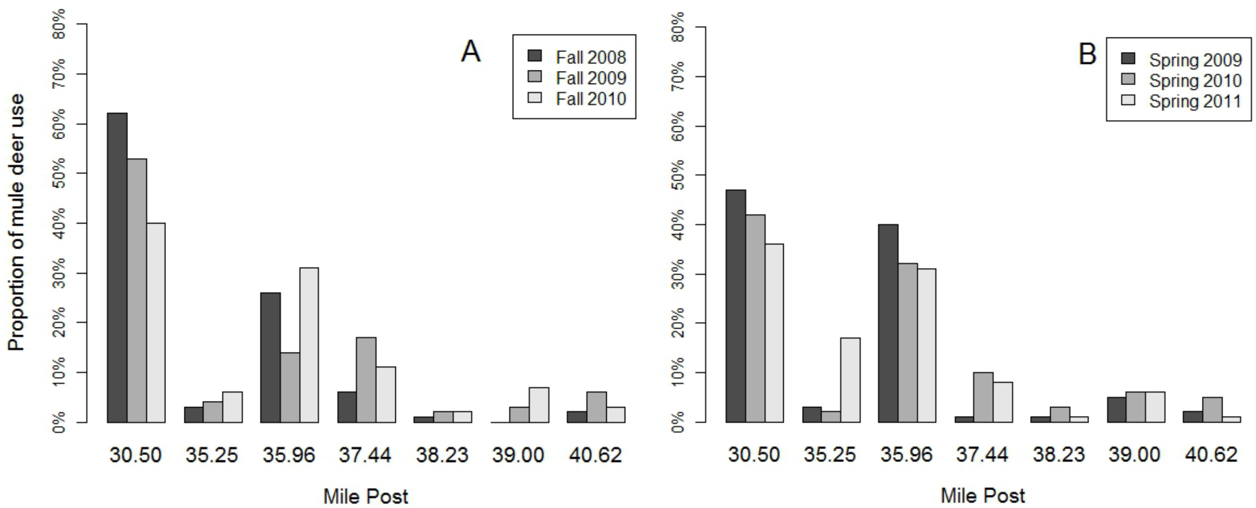

Figure 3. Proportional use of mule deer at each underpass during the fall (A) and spring (B) migrations, December 2008 through May 2011, Nugget Canyon, Wyoming.

The timing of peak movements during the fall migrations occurred in mid-December, with a maximum of 284 animals per day (Fig. 4). Spring migrations were characterized by multiple peaks of deer movement that generally occurred in mid-March and early-May, with a maximum of 223 animals per day (Fig. 4). On a daily basis, peak levels of underpass use occurred in the mornings (0600-0800 hrs) and evenings (1800-2000 hrs; Fig. 5). Morning use was more prominent during the spring, whereas evening use was more common in the fall.

