Effectiveness of Earthen Escape Ramps in Reducing Big Game Mortality in Utah

Mary L. Hammer
Utah State University

EFFECTIVENESS OF EARTHEN ESCAPE RAMPS IN REDUCING BIG GAME MORTALITY IN UTAH

by

Mary L. Hammer

A thesis submitted in partial fulfillment of
the requirements for the degree

of

MASTER OF SCIENCE

in

Fisheries and Wildlife

UTAH STATE UNIVERSITY
LOGAN, UTAH

2001

ABSTRACT

Effectiveness of Earthen Escape Ramps in Reducing

Big Game Mortality in Utah

by

Mary L. Hammer, Master of Science

Utah State University, 2001

Major Professor: Dr. John A. Bissonette
Department: Fisheries and Wildlife

One-way escape gates and earthen escape ramps are structures used to enable deer to exit the highway right-of-way along fenced roads. I compared the use of one-way escape gates and earthen escape ramps by mule deer on two highways in Utah to determine if deer exhibited a preference for either structure. Results showed that earthen escape ramps were used by mule deer 8-11 times more frequently than one-way gates. Highway mortality data suggest that the installation of the escape ramps likely reduced mortality of mule deer in both study locations, because we could not attribute reductions in mortality to decreased population densities of mule deer in either location. Because they provide a topographic solution for exiting the right-of-way, escape ramps may reduce deer mortality along other game-fenced highways throughout the United States. Management recommendations that address the placement and spacing

of escape ramps will help wildlife and highway personnel implement the use of these ramps in other locations

A cost-benefit analysis was conducted to determine if the cost of ramp installation was offset within a reasonable time period by the monetary savings associated with reduced deer-vehicle collisions. The cost-effectiveness of installing the earthen escape ramps at both locations was determined by using the number of successful ramp crossings and potential deer mortality levels to generate projected monetary losses associated with varying mortality levels. The assumption was made that at least some of these deer that crossed successfully would have been involved in a deer-vehicle collision had the ramps not been in place. Six arbitrary levels of potential mortality (from 2% to 15%) were generated based on those assumptions. These percentages were multiplied by the number of successful deer crossings at each location to generate potential deer mortality numbers. The number of deer mortalities was then multiplied by the average economic loss of a deer-vehicle collision ($3,845) to obtain an estimate of the mitigated benefits of installing the ramps through 1999. These values were compared to the cost of installing ramps at each location to determine the amortization period.

Results showed that the cost of installation of earthen escape ramps is very rapidly offset by the benefits gained in deer survival and reduced automobile collisions. At the 2% mortality level, the cost of ramp installation in both locations was offset by the monetary savings associated with reduced deer-vehicle collisions by the second year. Heavy use of the escape ramps as well as reduction in mortality observed at both study sites indicate that the mitigation benefits may be much greater than those projected at the 2% mortality level. Installing earthen escape ramps on big-game fenced highways is a very cost-effective way to further reduce deer mortalities along roadways.

DEDICATION

To my parents, Frank and Kay Hammer, for all their unconditional love, support and understanding throughout the years. Thank you for always being there for me and encouraging me to reach for my dreams. And to Jeff Mannino, whose love, support, and friendship has been the greatest gift in my life.

ACKNOWLEDGEMENTS

The Utah Department of Transportation (UDOT), Utah Division of Wildlife Resources (UDWR), and the United States Fish and Wildlife Service provided funding and support throughout this study. Mark Lehnert and Laura A. Romin (USFWS) collected highway mortality and census data for 5 years prior to the initiation of this study and Laura A. Romin provided measurements of the observable area sampled during spotlight counts for the Jordanelle area. Rick Schultz provided mortality data for the Sardine Canyon study site and personnel from Rocky Mountain Clean Rite provided mortality data for the Jordanelle area. A big thanks to my best friend, Catherine Billings, for her hard work during my second field season. Her great sense of humor and wonderful personality made carrying buckets of dirt a lot easier! Also, many thanks to Ryan Hillyard, Wade Evans, Hud Venard, and Justin Stevenson for your help with spotlighting and field work – you were all such a great help.

I would also like to express my heartfelt thanks to Dr. John A. Bissonette, my major professor, for all his enthusiasm, patience, and support – and, most of all, for giving me this opportunity. Thanks for taking a chance! I would also like to thank my committee members, Dr. Barrie Gilbert and Dr. Fred Provenza for all their contributions and support throughout my research.

Mary L. Hammer

CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

As road and highway networks rapidly expand in the United States, often through areas with large deer (Odocoileus sp.) populations, collisions between deer and vehicles continue to increase (Conover et al. 1995, Romin and Bissonette 1996). Based on data acquired from 36 states, an estimated 538,000 deer were involved in vehicle collisions in 1991 (Romin and Bissonette 1996). When this data is adjusted to account for the geographic area of states that did not respond to the survey, an estimated 726,000 deer are killed annually (Conover et al. 1995). Only about half of the deer vehicle collisions that occur are actually reported to authorities (Decker, et al. 1990, D. F. Reed, Colo. Div. Wildl. pers. comm., Romin 1994, Romin and Bissonette 1996). Additionally, Allen and McCullough (1976) reported that 92% of collisions result in the death of the deer, this suggests that greater than 1.3 million deer-vehicle collisions occur annually in the U.S. (Conover et al. 1995).

An average of 2,156 collisions were reported annually in Utah between 1994-1998 (Utah Department of Transportation, unpub. data). If the assumptions of a 50% reporting rate and a 92% mortality are correct, as many as 3,967 deer are killed on annually on Utah roads. This poses a concern for several reasons: 1) human injury and death, 2) vehicle damage, and 3) suffering and loss of the wildlife resource.

Rue (1989) reported a 4% incidence of human injury in deer-vehicle collisions. Conover et al. (1995) concluded that given a 4% injury rate and 726,000 deer-vehicle collisions, approximately 29,000 human injuries occur annually. If only 50% of deer-vehicle collisions are reported, 58,000 human injuries may occur annually. Based on the probable number of deer-vehicle collisions in Utah between 1994-1996 (both reported and unreported), approximately 86 people may be injured annually. An estimated 0.029% of all collisions result in a human fatality (Rue 1989). If representative, 726,000 deer-vehicle collisions result in a minimum of 211 deaths annually in the U.S.

Utah auto insurance claims during 1992 averaged $1,200 per big game-vehicle accident (Romin 1994, Romin and Bissonette 1996). Using the Consumer Price Index, this value was adjusted to 1999 dollars, resulting in an average monetary loss of $1,425 per claim. The mean value for auto insurance claims nationwide in 1995 was $1,577, equating to a cost of $1.1 billion annually in deer related claims (Conover et al. 1995).

Based on hunting expenditures and deer harvest rates, deer are a valuable economic resource in Utah. In 1996, hunters spent a total of $84,499,566 (U. S. Fish and Wildlife Service 1997) to harvest 37,159 deer in Utah (Utah Division of Wildlife Resources 1997), resulting in an economic value of $2,274 per deer. Using the Consumer Price Index adjusted to 1999 dollars, each deer harvested in 1999 can be valued at $2,420. Combining the 1999 values for deer ($2,420) and auto claim loss ($1,425) each deer vehicle collision results in approximately $3,845 in economic losses. Excluding the economic losses associated with human fatalities and injuries, losses associated with deer-vehicle collisions (deer loss and vehicle damage) totaled over $15.2 million in Utah in 1999.

Different techniques and structures have been used to reduce deer mortality along roadways to allow for safe passage of deer across the roadway. Most of these measures have shown little or no success in reducing deer mortality or have not been sufficiently tested to establish their efficacy (Reed 1993).

The most common and most expensive technique used to facilitate safe passage of deer across highways is a combination of deer fencing and underpasses. Less expensive at-grade big game crosswalks were installed along a section of US 40 near the Jordanelle Reservoir in Utah. Recent studies suggest these crosswalks have some success (35-39%) at reducing deer-highway mortality (Lehnert 1996). Underpasses and crosswalks have a common underlying premise; that big-game animals are directed by fencing to specially designated crossing areas. The intention is to restrict the location of crossings to specific areas, and in the case of crosswalks, to well-marked areas where motorists can anticipate encountering a deer. Underpasses coupled with game fencing may more effectively prevent deer-vehicle collisions than at-grade crosswalks in Utah, where the kill reduction has been measured at about 40% (Lehnert 1996).

This study focused on deer-vehicle collisions in two locations in Utah, each with different mitigation techniques in place: a section of US 40 near

Jordanelle Reservoir that used at-grade big game crosswalks and a section of US 91 near Mantua (Sardine Canyon) with underpasses. Observations in Sardine Canyon showed that despite the placement of big-game fencing and underpasses, approximately 50 deer were killed in 1996 along a four mile section of US 91 near Mantua (Rick Schultz, Utah Department of Fish and Game, pers.comm.).

Lack of maintenance, vandalism, fence flaws, and natural processes all result in decreased fence integrity, which allowed deer access to the highway right-of-way (ROW). Deer that become trapped on the highway ROW were frequently killed before they were able to escape. It is apparent that mechanisms that allow deer to exit the ROW are of great value in reducing deer-vehicle collisions in areas where roads are fenced.

A common problem with deer fencing is maintenance of the fence (Feldhamer et al. 1986, Reed 1993). Reed (1993) stated that in order to attain an 80-90% decrease in collisions, fences must be regularly maintained to prevent deer passage. Falk et al. (1978) found an average of 20.3 flaws/km of fence. These flaws included gaps underneath the fence and damage to top wires from fallen trees. Additionally, land contours and erosion often result in large gaps underneath the fence that allow deer access to the highway ROW (Feldhamer et al., 1986). Falk et al. (1978) found that gaps at the base of the fence greater than 23 cm allowed white-tailed deer access to the ROW. In addition to these natural occurrences, fences are sometimes illegally cut to gain access to adjacent lands. Large holes were cut in fences on both US 40 and US 91 on several occasions (Lehnert and Bissonette pers. obs., Hammer and Bissonette pers. obs.).

To facilitate trapped deer in exiting the ROW, one-way escape gates have been installed in conjunction with deer fencing in many areas, including California (Ford 1980), Colorado (Reed et al. 1974), Minnesota (Ludwig and Bremicker 1983), Utah (Lehnert 1996), and Wyoming (Ward 1982). Escape gates allow deer to return to the non-highway side of the fence, while preventing deer from accessing the ROW through the gate.

Studies on the use and effectiveness of escape gates have had mixed results. Reed et al. (1974) found that gates were relatively effective in allowing deer to escape the ROW. Lehnert (1996) found that only 16.5% of deer that approached the gates used them to escape the ROW, although deer appeared to learn over time to use the gates.

Another technique that has recently been employed is the use of one-way earthen escape ramps. Earthen ramps are sloping mounds of soil and gravel built on the ROW side with an abrupt drop of approximately 2 m allowing deer to jump to the non-highway side of the fence. Earthen ramps have a less obtrusive and more natural appearance than one-way gates. Earthen ramps are relatively maintenance free as well as inexpensive to install. The effectiveness of earthen ramps in allowing deer to escape the highway ROW has not been tested.

In order for a mitigation system to be considered cost-effective, the benefits associated with the implementation of the system must outweigh the costs associated with the installation of the system. Few studies have addressed a cost-benefit analysis of the implementation of a mitigation system designed to reduce deer mortality on highways. Wu (1998) used a cost-benefit analysis as a predictive model to determine which mitigation system would provide the maximum benefit (decreased collisions) relative to cost to decrease deer-vehicle collisions in Ohio. Reed et al. (1982) used a cost-benefit analysis to describe the cost effectiveness of differing methods of installation of big-game fencing and associated structures on highways in Colorado.

This study concentrated on the frequency of use of one-way gates and earthen escape ramps by ungulate species in an effort to determine which escape structure was the preferred exit route from the highway ROW and if deer mortality decreased along the study roads subsequent to the installation of the escape ramps. In addition, the installation of escape ramps is analyzed in terms of a cost-benefit analysis. The following two chapters address the primary objectives of the study. In Chapter II, ***Utilization of one-way earthen escape ramps by big game in Utah***, I compare the use of earthen escape ramps to the use of one-way escape gates to determine if the deer exhibit a preference for one structure over the other. I also compare pre-ramp installation mortality to post-installation mortality to determine if ramp installation resulted in a decrease in mortality of big game along study roads. Recommendations as to the optimal placement and spacing of earthen escape ramps along game-fenced highways are also addressed in this chapter. In Chapter III, ***Cost-benefit analysis for the installation of earthen escape ramps on game-fenced highways in Utah,*** I use a cost-benefit analysis to assess whether the economic savings associated reduced deer-vehicle collisions offsets the cost of earthen escape ramp installation.

LITERATURE CITED

Allen, R. E. and D. R. McCullough. 1976. Deer-car accidents in southern Michigan. J. Wildl. Manage. 40:317-325.

Conover, M.R., W.C. Pitt, K. K. Kessler, T.J. DuBow, and W.A. Sanborn. 1995. Review of human injuries, illnesses, and economic losses caused by wildlife in the United States. Wildl. Soc. Bull. 23:407-414.

