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Publication Date

2000

EFFECTIVENESS OF EARTHEN RETURN RAMPS IN REDUCING BIG GAME HIGHWAY MORTALITY IN UTAH

FINAL REPORT

John A. Bissonette and Mary Hammer

Cover photo by Mark McClure

EXECUTIVE SUMMARY

Conventional wisdom and highway practice across many states seemed to suggest that high (~2.4 m) 'deer-proof' fencing, coupled with underpasses are the mitigation of choice to prevent deer (and other ungulate) mortalities on U.S. highways. Our observations here in Utah and those elsewhere in the U.S. strongly suggested that few, if any, so called 'deer-proof' fences totally eliminated deer from accessing the Right-of Way (ROW) on fenced roads. In Sardine Canyon (US 91) in northern Utah, more than 50 deer were killed in one year on the road in a short section (MP 6.0- MP10) after the road was widened and fenced. This suggested to us that highway mitigation aimed at reducing deer-vehicle collisions needed to take into consideration measures that allowed deer to readily exit the highway ROW. We conducted a two-year study (October 1997- November 1999) to examine the effectiveness of earthen escape ramps in allowing deer to escape the highway ROW. We compared their performance with one-way steel escape gates

We identified two study sites in Utah with a history of high deer road kill and deer fencing, US 91 (MP 6 – MP 10) and US 40 (MP 4 – MP 13) as appropriate for study. During the period of the study (October 1997 – November 1999) we conducted regular spotlight counts to assess deer population trends at both sites. Concurrently, we recorded deer kills on both sites throughout the period. Earthen escape ramps were installed on US 91 in October 1997 (n = 9) and on US 40 between July and August 1998 (N = 7). We established track plots on each ramp in order to assess use by deer. Similarly, track plots were established at 10 one-way gates on US 91 and at 8 gates on US 40. At both sites, gates in the vicinity of the ramps were used. Ramps at the US 91 site were checked 61 times during the study and 188 successful crossings recorded. At the US 40 site, ramps were checked 42 times and 192 successful crossings recorded. Gates were checked 52 and 40 times during the study at the US 91 and US 40 sites, respectively. Fifteen of 45 (33.3%) deer at US 91 and 31 of 63 (49.2%) deer at US 40 passed through the gates successfully.

We compared the effectiveness of earthen escape ramps with one-way gates by standardizing their use into 'ramp' and 'gate' days. We then developed an index of use. At both sites, ramps were much more effective than gates in allowing deer to escape the ROW. Combined values from both sites suggest that earthen escape ramps were from approximately 8 to 11 times more effective than one-way gates. Our cost benefit analysis, using a deer valuation based on actual expenditures for deer hunting and adjusted for compensatory mortality, suggested that the cost of installing earthen escape ramps is rapidly offset by reduction in deer mortality. We recommend that earthen escape ramps be incorporated into mitigation when deer fencing is being considered for installation on Utah roads.

PROBLEM DEFINITION

Road-Kill Trends

Deer-vehicle collisions have increased in the United States over the past several years (Romin and Bissonette 1996a). Roads and highway networks have expanded rapidly, often through areas with ungulate populations. According to a nationwide survey, an estimated 538,000 deer were involved in collisions with vehicles in 1991 (Romin and Bissonette 1996a). When 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 deer vehicle collisions that occur were actually reported to authorities (Decker et al. 1990, D. F. Reed, Colo. Div. Wildl. pers. comm.), suggesting that as many as 1-1.5 million deer-vehicle collisions may occur in the United States each year (Conover et al. 1995). Additionally, Allen and McCullough (1976) reported that 92% of collisions resulted in the death of the deer. An average of 2,156 deer-vehicle collisions was reported annually in Utah between 1994-1998 (Utah Department of Transportation, unpub. data). If the assumptions of 50% reportability and 92% mortality are correct, as many as 3,967 deer are killed on Utah roads annually.

Wildlife Valuation

The valuation of wildlife is difficult at best, however deer are a valuable economic resource in Utah. Here we take a very simple approach to calculate deer value. We chose 1996 as our base year because both U.S. Fish and Wildlife Service data on dollars spent on deer hunting, and Utah Division of Wildlife Resources data on harvest were available. In 1996, hunters spent a total of $84,499,566 (U.S. Fish and Wildlife Service 1997) to harvest 37,159 deer (Utah Division of Wildlife Resources 1997). Hence, each deer harvested can be valued at approximately $2,274 in 1996 dollars. Data for Utah auto insurance claims for 1996 were not available, but during 1992 averaged $1,200 per big-game vehicle accident in Utah (Farmers Insurance Bureau, unpubl. data 1992, Romin and Bissonette 1996a). Using the Consumer Price Index we adjusted all values to 1999 dollars, with the result that each deer harvested in 1999 can be valued at $2,420 and each accident at $1,425 for a total value of $3,845. In addition, the Federal Highway Administration placed a monetary loss of 1.5 million dollars on each human fatality (Romin and Bissonette 1996a). Excluding 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. Although these figures will vary by number of deer killed on the road, number of deer hunters, and monies spent to hunt deer, it is not difficult to see that deer are indeed a valuable asset to Utah citizens, and road mortality entails significant economic losses annually.

Mitigation

Numerous techniques and structures have been used to reduce highway mortality and to allow for safe passage across the roadway. Most efforts have shown limited or no success, and many have not been tested sufficiently to determine their effectiveness (Reed 1996). Common wisdom suggests that the most effective technique used to allow safe passage of deer across roadways is a combination of deer fencing and underpasses.   Underpasses coupled with game fencing have been considered to be the mitigation of choice (albeit the most expensive) with a presumed 100% effectiveness in preventing deer-vehicle collisions. However, fences are seldom, if ever, 'deer-proof'. In spite of recently installed big game fencing and underpasses, observations on US 91 in Sardine Canyon in 1996 documented over 55 deer killed in a four-mile section of highway near Mantua, Utah (Rick Schultz, UDWR, personal comm.). Deer continue to gain access to fenced highway right-of-ways in most locations.

A common problem with deer fencing is maintenance of the fence (Reed 1996). Often fences are installed but routine inspection and repair are not conducted regularly, resulting in problems with fence integrity. Additionally, vandalism appears to be a common problem with ROW fences. We found that fences on US 91 and US 40 were breached on several occasions (Lehnert and Bissonette pers. obs., Hammer and Bissonette pers. obs.). Additionally, lack of quality control when fences are installed, combined with gravitational forces causing earth slumping and erosion resulted in large gaps underneath fences on US 40 and US 91allowing deer access to the highway ROW.

Given these realities, it is easy to understand that structures that allow deer to escape the ROW are important components of highway safety when roads are fenced. One-way galvanized steel escape gates are the most common structure that have been installed in conjunction with deer fencing in many areas to allow deer a one-way exit from the ROW (Photo 1). However, one-way gates were not designed with deer behavior in mind. Deer are prey animals whose response is to run from danger. They are reluctant to squeeze through the tines of a one-way gate gate. Indeed, studies on the use and effectiveness of the

gates have had mixed results. Reed et al. (1974) found that gates were 'relatively' effective in allowing deer to escape the ROW, however, Lehnert (1996) found that only 16.5% of deer that approached the gates at Jordanelle used them to escape the ROW. Apparently, some deer appear to learn to use the gates, others do not (Photo 2).

Earthen escape ramps are an alternative to one-way steel gates (Photo 3). They have been used in Wyoming, but their effectiveness has not been tested. Earthen escape ramps are mounds of dirt 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 (Photo 3). However, deer cannot use the ramp to access the ROW. Deer readily traverse steep terrain and are accustomed to maneuvering over drop-offs. Earthen ramps are virtually maintenance free, an advantage over one-way gates. We tested the effectiveness of earthen ramps installed along a portion of U.S. 91 in Sardine Canyon and on U.S. 40 near Jordanelle Reservoir in northern Utah.