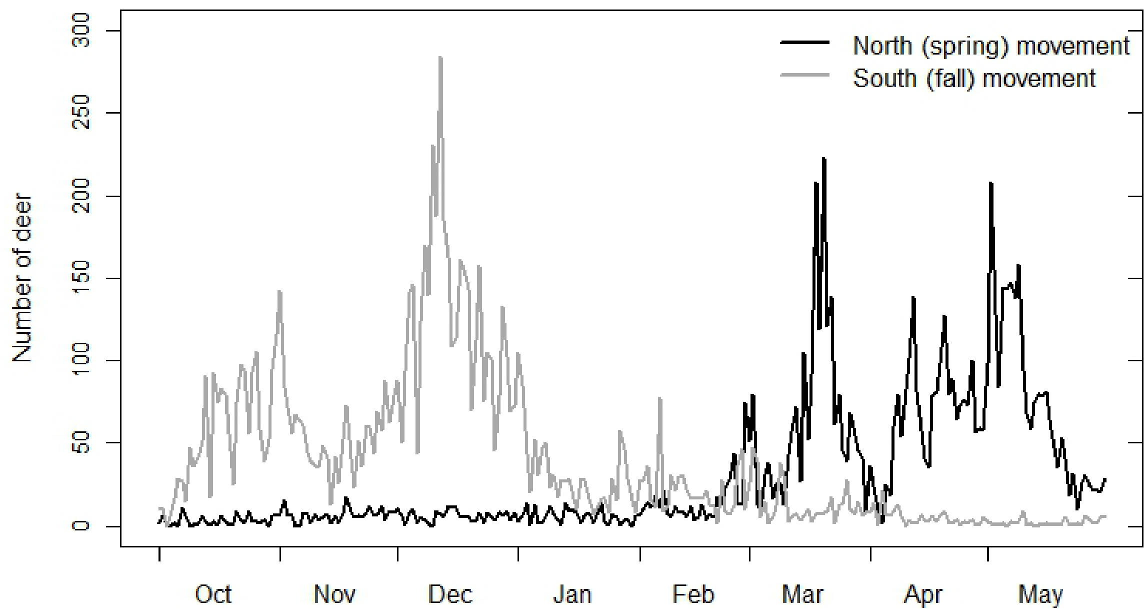

Figure 4. Mean number of mule deer moving south to north (spring migration) and north to south (fall migration). Peak spring movements occurred in mid-March and early-May, while peak fall movements occurred in mid-December.

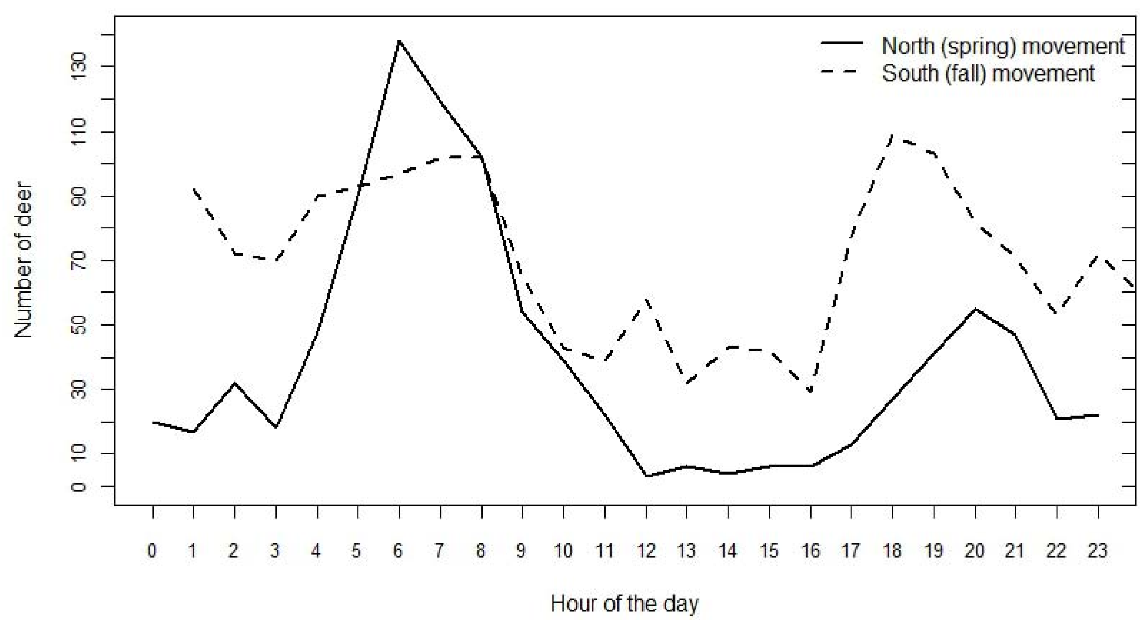

Figure 5. Number and time of day that mule deer moved through underpasses during the spring and fall migrations, December 2008 through May 2011, Nugget Canyon, Wyoming.

Underpass Success Rates

We evaluated the success of deer crossings by comparing the number of deer that approached each underpass and moved through, versus the total number that approached. The success rate of deer passing through the underpasses averaged 54% among all seven structures during the first year (Fig. 6). The average success rate increased to 72% during the second year and 92% by the third year (Fig. 6). The existing underpass at milepost 30.50 had a relatively high success rate to begin with, presumably because it had been in place already for 7 years. Success rates observed at the six new underpasses steadily increased through the 3-year study period, further suggesting that it may take mule deer up to three years to acclimate to underpasses before using them without hesitation.