Decker, D. J., K. M. Loconti Lee, and N. A. Connelly. 1990. Incidence and cost of deer-related vehicular accidents in Tompkins County, New York. Human Dimensions Research Group 89-7. Cornell Univ., Ithaca, N. Y. 21 pp.

Falk, N.W., H.B. Graves, and E.D. Bellis. 1978. Highway right-of-way fences as deer deterrents. J. Wildl. Manage. 42: 646-650.

Feldhamer, G.A., J.E. Gates, D.M. Harman, A.J. Loranger, and K.R. Dixon. 1986 Effects of interstate highway fencing on white-tailed deer activity. J. Wildl. Manage. 50: 497-503.

Ford, S. G. 1980. Evaluation of highway deer kill mitigation on SIE/LAS-395. Calif. Dept. Transp. Publ. No. FHWA/CA/TP-80/01. 45 pp.

Lehnert, M.E. 1996. Mule deer highway mortality in northeastern Utah: an analysis of population-level impacts and a new mitigative system. M.S. Thesis, Utah State Univ., Logan. 82 pp.

Ludwig, J. and T. Bremicker. 1983. Evaluation of 2.4 m fences and one-way gates for reducing deer-vehicle collisions in Minnesota. Transp. Res. Record. 913: 19-22.

Reed, D.F. 1993. Efficacy of methods advocated to reduce cervid-vehicle accidents: research and rationale in North America. Colorado Division of Wildlife Resources, Fort Collins, CO. 13 pp.

Reed, D. F., T. D. I. Beck, and T. N. Woodard. 1982. Methods of reducing deer-vehicle accidents: benefit cost analysis. Wildl. Soc. Bull. 10: 349-354.

Reed, D. F., T. M. Pojar, and T. N. Woodard. 1974. Use of one-way gates by mule deer. J. Wildl. Manage. 38: 9-15.

Romin, L.A. 1994. Factors associated with the highway mortality of mule deer at Jordanelle Reservoir, Utah. M.S. Thesis, Utah State Univ. Logan. 83 pp.

Romin, L.A. and J.A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildl. Soc. Bull. 24:276-283.

Rue, L.L., III. 1989. The deer of North America. Outdoor Life Books, Danbury, Conn. 544 pp.

U. S. Fish and Wildlife Service. 1997. National survey of fishing, hunting, and wildlife-associated recreation – Utah. U. S. D. I. Fish and Wildlife Service, Washington, D. C. 81 pp.

Utah Division of Wildlife Resources. 1997. Utah big game report. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah. 259 pp.

Ward, L. A. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Trans. Res. Rec. 859: 8-13.

Wu E. 1998. Economic analysis of deer-vehicle collisions in Ohio. Proc. Int'l Conf. Wildl. Ecol. and Transp. 10-12 February 1998. Ft. Myers, Florida.

CHAPTER II

UTILIZATION OF EARTHEN ESCAPE RAMPS BY BIG GAME IN UTAH

Abstract: One-way escape gates and earthen escape ramps are structures used to enable deer to exit the highway right-of-way along fenced roads. I compared the use of one-way escape gates and earthen escape ramps by mule deer on two highways in Utah to determine if deer exhibited a preference for either structure. Results showed that earthen escape ramps were used by mule deer 8-11 times more frequently than one-way gates. Highway mortality data suggest that the installation of the escape ramps likely reduced mortality of mule deer in both study locations, because we could not attribute reductions in mortality to decreased population densities of mule deer in either location. Because they provide a topographic solution for exiting the right-of-way, escape ramps may reduce deer mortality along other game-fenced highways throughout the United States. Management recommendations that address the placement and spacing of escape ramps will help wildlife and highway personnel implement the use of these ramps in other locations.

INTRODUCTION

The continual expansion of highway networks in the United States and throughout the world has caused numerous problems for wildlife populations, including habitat loss, landscape fragmentation, and direct mortality. Highways are often constructed in critical habitat areas and migratory corridors, and result in high road mortality for many species. Ungulates, in particular, white-tailed deer and mule deer, often are impacted seriously by highway corridors.

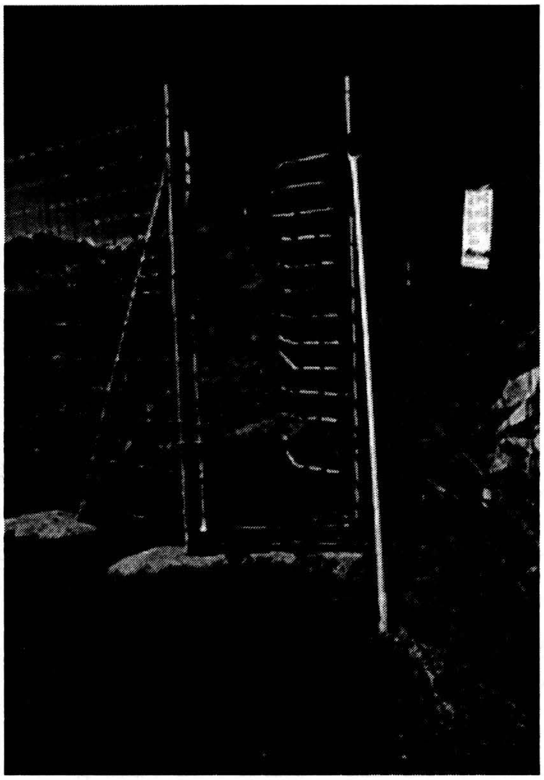
Many techniques have been implemented in an effort to reduce deer-mortality along highways. These techniques include: increased highway lighting (Reed et al. 1981), deer warning signs (Pojar et al. 1975), Swareflex reflectors (Gladfelter 1984, Schafer and Pendland 1985, Ford and Villa 1993, Reeve and Anderson 1993, Waring et al. 1991), intercept feeding (Wood and Wolfe 1988), ultrasonic warning whistles (Romin and Dalton 1992), at-grade deer crosswalks (Lehnert 1996), and game-fencing (Falk et al. 1978, Lehnert 19996, Ludwig and Bremicker 1983, Feldhamer et al. 1986, Reed et al. 1974, Ward 1982). Wyoming has recently installed a wildlife detection system that triggers flashing lights when animal movement is detected adjacent to the road, however it's effectiveness is still undetermined (Bonds 1999). Common wisdom holds that properly maintained game-fencing is the most effective of these techniques.

Routine inspection and repair of game-fences is critical to the effectiveness of the fence in preventing deer movements onto the highway (Putnam 1997, Reed 1993). Reed (1993) stated that in order to maintain an 80-90% reduction in deer-vehicle collisions, fences must be regularly inspected and maintained. Because fence maintenance is expensive and time-consuming, fences are rarely, if ever, impermeable to deer movement. Falk et al. (1978) found that white-tailed deer accessed the highway right-of-way (ROW) by crawling under gaps as small as 23 cm in height. These gaps are often caused by soil erosion and natural land contours (Falk et al. 1978, Feldhamer et al. 1986).

Damage to deer fences often results from fallen trees, as well as deer efforts to gain access to the ROW (Falk et al. 1978, Feldhamer et al. 1986). Vandalism is a common problem with ROW fences. Perpetrators will often cut fences to gain access to adjacent lands (Lehnert and Bissonette pers. obs., Hammer and Bissonette pers. obs.). Falk et al. (1978) found an average of 20.3 flaws/km of fence, including gaps beneath the fence, damage to top wires, and illegal fence cutting.

Deer also access the ROW by moving around the end of the game fence where it meets regular height (~1 m) ROW fencing, and thus become trapped as they move farther up the ROW (Bellis and Graves 1971). Along I-80 in Wyoming Bonds (1999) reported that more elk are hit in areas where the deer fence reverts to regular height ROW fencing. One-way escape gates typically have been installed along game-fenced roads to allow trapped deer to escape the ROW to the non-highway side of the fence (Fig. 1). Two studies have been conducted to determine the utilization of one-way gates by mule deer. Lehnert (1996) found that 40/243 (16.5%) of the deer that approached the gates proceeded to jump through the gate to exit the ROW. Reed et al. (1974) estimated that approximately 223 deer used one-way gates to exit the ROW along I-70 near Vail, Colorado during 1970-1972, though the data regarding the number of approaches without successful passage was not given.

Figure 1. One-way steel escape gate.



Earthen escape ramps are also used to enable deer to exit the highway ROW (Fig. 2). Earthen ramps are gently sloping mounds of soil placed against a backing material approximately 1.5 m in height and constructed on the ROW side of the fence. The taller ROW fence (2.4 m) is lowered at the ramp site and forms an integral part of the drop-off that allows deer to jump to the non-highway side of the fence. The drop-off is not a deterrent for deer because they are accustomed to traversing steep terrain and maneuvering over drop-offs. The design of escape ramps precludes deer from using them to gain access to the ROW from the non-highway side of the fence.

Figure 2. Earthen escape ramp.

Approximately 15-20 earthen escape ramps were constructed along I-80 near Laramie, Wyoming in the mid -1980's, though their effectiveness has not been quantified through scientific study (R. Guenzel, Wyoming Department of Fish and Game, pers. comm). However, tracks were often seen on these ramps (B. Hailey, Wyoming Department of Fish and Game, pers. comm.) These ramps are also used by wildlife personnel to drive large numbers of ungulates off the highway when they become trapped. There is also one earthen ramp along US 191 at the northern edge of the city limits of Jackson, Wyoming that was designed specifically for use by elk from the National Elk Refuge.

The primary objective of this study was to determine if one-way escape gates or earthen escape ramps were more effective in allowing deer to exit the highway ROW. In addition, mortality levels prior to ramp installation were compared to levels subsequent to ramp installation to determine if the presence of ramps decreased mortality of deer.

To address the objectives of this study track counts at earthen escape ramps and one-way gates were monitored. Highway mortality levels were monitored and spotlight censuses were conducted to document deer densities.

STUDY AREAS

Two highways in Utah with a relatively high incidence of deer-vehicle collisions were selected as study sites: 1) US 40 near the Jordanelle Reservoir and 2) US 91 in Sardine Canyon.

Jordanelle--

The US 40 study site was located near the Jordanelle Reservoir, approximately 6 km southeast of Park City in Summit and Wasatch counties and has been the focus of prior studies on deer-highway mortality and mitigation measures (Romin 1994, Lehnert 1996, Lehnert et al. 1998). The study section of US 40 is a four-lane divided highway with a speed limit of 65 mph. The study segment of this highway extended from milepost (MP) 4.0 south to MP 13.1.

Drainage slopes and foothill areas in this region are dominated by oakbrush (Quercus gambelii) and sagebrush (Artemisia spp.) –grass communities. The riparian areas consisted primarily of cottonwood (Populus angustifolia) trees and willow (Salix spp.) (Romin 1994). These communities are typically found in the lower valley areas near the Provo River. Pastureland is also a significant component of the lower valley areas (Lehnert 1996). Elevations in this area range from 1,890-2,380 m.

Mule deer typically occupy the study area year round. However, during severe winters deer are forced into the lower valley areas where forage is more accessible. During milder winters, deer confine most of their activities to south-facing slopes.

Sardine Canyon--

The Sardine Canyon area encompassed a section of US 91 located in Box Elder county just south of Cache county. US 91 is an undivided two-lane highway with a passing lane. When this study was initiated the speed limit was 65 mph, however just prior to the termination of the study the speed limit was lowered to 60 mph. This highway is the primary route between Logan and Brigham City, Utah and between Salt Lake City and Yellowstone National Park. The study segment of road where the most deer mortality occurred began at MP 6.0 and extended north to MP 10.0.

The predominant flora of this area is a sagebrush (Artemisia spp.) –grass community along south-facing slopes and foothill regions. North facing slopes and drainages have a dominant conifer community. Pastureland is also present in certain areas. The area is mountainous with elevations ranging from 1477-1786m. Mule deer use this area during all four seasons, however summer use is limited. Deer usually moved to higher elevations to forage in the summer. Because of heavy snowfall deer are found predominantly on south-facing slopes with access to forage during winter.