GOAL AND OBJECTIVES

The primary goal of this study was to determine the relative effectiveness of earthen ramps vs. one-way gates in allowing deer to exit the highway ROW. We asked the question: "would deer use earthen escape ramps preferentially over one-way gates?" We wanted to determine if there was a reduction in mortalities along study roads that could be attributed to the installation of the escape ramps. To do this we compared mortality levels prior to ramp installation to mortality levels subsequent to ramp installation. We also estimated ramp cost effectiveness in these locations by comparing

the cost associated with ramp installation to the economic benefits of projected mortality reductions.

METHODS AND TASKS

TASK 1 - SELECTION OF LOCATIONS AND CONSTRUCTION OF DEER RAMPS

ACCOMPLISHMENTS
Selection of Study Sites----.

Two areas were selected as study sites: 1) US 91 in Sardine Canyon and 2) US 40 near the Jordanelle Reservoir.

The Sardine Canyon area encompassed a section of US 91 (undivided two-lane with passing lane) located in Box Elder county just south of Cache county (Fig. 1). Elevations ranged from 1477-1786m. US 91 is the primary route between Logan and Brigham City, Utah. Prior to the onset of this study in 1977, big-game fencing, one-way gates, and underpasses were in place as mitigation to reduce deer-vehicle collisions. The study segment of road began at MP 6.0 and extended north to MP 10.0.   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.

The US 40 study site was located near Jordanelle Reservoir, approximately 6 km southeast of Park City in Summit and Wasatch counties (Fig. 2). This site has been the focus of prior studies on deer-highway mortality and mitigation measures (Romin 1994, Lehnert 1996, Lehnert et al. 1998. Elevations in the area ranged from 1,890-2,380 m. 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. From MP 4.0 to MP 8.1 big game fencing (2.4 m), at-grade crosswalks, and one-way gates had been installed previous to our study as mitigation designed to reduce deer-vehicle collisions. At-grade crosswalks (Photo 4) were designed to allow normal seasonal and daily movements by directing deer across the highway in well-marked crosswalks where motorists can anticipate their presence. The segment of US 40 from MP 8.1 to MP 13.1 had normal height (~ 1 m) ROW fencing and no mitigation measures in place. This section served as a control.

Fig. 1. Study segment of US 91 in Sardine Canyon, Utah showing location of earthen escape ramps.
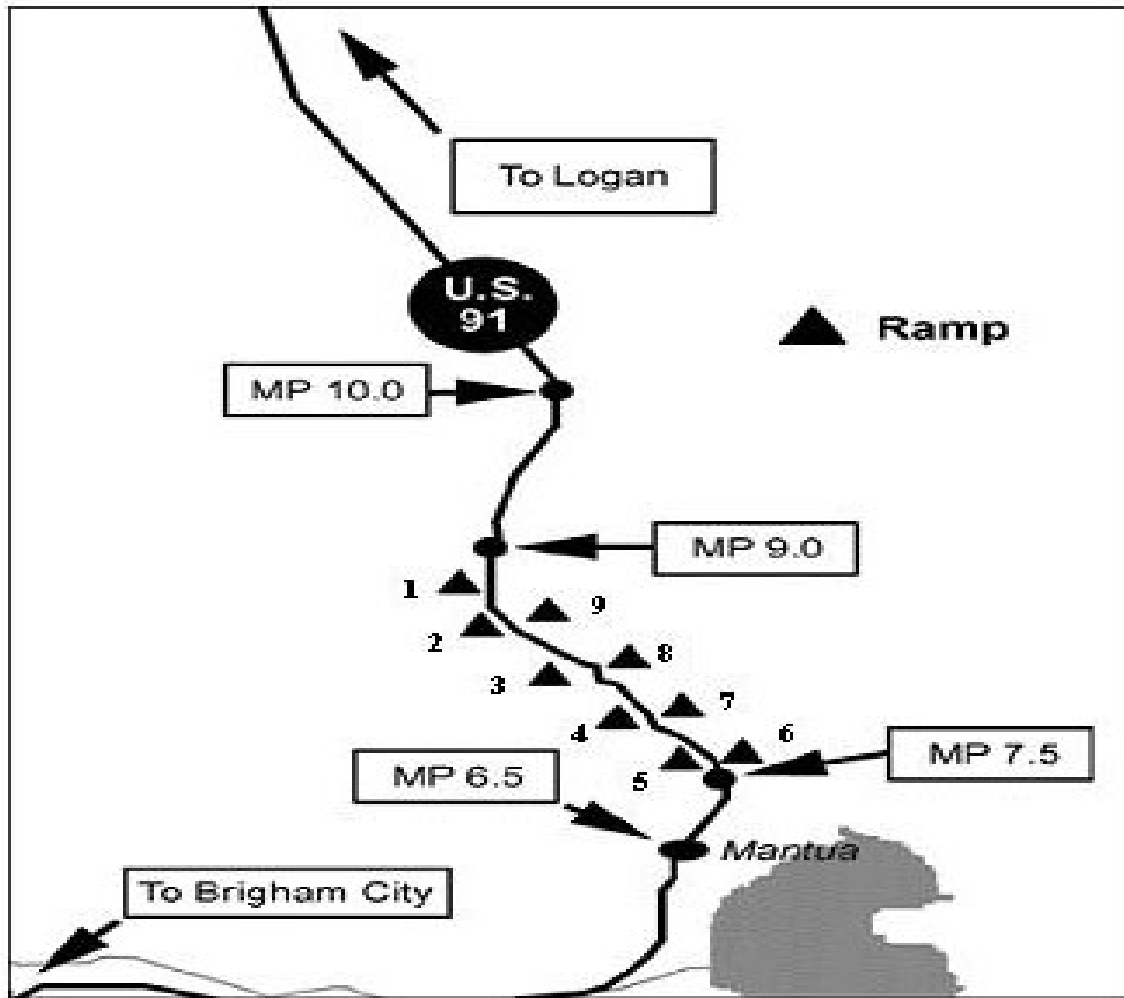
Sardine Canyon:

In October 1997, nine earthen ramps were installed along a 1.5-mile (MP 7.5-9.0) section of deer fence on US 91 in Sardine Canyon (Fig. 1). The inclines were moderate, had a flattened area at the top, and were useable for determining track counts (Photo 5)

Jordanelle Area:

In July 1998, three earthen ramps were installed along a 1.5-mile section (MP 5.0-6.5) of US 40 (Fig. 2). Their design was similar to the Sardine Canyon ramps and they were useable for track counts. Five additional ramps were installed on 12 August 1998, but these ramps were poorly constructed. One ramp was too steep and did not have an area large enough at the top to construct a track bed, and was not useable (Photo 6). Our efforts to remedy the situation through UDOT channels were not successful. Our conclusions regarding US 40 are based on data from 7 ramps.