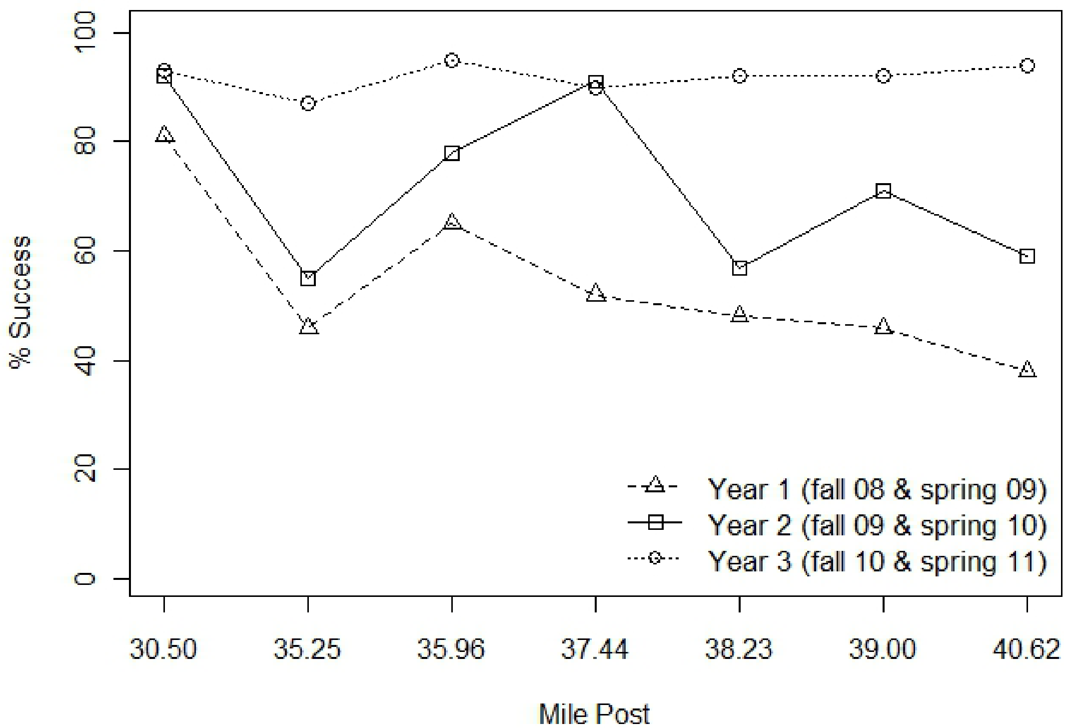

Figure 6. Success rates of mule deer passing through each underpass during the first three years of study. Crossing success increased each year of the study**.**

Underpass Use by other Wildlife

Between December 2008 and May 2011, we recorded 1,953 elk (*Cervus elaphus)*, 201 pronghorn (*Antilocapra americana*), 13 coyotes (*Canus latrans)*, 77 bobcats (*Lynx rufus*), 9 badgers (*Taxidea taxus*), 13 moose (*Alces alces*), 3 raccoon (*Procyon lotor*), and 1 cougar (*Puma concolor*) move through the underpasses (Table 2; Plate 3). Most elk, moose, and pronghorn use occurred at the milepost 30.50 underpass.

Table 2. Number of other wildlife species that moved through underpasses, December 2008 through May 2011, Nugget Canyon, Wyoming.