METHODS

Description of mitigation techniques

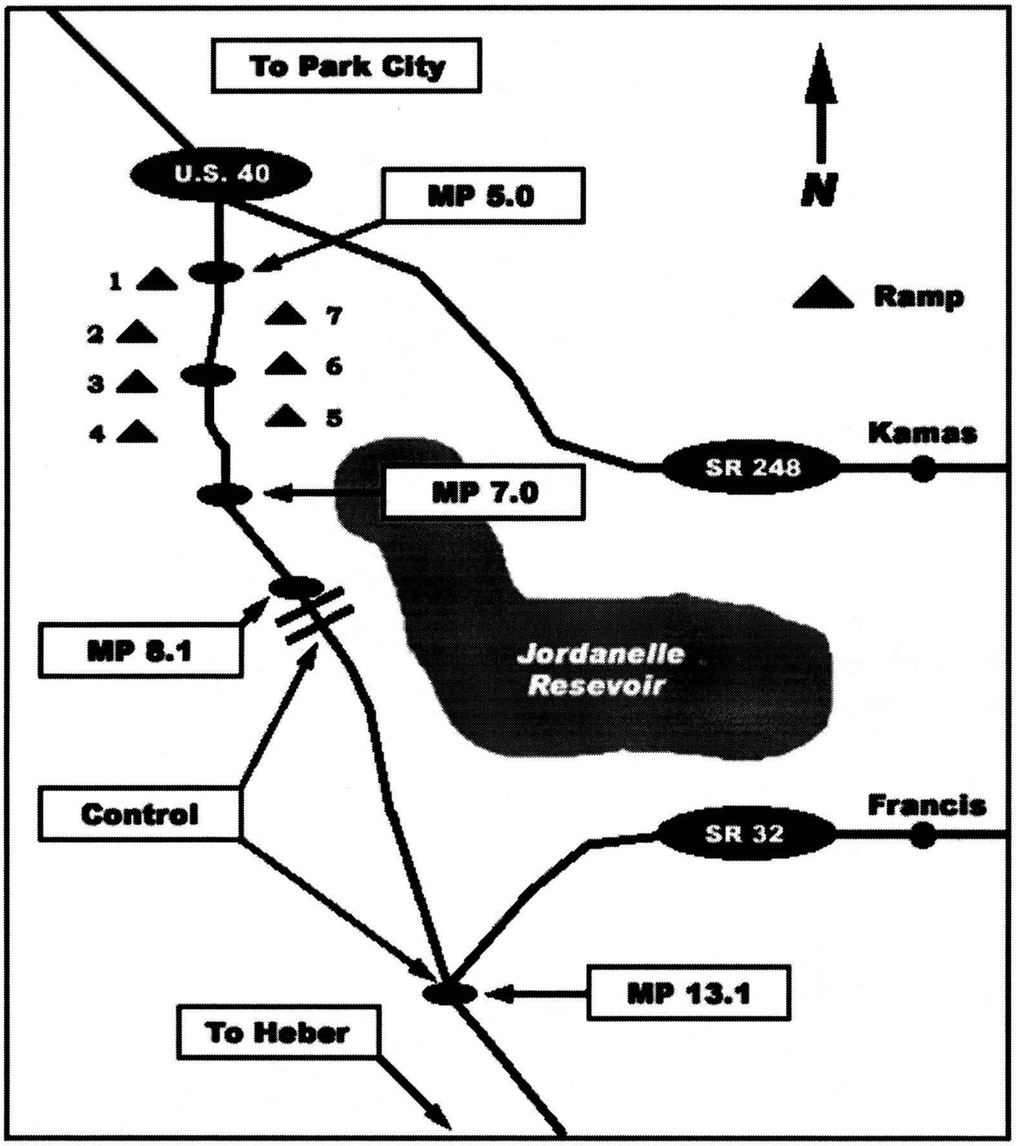
Jordanelle--

The study segment of US 40 extended from MP 4.0 south to MP 13.1. Game-fencing (2.4 m), at-grade crosswalks (Lehnert 1996), and one-way escape gates were installed in 1994 between MP 4.0-8.1 as mitigation designed to reduce deer-vehicle collisions. Crosswalks were designed to allow normal seasonal and daily movements of deer by directing them to cross the highway in well-marked locations where motorists could anticipate their presence. The section of US 40 from MP 8.2 –13.1 has regular height (~ 1 m) ROW fencing and no mitigation techniques in place. This section of US 40 served as a control for the game-fenced portion of US 40 in a prior study (Lehnert 1996) as well as this study.

Because the crosswalk system allows deer to access the roadway, structures that offer an escape for deer trapped on the ROW are a necessity. In 1994 paired one-way escape gates were installed at each crosswalk in conjunction with the deer fence. After the installation of the fencing and the crosswalks, deer mortality was reduced when compared to prior years, however deer continued to be involved in collisions.

In order to further reduce deer-vehicle collisions, UDOT installed earthen escape ramps in 1997 as an alternative to one-way gates. Three ramps were installed between MP 5.0 and MP 6.5 on US 40 in June 1998 (Fig. 3). Five additional ramps were constructed within the same highway segment in August 1998.

Figure 3. Location of earthen escape ramps on US 40 near the Jordanelle Reservoir.



Sardine Canyon--

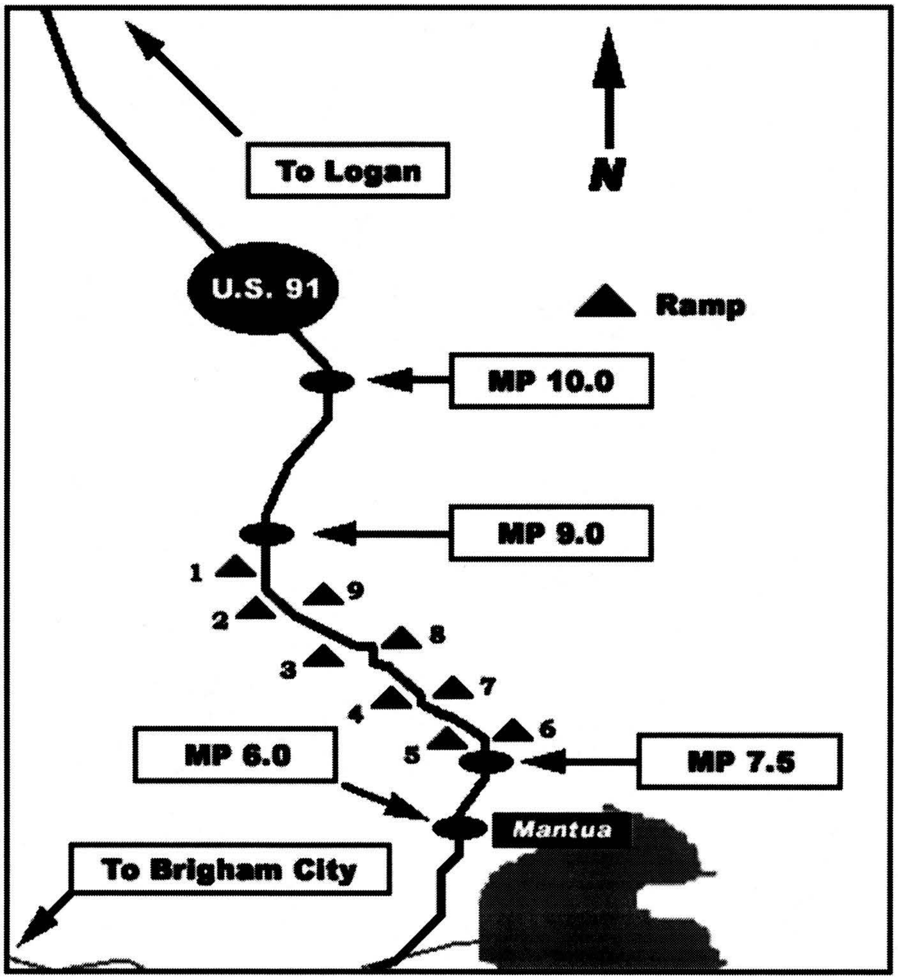
US 91 in Sardine Canyon has 2.4 m fencing in place from MP 5.0 to MP 16.5. Five underpasses are present along this section of the highway. One-way escape gates were installed at the same time the fence was installed.

Observations in Sardine Canyon showed that despite the placement of game fencing and underpasses, approximately 50 deer were killed in 1996 along a four-mile section of US 91 near Mantua (R. Schultz, Utah Division of Wildlife Resources, pers. comm.). In an effort to reduce mortality, nine earthen escape ramps were installed in between MP 7.0-9.0 in October 1997, where deer kill was concentrated (Fig. 4). Due to a lack of prior mortality data for the fenced portion of US 91 past MP 10, an adequate control (section of US 91 with no ramps) was not available.

Assessing deer use of earthen escape ramps and one-way escape gates

To quantify use of earthen escape ramps and one-way escape gates, track beds were established at the top of each ramp and on both the highway and non-highway side of each one-way gate (Fig. 5). Topsoil and sand were used to construct the track beds at the top of each ramp and on both the highway and non-highway side of each gate. Dry weather conditions made determining the number of tracks present difficult. To remedy this problem and facilitate reading of the track beds, 2-3 gallons of vegetable oil was mixed with the soil of the track beds, resulting in soil characteristics that provided distinct hoof prints with each use. Oiled track beds were easy to maintain and reliable in determining deer use of the ramps and gates.

Figure 4. Location of earthen escape ramps on US 91 in Sardine Canyon.



The number of deer using the ramps was enumerated by counting the number of deer trails on the track beds. The soil composition of some ramps was such that track trails leading to the top of the ramp could also be monitored, enhancing the ability to accurately count the number of deer using the structure.

The number of trails leading to the top of the ramp was recorded, as well as the number of deer that left impressions on the track bed. Ramp use was grouped into the following categories: 1) none, 2) one cross, 3) two crosses, and 4) 3 or more crosses. The last category was used due to difficulties in ascertaining exactly how many deer used the structure when more than two deer had been present on the ramp.

Figure 5. Earthen escape ramp with oiled track beds.

Track beds were constructed on both the highway and non-highway side of each one-way gate. Gate effectiveness was defined by the number of approaching animals that successfully used the structure to exit the highway ROW as determined by track trails on both sides of the gate. When analyzing track beds at one-way gates the number of approaches and passages was recorded. Attempted passages from the non-highway side of the gate were also noted. Track beds at gates and ramps were checked at least twice weekly during the summer months and the beds were raked smooth after each reading. Gate and ramp data were collected concurrently on both US 91 and US 40.

To determine if the installation of earthen escape ramps may have led to a subsequent decrease in deer mortality, highway mortality levels were monitored in experimental and control areas before and after the installation of earthen return ramps and spotlight censuses were used to compensate for any changes in the number of deer using the highway ROW and adjacent areas.

Jordanelle--

Track beds were established at three earthen escape ramps and four one-way gates along US 40 in July 1998 and monitored until October 1998. One-way gates are installed in pairs, and rather than omit one from a pair (due to the odd number of ramps), both gates in a pair were sampled for tracks. The one-way gates and ramps were all located between MP 5.0 – MP 6.5, allowing deer equal access to either structure for escape and avoiding bias that might be associated with different deer densities in different locations. Track beds were established at seven earthen ramps and eight one-way gates along US 40 in May 1999 and monitored until October 1999.

Sardine Canyon--

Track beds were established at nine earthen return ramps and ten one-way gates on US 91 and monitored for use from June 1998 until October 1998 and from May 1999 until October 1999. All ramps and gates were located between MP 7.5 – MP 9.0.

Deer mortality

Jordanelle--

Deer mortality was monitored on US 40 before and after installation of the escape ramps. Because the Jordanelle area had been the focus of prior studies on deer-highway mortality, mortality levels on the study section of US 40 have been closely monitored October 1991. However, only mortality data collected subsequent to the installation of mitigation measures in 1994 was used to address changes in deer mortality observed in this study. Mortality information was obtained from private contractors; the Utah Department of Transportation, the Utah Division of Wildlife Resources, and M. Lehnert (Lehnert 1996) for the time period of 1995-1997. Mortality information for this study was provided by a private contractor and study surveys. Mortality on US 40 was documented bi-weekly during the summer field seasons and bi-monthly at all other times for the duration of the study. Sex, age (adult, yearling, fawn), and location to the nearest milepost were recorded for each deer.

As part of the protocol for previous studies, spotlight censuses were conducted on US 40 prior to the installation of the escape ramps (Romin 1994, Lehnert 1996). Spotlight censuses conducted from December 1994 until October 1999 were used for the purpose of this study. They were conducted at the following intervals:

1. December 1994 - July 1997 -- bimonthly
2. November 1997 - October 1998 – monthly
3. November 1998 – October 1999 -- monthly

During the course of a spotlight census a technician used a 400,000 candlepower handheld spotlight to illuminate deer from a vehicle traveling 30-40 kph. When deer were detected, the vehicle was stopped and the deer were counted. Deer activity, sex, habitat information, and location on the highway ROW were also recorded. Rangefinder readings were taken at 0.1 mile intervals to determine the effective observable area along US 40. These readings were used to calculate deer densities along the study route.

The experimental design enabled us to compare mortalities on the experimental section of US 40 prior to and post installation of the ramps. We compared mortalities along the experimental section of US 40 to mortalities on the control section to determine if any changes in mortality on the experimental section were also reflected in changes on the control.

Sardine Canyon--

Highway mortality levels on US 91 were monitored before and after the installation of the earthen escape ramps. R. Schultz (Utah Division of Wildlife Resources, pers. comm.) provided mortality data for the 21 months prior to the installation of the escape ramps (October 1997) as well as mortality information subsequent to the installation of the escape ramps. In addition to information provided by UDWR on road mortality, mortality on US 91 was documented bi-weekly during the summer field seasons and bi-monthly at all other times for the duration of the study. Date, location (to nearest 1.0 mile), sex, and age (adult, yearling, fawn) were recorded for every deer found killed by vehicles in the study area.

Spotlight counts were conducted to detect any changes in deer population densities within the study area. These counts took place along US 91 from January 1998 through October 1999. These counts were conducted monthly from January-October 1998, and bi-monthly from November 1998-October 1999. Spotlight and rangefinder methodology followed the same protocol used at the Jordanelle study site.

RESULTS

Deer use of one-way gates and earthen escape ramps

Each gate track bed along US 40 was analyzed 40 times over the course of the study. Sixty-three deer approached the gate from the ROW and 31 (49.2%) of these deer used the gate to exit the ROW. Each one-way gate track bed along US 91 in Sardine Canyon was analyzed 52 times over the study period. Forty-five animals approached the gate from the ROW and 15 (33.3%) passed through the gate. None of the deer that approached the gates from the non-highway side of the fence passed through to access the ROW.