Fig. 2. Study segment of US 40 near the Jordanelle Reservoir showing the location of earthen escape ramps. Also shown is the location of the control section of US 40.
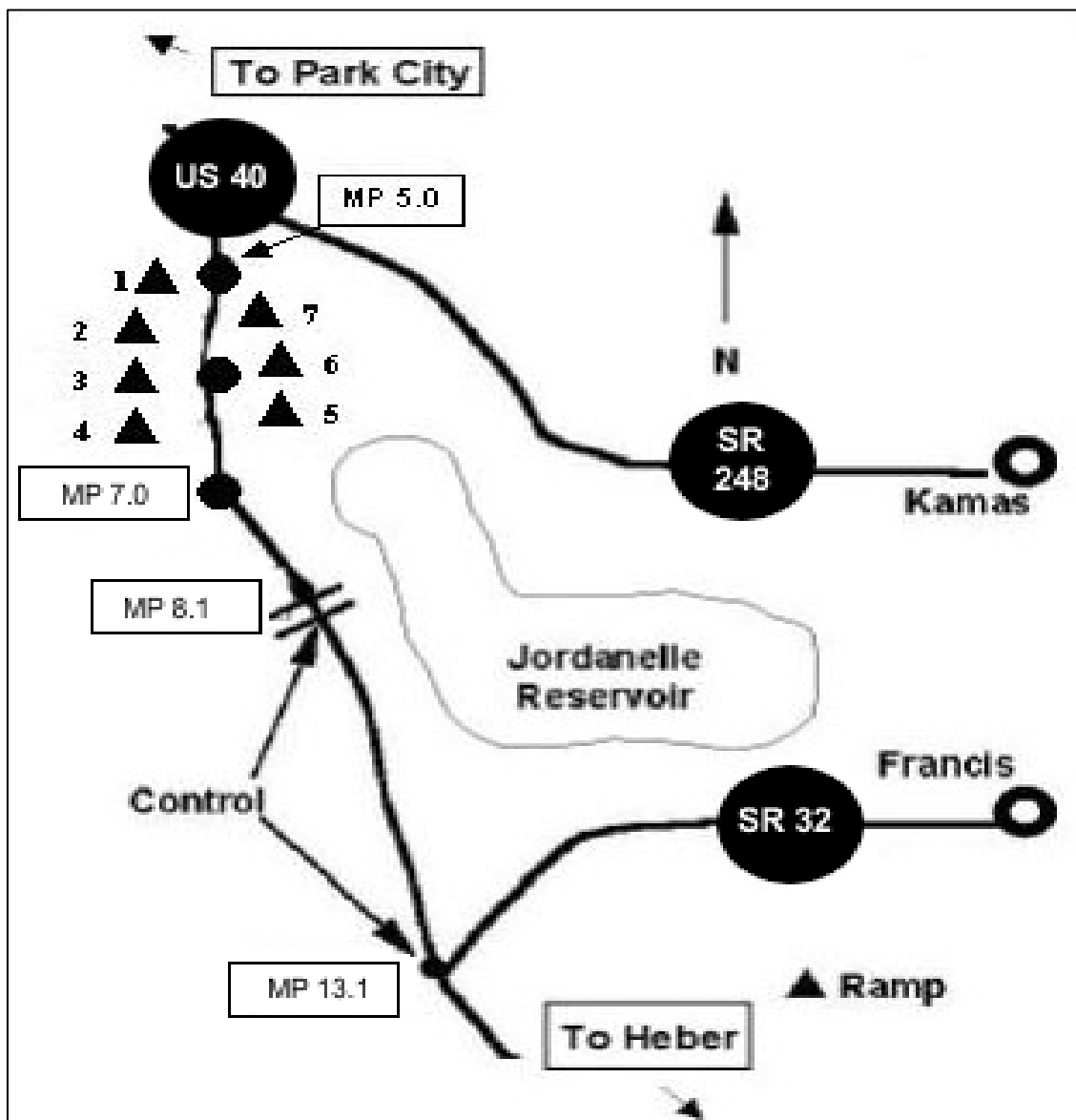
Track Bed Counts:

We monitored use of the earthen ramps and one-way gates by recording track counts on oiled track beds established to meet this objective. The number of deer using the ramps was enumerated by counting track trails on the ramps when possible as well as track counts on track beds Photo 7). The ramps were raked smooth after each reading to facilitate counting. Similarly, track beds were constructed on both the non-highway and highway side of each gate, oiled in the same manner as ramp track beds, and raked smooth after each reading. Gate and ramp data were collected concurrently at both the Sardine Canyon (US 91) and the Jordanelle Reservoir (US 40) study sites.

TASK 2 – MONITORING OF RAMP USAGE

ACCOMPLISHMENTS
General Methods----.

Each ramp was examined for the presence of tracks on track beds. Use of track beds established on ramps was classified into four categories; (1) none, (2) light (one cross), (3) moderate (two crosses), and (4) heavy (many

crosses). If it seemed apparent that more than three deer had used the ramp, we classified use as "heavy" due to the difficulty in ascertaining the exact number of deer that had crossed Photo 8). A crossing was deemed "successful" if a track trail led to the edge of the track bed and terminated at the drop off point. Ramps were checked at least twice weekly during the sampling seasons (Photo 1).

Sardine Canyon:

Track beds were established at nine ramps on US 91and monitored for use from mid-June 1998 until October 1998 and from May 1999 until October 1999. Topsoil and sand were used to construct track beds at the level area at the top of each ramp. Often it was difficult to ascertain with certainty that tracks were present because of dry weather conditions. To remedy this problem and facilitate the reading of track beds, we mixed vegetable oil into the soil of the track bed. This resulted in soil characteristics that provided distinct hoof prints with each use. Approximately 2-3 gallons of oil were used per ramp. Oiled ramps proved easy to maintain and reliable in determining deer use of the ramps (Photo 9).

Each of the ramp track beds on US 91 in Sardine Canyon was checked 61 times during the duration of the study. A total of 188 successful crossings occurred during this time.

Jordanelle Area:

Track beds were established at three earthen ramps on US 40 in mid-July 1998, with sampling continuing until October 1998. In May 1999, track beds were established at seven earthen ramps and sampling continued until October 1999. Methodology for establishing track beds followed the same protocol used for Sardine Canyon. Ramps on US 40 were checked 42 times during the duration of the study and 192 successful crossings were recorded. Given that three ramps were sampled for two years and four ramps for only one year, we used the results from 1999 when all seven ramps were sampled in order to avoid skewing the results.

TASK 3 - MONITORING OF GATE USAGE

We monitored one-way gate use by using track beds constructed on both the ROW and the non-highway side of each gate. We determined the number of deer that

approached the gates from both sides, and the number that successfully passed through. During the sampling period, tracks were counted at least twice a week.

ACCOMPLISHMENTS
General Methods---.

Ten one-way gates in Sardine Canyon were monitored for successful crossings by deer. The gates were located within the same 1.5-mile section of highway as the earthen ramps.   Four one-way gates were monitored on US 40 in 1998 and eight were monitored in 1999. The gates on US 40 were all located within the same 1.5-mile section of highway as the escape ramps. A gate crossing was deemed successful if tracks were found on both sides of the gate <u>and</u> were oriented in the same direction (Photo 1).

Sardine Canyon:

 Monitoring of the gates on US 91 was conducted from mid-June 1998-October 1998 and from May 1999-October 1999. Gates on US 91 were checked 52 times during the study period. A total of 45 animals approached the gates from the ROW and 15 (33.3%) passed through the gate (Photo 2). None of the deer that approached the gate from the non-highway side passed through the tines to access the ROW.

Jordanelle Area:

Monitoring of the gates on US 40 occurred from July 1998-October 1998 and from May 1999-October 1999. Gates on US 40 were checked 40 times over the study period. A total of 63 deer approached the gates from the ROW side and 31 (49.2%) of these animals proceeded to use the gate to escape the ROW. No deer accessed the ROW by passing through the gate in the wrong direction.

TASK 4 - COMPARISON OF RAMP AND GATE USAGE AND EFFECTIVENESS

We assessed comparative use of earthen ramps and one-way gates for both study sites. Additionally, we compared pre- and post-ramp mortality levels at both the Jordanelle and Sardine study sites.

ACCOMPLISHMENTS
General----.

In order to standardize data comparisons, we first calculated the number of gate and ramp use days during the study period, allowing a direct comparison between the uses of earthen escape ramps and one-way escape gates. We then calculated an index of use for each treatment (gates and ramps) by study site (US 40, US91), 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 nearby gates. When combined, ramp use at both sites was between 8 & 11 times higher than one-way escape gates (Table 1). The relatively higher index of ramp use at Jordanelle as compared to Sardine Canyon corresponds to increased deer numbers in this area in the summer. Sardine Canyon has lower deer numbers in the area of the road during summer because deer move to higher summer range. 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.