Other Wildlife Crossings								
Underpass	**Badger**	**Bobcat**	**Coyote**	**Elk**	**Moose**	**Cougar**	**Pronghorn**	**Raccoon**
MP 30.50	4	24	6	1,829	8	0	200	1
MP 35.25	0	33	0	89	0	0	0	0
MP 35.96	1	9	2	10	2	0	0	1
MP 37.44	1	4	3	4	1	1	0	0
MP 38.23	2	1	0	17	0	0	0	1
MP 39.00	0	4	2	3	1	0	1	0
MP 40.62	1	2	0	1	1	0	0	0
Total:	**9**	**77**	**13**	**1,953**	**13**	**1**	**201**	**3**

Plate 3. Photos of other wildlife, including elk at milepost 30.50 (top left), bobcats at milepost 35.96 (top right), mule deer and pronghorn at milepost 30.50 (bottom left), and moose at milepost 30.50 (bottom right).

Mule Deer-Vehicle Collisions

Before the underpass at milepost 30.50 was built in the summer of 2001, the number of deer-vehicle collisions varied across the 13 miles of highway, but averaged 0.75 per month at each milepost. Across the 13-mile project area this translated into 9.75 deer fatalities per month. Road segments with the highest collision rates occurred near mileposts 30, 35, 36, 37, and 38, and ranged from 0.89 to 3.06 deer fatalities per month (Fig. 7). Following construction of the underpass at milepost 30.50 in 2001, the average number of deer-vehicle collisions throughout the 13-mile stretch was reduced to 0.66 per month per milepost (or 8.58 deer fatalities per month), between 2001-2008 (Fig. 7). Although the total number of deer-vehicle collisions did not decline considerably (12%), the number of collisions near milepost 30.50 dropped by 79% (from 1.81 to 0.39 per month; Fig. 7). After the six new underpasses and seven additional miles of game fencing were constructed in 2008, the number of deer-vehicle collisions per month recorded at each mile post was reduced to 0.14, or 1.82 deer fatalities per month in the 13-mile corridor. Overall, the construction of seven underpasses and game-proof fencing reduced deer-vehicle collisions by 81%.