Track beds located on earthen escape ramps on US 40 were checked 42 times during the study period. A total of 192 successful crossings occurred. Ramp track beds on US 91 were checked 61 times during the study period, resulting in 183 successful jumps.

I assessed comparative use of earthen escape ramps and one-way gates for both study sites. In order to standardize data comparisons, I first calculated the number of gate and ramp use days during the study period, allowing a direct comparison between the use of earthen escape ramps and one-way escape gates. I then calculated an index of use for each treatment (gates and ramps) by study site (US 40, US 91), and by year (1998, 1999), and compared the indices. The following equations were used:

Eq. 1. $G_d = (N_o)(N_g)$
Eq. 2. $R_d = (N_o)(N_r)$
Eq. 3. $I_{ug} = (N_{tg} / G_d)\,10$
Eq. 4. $I_{ur} = (N_{tr} / R_d)\,10$

Where: G_d equals gate days, R_d equals ramp days, I_{ug} equals gate index of use, I_{ur} equals ramp index of use, N_o is the number of days in the observation period, N_g is the number of gates, N_r is the number of ramps, N_{tg} is the number of successful gate crossings in the observation period, and N_{tr} is the number of successful ramp crossings in the observation period.

On both US 91 and US 40, ramps were used much more frequently than gates during both sampling seasons. The ramps on US 40 were used approximately 7-9 times more frequently than the gates, while the ramps on US 91 were used 9-13 times more frequently than the gates. When averaged, ramp use on US 40 was 8 times higher than gate use, and 11 times higher on US 91 (Table 1). The relatively higher index of ramp use at Jordanelle as compared to Sardine Canyon corresponds to increased deer numbers (and higher ramp use) in this area in the summer. Sardine Canyon has lower deer numbers in the area during the summer because deer move to higher summer range, thus ramp use for Sardine Canyon likely peaks in the spring and fall when more deer are present in the area. In contrast, the area surrounding US 40 at Jordanelle is summer range for deer.

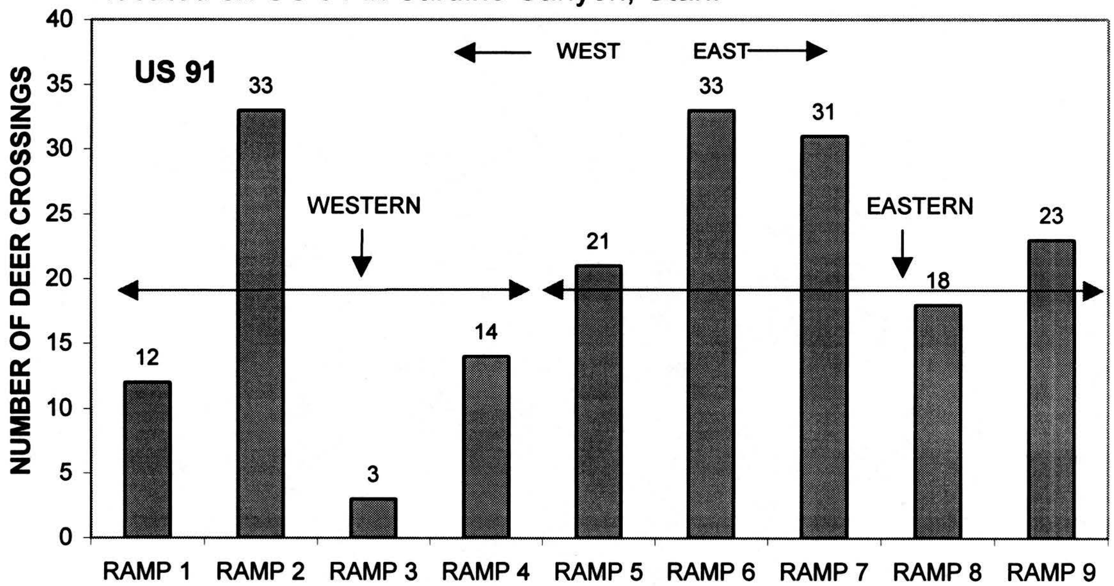
Table 1. Comparison of use of earthen escape ramps and one-way escape gates on US 91 (Box Elder county) and US 40 (Summit county) Utah

	US 91-SARDINE					**US 40-JORDANELLE**				
	RAMPS[A]		**GATES[B]**			**RAMPS**		**GATES**		
	DAYS[A]	CROSS[B]	DAYS	WALK TO	CROSS	DAYS	CROSS	DAYS	WALK TO	CROSS
1998	167	101	152	29	8	88	44	83	15	6
INDEX	0.67		0.05			1.67		0.18		
1999	212	82	155	16	7	128	148	122	48	25
INDEX	0.43		0.05			1.65		0.24		
	RAMP/GATE RATIO					**RAMP/GATE RATIO**				
1998	13.4					9.3				
1999	8.6					6.9				
MEAN RAMP/GATE RATIOS[C]:	**11.0** [D]					**7.9**				

[A] # days in observation period, # of ramp crossings, [B] # days in observation period, # of approaches, and # of successful passages through the gates, [C] simple mean, [D] rounding error.

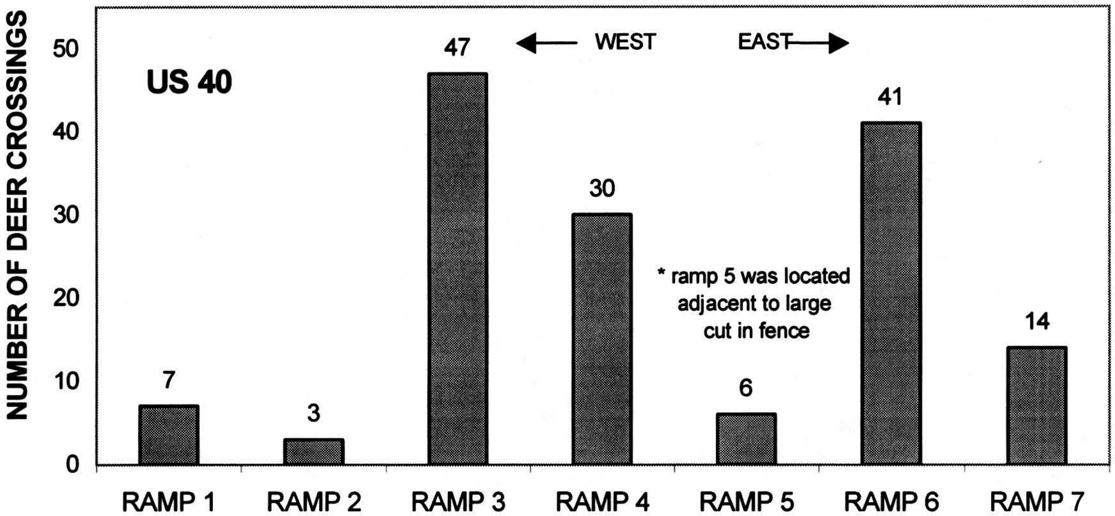
Deer showed preferential use of certain ramps over the use of others at both study sites. In Sardine Canyon ramps 1-5 were located on the western side of the highway and ramps 6-9 were located on the eastern side. Ramps 2, 6, and 7 all had over 30 crosses (Fig. 6). Overall, substantially more crosses occurred on those ramps on the eastern side of the highway, even though fewer ramps were located on the eastern side. Ramp 2 had special 'wing' fence segments extending from the ROW fence at approximately 45 degree angles towards the ROW and acted to direct deer towards the ramp, thus possibly increasing use of this ramp. Ramp 3 was located immediately adjacent to fencing and an underpass. Deer could only approach this ramp from one direction, contributing to its limited use.

Figure 6. Number of deer crossings on individual escape ramps located on US 91 in Sardine Canyon, Utah.



On US 40 ramps 1-4 were located on the western side of the highway and ramps 5-7 were located on the eastern side. Ramps 3, 4, and 6 showed substantially higher use than the other ramps (Fig. 7). Ramp 5 had received heavy use in 1998, but virtually no use in 1999. Contractors installing a pipeline in the area removed a section of fence immediately adjacent to Ramp 5 in June 1999 and that section remained open for the duration of the sampling season. Deer that potentially would have used the ramp to exit the ROW only had to walk through the breech in the fence. Both ramps 2 and 6 are located such that they were shielded from highway noise. Ramp 2 is located at the top of a highway slope and Ramp 6 is situated behind a slight hill on the ROW.

Figure 7. Number of deer crossings on individual escape ramps located on US 40 near Jordanelle Reservoir, Utah.

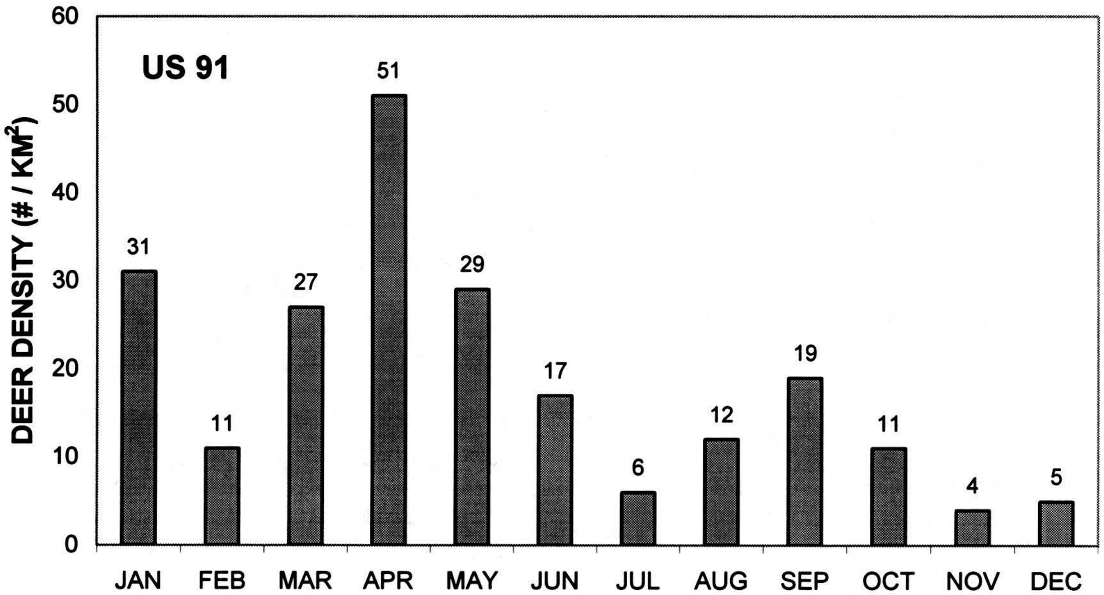


Spotlight Surveys

Sardine Canyon--

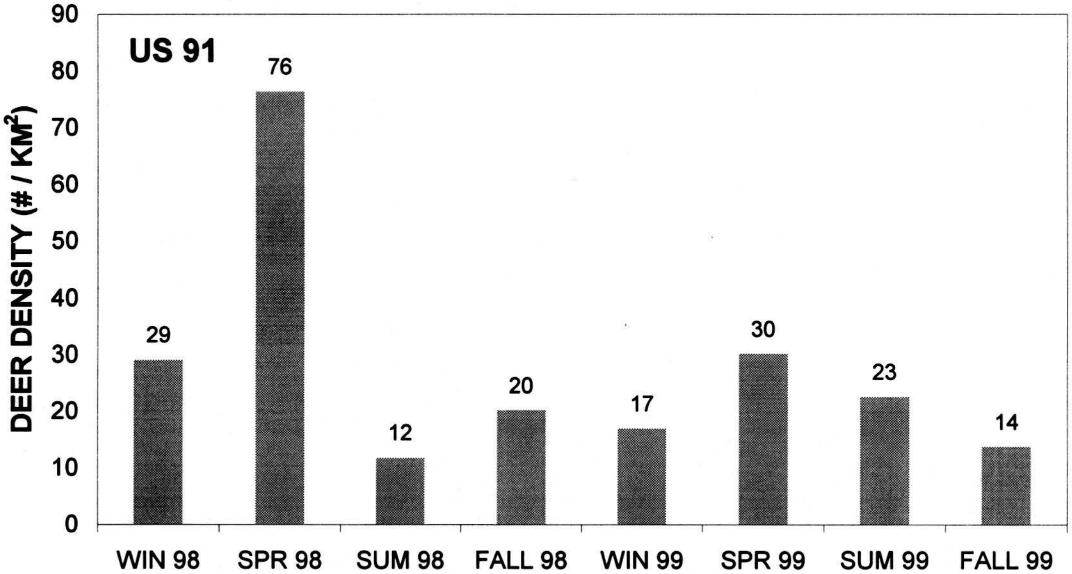
Spotlight surveys in Sardine Canyon showed a peak in deer densities from March-May with a smaller peak from August-October (Fig. 8). This corresponds closely to the migratory movements of mule deer during the spring and fall as they move to winter or spring ranges (R. Schultz, UDWR, pers. comm.). Deer move from the highway area in Sardine Canyon during the summer months, traveling to higher country to forage. Deer densities during the spring, summer, and fall months closely track the use of escape ramps during these months. Use of escape ramps was higher during the spring and early fall and decreased substantially during the months of July and August. Overall, deer numbers tend to decrease in Sardine Canyon during the winter months, however we observed an increase of deer in January when they clustered in an open field at MP 6.5 along the highway. Deer were more visible during January when they were present in large numbers in this open field, probably due to more accessible forage in this area.