In addition, it appears that some ramps were used preferentially over others. 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 3.). Overall, substantially more crosses occurred on those ramps on the eastern side of the highway, even though fewer ramps were involved. Ramp 2 had two 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

Fig. 3. Number of deer crossings on individual escape ramps located on US
91 in Sardine Canyon, Utah.
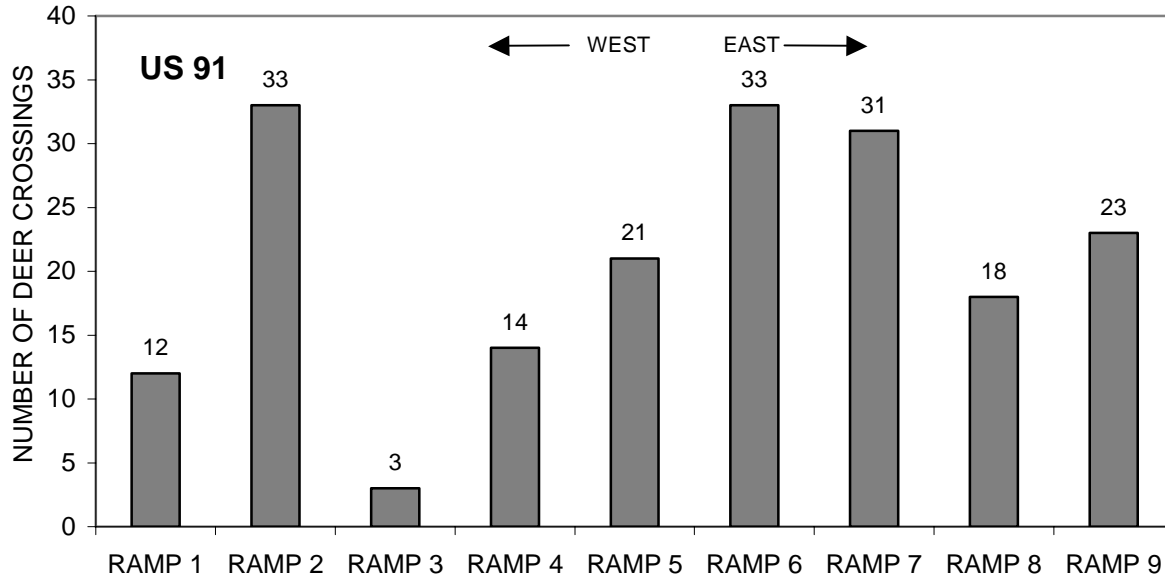
use of this ramp. Ramp 3 was located immediately adjacent to fencing and an
underpass. Deer could only approach this ramp from one direction, contributing to its
limited use.

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. 4). Ramp 5 had received use in 1998, but virtually no use in
1999. Contractors working in the area removed a section of the 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 up on a highway slope and
ramp 6 is situated behind a slight hill on the ROW. Placement of ramps in locations
where they are shielded from highway effects might increase their use even more.

TASK 5 - ASSESSMENT OF DEER MORTALITY
To accomplish this objective we assessed whether live deer numbers and road
mortalities changed over time and by treatment. We collected data on road mortalities
as well as live deer densities on both treatment and control road segments. Although
road segments are seldom ever identical, attaining a close similarity of structural and
environmental features is possible and provides valid comparisons. We collected data
from third party entities under contract to State agencies to remove deer from the
roadways, as well as from the DEPARTMENT. Deer mortality data was collected from
November 1997 until October 1999. We monitored road kills closely, especially for

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Fig. 4. Number of deer crossings on individual escape ramps located on
US 40 near Jordanelle Reservoir, Utah.
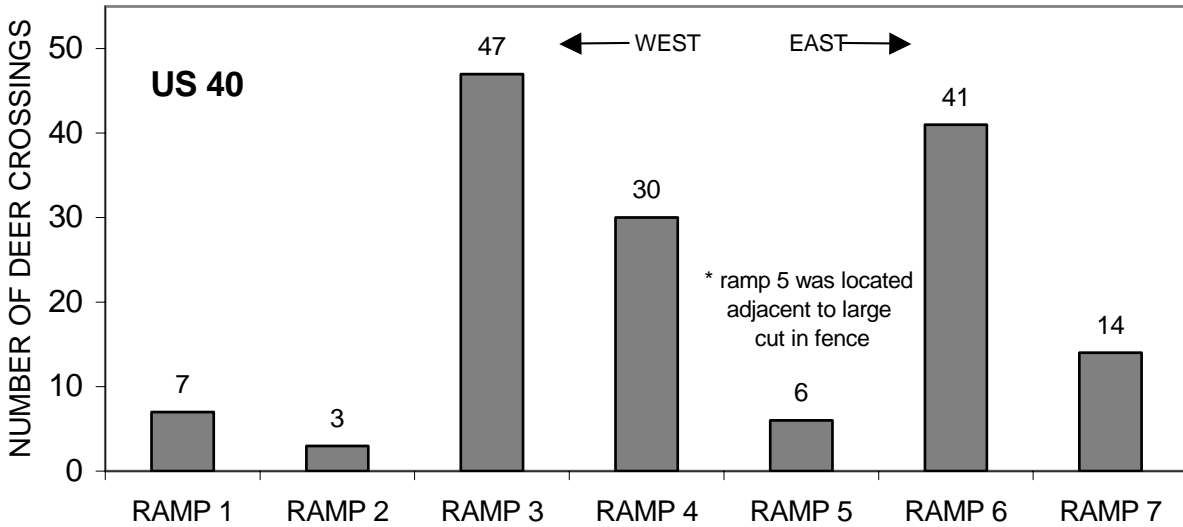
those road segments for which no formal collection of dead deer was scheduled by the
DEPARTMENT. Date, location (to nearest 1.0 mile), sex, and age (adult, yearling,
fawn) was recorded for every deer found killed by vehicles in the study areas.
Additionally, we surveyed each road for mortalities when spotlight censuses were
conducted. Data on deer mortality for years preceding the onset of this study were
used in the final data analysis when applicable.

Spotlight counts were conducted monthly in order to detect changes in deer
population densities within the study areas. We used a hand-held 400,000 candlepower
spotlight to illuminate deer from a vehicle traveling at 20-30 mph along the roadside
after dark. In order to calculate deer density, we calculated an effective area for each
site by recording range finder readings at each 0.1-mile interval and integrated the
result into an estimate of observable area for each site. We then took monthly and
seasonal spotlight counts and divided them by effective area to obtain estimates of deer
density per km^2.

The DEPARTMENT provided information regarding the number of deer-vehicle
collisions on study roads from 1995-1998. We used this information to compare the
number of dead deer documented on the study highways to the number of collisions
reported to authorities.

## ACCOMPLISHMENTS
General Spotlight Counts----.

Spotlight counts commenced on US 40 (Jordanelle) in November 1997 (total number
of deer counted = 499) and on US 91 (Sardine Canyon) in January 1998 (total number
of deer counted = 469) and continued in both locations until October 1999. Spotlight

counts were conducted on a monthly basis for the first year of the study, except during the summer months when counts were conducted bi-monthly, but were then increased to a bi-monthly basis year-round to increase sample size. In addition, data existed for deer density in the Jordanelle area prior to the initiation of this study [from January 1994 until July 1997 (Romin 1994, Lehnert 1996)]. No prior data on deer densities existed for Sardine Canyon. Effective observable area for the US 91 site was 2.12 km^2 and for US 40 was 2.48 km^2.