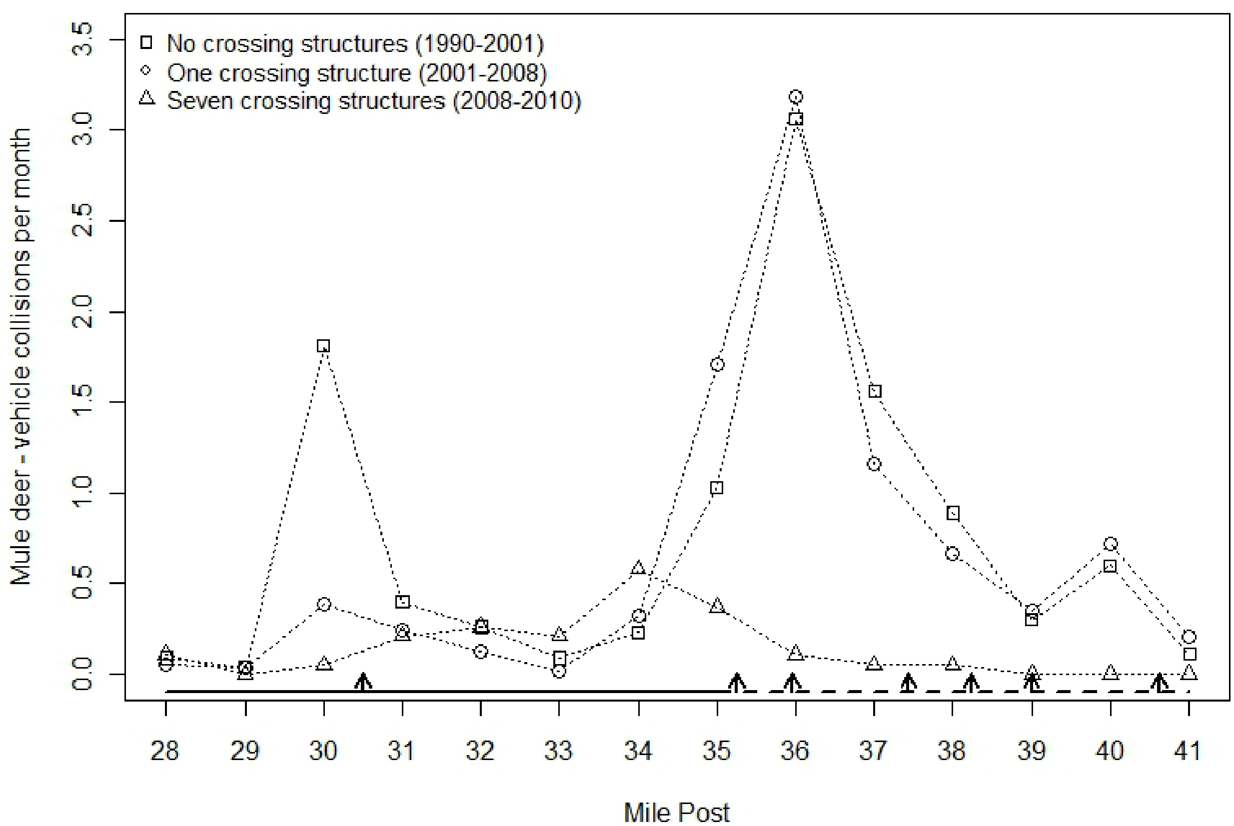

Figure 7. Average number of mule deer-vehicle collisions per month before underpass construction (1990-2001), after one underpass was constructed at milepost 30.50 (2001-2008), and after all seven underpasses were constructed (2008-2011). Vertical arrows at bottom of graph depict location of underpasses. Horizontal lines below the arrows depict fencing associated with underpasses.

DISCUSSION

Reducing deer-vehicle collisions is needed across wide regions of North America to improve highway safety and minimize deer mortality. In Wyoming, one of the more problematic areas has been U.S. 30 west of Kemmerer, Wyoming, where 13 miles of two-lane highway pass through Nugget Canyon – an area that provides crucial winter range and bisects an important mule deer migration route. Previous studies have shown that game-proof fencing used in conjunction with underpasses can effectively move animals underneath roadways and reduce wildlife-vehicle collisions (Romin and Bissonette 1996, Clevenger et al. 2001, McCollister and Van Manen 2010). Here, we show that continuous fencing between a series of underpasses reduced mule deer-vehicle collisions by >80% in a 13-mile stretch of highway. Importantly, deer-vehicle collisions did not increase in areas immediately adjacent to the fencing, where deer were free to move across the highway at grade-level (Sawyer and LeBeau 2010). Deer-vehicle collisions that occurred after fence and underpass construction resulted from deer that crossed cattle guards filled with snow or passed through gates left open by recreational users. Fortunately, both of these problems are correctable and if the fencing infrastructure (i.e., cattle guards, gates) is managed properly during the peak movement periods during spring and fall migrations, then we can expect deer-vehicle collisions to be eliminated altogether.

As traffic volumes increase and roadways are widened, there is increasing concern of maintaining habitat connectivity (Foreman et al. 2003), especially for migratory wildlife that must cross roadways in order to access critical seasonal habitats. For example, western Wyoming supports some of the largest mule deer populations in North America and many of these animals travel 20 to 100 miles between their seasonal ranges (Sawyer et al. 2005, Sawyer et al. 2009, Sawyer and Kauffman 2011). Sustaining these herds will require that deer maintain their ability to safely cross roadways that overlap with established migration routes. Our data suggest that underpass and fence construction did not affect the permeability of U.S. 30 to deer. Rather, the underpasses provided deer with a safe means to cross the highway and maintain connectivity with their distant seasonal ranges. During the 3-year study period, we documented 49,146 mule deer move underneath U.S. Highway 30. Although most of this use (83%) was associated with migratory movements, the other 17% of deer crossings were recorded during the winter period. The fact that deer utilized underpasses during the winter suggests they were comfortable using the structures for routine daily movements, as well as the more conditioned migratory movements.

The success rates of underpasses, as measured by the number of animals that approach versus the number of animals that cross, steadily increased through the duration of the study, with an average of 54% in Year 1 and 92% in Year 3. This trend suggests that deer did not fully habituate to the underpasses until year 3. These results are consistent with recent work in Arizona that found elk habituation to underpasses took approximately four years (Gagnon et al. 2011).