Figure 8. Mean monthly deer densities per km^2 in Sardine Canyon from milepost 6.0-10.0 based on spotlight counts from January 1998 to October1999.



It is difficult to determine whether any significant changes occurred in deer population densities over the course of this study (Fig. 9). Deer numbers appear to have been fairly stable except for the peak in deer densities observed during the spring of 1998. This peak may be related to an increase in the number of deer using this area as a migratory corridor during this time period or could be due to random variation in spotlight censuses.

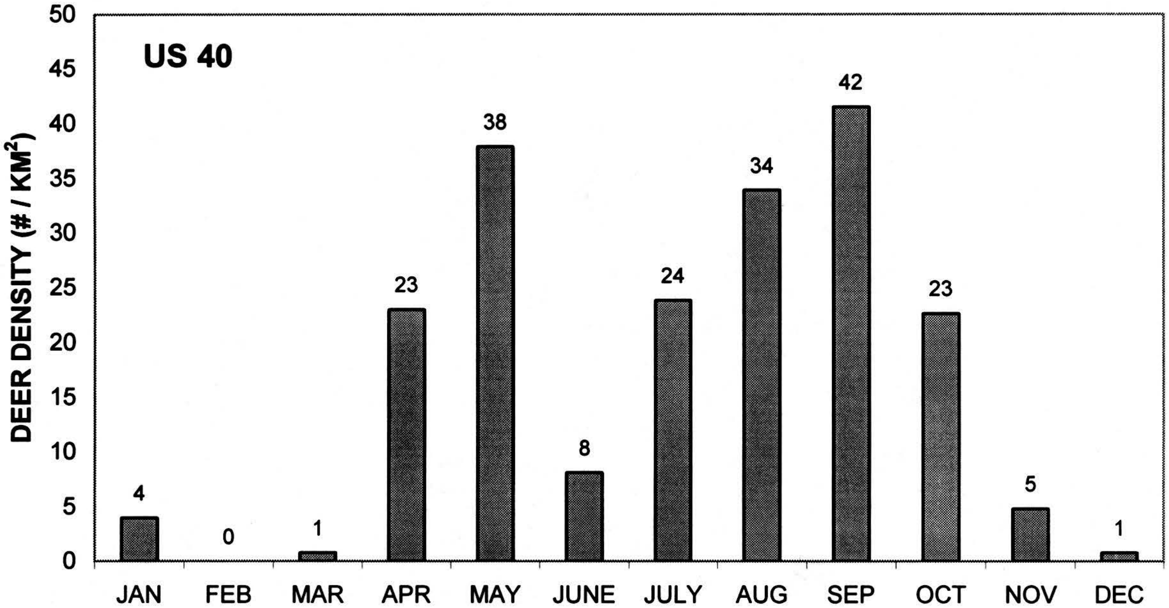
Figure 9. Mean seasonal deer densities per km^2 in Sardine Canyonfrom milepost 6.0-10.0 based on spotlight counts from January 1998 to October 1999.



Jordanelle--

There was a significant decrease in the number of deer spotlighted from January-March on US 40 (Fig. 10). This area receives heavy snowfall in the winter and is not winter range for mule deer. An increase in deer activity began in April, with deer densities reaching a peak during the months of July, August, and September. The observable area as calculated by rangefinder readings was greater for the experimental area (1.26 km^2) than the control area (0.71 km^2). However, significantly more deer were detected in the control section of US 40 than the experimental section. Deer fencing in the experimental section may keep deer farther from the ROW than in the control section, making detection by spotlight more difficult. There appears to have been no significant change in seasonal deer densities when the two years are compared (Fig. 11).

Figure 10. Mean monthly deer densities per km^2 at Jordanelle from milepost 4.0 - 13.1 based on spotlight counts collected from November 1997-October 1999.

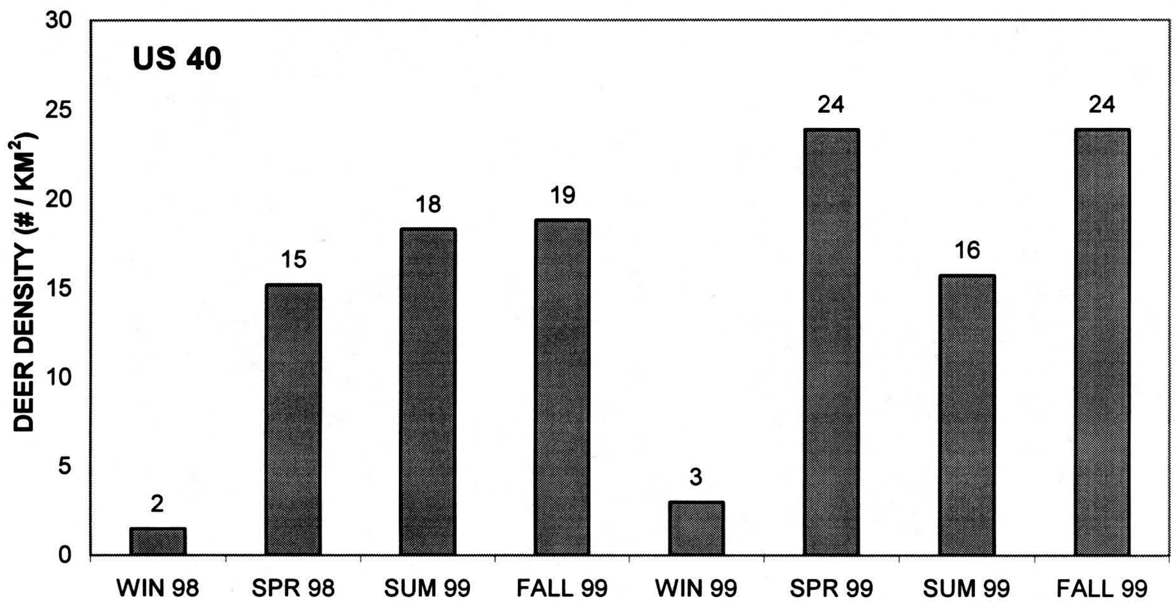


Deer Mortality

Sardine Canyon--

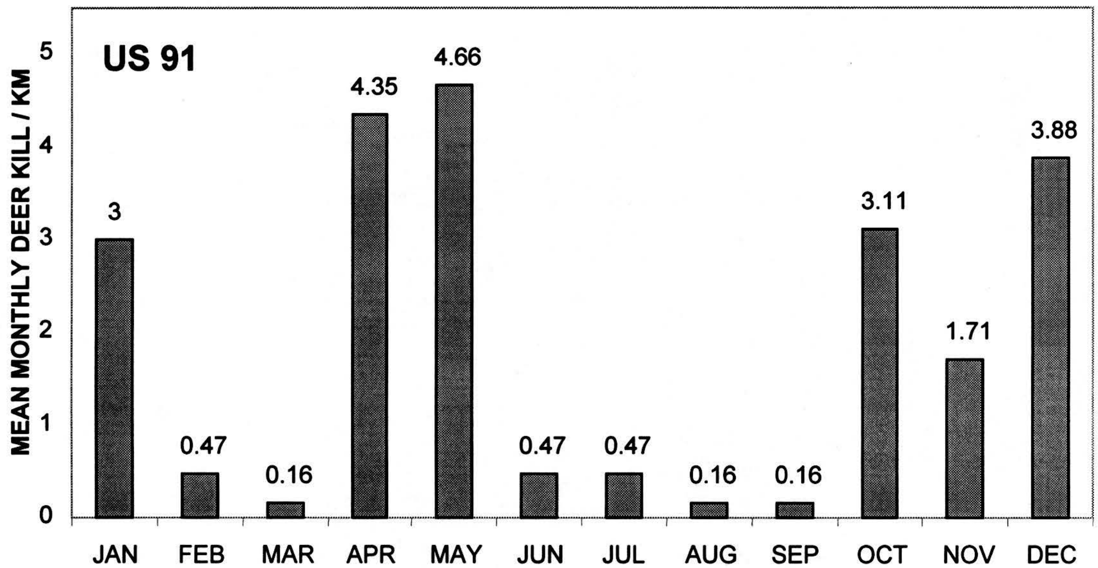
Deer mortality along the study section of US 91 had been monitored closely for several years prior to this study (R. Schultz, UDWR, unpub. data). Including this data in the analysis allowed an increased sample size that more accurately reflected monthly and yearly mortality patterns, as well as changes in mortality subsequent to the installation of the escape ramps.

Figure 11. Mean seasonal deer densities per km^2 at Jordanelle from milepost 4.0 - 13.1 based on spotlight counts conducted from November 1997-October 1999.



Deer mortality in Sardine Canyon appears to have a bi-modal peak, with mortalities increasing during April-May and again from October-January (Fig. 12). The peak in mortality during the spring and fall correlated with increased deer densities observed during the spring and fall migratory periods and was closely associated with the movement of the deer to and from summer and winter ranges. I also compared mortality prior to installation of the escape ramps to mortality after installation (Fig. 13). Mortality levels decreased after the installation of the escape ramps in October 1997. In 1996 and 1997, mortality was 6.5 and 6.8 deer/km respectively. Subsequent to the installation of the escape ramps, mortality decreased to 4.5 deer/km (1998) and 5.0 deer/km (1999). This data reflected only those mortalities associated with the section of the road with escape ramps in place and the decrease appears to be attributable to the escape opportunities afforded by the ramps. Mean overall mortality from 1996-1999 was 147 deer (mean = 36.7 deer per year, s.d. = 7.37) for a mean of 9.1 deer killed per km of road.

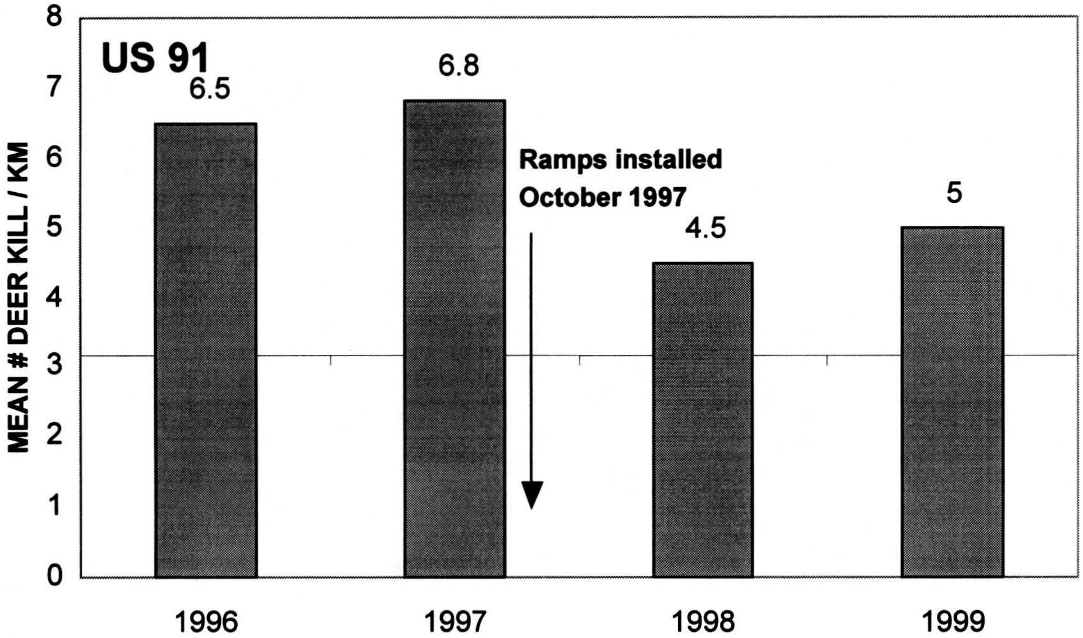
Figure 12. Mean monthly deer kill per km on US 91 from milepost 6.0-10.0 based on data collected from January 1996-October 1999.



Jordanelle--

Deer mortality data was collected on US 40 from 1995 –1997 for a prior study on deer-highway mortality (Lehnert 1996). Including this data in the analysis allowed an increased sample size and more accurately reflected seasonal and yearly changes in deer mortality. It also enabled a direct comparison between mortality levels on US 40 before the ramps were installed to levels after ramp installation, thus reflecting any potential decreases in mortality that might have been attributable to the installation of the escape ramps.