Sardine Canyon:

Spotlight surveys in Sardine Canyon showed deer densities that peaked from March-May with a smaller peak from August to October (Fig. 5). This corresponds closely to the migratory movements of mule deer during the spring and fall as they move to winter or spring ranges (R. Shultz, UDWR pers. comm.). Deer move from the highway 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 as well. Use of escape ramps was higher during

Fig. 5. Mean monthly deer densities per km^2 from milepost 6.0-10.0 based on spotlight counts from January 1998 to October1999.
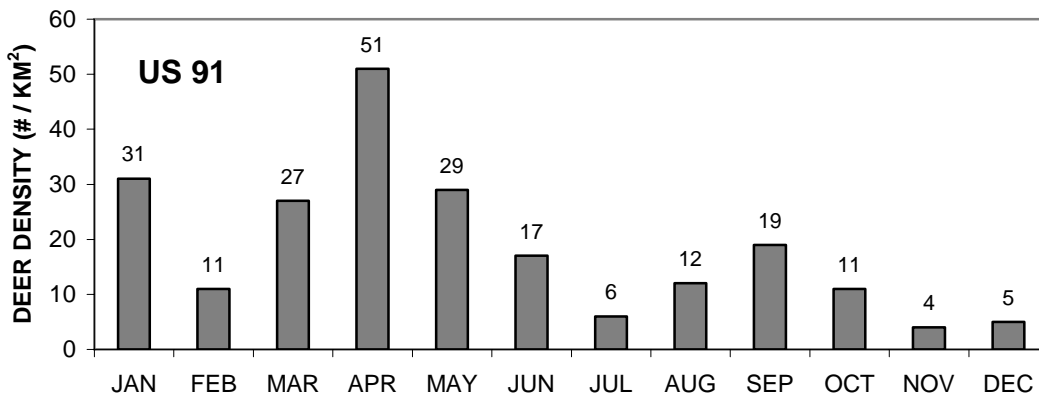

the spring and early fall and decreased substantially during the months of July and August. Overall, deer numbers tend to decrease in Sardine Canyon during the winter months, however we observed an increase of deer in January when they tended to cluster in an open field at MP 6.5 along the study highway. Deer tended to be more visible during January when they were present in large numbers in this open field, probably due to more accessible forage.

It is difficult to determine whether any changes occurred in deer population densities over the course of this study (Fig. 6). Deer appear to have been relatively stable except

for the peak in deer densities observed during spring, 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.

Fig. 6. Mean seasonal deer densities per km^2 from milepost 6.0-10.0 based on spotlight counts from January 1998 to October 1999.
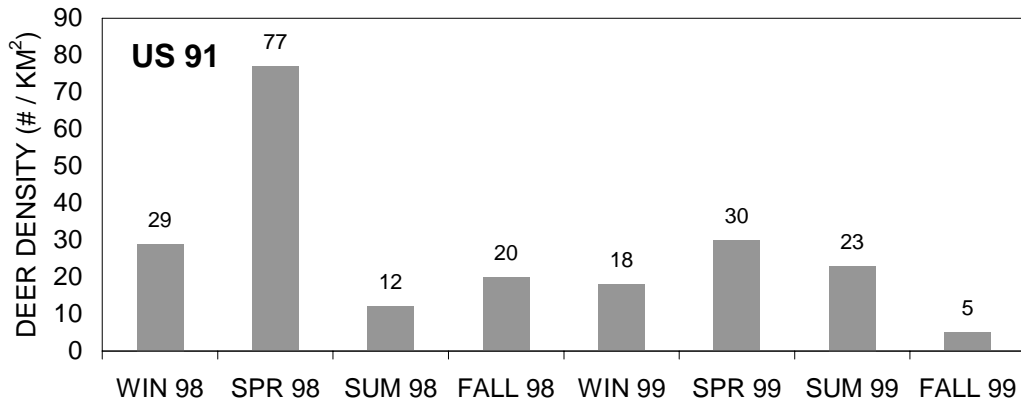
Jordanelle Area

There was a significant decrease in the number of deer spotlighted from January-March on US 40 (Fig. 7). This area receives heavy snow in winter and is not winter range for mule deer. An increase in deer activity began in April, with deer densities

Fig. 7. Mean monthly deer densities per km^2 from milepost 4.0 - 13.1 based on spotlight counts collected from November 1997-October 1999.
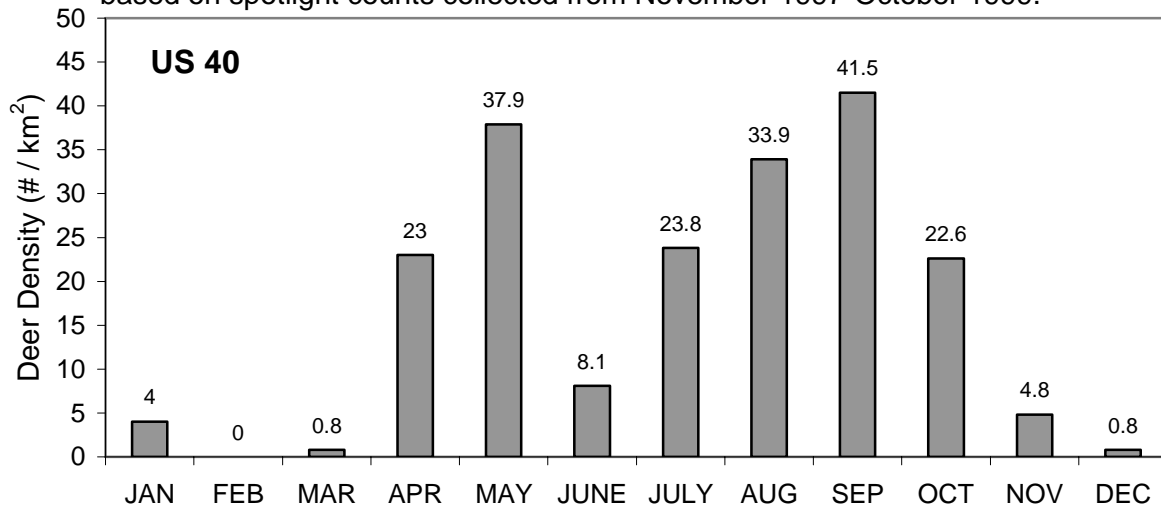
reaching a peak during the months of July, August, and September. The observable

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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. 8).

Fig. 8. Mean seasonal deer densities per km^2 from milepost 4.0 - 13.1 based on spotlight counts conducted from November 1997-October 1999.
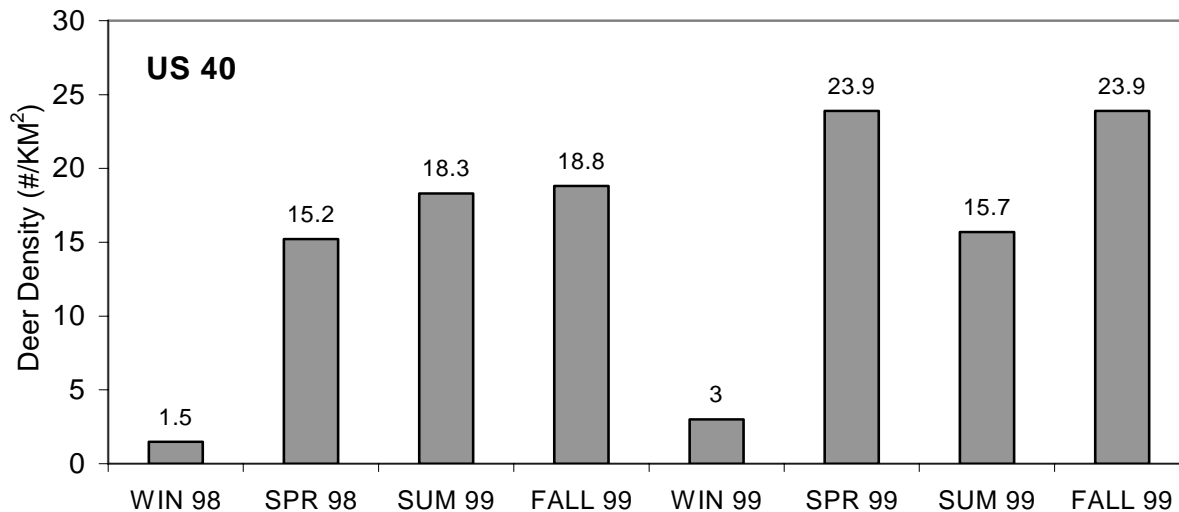

General Highway Mortality----.

