WILDLIFE FENCING AND ESCAPE RAMP MONITORING: PRELIMINARY RESULTS FOR MULE DEER IN SOUTHWEST COLORADO

Jeremy L. Siemers (970-491-3342, jsiemers@colostate.edu), Research Associate, Colorado Natural Heritage Program, Department of Fish, Wildlife, and Conservation Biology, Colorado State University, CO 80523-1475

Kenneth R. Wilson (970-491-5020, Kenneth.Wilson@colostate.edu), Professor, Department of Fish, Wildlife, and Conservation Biology, Colorado State University, Fort Collins, CO 80523-1474

Sharon Baruch-Mordo (970-484-9598, sbaruch-mordo@tnc.org), Spatial Scientist, The Nature Conservancy, Fort Collins, CO 80524

ABSTRACT

Animal-vehicle collisions have negative impacts to human safety and wildlife populations and are therefore a topic of great concern to transportation and wildlife managers. Beyond risks of injury or death, animal-vehicle collisions can result in high economic costs from property damage and loss of wildlife recreation opportunities. A key mitigation measure includes use of wildlife fencing. However, fencing can also create a physical barrier that traps wildlife in right-of-way areas near the road and it blocks wildlife linkages across the landscape; thus it has the potential to increase animal-vehicle collisions and hinder wildlife movement. To allow escape for wildlife, earthen ramps are often constructed from inside of the right-of-way with a gradual slope to the height of the wildlife fence, which creates a sharp drop outside the fence allowing wildlife to jump to safety. We provide preliminary results for a monitoring effort that will eventually have 2 years of data. From August 2012 – April 2013, we monitored 11 escape ramps embedded within a 5-mile stretch of wildlife fencing along Highway 550, north of Ridgway, Colorado. We focused on quantifying successful escape ramp usage by mule deer as a function of escape ramp design using motion-activated infra-red video cameras. Ramp characteristics important in determining escape success included jump height, slope, and whether a horizontal bar was present. Ramp visits had strong seasonality with greatest use in fall and early spring. We also report on the use of these ramps by other wildlife species. In addition to a better understanding of the seasonality in ramp use over the remainder of our study, we plan to assess whether road or landscape characteristics help explain ramp use.

INTRODUCTION

Animal-vehicle collisions (AVC) have negative impacts to human safety and wildlife populations and are of great concern to transportation and wildlife managers (Forman et al. 2003, Mastro et al. 2008). Beyond risks of injury or death, AVC can result in high economic costs from property damage and loss of wildlife recreation opportunities (Huijser et al. 2009). A key mitigation measure includes use of wildlife fencing (Clevenger et al. 2001, Huijser et al. 2007). However, fencing can also create a physical barrier that traps wildlife in right-of-way (ROW) areas near the road and it blocks wildlife linkages across the landscape (Huijser and Kociolek 2008); thus it has the potential to increase AVC and hinder wildlife movement (Knapp et al. 2004). One-way gates and earthen escape ramps (ER) have been implemented to alleviate the barrier effects of fencing for large ungulates, and data from Utah suggested ER were more effective than gates (Bissonette and Hammer 2000).

Earthen escape ramps are generally designed from inside of the ROW with a gradual slope to the height of the wildlife fence; this creates a sharp drop that allows wildlife to jump to safety outside of the ROW (Huijser et al. 2007). Such designs are believed to permit escape of animals trapped within the fenced ROW area, while preventing movement into the ROW. Escape ramp design features such as ramp slope, ramp vegetation, wildlife fence height at ramp, and presence of guide wings or horizontal bars can vary. Additionally, nearby fence attributes (e.g., proximity to nearby fence gaps) and landscape features (e.g., proximity to wildlife movement corridors) can influence use of ER. Thus, there is a need for a comprehensive evaluation of ER design and environmental characteristics to maximize the effectiveness for target wildlife.

In August 2012 we began a monitoring effort of ER focused on quantifying use and escape success by ungulates, namely mule deer (*Odocoileus hemionus*) and elk (*Cervus elaphus*). Our overall goal is to relate usage levels to ER structure design and its surrounding environmental characteristics such as road and landscape covariates. This is a 2-year study, and in this paper, we summarize usage data to date and provide preliminary modeling results for mule deer.