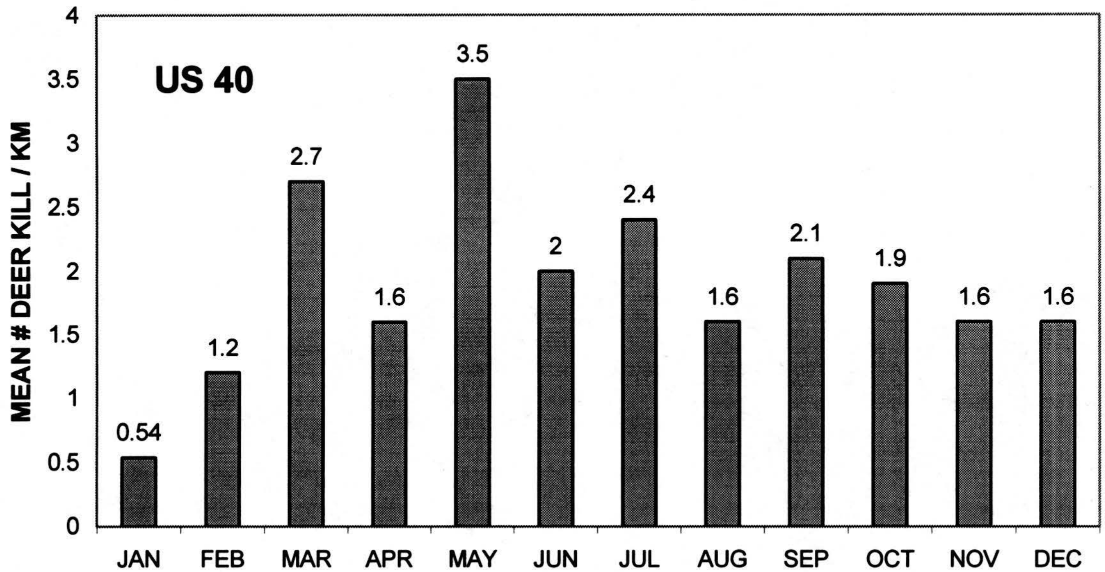
Figure 13. Mean annual deer kill per km on US 91 from milepost 6.0-10.0 based on data collected from January 1996-October 1999.



Deer mortality showed little variation from June to December, but decreased substantially during January and February, and increased from March to May (Fig. 14). Mortality data on US 40 correlated closely with spotlight count numbers for this area. Deer densities along US 40 show little variation during the spring, summer, and fall months; but dropped substantially during the winter months.

The number of mortalities from MP 4.0-7.5 in the experimental section of US 40 was compared to the number of mortalities from MP 9.0-12.5 in the control section to determine if the installation of the escape ramps resulted in a decrease in deer mortality (Fig. 15). Mortalities from MP 8.0-8.9 were eliminated because the deer fence terminated at MP 8.1 and some mortality data only provided

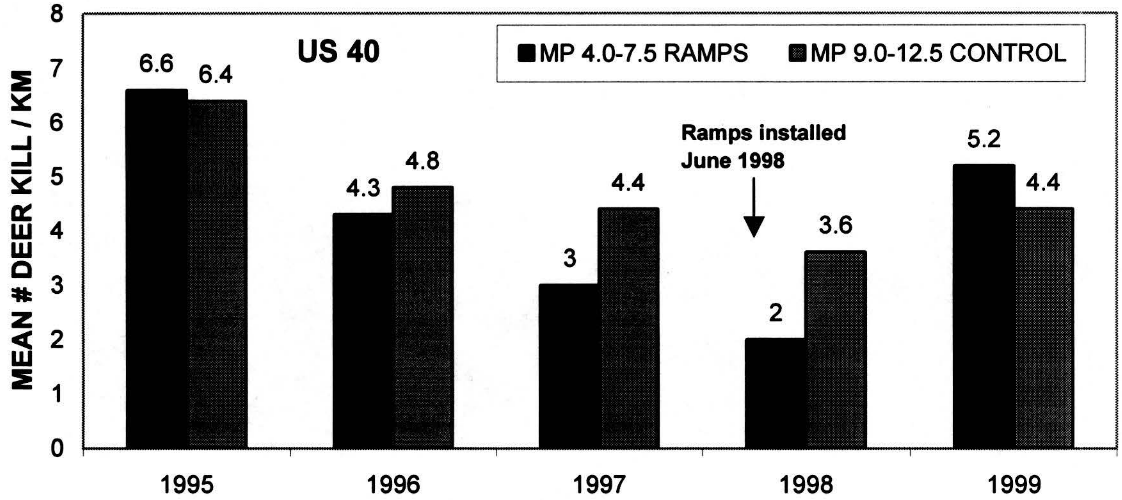
Figure 14. Mean number of deer killed per km on US 40 from January 1995-October 1999.



carcass location to the nearest milepost. Therefore, it could not be determined if these mortalities occurred within the experimental (fenced) or control (unfenced) areas. In addition, all mortalities from MP 13 were eliminated because the study area terminated at MP 13.1. Thus any mortalities recorded as MP 13, might have occurred outside the study area. This approach allowed a comparison of mortalities along road segments of identical length in the experimental and control sections. Overall mortality from 1995-1999 was 257 deer (mean per year = 50.2, s.d. = 15.6). This equated to a mean of 5.9 deer killed per km of road.

Examination of mortality data on US 40 showed an obvious reduction in mortalities in 1998 when compared to mortality in 1996 and 1997, however this trend did not continue into 1999. The increase in mortality in the experimental

Figure 15. Comparison of deer mortality before and after installation of escape ramps on experimental and control areas of US 40 near Jordanelle Reservoir, Utah.



section of US 40 may have been influenced by several variables. In February of 1999, 11 deer were killed along US 40, which is unusually high for this month. Prior to 1999, documented mortality for February never exceeded two deer. In addition, in June 1999 a large section of the game fence was removed by construction contractors adjacent to Ramp 5 and the gap created remained throughout the duration of the study season. This allowed deer to access the highway ROW freely, negating the purpose of the fence. Extensive development along US 40 and surrounding areas also may be affecting deer movement patterns, resulting in more deer crossing US 40 than in previous years.

DISCUSSION

The results of this study showed mule deer preferred using earthen escape ramps to exit the highway ROW when trapped on game-fenced roads.

When presented with the opportunity to use escape ramps or one-way escape gates, mule deer used the escape ramps 8-11 times more frequently than one-way gates at both study locations. Successful use of gates ranged from 33%-49% of deer that approached the gate from the ROW side of the fence. It also appears that mule deer exhibited preferential use of certain ramps, likely based on location and surrounding topography.

Deer mortality appeared to decrease in both study locations subsequent to the installation of the escape ramps. Mean annual deer kill/km in Sardine Canyon dropped by 1.5-2.3 deer/km in 1998 and 1999 when compared to mortality levels in 1996 and 1997. This decrease was likely due to the installation of the escape ramps as spotlight censuses reflect little variation in deer population numbers during the study period.

In 1998 deer mortality on US 40 decreased on the experimental section of the road after the installation of the escape ramps, whereas mortality levels on the control section remained approximately the same as in previous years. This data strongly suggests the ramps may have decreased deer mortality on the experimental section of US 40. However, in 1999 mortality levels on the experimental section of US 40 increased as compared to previous years while the control levels remained stable. This increase in mortality is likely due to several factors. The hole cut in the fence by pipeline contractors in June 1999 remained present through the duration of the study season, allowing more deer access to the highway ROW. Significant housing and resort development also was initiated in 1999 in this area, which may have influenced deer movement patterns, resulting in more deer crossing US 40 than in previous years. The majority of this development occurred within the boundaries of the experimental section of US 40, whereas the control section remained relatively uninfluenced by development. In 1999, spring and fall spotlight censuses of deer showed a slight increase deer densities in the area when compared to 1998 densities. This may be a reflection of an increased number of deer being forced to relocate from areas under development to alternate habitat.

Results of this study clearly show that earthen escape ramps are an effective and preferred escape mechanism for deer trapped on game-fenced highways. It is safe to assume that at least some of the 375 deer that used escape ramps to exit the ROW would have been involved in a collision had these structures not been in place. Therefore, deer mortality reductions should be expected to occur along game-fenced roads using escape ramps as a mitigation measure.

MANAGEMENT RECOMMENDATIONS

Significant numbers of deer-vehicle collisions occur throughout the United States, even when game-fencing and one-way escape gates are installed. Lack of maintenance, natural processes, and vandalism result in game fences that are seldom, if ever, 'deer proof'. Unless fences are diligently inspected and maintained, deer will continue to access the ROW in significant numbers. Even if fences are maintained, some deer will still access the ROW at the end of the fence, however, implementing a diligent regime of fence inspection and repair is critical to reducing deer-vehicle collisions along these roadways. The following management recommendations should assist wildlife professionals and highway personnel in reducing deer mortality along game-fenced highways by suggesting proper maintenance regimes as well as ensuring proper ramp location and spacing.

1) It is recommended that a fence maintenance and repair task be institutionalized as an annual work effort in every state that has game fenced roads. Particular emphasis should be placed on inspecting fences in areas that experience high deer mortality or areas that are important migratory corridors.

It is apparent that deer will inevitably gain access to the ROW on game fenced roads. As a result, mechanisms that allow trapped deer to escape the highway ROW on game-fenced roads are a necessity to reduce deer-vehicle collisions. One-way escape gates have been the chosen structure on most game-fenced highways. However, previous studies (Lehnert 1996) as well as this study, have demonstrated that deer are reluctant to use these dates, with effectiveness varying from 17-50%. Further, because deer were not marked, we have no way of knowing whether successful gate passage is confined to a few deer passing several times or if the behavior is more wide spread. Behavioral considerations regarding the use escape ramps by deer is also unknown. However, we found escape ramps were 6 to 12 times more effective than gates in allowing deer to escape the ROW. Further, they mimic natural topography, suggesting their use does not entail fright behavior by deer. Escape ramps may also be more frequently used by larger ungulates such as elk and moose, which may find the narrow passage of one-way gates confining. One-way gates may also allow smaller animals (coyotes, raccoons, mountain lions) access to the highway ROW by their design. Smaller animals are not restricted from using the gate to access the highway ROW from the non-highway side as are deer. This may increase road mortality in non-ungulate species. On two occasions mountain lion tracks were seen on track beds at one-way gates in Sardine Canyon and both times it appeared that the animal had used the gate to enter the ROW. Escape ramps have the added benefit of being more aesthetic and less conspicuous when vegetated and should require much less maintenance that one-way gates.

2) We recommend the placement of earthen escape ramps in areas of high deer road kill where fences have been installed.

Proper site location and spacing of earthen escape ramps along fenced highways is important and will be dictated in part by local conditions. Ideally, an assessment of localized mortality patterns along specific fenced road segments will provide the best data for placement of earthen escape ramps.

3) Deer mortality along road segments should be assessed by qualified personnel to determine the optimal placement of escape ramps, this is of particular importance in areas of high mortality. If this is not feasible or possible, we recommend that in road segments with high road mortality that ramps be installed no less than 0.25 mile apart, and on both sides of the road.

4) In areas of low mortality or when mortality information is unavailable, we recommend that escape ramps be spaced at 0.5 mile intervals throughout the length of the fence, except for fence ends where spacing should be no less than 0.25 mile intervals for the first one mile of fencing.

It may not be possible or feasible to examine every road segment of potentially high deer mortality. For example, road segments scheduled for fence installation may show different patterns of deer kill after installation of the fence. It often is not possible to assess the level or location of kill in advance of fence installation. In these cases, some generalizations can be made.

5) In areas of known or suspected, but undocumented high kill, ramps should be placed no less than 0.25 miles apart, on both sides of the road subsequent to fence installation. It is particularly important that ramps be placed no less than 0.25 miles apart near the first and last mile of the fence. It has been observed that many deer gain access to the ROW by walking around the ends of fences and thus become trapped as they travel up the ROW. Allowing several escape options for deer near the termination of the fence should help to reduce deer-vehicle collisions substantially.
6) If deer mortality is low in locations scheduled for game-fencing, it is recommended that escape ramps be installed at 0.5 mile intervals on both sides of the road, with closer placement within one mile of the termination of the fence.

OTHER CONSIDERATIONS

These primary recommendations for the placement of escape ramps for fenced road segments are based on an on-site evaluation of the history of deer mortality in the area. When this is not possible, we have recommended general guidelines for placement and spacing of escape ramps. Additional considerations will help in reducing deer mortality.

7) Placing ramps close to natural migratory corridors on road segments; i.e., near drainages, depressions, and areas of vegetation cover that deer would normally use to access the ROW may increase the frequency of use by deer.
8) Ramps should be placed closer together (i.e., at 0.25 mile intervals) in areas with desirable ROW forage as deer often access the ROW in these areas.
9) Allowing natural vegetation to become established on the escape ramps will reduce erosion and make them appear more natural (Fig. 16). Shielding escape ramps from highway noise and view by using topographic contours (hills, ditches, drainages) when possible may also make them more appealing to deer.

These recommendations should serve to help reduce deer-vehicle collisions on roads by providing natural escape routes for deer that have accessed the ROW.

Figure 16. Naturally vegetated earthen escape ramp.

LITERATURE CITED

Bellis, E. D. and H. B. Graves. 1971. Deer mortality on a Pennsylvania Interstate highway. J. Wildl. Manage. 35: 232-237.

Bonds, B. 1999. Wildlife habitat mitigation. in Proc. Int'l Conf. Wildl. Ecol. and Transp. FL-ER-73-99. Florida Depart. Transp. Tallahassee, Florida. pp. 173.