Mortality data was collected by UDOT personnel, UDWR personnel, a private contractor (Rocky Mountain Clean Rite) and by us for all study areas. Previous year deer mortality data was available for both the Jordanelle and Sardine study sites.

Sardine Canyon:

We included in our analysis mortality data that was collected prior to the initiation of this study (R. Schultz, UDWR, unpub. data). The increased sample size allowed a more accurate reflection of monthly and yearly mortality patterns. Deer mortality in Sardine Canyon had a bi-modal peak, with mortalities increasing during April-May and again from October-January (Fig. 9). The peak in mortality during spring and fall correlated with increased deer densities we 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. We also compared mortality prior to installation of the ramps to mortality after installation (Fig. 10). Mortality levels decreased after the installation of the earthen ramps in October 1997. In 1996 and 1997, mortality was 6.5

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Fig. 9. Mean monthly deer kill per km from milepost 6.0-10.0 based on data collected from January 1996-October 1999.
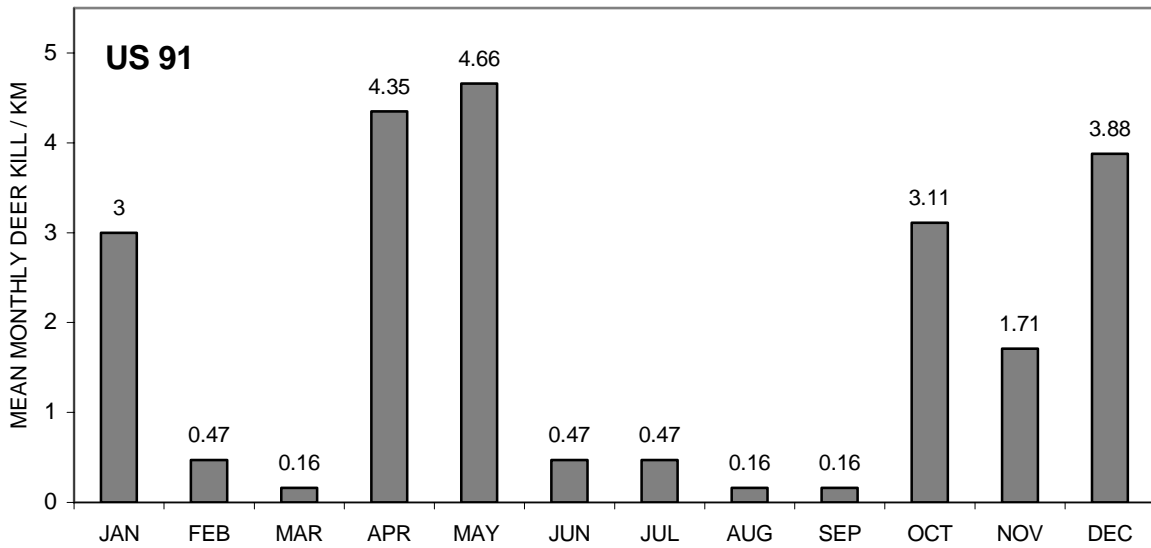
and 6.8 deer/km, respectively. Subsequent to the installation of the ramps, mortality decreased to 4.5 deer/km (1998) and 5.0 deer/km (1999). These data reflect only

Fig. 10. Mean annual deer kill per km from milepost 6.0-10.0 based on data collected from January 1996-October 1999.
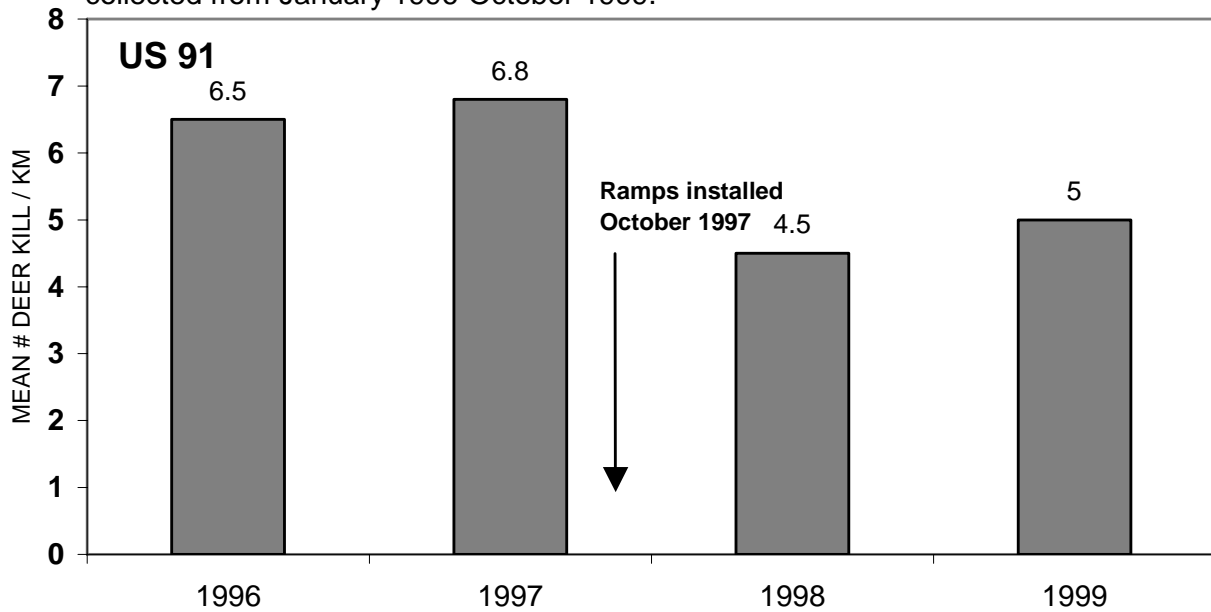
mortalities associated with the section of road with escape ramps in place and appears attributable to the escape opportunities afforded by the ramps. Mean overall mortality from 1996-1999 was 147 deer (mean = 36.7 per year, s.d. = 7.37) for a mean of 9.1 deer killed per km of road.

Jordanelle area:

We analyzed deer mortality based on data collected from 1995 to 1999 to increase sample size in order to more accurately reflect seasonal and yearly changes. Deer mortality on US 40 showed little variation from June to December, but decreased substantially during January and February (Fig. 11), and increased from March to May. Mortality data on US 40 correlated closely with spotlight count numbers for this area. Deer spotlight numbers along US 40 show little variation during the spring, summer, and fall months, but dropped substantially during the winter months. We compared the

Fig. 11. Mean number of deer killed per km of road from January 1995-October 1999.
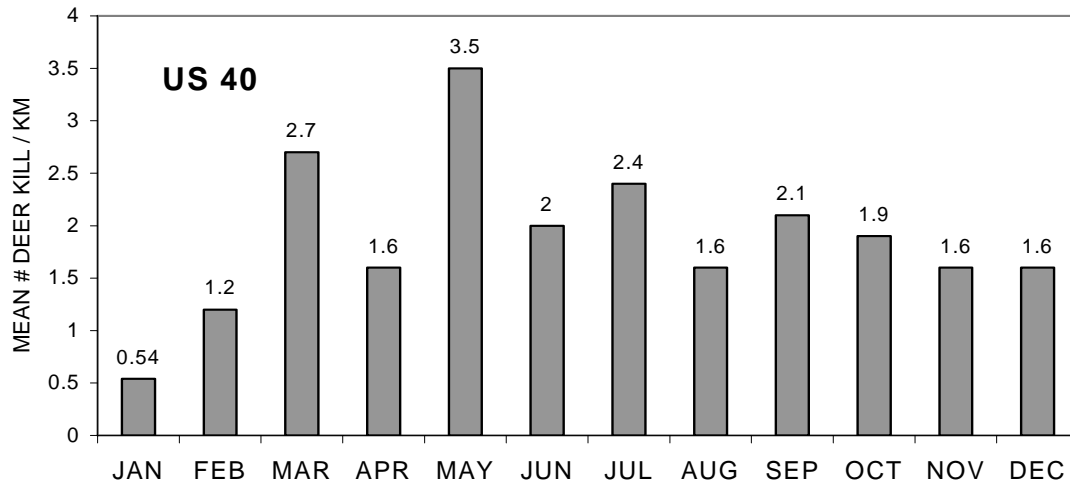
number of mortalities from MP 4.0-7.5 in the experimental section of US 40 to the number of mortalities from MP 9.0-12.5 in the control section of US 40 to determine if the installation of the escape ramps resulted in a decrease in deer mortality (Fig 12). Mortalities from MP 8.0-8.9 were eliminated because the deer fence terminated at MP 8.1 and some mortality data provided to us were only recorded to the nearest mile point. Therefore, we could not determine 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. Our approach allowed