METHODS

Study Area

The study area consists of a 5-mile segment of US Highway 550 north of Ridgway, Ouray County, Colorado (Fig. 1). Speed limit in the study area is 60 mph (Colorado Department of Transportation [CDOT] 2011). Average Annual Daily Traffic (AADT) counts range from 6,700 – 7,300 and are projected to increase to approximately 9,500 – 10,500 in the next 20 years. The number of travel lanes and lane width do not change along this segment of highway, but the primary outside shoulder width does (CDOT 2011). Billy Creek State Wildlife Area is located to the northeast and Ridgway State Park, surrounding Ridgway Reservoir, is located to the west. The entire segment has fencing to exclude wildlife, but several subdivisions have driveway access from this segment of the highway that create breaks in the fence and provide entry points for animals to the highway.

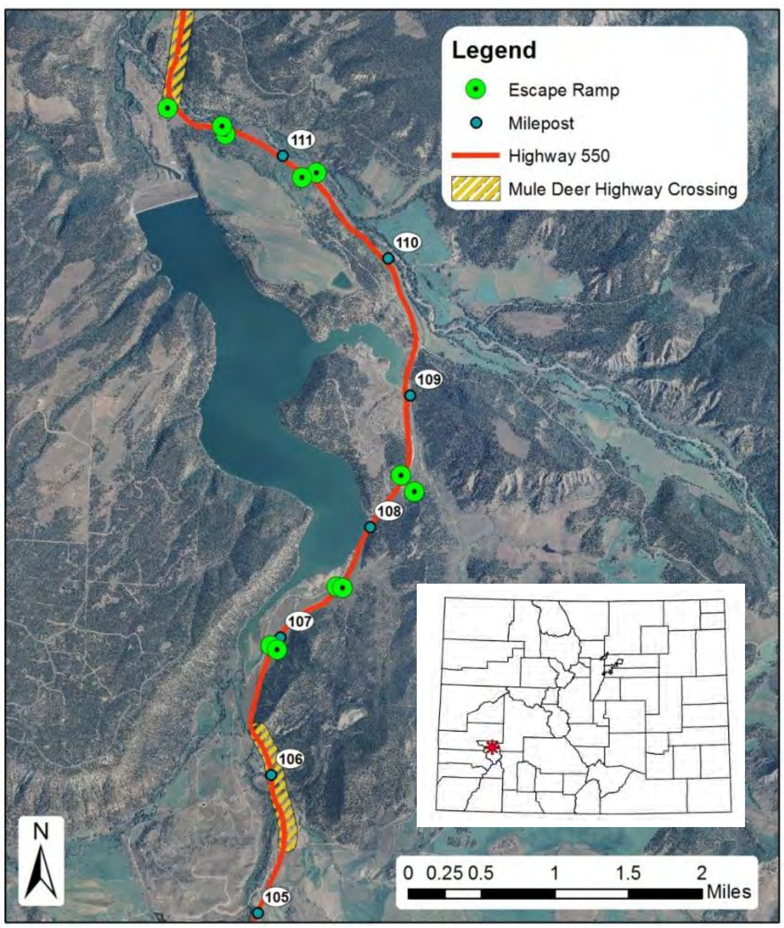

FIGURE 1 Study area north of Ridgway, Colorado. Mule deer highway crossing are areas identified as traditional deer crossing by Colorado Parks and Wildlife (CDOW 2010). Red star on inset map depicts the location in Colorado.

The dominant road topography in this area is rolling terrain (CDOT 2011). Wildlife habitat is primarily pinõn-juniper and mountain shrub vegetation communities with some irrigated agriculture as well as riparian habitats of the Uncompahgre River and its tributaries (Colorado Division of Wildlife [CDOW] 2004). The wildlife fence exists on both sides of the highway from mile markers 105.5 – 113.5 (Southern Rockies Ecosystem Project 2006). Fencing bisects important habitat for elk and mule deer (hereafter deer), and the area has several resident deer populations. Additionally, road segments between mile markers 105 and 106 and north of mile marker 111.5 have been identified as traditional deer crossings (CDOW 2010; Fig. 1). Along this 5-mile segment of highway, 3 ER were constructed in 2005 and 8 were constructed in 2010.