Falk, N.W., H.B. Graves, and E.D. Bellis. 1978. Highway right-of-way fences as deer deterrents. J. Wildl. Manage. 42: 646-650.

Feldhamer, G.A., J.E. Gates, D.M. Harman, A.J. Loranger, and K.R. Dixon. 1986 Effects of interstate highway fencing on white-tailed deer activity. J. Wildl. Manage. 50: 497-503.

Ford, S. G. and S. L. Villa. 1993. Reflector use and the effect they have on the number of mule deer killed on California highways. Report FHWA/CA/ PD94/01. California Department of Transportation. Sacramento.

Gladfelter, J. R. 1982. Effect of wildlife highway warning reflectors on deer-vehicle accidents. Iowa Highway Res. Board. Project HR-210. 11pp.

Lehnert, M.E. 1996. Mule deer highway mortality in northeastern Utah: an analysis of population-level impacts and a new mitigative system. M.S. Thesis, Utah State Univ., Logan. 82 pp.

Ludwig, J. and T. Bremicker. 1983. Evaluation of 2.4 m fences and one-way gates for reducing deer-vehicle collisions in Minnesota. Transp. Res. Record. 913: 19-22.

Pojar, T. M., R. A. Prosence, D. F. Reed and T. N. Woodard. 1975.

Effectiveness of a lighted, animated deer crossing sign. J. Wildl. Manage. 39: 87-91.

Putnam, R. J. 1997. Deer and road traffic accidents: options for management. J. Environ. Manage. 51: 43-57.

Reed, D. F. 1981. Effectiveness of highway lighting in reducing deer-vehicle accidents. J. Wildl. Manage. 45: 721-726.

Reed, D. F. 1993. Efficacy of methods advocated to reduce cervid-vehicle accidents: research and rationale in North America. Colorado Division of Wildlife Resources, Fort Collins, CO. 13 pp.

Reed, D. F., T. M. Pojar, and T. N. Woodard. 1974. Use of one-way gates by mule deer. J. Wildl. Manage. 38: 9-15.

Reeve, A. F. and S. H. Anderson. 1993. Ineffectiveness of Swareflex Reflectors at reducing deer-vehicle collisions. Wildl. Soc. Bull. 21: 127-132.

Reeve, A. F. 1986. Vehicle-related mortality of big-game in Nugget Canyon, Wyoming, a review of the problem, mitigation alternatives, and recommendations. Wyoming Cooperative Fishery and Wildife Research Unit. Laramie, Wyoming. 87 pp.

Romin, L. A. and L. B. Dalton. 1992. Lack of response by mule deer to wildlife warning whistles. Wildl. Soc. Bull. 20: 382-384.

Romin, L.A. 1994. Factors associated with the highway mortality of mule deer at Jordanelle Reservoir, Utah. M.S. Thesis, Utah State Univ. Logan. 83 pp.

Romin, L.A. and J.A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildl. Soc. Bull. 24:276-283.

Schafer, J. A. and S. T. Penland. 1985. Effectiveness of Swareflex reflectors in reducing deer-vehicle accidents. J. Wildl. Manage. 49: 774-776.

Ward, L. A. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Trans. Res. Rec. 859: 8-13.

Waring, G. H., J. L. Griffis, and M. E. Vaughn. White-tailed deer roadside behavior, wildlife warning reflectors, and highway mortality. App. Anim. Behav. Sci. 29: 215-223.

Wood, P. and M. L. Wolfe. 1988. Intercept feeding as a means of reducing deer-vehicle collisions. Wildl. Soc. Bull. 16: 376-380.

CHAPTER III

COST-BENEFIT ANALYSIS FOR THE INSTALLATION OF EARTHEN ESCAPE RAMPS ON GAME-FENCED ROADS IN UTAH.

Abstract: A cost-benefit analysis was conducted to determine if the cost of ramp installation was offset within a reasonable time period by the monetary savings associated with reduced deer-vehicle collisions. Producing a cost-benefit analysis for the installation of the escape ramps involved incorporating four components in the analysis: 1) vehicle accident costs, 2) deer value, 3) mitigation costs, and 4) effectiveness of the ramps in reducing mortality. The cost-effectiveness of installing the earthen escape ramps at both locations was determined by using the number of successful ramp crossings and potential deer mortality levels to generate projected monetary losses (cost of deer-vehicle collisions) associated with varying mortality levels. The assumption was made that at least some of these deer that crossed successfully would have been involved in a deer-vehicle collision had the ramps not been in place. Six arbitrary levels of potential mortality (from 2% to 15%) were generated based on those assumptions. These percentages were multiplied by the number of successful deer crossings at each location to generate potential deer mortality numbers. The number of deer mortalities was then multiplied by the average economic loss of a deer-vehicle collision ($3,845) to obtain an estimate of the mitigated benefits of installing the ramps through 1999. These values were compared to the cost of installing ramps at each location to determine the amortization period.

Results showed that the cost of installation of earthen escape ramps is very rapidly offset by the benefits gained in deer survival and reduced automobile collisions. At the 2% mortality level, the cost of ramp installation in both locations was offset by the monetary savings associated with reduced deer-vehicle collisions within two years. Heavy use of the escape ramps as well as reduction in mortality observed at both study sites indicate that the mitigation benefits may be much greater than those projected at the 2% mortality level. Installing earthen escape ramps on big-game fenced highways is a very cost-effective way to further reduce deer mortalities along roadways with high to moderate deer kill.

INTRODUCTION

Numerous studies have investigated the effectiveness of game fencing (2.4 m) as a mitigation technique designed to reduce deer-vehicle collisions (Falk et al. 1978, Lehnert 1996, Ludwig and Bremicker 1983, Feldhamer et al. 1986, Reed et al. 1974, Ward 1982). However, only a few studies have addressed the implementation of game-fencing and other mitigation techniques in terms of a cost-benefit analysis. Wu (1998) used a cost-benefit analysis as a predictive model to compare mitigation systems to determine which system would provide the maximum benefit (decreased deer-vehicle collisions) relative to cost in Ohio. Reed et al. (1982) used a cost-benefit analysis to describe the most cost-effective method to install game-fencing and associated structures in Colorado. In order for a mitigation system to be considered cost-effective, the benefits (reduction in accidents, reduction in deer kill) associated with the implementation of the system must outweigh the costs associated with the installation of the system. Ideally, amortization should occur within a few years.

Game-fencing is the most common technique used to reduce deer-vehicle collisions. However, lack of maintenance, vandalism, fence flaws, and natural processes all result in decreased fence integrity, allowing deer access to highway right-of ways. Therefore, game-fencing must be viewed as a deterrent to deer road crossings, not as an absolute barrier. Deer that become trapped on the highway right of way (ROW) are frequently killed before they can escape. Mechanisms that allow deer to exit the highway ROW on game-fenced roads serve to further reduce deer-vehicle collisions in these areas. Two structures have been used along highways to enable trapped deer to escape the highway ROW; one-way escape gates and earthen escape ramps.

One-way escape gates have been installed in conjunction with game-fencing in many areas, including California (Ford 1980), Colorado (Reed et al. 1974), Minnesota (Ludwig and Bremicker 1983), Utah (Lehnert 1996) and Wyoming (Ward 1982). Escape gates are steel gates that open in only one direction, allowing deer trapped on the ROW to return to the non-highway side of the fence, while preventing deer from accessing the ROW from the gate. By default, they have been the structure of choice to allow deer to escape the ROW.

Earthen escape ramps are sloping mounds of soil that are placed against a backing material against the ROW side of the game fence. Ramps are designed so deer can walk to the top of the ramp and jump to the non-highway side of the fence. Deer on the non-highway side of the fence are not able to use the ramps to access the ROW. Ramps are used in a few states, including Wyoming, but no assessment of their efficacy had been conducted.

Earthen escape ramps were installed on two game-fenced highways in Utah. In October 1997, nine earthen escape ramps were installed on US 91 between Brigham City and Logan. Eight escape ramps were installed on US 40 near the Jordanelle Reservoir in 1998. These areas both use game-fencing and one-way gates to reduce deer-vehicle collisions. The use of earthen escape ramps and one-way escape gates by mule deer was compared to determine if deer exhibited a preference for ramps or gates and whether mortality decreased along study roads subsequent to the installation of the escape ramps. Earthen escape ramps were, on average, 8 to 11 times more effective in allowing deer to escape the ROW than the traditional, more commonly used one-way gates (see Chapter 2). The data in this study demonstrate that earthen escape ramps are an important component of mitigation on game-fenced highways because they provide deer that access the ROW an effective means of escape. Even though their biological effectiveness is clear, the costs associated with the implementation of the system should be offset by the benefits gained (reduced deer-vehicle collisions) to make the system cost-effective. The objective of this study was to determine if the costs associated with the installation of escape ramps was justified by the reduction in deer-vehicle collisions.

METHODS

Producing a cost-benefit analysis for the installation of the escape ramps involved incorporating four components in the analysis: 1) vehicle accident costs,

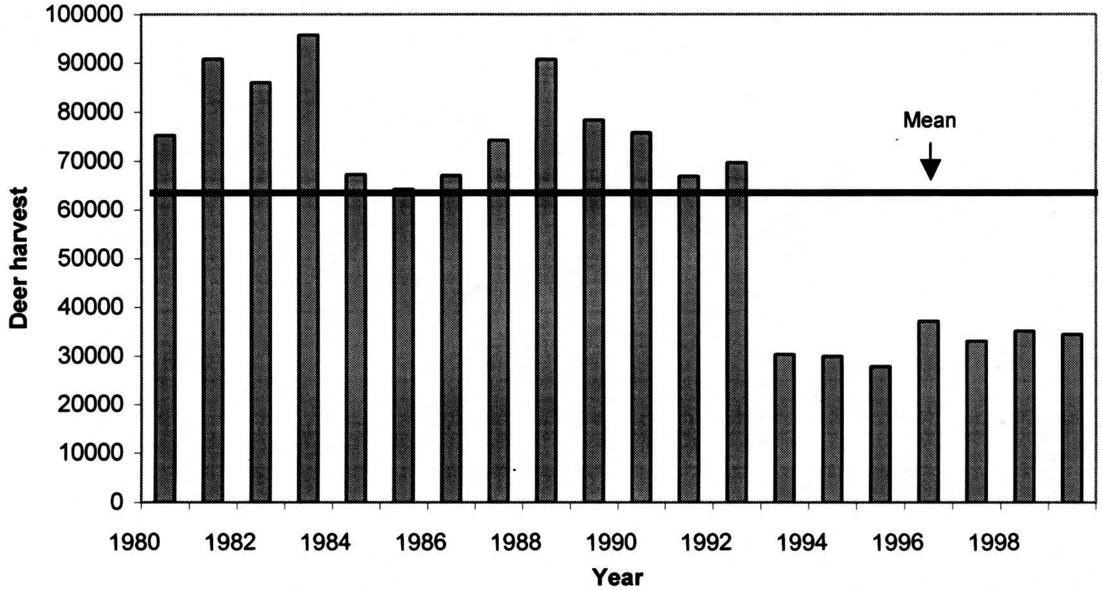
2) deer value, 3) mitigation costs, and 4) effectiveness of the ramps in reducing mortality. Data on human injuries and fatalities resulting from deer vehicle accidents was not included in this analysis as not all deer-vehicle collisions result in human injury. Deer mortality on game-fenced highways is dependent upon the number of trapped deer on the ROW that are unable to escape. However, determining what percentage of deer that become trapped on a game-fenced highway ROW are involved with a vehicle collision is difficult to assess. Indeed, that data cannot be collected by any reasonable means available, short of camera surveillance along the entire road segment. The number of trapped deer involved in collisions is dependent upon numerous factors including; traffic volume, traffic speed, length of fence segment, weather conditions, and mechanisms for escape. However, there are indirect ways of assessing ramp effectiveness. I made the assumption that at least some of the deer that used the escape ramps to exit the highway ROW would have been killed on the road had these structures not been in place. This assumption is based on the observed reductions in mortality seen on US 91 and US 40 subsequent to the installation of the escape ramps. On US 40 deer mortality was reduced by 1.0 deer/km in 1998 when compared to 1997. On US 91 deer mortality was reduced by 1.5-2.3 deer/km in 1998 and 1999 when compared to 1996-1997 deer mortality levels.

Deer valuation was estimated to be $2,274 based on Utah hunting expenditures and harvest rates for 1996 (Utah Division of Wildlife Resources 1997, U. S. Fish and Wildlife Service 1997). In 1992 big-game vehicle damage claims averaged $1,200 in Utah (Romin 1994, Romin and Bissonette 1996).

I adjusted both the vehicle damage claim amount and the deer valuation to 1999 values using the Consumer Price Index (CPI) adjustment. This adjustment placed monetary losses due to insurance claims at $1,425 per deer-vehicle collision and resulted in a deer valuation of $2,420. Thus, the monetary losses associated with each deer-vehicle collision averaged $3,845. This is a very straightforward way to calculate deer valuation, but may tend to over- or under-estimate the costs involved. Changes in any of the variables will tend to change the valuation. Recently, number of deer harvested in Utah has declined (Fig. 17), although the number of hunters has not declined proportionally (Utah Division of Wildlife Resources 2000). Because deer value is based on number of deer harvested, the number of hunters in the field, and the total amount of money spend on deer hunting in Utah for any given year; valuation will vary from year to year. However, because the valuation estimates are based on a multi-year mean, they are reasonable and should be representative of the current situation. Further, as deer numbers decline with harvest, one can argue that each animal assumes a greater value because of scarcity.