Fig. 12. Comparison of deer mortality before and after installation of escape ramps on experimental and control areas of US 40 near Jordanelle Reservoir, Utah.
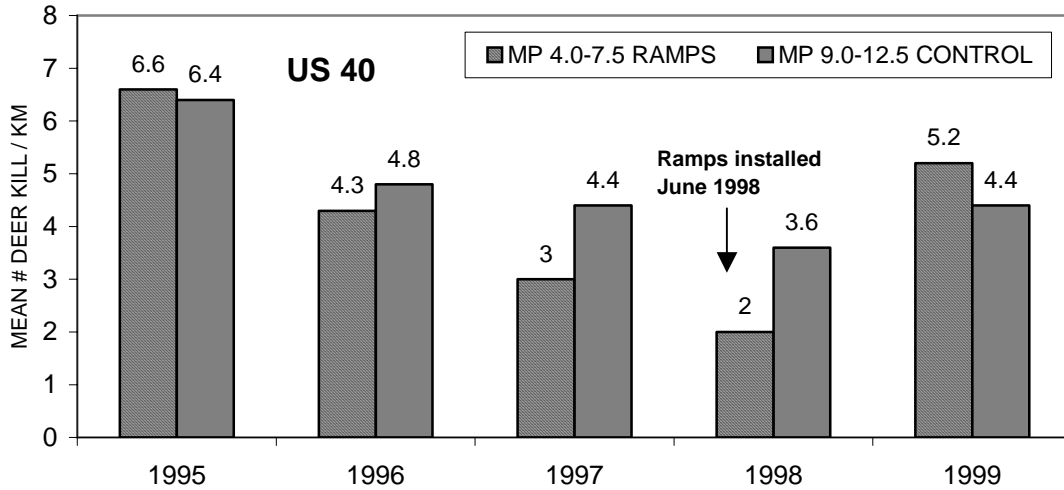
us to compare mortalities along road segments of identical length in the experimental and control sections. Mean overall mortality from 1995-1999 was 257 deer (mean per year = 50.2, s.d. = 15.6) for a mean of 5.9 deer killed per km of road.

Examination of mortality data on U S 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 section of US 40 observed in 1999 was influenced by several variables. In February of 1999, eleven deer were killed along US 40, which is unusually high for this month. Prior to this time, documented mortality for the month of February never exceeded two deer. In addition, in June 1999 a large section of the deer 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 to 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.

TASK 6 - MONITORING OF TRAFFIC VOLUME

ACCOMPLISHMENTS

The DEPARTMENT provided average daily traffic volume for US 40 and US 91 for 1996, 1997, and 1998. Mean daily traffic volume is similar between US 40 and US 91 (Table 2) and both study roads show similar patterns of increasing traffic volume. We expected that in areas of similar deer densities, roads with higher traffic volume would have more deer-vehicle collisions than roads with lesser volume. Additionally, we expected that four lane divided highways would have more deer mortalities than two

lane highways, given similar traffic volumes. However, even though we recorded more deer kills on US 40 (mean = 50.2/yr) vs. Sardine (mean = 36.7/yr), US 40 had a lower kill/km of road (mean = 5.9/km) than Sardine (mean = 9.2/km). The nature of deer movements near US91 certainly influenced the total deer kill. As discussed earlier in this report, deer associated with the US91 study site make migratory movements and few remain in the vicinity of the road during summer. Road mortality is multi-causal, and is the result of numerous factors including, but not limited to traffic volume, timing of traffic pulses, speed limit, weather conditions, seasonal traffic patterns, deer population trends, topography, and the design of the road (two-lane, four-lane).

Table 2. Average daily traffic volume on US 91 and US 40 from 1996-1998.

YEAR	Average number of vehicles/day			
	US 91	% increase	US 40	% increase
1996	13,180		11,310	
1997	14,058	6.6	11,802	4.4
1998	14,775	5.1	12,561	6.4

TASK 7 – COST– BENEFIT ANALYSIS FOR THE INSTALLATION OF EARTHEN ESCAPE RAMPS ON US 91 AND US 40

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. Ideally, amortization should be on the order of a few years. Reduction of deer mortality on US 91 and US 40 involved construction of fencing with the primary aim of excluding deer from accessing the ROW. The installation of the at-grade crossings (Romin 1994, Lehnert 1996) at the Jordanelle Reservoir site (US 40 and SH 248) allowed deer to access the ROW. However, at the study site on US 91, no at-grade crossings were installed and yet deer were able to access the ROW and the road surface, demonstrating that few, if any, 'deer proof' fences are able to totally eliminate deer from roads and the ROW. The problem then becomes one not only of fence maintenance, but of providing escape routes for deer and other ungulates that access the roadway. The data in this study demonstrate that earthen escape ramps are an important component of mitigation that employs big-game fencing because they provide deer that access the highway ROW an effective means of escape. 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. Even though their biological effectiveness is clear, we wanted to determine if costs associated with the installation of escape ramps were justified by the expected drop in deer mortality.

We were unable to determine what percentage of deer that become trapped on a fenced highway ROW are involved in a vehicle collision. Indeed, that data cannot be collected by any reasonable means available, short of camera surveillance along the entire road segment. However, there are indirect ways of assessing ramp cost effectiveness. We first assumed 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 data presented under Task 5 and in Figs. 10 and 12, where we documented the reduction in deer mortality after escape ramps were installed on both US 40 and US 91.

We used a base valuation of $2,274 for deer in 1996 (based on hunting expenditures and harvest rates) and a base value for the average cost of an vehicle damage insurance claim in Utah in 1992 ($1,200) (Farmers Insurance Bureau, unpubl. data) to determine the average monetary losses associated with a deer-vehicle collision. We adjusted the vehicle damage claim to 1999 values using the Consumer Price Index (CPI) adjustment, placing monetary losses due to insurance claims at $1,425 per deer-vehicle collision. We made no adjustment for the increased costs that may be associated with repairing higher technology newer cars. We also adjusted the deer valuation estimate to 1999 values using the CPI, with a resulting value of $2,420. Thus, the monetary costs associated with each deer/vehicle collision averages $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. 13), although the number of hunters has not declined proportionally. Because the valuation of what a deer is worth 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 our valuation estimates are based on a multi-year mean, we suggest that they are reasonable and representative of the current situation.