Ramp Monitoring

We monitored 11 escape ramps along Highway 550 using motion-sensitive infra-red cameras (Attack IR™, Cuddeback, De Pere, WI). We monitored ramps continuously for a period of 9 months (August 2012 – April 2013) and deployed 2 cameras at each ramp by bolting them within protective cases (CuddeSafe™, Cuddeback, De Pere, WI) to posts of the wildlife fence (Fig. 2). We positioned cameras such that animals could be observed on the ER and successful escapes or movements back toward the ROW area could also be observed. Each trigger event resulted in a time-stamped photo followed by a video clip (up to 30 seconds) to record animal activity. We revisited cameras periodically to replace batteries and collect data memory cards.

FIGURE 2 A representative escape ramp along Highway 550 depicting camera placement (cameras circled in red).

We viewed photo and video footage to document animal visits to each ER and determine whether or not a successful escape was made. We defined a successful escape as a visit to an ER by an animal with sufficient picture or video evidence to indicate the animal jumped from the ramp (or crawled under a horizontal bar) to the safe side of the wildlife fence. Unsuccessful escapes were defined as a visit to an ER when an animal did not jump to safety, but left the ramp on the ROW side of the fence. We did not consider the amount of time an animal spent at the ramp before making an escape or leaving the ramp in defining successful versus unsuccessful escapes.

Data Analysis

We used logistic regression (glm function in R, R Core Team 2013) to model successful and unsuccessful attempts of mule deer at ER as a function of 5 dependent variables: 1) presence of a horizontal bar at top of ramp, 2) ER jump height measured as the rise of the ground to the ramp apex or, if a horizontal bar was present, the rise of the ground to the top of the bar, 3) ER slope, 4) ER opening width measured as the span of the break in the fence at the apex of the ramp, and 5) date of observation which we transformed using sine and cosine functions to account for seasonal periodic variation (Stolwijk et al. 1999). In this preliminary analysis, we examined all possible models based on combinations of these 5 variables. We compared models using Akaike's information criterion for small sample size (AIC_c) and AIC_c model weights (w_i) (Burnham and Anderson 2002). For each variable, we calculated a cumulative AIC_c weight (w_+) and we report estimates for the regression coefficients (β_i) with 95% confidence intervals (CI) using the highest-ranked model for that variable in the modeling set. Estimates with a 95% CI that did not overlap 0 were considered to have a strong effect (Burnham and Anderson 2002).

RESULTS

We recorded 784 visits of mule deer to the 11 ER, 318 of which resulted in successful crossings to the safe side of the wildlife fence (41%). Mule deer visits to ER were also quite variable temporally on both hourly (Fig. 3) and monthly (Fig. 4) scales. Most visits occurred daily during the early morning and late evening, and seasonally during the fall, peaking in November. Visits decreased during the winter and increased again in March and April.