Of the seven underpasses we monitored, the majority of deer use occurred at mileposts 30.50 and 35.96. Given each underpass was the same size, it is of interest why those two were used more than others. Certainly, factors such as vegetation, human activity, and topography may influence the effectiveness of underpasses (Clevenger and Waltho 2000, Ng et al. 2004). Although we did not conduct any formal analysis to evaluate how these factors may differ between the seven underpasses, we suspect that the location of the underpasses relative to established migration routes was the most likely explanation for the differential use. In other words, because underpasses at milepost 30.50 and 35.96 were situated in close proximity to existing migration routes, they received the highest levels of deer use. Although we do not have telemetry data to document where established migration routes occurred before construction, we do know that road segments with the highest levels of deer-vehicle collisions closely correspond with milepost 30.50 and 35.96, suggesting higher numbers of deer historically crossed the highway in these areas. It has long been recognized that wildlife crossing structures should be situated along existing movement corridors or migration routes to increase the effectiveness of the structure (Singer and Doherty 1985). New methods to identify migration routes and prioritize sites for crossing structures are quickly emerging (e.g., Sawyer et al. 2009, Lewis et al. 2011) and will improve the ability of transportation planners to ensure underpasses are located within existing movement corridors.

The benefits of reduced vehicle mortality and safe passage across U.S. 30 were not limited to mule deer. We documented a variety of other animals that utilized the underpasses. Of particular interest was use by pronghorn, moose, and elk. Although pronghorn were documented using the underpass at milepost 30.50 shortly after construction (Plumb et al. 2003), underpass use by all three species is considered relatively rare (Foreman et al. 2003). Plate 4 includes additional photos of moose and pronghorn moving through the underpasses. A variety of small mammals (e.g., badger, raccoon) and carnivores (e.g., coyote, bobcat, cougar) also utilized the underpasses.

Plate 4. Moose (left) and pronghorn (right) move through underpasses at milepost 35.96 and 30.50, respectively.

MANAGEMENT RECOMMENDATIONS

- Underpasses at Nugget Canyon were equipped with three cameras for wildlife monitoring, including one at the entrance, one in the middle, and one at the exit. We found two cameras were adequate to monitor wildlife use of underpasses. Future monitoring efforts could reduce costs by using only two cameras.

- Our results suggest that continuous fencing should be used to connect underpasses in areas with large concentrations of mule deer. However, completely eliminating deer-vehicle collisions will require careful maintenance of fence infrastructure (e.g., cattle guards and gates), especially during periods of peak deer movement.

- Careful consideration should be given to underpass location. Results from Nugget Canyon emphasize the importance of placing underpasses in close proximity to existing migration routes or wildlife-vehicle collision hot-spots.

- Although many ungulates (e.g., pronghorn) are believed to prefer overpasses, our results suggest that underpasses can effectively move a variety of ungulate species underneath a two-lane highway, including mule deer, elk, moose, and pronghorn. Future mitigation efforts should consider underpasses for ungulate species other than mule deer.

- Our results and others (e.g., Gagnon et al. 2011) illustrate the benefits of monitoring underpasses and evaluating their effectiveness. Aside from documenting animal use, the camera monitoring identified underpasses with potential snow drifting and drainage problems. For example, snow drifts and water accumulation were common at mileposts 35.25 and 40.62 (Plates 5 & 6). For cases where snow drifting is a problem, the effectiveness of the underpass could likely be improved by snow fencing or excavation work that minimizes drifting and improves drainage.

- State wildlife agencies traditionally monitor sex and age composition of big game populations with aerial surveys that can be costly. In areas like Nugget Canyon, where large concentrations of animals move through underpasses, there is potential to collect accurate sex and age data on big game herds and possibly eliminate the need to conduct aerial surveys. This application of camera-monitoring should be considered where appropriate.

Plate 5. Mule deer attempt to walk around water and ice accumulation at milepost 35.25 underpass.

Plate 6. Bobcat (left) and mule deer (right) walk around water accumulation at milepost 40.62 underpass.

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