The cost-effectiveness of installing the earthen escape ramps on US 91 and US 40 was determined by using the number of successful ramp crossings and potential deer mortality levels to generate projected monetary losses associated with varying mortality levels. I made the assumption that at least some of the deer that crossed successfully would have been involved in a deer-vehicle collision had the ramps not been in place. Six arbitrary levels of potential mortality (from 2% to 15%) were generated based on those assumptions.

Figure 17. Annual deer harvest in Utah from 1980-1999



These percentages were purposefully low, in order to be conservative. The purpose of this method was to evaluate the economic loss if 2%, 5%, 7%, 10%, 12%, or 15% of the deer that actually crossed to safety by using the ramp had instead been hit on the roads. These percentages were multiplied by the number of successful deer crossings at each location to generate potential deer mortality numbers (e.g., on US 91, 188 successful crosses x 2% equals 4 deer; similarly, on US 40, 192 successful crosses x 15% equals 29 deer). The number of deer mortalities was then multiplied by the average economic loss of a deer-vehicle collision ($3,845) to obtain an estimate of the mitigated benefits of installing the ramps through 1999. These values were compared to the cost of installing ramps at each location to determine the amortization period. Typically maintenance costs for mitigation structures are included in a cost-benefit analysis. However, escape ramps are essentially maintenance free, therefore maintenance costs were not considered in the analysis.

RESULTS

On US 91, 188 deer used escape ramps to exit the ROW and 192 deer used ramps on US 40. Monetary losses associated with mortality of only 2% of these deer would have approached $15,000 (Table 2). At approximately $2,000 each to install, total cost for ramp installation was $16,000 on US 40 and $18,000 on US 91. If deer use of escape ramps had remained approximately the same in both areas through 2000, even at the 2% mortality rate, the benefits associated with ramp installation offsets the costs. We argue that a 2% reduction of mortality rate for these deer is a very conservative estimate, based on the documented reductions in mortality that were observed at both study sites. Ramp cost may vary depending on the source of materials used in their construction. Highway departments may use soil and backing material left over from construction operations, reducing the cost of ramp installation considerably. These savings would be reflected in faster amortization.

DISCUSSION

The cost of installation of earthen escape ramps is very rapidly offset by the benefits gained in deer survival and reduced automobile collisions. It is safe to assume that at least 2% of trapped deer will be killed on the highway if they cannot escape and indeed, the data from this study show that this percentage is much higher. At the 2% mortality level, the cost of ramp installation is offset by

Table 2. Estimated return on investment for the installation of earthen escape ramps on US 91 and US 40 in Utah. Based on data collected from October 1997 – October 1999 (two year amortization).

	Potential Mortality[b]					
	2%	5%	7%	10%	12%	15%
# DEER[a] US 91	4	9	13	19	23	28
ESTIMATED[c] MITIGATIVE BENEFIT $	14,796	33,291	48,087	70,281	85,077	103,572
# DEER US 40	4	10	13	19	23	29
ESTIMATED MITIGATIVE BENEFIT $	14,796	36,990	48,087	70,281	85,077	107,271

[a] 188 successful crossings on US 91, 192 successful crossings on US 40

[b] Potential percent of deer killed on the road had they not escaped over the earthen escape ramp and associated monetary value

[c] Valuation of deer-vehicle accident costs potentially saved by earthen ramps at six level of road mortality.

the monetary savings associated with reduced deer-vehicle collisions in both locations within two years. Heavy use of the escape ramps as well as reduction in mortality observed at both study sites indicate that the mitigation benefits may be much greater than those projected at the 2% mortality level. In addition, deer use escape ramps 8-11 times more frequently to exit the ROW than one- way gates (see Chapter 2). Ramps require little or no maintenance and are more aesthetically appealing to deer than one-way gates. Installing earthen escape ramps on big-game fenced highways is a very cost-effective way to further reduce deer mortalities along roadways with moderate to high levels of deer mortality.

LITERATURE CITED

Falk, N.W., H.B. Graves, and E.D. Bellis. 1978. Highway right-of-way fences as deer deterrents. J. Wildl. Manage. 42: 646-650.

Feldhamer, G.A., J.E. Gates, D.M. Harman, A.J. Loranger, and K.R. Dixon. 1986 Effects of interstate highway fencing on white-tailed deer activity. J. Wildl. Manage. 50: 497-503.

Ford, S. G. 1980. Evaluation of highway deer kill mitigation on SIE/LAS-395. Calif. Dept. Transp. Publ. No. FHWA/CA/TP-80/01. 45 pp.

Lehnert, M.E. 1996. Mule deer highway mortality in northeastern Utah: an analysis of population-level impacts and a new mitigative system. M.S. thesis, Utah State Univ., Logan. 82 pp.

Ludwig, J. and T. Bremicker. 1983. Evaluation of 2.4 m fences and one-way gates for reducing deer-vehicle collisions in Minnesota. Transp. Res. Record. 913: 19-22.

Reed, D. F., T. D. I. Beck, and T. N. Woodard. 1982. Methods of reducing deer-vehicle accidents: benefit cost analysis. Wildl. Soc. Bull. 10: 349-354.

Romin, L. A. 1994. Factors associated with the highway mortality of mule deer at Jordanelle Reservoir, Utah. M. S. Thesis, Utah State Univ. Logan. 83 pp.

Romin, L. A. and J. A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildl. Soc. Bull. 24: 276-283.

Utah Division of Wildlife Resources. 1997. Utah big game report. Utah

Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah. 259 pp.

Utah Division of Wildlife Resources. 2000. Utah big game report. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah. 166 pp.

U. S. Fish and Wildlife Service. National survey of fishing, hunting, and wildlife-Associated recreation – Utah. U. S. D. I. Fish and Wildlife Service, Washington, D. C. 81 pp.

Ward, L. A. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Trans. Res. Rec. 859: 8-13.

Wu E. 1998. Economic analysis of deer-vehicle collisions in Ohio. in Proc. Int'l Conf. Wildl. Ecol. and Transp. pp 43-52.

CHAPTER IV

CONCLUSION

Game-fences are the most common mitigation technique used to reduce deer-highway mortality (Falk et al. 1978, Lehnert 1996, Ludwig and Bremicker 1983, Feldhamer et al. 1986, Reed et al. 1974, Ward 1982), however, they usually are not inspected and repaired routinely. The result is deterioration of fences, which allows deer access to the highway right-of-way (ROW). Therefore, fences are rarely impermeable to deer movement, and should be viewed as a deterrent to crossing, but not as an absolute barrier. It is clear that deer will access the ROW, however, access appears easier than exit, because many deer are killed on fenced roads. Therefore, structures that enable trapped deer to exit the highway ROW are critical along game fenced highways and serve to further reduce deer mortality on these road segments. This study tested the effectiveness of two types of structures designed to reduce deer mortality on game-fenced highways, the conventional one-way steel escape gates commonly used throughout the country, and earthen escape ramps. Earthen ramps have been installed in Wyoming and Utah, but had not been tested for efficacy. Deer use of these structures was compared using track beds counts. Mortality levels subsequent to ramp installation were compared to mortality prior to ramp installation at two study locations to determine if deer mortality decreased after the ramps were installed. Additionally, a cost benefit-analysis was conducted to determine if the cost incurred by retrofit ramp installation could be amortized over a reasonable time period by monetary savings associated with reduced deer-vehicle collisions.

Summary of Conclusions

Deer use of earthen escape ramps and one-way escape gates was evaluated on two highways in Utah, US 91 in Sardine Canyon and US 40 near the Jordanelle Reservoir. On US 91, 183 deer used the escape ramps to exit the ROW and 15/45 (33.3%) deer that approached the one-way gates used them to exit the ROW. On US 40, 192 deer exited the ROW via the ramps and 31/63 (49.2%) used the one-way gates. Ramp use at both sites was between 8-11 times higher than use of one-way gates.

Mortality levels on US 91 decreased after the installation of the escape ramps in October 1997. In 1996 and 1997, mortality was 6.5 and 6.8 deer/km respectively. After the installation of the escape ramps, mortality decreased to 4.5 deer/km (1998) and 5.0 deer/km (1999). This reflects a 23-34% reduction in mortality subsequent to ramp installation, or a reduction in kill of 1.5-2.3 deer/km.

Ramps on US 40 were installed in June and August of 1998. Deer mortality levels decreased in 1998 when compared to mortality in 1996 and 1997. In 1996 and 1997, 4.3 deer/km and 3.0 deer/km, respectively, were killed on the fenced portion of US 40, whereas in 1998 deer kill was 2.0 deer/km. This reflects a 33-54% reduction in mortality subsequent to ramp installation. This trend did not continue into 1999 when deer kill was measured at 5.2 deer/km on the fenced portion of US 40. This increase in mortality is likely due to a large hole cut in the fence by contractors in June of 1999 that remained in place for the duration of the study season, in effect negating the effect of the fence and escape ramp located adjacent to the hole. Additionally there were an unusually large number of deer killed in February 1999. New housing and resort development in the area that was initiated in 1999, almost certainly had an impact on deer movements and likely resulted in more road crossings.

Producing a cost-benefit analysis for the installation of the escape ramps involved incorporating four components in the analysis: 1) vehicle accident costs, 2) deer value, 3) mitigation costs, and 4) effectiveness of the ramps in reducing mortality. The value of a deer was calculated to be $2,420 based on hunting expenditures and deer harvest rates (Utah Division of Wildlife Resources 1997, U. S. Fish and Wildlife Service 1997). The average cost of an insurance claim was $1,425 per deer-vehicle collision (Romin 1994, Romin and Bissonette 1996). Thus, the monetary losses associated with each deer-vehicle collision averaged $3,845. Earthen escape ramps cost approximately $2,000 each to install. The assumption was made that had the ramps not been installed a certain percentage of deer that used them to escape the ROW would have been involved in a deer vehicle collision. Several projected levels of deer mortality ranging from 2-15% were developed based on that assumption. These projected mortality levels were multiplied by the cost of a deer-vehicle accident to determine the mitigative benefits associated with the installation of the ramps. At the 2% projected mortality level, the cost of ramp installation was offset by the monetary savings associated with reduced deer-vehicle collisions within two years. The cost-benefit analysis results showed that the cost of installation of earthen escape ramps is very rapidly offset by the benefits gained in deer survival and reduced automobile collisions. Heavy use of the escape ramps as well as reduction in mortality observed at both study sites indicate that the mitigation benefits may be much greater than those projected at the 2% mortality level. Mortality reductions observed subsequent to the installation of the escape ramps ranged from 23-54% along the study highways, a much greater reduction in mortality than the highest level of 15% used in the cost-benefit calculations.

Results of this study clearly show that earthen escape ramps are an effective and preferred escape mechanism for deer trapped on game-fenced highways. Escape ramps are very cost-effective and virtually maintenance free. Properly placed escape ramps should serve to significantly reduce deer mortality on game-fenced highways throughout the United States.

LITERATURE CITED

Falk, N.W., H.B. Graves, and E.D. Bellis. 1978. Highway right-of-way fences as deer deterrents. J. Wildl. Manage. 42: 646-650.

Feldhamer, G.A., J.E. Gates, D.M. Harman, A.J. Loranger, and K.R. Dixon. 1986 Effects of interstate highway fencing on white-tailed deer activity. J. Wildl. Manage. 50: 497-503.

Lehnert, M.E. 1996. Mule deer highway mortality in northeastern Utah: an analysis of population-level impacts and a new mitigative system. M.S. Thesis, Utah State Univ., Logan. 82 pp.

Ludwig, J. and T. Bremicker. 1983. Evaluation of 2.4 m fences and one-way gates for reducing deer-vehicle collisions in Minnesota. Transp. Res. Record. 913: 19-22.

Reed, D. F., T. M. Pojar, and T. N. Woodard. 1974. Use of one-way gates by mule deer. J. Wildl. Manage. 38: 9-15.

Romin, L. A. 1994. Factors associated with the highway mortality of mule deer at Jordanelle Reservoir, Utah. M. S. Thesis, Utah State Univ. Logan. 83 pp.

Romin, L. A. and J. A. Bissonette. 1996. Deer-vehicle collisions: status of state monitoring activities and mitigation efforts. Wildl. Soc. Bull. 24: 276-283.

Utah Division of Wildlife Resources. 2000. Utah big game report. Utah Department of Natural Resources, Division of Wildlife Resources, Salt

Lake City, Utah. 166 pp.

U. S. Fish and Wildlife Service. National survey of fishing, hunting, and wildlife-Associated recreation – Utah. U. S. D. I. Fish and Wildlife Service, Washington, D. C. 81 pp.

Ward, L. A. 1982. Mule deer behavior in relation to fencing and underpasses on Interstate 80 in Wyoming. Trans. Res. Rec. 859: 8-13.

Mary:

BS Corpus Christi State University 1987

Cytogenetic lab tech in labs in both Seattle and Tulsa

High School teacher in Oklahoma and now in California

Jesse Ray

Ed [illegible] Childhood