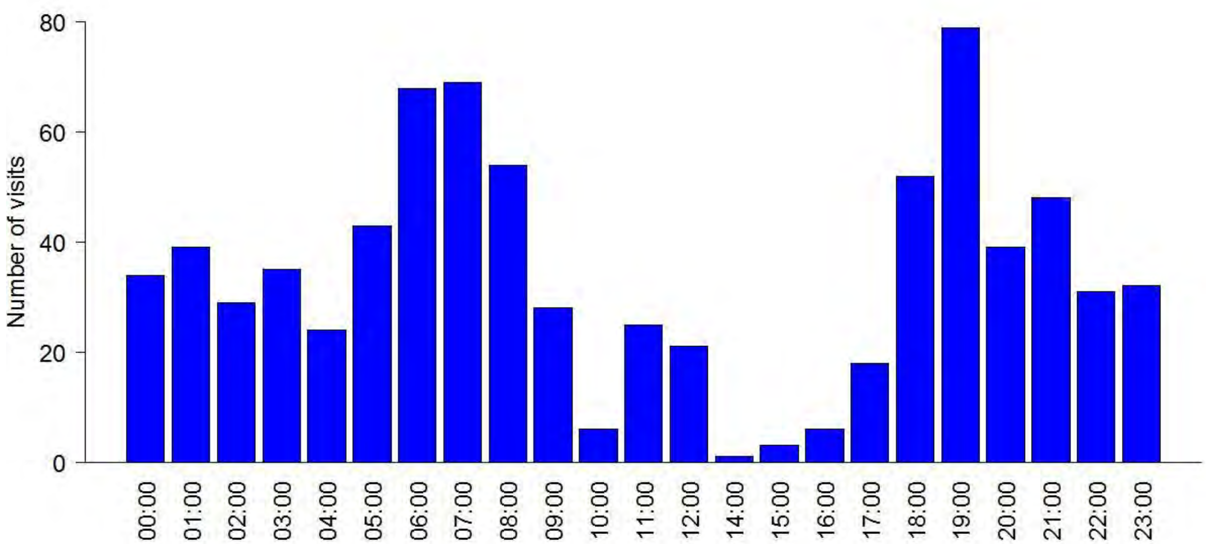

FIGURE 3 Hourly distribution of visits of mule deer to 11 escape ramps along Highway 550, Ouray County, Colorado USA, from August 2012 – April 2013.

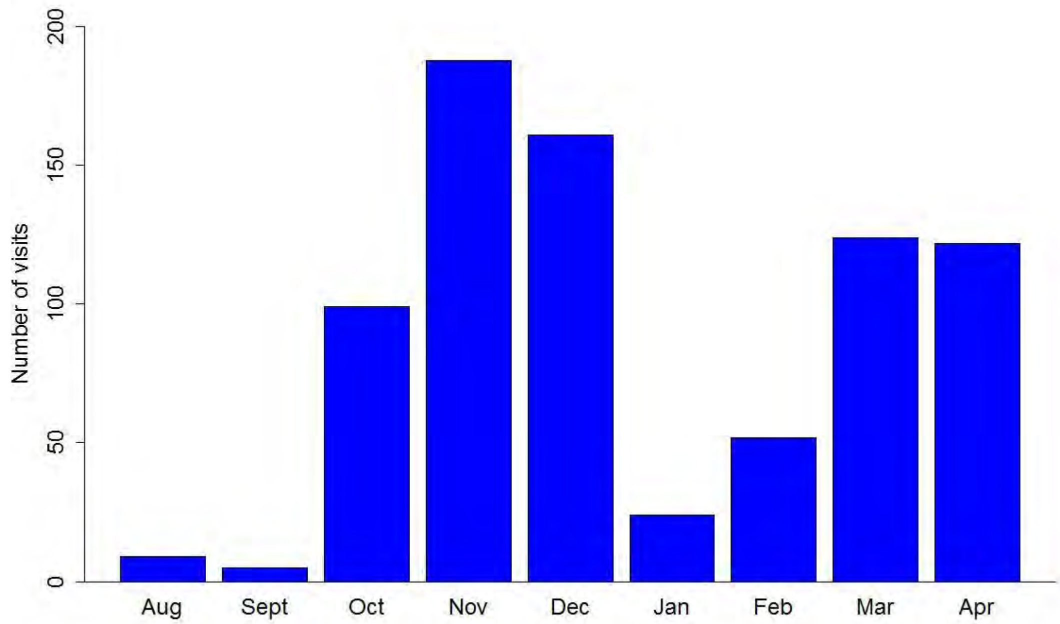

FIGURE 4 Monthly distribution of visits of mule deer to 11 escape ramps along Highway 550, Ouray County, Colorado USA, from August 2012 – April 2013.

In addition to deer, we documented visits to ER by other medium to large mammals including bobcat (*Lynx rufus*), mountain lion *(Puma concolor*), coyote (*Canis latrans*), red fox (*Vulpes vulpes*), American black bear (*Ursus americanus*), and elk. While escapes by these animals were too infrequent to conduct regression analyses, hourly (Fig. 5) and monthly (Fig. 6) visits had similar patterns to deer, where usage peaked during early morning and late evening and was highest in fall and spring.