We then determined the cost-effectiveness of installing the earthen escape ramps on US 91 and US 40 in the following manner. First, we knew that 188 deer had used the earthen ramps successfully on US 91 and 192 deer had crossed successfully on US 40. We assumed that some deer had made more than one crossing but because we were unable to estimate the frequency distribution of crossings by a single deer, we assumed that each crossing represented an individual deer. We then assumed 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. We generated 6 arbitrary levels of potential mortality (from 2% to 15%) based on those assumptions. These percentages were purposefully low, in order to be conservative. We took this approach in order to evaluate the economic loss if 2%, 5%, 7%, 10%, 12%, or 15% of the deer that actually crossed to

Fig. 13. Annual deer harvest in Utah from 1980-1996
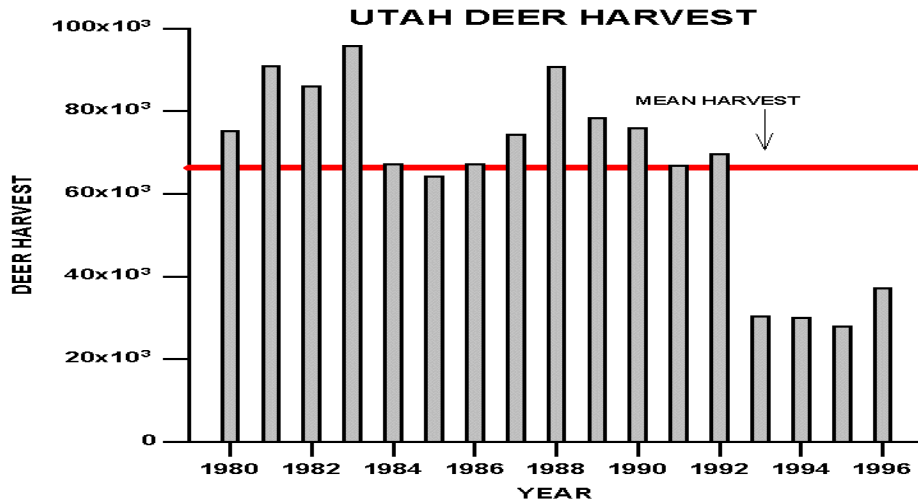
safety by using the ramp had instead been hit on the roads. We then took the product of each percentage times the number of successful crosses (e.g., on US 91, 188 successful crosses x 2% equals 4 deer; similarly, on US 40, 192 successful crosses x 15% equal 29 deer). The number of deer was then multiplied by the average economic loss of a deer-vehicle collision (i.e., $3,845) to obtain an estimate of the mitigated benefits of installing the ramps through 1999 (Table 3).

Table 3. Estimated return on investment for the installation of earthen escape ramps on US 91 and US 40

	Potential Mortality[b]					
	2%	5%	7%	10%	12%	15%
# DEER[a] US 91	4	9	13	19	23	28
ESTIMATED 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] Arbitrary percent of the number of deer that might have been killed on the road had they not escaped over the earthen ramp and associated monetary value

Compensatory Mortality

There is an unstated and often unrecognized assumption that underpins valuation of road killed animals that is seldom if ever considered. The assumption is that road mortality is completely additive to other causes of mortality. In other words, deer killed on the road would not have died by other causes and would have survived for some specified length of time, usually equivalent to the mean life span of like individuals in the population. This does not necessarily mean that an individual animal would have the longest life span of its cohort, rather it would have survived some arbitrary longer length of time, typically past the period of juvenile recruitment, often considered to be the following breeding season. Lehnert et al. (1998) demonstrated that for the Jordanelle deer population, road mortality most closely fit a partial compensation model. In this model, 50% of all animals killed on the highway would have died anyway from non-highway causes before the next breeding season. This does not mean that road mortality is any less than presented. Indeed, the animals we recorded as mortalities were killed on the road. Rather, our point is that if additive mortality characterizes a population subject to road mortality, estimates of the <u>cost effectiveness</u> of any mitigative structure is more conservative if compensatory mortality is taken into consideration.

Road Costs and Mitigative Benefits

The cost of installing each earthen escape ramp was approximately $2,000. Total costs for installing all ramps on US 91 was approximately $18,000 and on US 40 was approximately $16,000, for a total cost of approximately $34,000. Current year 2000 costs may be higher.

If we assume that only 5% of deer that used the escape ramps would have been involved in a collision if the structures had not been in place, the cost of ramp installation at both sites would have been offset by the benefits within 1-2 years. Monetary losses associated with mortality of only 2% of these deer would have approached $15,000 whereas the cost of the installation of the ramps ranged from $16,000-18,000. 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 appears to have offset the costs. We argue that a 2% reduction of mortality rate for these deer is a <u>very</u> conservative estimate, based on the documented reductions in mortality we report in Task 5 (pages 16-19, Fig. 10 and Fig. 12).

We conclude that the cost of installation as well as the low level of maintenance required of earthen escape ramps is very rapidly offset by the benefits gained in deer survival and reduced automobile collisions. Our data (Figure 9 and Figure 11) suggest that a greater number of deer than we reported would have been killed on the road had the ramps not been in place. We conclude that installing earthen escape ramps on big-game fenced highways is a very cost-effective way to further reduce deer mortalities along roadways.

MANAGEMENT RECOMMENDATIONS

Significant numbers of deer-vehicle collisions occur along highways in Utah, even when big game fencing and steel return gates are installed. One of the primary reasons that deer are able to access the ROW is that fences are seldom, if ever 'deer proof'. Deer are adept at using small gaps in fences caused by erosion and earth slumping, or associated with topographical contours where the fence is not in close contact with the ground surface. In addition, we have documented that fences often are breeched illegally, presumably to gain access to adjacent land. Unless fences are diligently maintained, deer will continue to access the ROW in significant numbers. We expect that even if fences are maintained, some deer will still access the ROW, however, implementing a diligent regime of fence inspection and repair is critical to reducing deer-vehicle collisions along these roadways.

> 1) We recommend that a fence maintenance and repair task be institutionalized as an annual work effort in every area in the state where significant deer mortality occurs and where fences have been installed.

It is a given that deer will access the ROW on any fenced road in Utah. As a result, mechanisms that allow trapped deer to escape the highway ROW on big-game fenced roads are a necessity to reduce deer-vehicle collisions. One-way steel escape gates have been the chosen structure on most big-game fenced highways. However, previous studies (Lehnert 1996) as well as this study have demonstrated that deer are reluctant to use one-way gates, with effectiveness varying from 17 to about 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. We admit the same lack of data for ramp use. However, we found earthen escape ramps were 6 to 12 times more effective than gates in allowing deer to escape the ROW. Further, they mimic natural topography, suggesting that their use does not entail fright behavior by deer.

Escape ramps have the added benefit of being more aesthetic and less conspicuous

when vegetated and should require much less maintenance than one-way gates (Photo 10).

2) We recommend the placement of earthen escape ramps in areas of high deer road kill across the state 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) We recommend that in fenced road segments where high deer kill has been a persistent problem that each road segment be assessed by qualified personnel for placement of earthen escape ramps. If this is not feasible or possible, we recommend that in road segments with high road kill that ramps be installed no less than 0.25 miles apart, and on both sides of the road

4) In fenced road segments where little road kill information is available, or where the kill is less, 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 mile of fencing.

It may not be possible or feasible to examine every road segment where potential high mortality may occur. 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 generalities can be made.

5) In areas of known or suspected but undocumented high kill, we recommend that in areas to be fenced that escape ramps should be placed no less than 0.25 miles apart, on both sides of the road. It is particularly important that ramps be placed no less than 0.25 miles apart near the first and last mile of the fence. We have observed that many deer gain access to the ROW by walking around the end of fences and thus become trapped as they walk farther up the ROW. Allowing several escape options for deer near the termination of the fence should help to reduce deer-vehicle collisions substantially.

6) In road segments to be fenced where deer kill is low, we recommend that escape ramps be installed at 0.5 mile intervals on both sides of the road, with closer placement within 1 mile of the end of the fence.

Other Considerations:

Our primary recommendation for the placement of escape ramps for fenced road

segments is based on an on-site evaluation of the kill history. Where this is not possible, we have recommended general guidelines for placement and spacing of earthen ramps. Additional considerations will help in reducing deer mortality.

7) We recommend 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.

8) We recommend that ramps be placed closer together (i.e., at 0.25 mi. intervals) in areas with desirable ROW forage.

9) We also recommend establishing natural vegetation on the earthen escape ramps to reduce erosion as well as to make them more natural in appearance (Photo 10). 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.

The recommendations we have made should serve to help reduce deer-vehicle accidents on roads by providing natural escape routes for deer who have accessed the ROW.

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