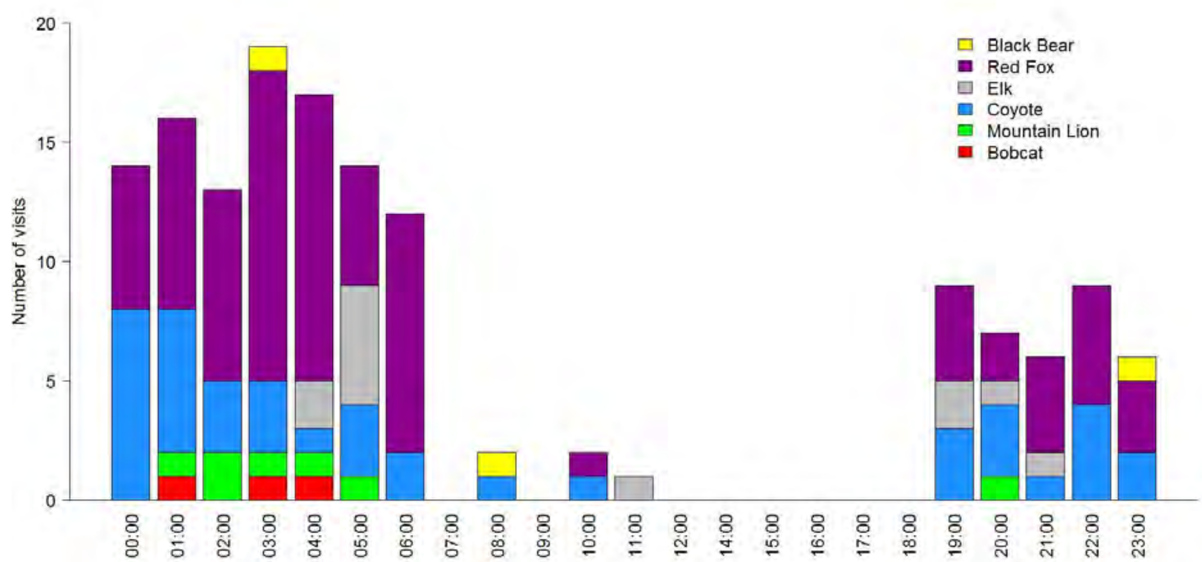

FIGURE 5 Hourly distribution of visits of medium to large mammals other than mule deer to 11 escape ramps along Highway 550, Ouray County, Colorado USA, from August 2012 – April 2013.

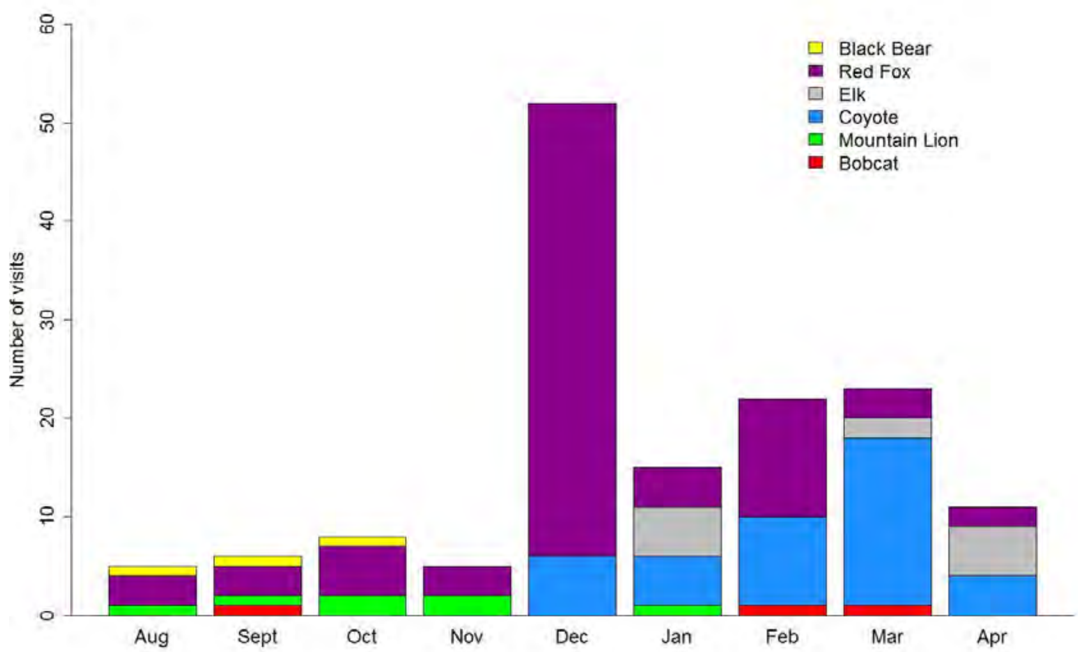

FIGURE 6 Monthly distribution of visits of medium to large mammals other than mule deer to 11 escape ramps along Highway 550, Ouray County, Colorado USA, from August 2012 – April 2013.

We documented 3 successful deer reversals, i.e., instances where animals used an ER to cross the wildlife fence from the safe side to the ROW, 1 successful mountain lion reversal, and 1 successful bear reversal. The 3 successful deer reversals occurred at 2 different ER, one of which had a horizontal bar present. One unsuccessful reversal attempt by a deer was observed when the animal was able to get its forelegs onto the ramp platform, but then fell back to the safe side of the fence; this ER also had a horizontal bar present.

The top 3 models in our model set for the probability of a deer making a successful escape included the variables jump height, ramp slope, date (represented by cosine and sine functions), bar presence, and opening width (Table 1). The top 2 models combined made up 0.70 of the cumulative model weights and included the 4 variables with the highest w_+ (Table 2).

TABLE 1 Log-likelihood, number of parameters (*K*), Akaike's information criterion for small sample size (AIC$_c$), AIC$_c$ difference (Δ AIC$_c$), and AIC$_c$ model weight (w_i) for the five most-parsimonious models of escape probability at 11 escape ramps on Highway 550, Ouray County, Colorado USA

Model	Log-likelihood	K	AIC$_c$	ΔAIC$_c$	w_i
jump height + slope + cos + sin	-438.120	6	887.44	0	0.38
jump height + bar presence + slope + cos + sin	-437.425	7	887.79	0.35	0.32
jump height + slope + opening width + cos + sin	-438.120	7	889.20	1.75	0.16
jump height + bar presence + slope + opening width + sin + cos	-437.375	8	902.56	1.97	0.14
bar presence + slope + cos + sin	-445.630	6	903.89	15.12	0.00

Variables with the highest cumulative AIC$_c$ weight included jump height ($w_+ = 1.00$), slope ($w_+ = 1.00$), date (both sine and cosine transformations) ($w_+ = 1.00$), bar presence ($w_+ = 0.46$), and opening width ($w_+ = 0.30$). Variables that had 95% CI of β_i that did not overlap 0 included jump height, slope, and date (Table 2). Jump height, ramp slope, and horizontal bar presence were each negatively correlated with the probability of a visit by a deer to an ER resulting in a successful escape, although the 95% CI for bar presence overlapped 0. Date, represented by the cosine and sine functions, was positively correlated with the probability of a successful escape indicating that there was seasonal variability (Fig. 4).

TABLE 2 Cumulative AIC$_c$ weight (w_+), regression coefficient estimate (β_i), standard error (SE), and 95% confidence interval (CI) for variables used in the full set of models

				95% CI	
Variable	w_+	β_i	SE	Lower	Upper
jump height	1.00	-0.08	0.014	-0.11	-0.05
slope	1.00	-10.86	2.384	-15.53	-6.19
date (cos)	1.00	1.46	0.260	0.95	1.97
date (sin)	1.00	0.65	0.143	0.37	0.93
bar presence	0.46	-0.26	0.219	-0.69	0.17
opening width	0.30	0.00	0.282	-0.55	0.55

DISCUSSION

Our preliminary results indicated that ramp characteristics of height from which a deer needs to jump and slope of the ER negatively affected whether or not a successful escape resulted when a deer visited an ER. While the presence of horizontal bars appears not to have had a significant effect on successful escapes, we note that the additional height of the bar was factored into the total jump height which was negatively correlated with the probability of a successful cross; therefore it is possible that a horizontal bar has an overall negative effect on ramp use, and it did not appear to completely prevent reversal entries from the safe side to the ROW. Further data collection and analysis may elucidate some of these trends for deer as well as other species.

Most of the deer activity we observed at ER was nocturnal with peaks during the crepuscular time periods (Fig. 3 & Fig. 5). This pattern is consistent with other studies observing crepuscular and nocturnal ungulate activity (Ager et al. 2003) and indicates that usage levels at ER may be generally reflective of overall activity patterns of deer in the area. We observed a seasonal peak of visits during the fall with decreased activity during the winter and another increase in March and April. The presence of snow or snow depth may be a component of seasonality that negatively influence successful escapes, and we will evaluate such factors related to seasonality in future analysis.

Activity of other mammalian species had a strong peak in December due to a high number of visits of red fox to the ER (Fig. 6). Fox during this time period were using the ER for hunting and resting, but did not appear to use the ramps for crossing movements, and so none of these visits resulted in a successful escape. Aside from the peak in December due to fox activity, overall mammalian activity was relatively low with an increase in February and March, primarily due to an increase in use by coyote. Elk, another focal species for which ER were built, were not observed using ER until January and a total of 12 visits have been observed thus far, 7 of which resulted in successful escapes.

We will conduct additional spatial analyses upon study completion to better understand the landscape context of each ramp and investigate any patterns that may exist. Therefore, in addition to ramp characteristics and temporal variables, we plan to analyze escape ramp usage as a function of highway characteristics, proximity to other crossing structures, fencing gaps, topography, and other landscape features. We also hope to assess the cost-benefit of ER as a mitigation tool by comparing construction costs of ER with the change in AVC from pre- to post-construction years. Preliminary analysis of AVC records from 1986 – 2004 for the study area indicated most collisions occurred in July, followed by November, and most collisions for which species were identified involved deer. Crooks et al. (2008) also found in a statewide analysis that the majority of categorized accidents involved deer. We have not yet collected activity data at ER for the month of July, but the greatest amount of deer activity at ER thus far has occurred in November conforming to the state-wide AVC patterns. As monitoring continues and further analyses are conducted, more insights into the factors influencing successful use of ER by ungulates and other mammals will be gained.

ACKNOWLEDGEMENTS

This project was funded by the Colorado Department of Transportation. We thank Bryan Roeder, Matt Muraro, and Tony Cady of Colorado Department of Transportation, and Brad Banulis of Colorado Parks and Wildlife for project initiation and logistic support. Adam Wagner and Justin Unrein provided assistance in the field.

BIOGRAPHICAL SKETCHES

Jeremy Siemers, M.S. is a research associate with the Colorado Natural Heritage Program in the Fish, Wildlife, and Conservation Biology Department at Colorado State University. He works as a vertebrate zoologist on projects focused on rare species distribution, conservation, and population status. He investigates management issues related to transportation, disease, energy development, and climate change. He is the leader of the Zoology Section of the Colorado Natural Heritage Program where he has worked for the last 15 years.

Kenneth Wilson, Ph.D. is a professor and the department head in the Department of Fish, Wildlife, and Conservation Biology at Colorado State University (CSU). He and his students work on issues related to wildlife management, conservation biology, and ecology such as impacts of human activities on wildlife, population ecology, and understanding landscape patterns of biodiversity. He currently has 3 graduate students (2 M.S. and 1 Ph.D.) working on research focused on understanding black bear-human conflicts in urban areas, examining changes in biodiversity after closing of Artesian wells in Great Sand Dunes National Park and Preserve, and understanding the effects of noise from natural gas extraction on wildlife. He currently teaches a Basic Outdoor Skills course for undergraduates and a graduate course in Design of Fish and Wildlife Studies. He has led, supervised, and collaborated on numerous research projects, including being a co-PI on two projects for the Colorado Department of Transportation that investigated highway corridors and habitat connectivity for wildlife in Colorado (Crooks et al. 2008).

Sharon Baruch-Mordo, Ph.D. is a spatial scientist with the Development by Design team at The Nature Conservancy. Her current research is focused on developing and implementing models to inform greater sage-grouse conservation. She received her Ph.D. in Ecology in the Department of Fish, Wildlife, and Conservation Biology at CSU in 2012, where her graduate research focused on human-bear conflicts and urban black bear ecology in Colorado. She participated in several multi-agency collaborations, including a collaboration between CSU and CDOT, where she analyzed statewide patterns of AVC hotspots (Crooks et al. 2008).

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