FINAL REPORT

FHWA-WY-03/01F

State of Wyoming
Department of Transportation

U.S. Department of Transportation
Federal Highway Administration

EVALUATION OF AN UNDERPASS INSTALLED IN U.S. HIGHWAY 30 AT NUGGET CANYON, WYOMING, FOR MIGRATING MULE DEER

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June, 2003

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Technical Report Documentation Page

Report No. FHWA-WY-03/01F	Government Accession No.	Recipients Catalog No.
Title and Subtitle Evaluation of an Underpass Installed in U.S. Highway 30 at Nugget Canyon, Wyoming, for Migrating Mule Deer		Report Date June 2003 Performing Organization Code
Author(s) Kelly Gordon, Stan Anderson		Performing Organization Report No.
Performing Organization Name and Address Wyoming Cooperative Fish and Wildlife Research Unit P.O. Box 3166 University of Wyoming Laramie, Wyoming 82071-3166		Work Unit No. RS04(200) Job No. A12C Contact or Grant No.
Sponsoring Agency Name and Address Wyoming Department of Transportation 5300 Bishop Blvd. Cheyenne, WY 82009-3340 Planning - Research Center (307) 777-4182		Type of Report and Period Covered Final Report Sponsoring Agency Code
Supplementary Notes WYDOT Technical Contact: John Eddins, P.E.		

Abstract

A fifteen-mile stretch of U.S. Highway 30 through Nugget Canyon between Kemmerer and Cokeville, Wyoming bisects the migration route of a subunit of the Wyoming Range mule deer herd. Consequently this highway is crossed by approximately 14,000 mule deer each fall and spring as they migrate between their winter range in Red Eye Basin and their summer range in the Wyoming Mountains. An average of 130 mule deer per year have been killed in deer-vehicle collisions since 1990. An underpass was installed in association with 8-foot-high deer-proof fence at milepost 30.5 in the summer of 2001 in an attempt to mitigate this problem.

Starting in the fall of 2001 the Wyoming Cooperative Fish and Wildlife Research Unit (WCFWRU) conducted a study to evaluate mule deer activity at the underpass and to determine the optimal size and potential locations of future underpasses to be built in Nugget Canyon. We monitored the underpass using a videocamera system activated by infrared sensors to examine deer activity at the underpass. Starting in the spring of 2002, we initiated a series of trials in which we manipulated the size of the underpass using plywood dividers and gauged mule deer response to the underpass at different sizes. We collected data on the number of deer entering the underpass, the number of deer repelling from the underpass, the time needed for deer to enter the underpass, and behavioral indicators of hesitancy as deer approached the underpass.

Based on video footage of the 2000-2003 migrations and herd estimates provided by the Wyoming Game and Fish Department (WGFD), we found that between 8.4% and 11.0% of the mule deer crossing the highway in Nugget Canyon used the underpass at milepost 30.5. In the years the underpass was monitored the peak of fall migration occurred in December and the peak of spring migration occurred in March and April. We found that deer approaching the underpass were more likely to repel in response to smaller underpass sizes than larger. Deer were more sensitive to changes in the width of the underpass than the height. Height reductions down to 8 feet did not appear to substantially impact deer willingness to use the underpass, but reductions to 6 feet resulted in a large increase in percentage of deer repelling from the underpass. Deer crossing traffic on U.S. Highway 30 was heaviest at mileposts 35 and 36, at the east end of the deer proof fence.

We recommend that future underpasses built in Nugget Canyon be at least 20 feet wide and 8 feet tall, and have an openness ratio of at least 0.8. At least one additional underpass should be built in Nugget Canyon near mileposts 35 and 36, and the deer-proof fence extended at least 3 miles east of its current extent to prevent deer from moving around the end of the fence.

Key Words Wyoming, deer, mule deer, underpass, animal vehicle mitigation, migration, Nugget Canyon, infrared sensor, video camera, highway, and range.		Distribution Statement Unlimited	
Security Classif. (of this report) Unclassified	Security Classif. (of this page) Unclassified	No. of Pages 32	Price

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SI* (Modern Metric) Conversion Factors

Approximate Conversions from SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
Area				
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
Volume				
ml	milliliters	0.034	fluid ounces	fl oz
l	liters	0.264	gallons	gal
m^3	cubic meters	35.71	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
Mass				
g	grams	0.035	ounces	oz
kg	kilograms	2.202	pounds	lb
Mg	megagrams	1.103	short tons (2000 lbs)	T
Temperature (exact)				
°C	Centigrade temperature	1.8 C + 32	Fahrenheit temperature	°F
Illumination				
lx	lux	0.0929	foot-candles	fc
cd/m^2	candela/m^2	0.2919	foot-Lamberts	fl
Force and Pressure or Stress				
N	newtons	0.225	poundforce	lbf
kPa	kilopascals	0.145	pound-force per square inch	psi

Approximate Conversions to SI Units

Symbol	When You Know	Multiply By	To Find	Symbol
Length				
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
Area				
in^2	square inches	645.2	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yards	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	square kilometers	km^2
Volume				
fl oz	fluid ounces	29.57	milliliters	ml
gal	gallons	3.785	liters	l
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
Mass				
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lbs)	0.907	megagrams	Mg
Temperature (exact)				
°F	Fahrenheit temperature	5(F-32)/9 or (F-32)/1.8	Celsius temperature	°C
Illumination				
fc	foot-candles	10.76	lux	lx
fl	foot-Lamberts	3.426	candela/m^2	cd/m^2
Force and Pressure or Stress				
lbf	pound-force	4.45	newtons	N
psi	pound-force per square inch	6.89	kilopascals	kPa

ACKNOWLEDGEMENTS

The Wyoming Department of Transportation (WYDOT) provided funding for this project. John Eddins, District Engineer for WYDOT, sponsored the project and provided important input and support over the course of the study. William Gribble, Matt Johnson, and Kevin McCoy of the WYDOT counter shop were invaluable in developing and installing infrared detection systems and video cameras. William Rudd of the Wyoming Game and Fish Department (WGFD) provided important input into study design as well as deer mortality data for Nugget Canyon. John Miller of the Research Support Shop at University of Wyoming assisted in the design of the underpass dividers. Regan Plumb, Paul Sutherland, and Ken Keffer of the Wyoming Cooperative Fish and Wildlife Research Unit (WCFWRU) provided valuable assistance with data collection.

TABLE OF CONTENTS

CHAPTER **PAGE**

Executive Summary 1

CHAPTER 1: Problem Description 2

CHAPTER 2: Objectives 3

CHAPTER 3: Task Description 4

Study Area 4
Preliminary Monitoring 4
Underpass Monitoring 5
Spring 2002 Size Manipulations 5
Fall 2002 Size Manipulations 6
Spring 2003 Size Manipulations 7
Tracking Data Collection 7
Data Analyses 8

CHAPTER 4: Findings and Conclusions 10

Seasonal and Daily Patterns of Movement 10
Underpass Use by Other Species 12
Underpass Size Manipulations 14
Tracking and Mortality Data 20

CHAPTER 5: Implementation Recommendations 23

LITERATURE CITED 25

LIST OF FIGURES

FIGURE **PAGE**

Figure 1: Average number of deer passing per day by month for three migrations....................11

Figure 2: Number of deer using the underpass by time of day....................11

Figure 3: Daily snowfall and number of deer entering underpass, fall 2001.....12

Figure 4: Average snowdepth and repel rates for fall 2001....................13

Figure 5: Openness ratio and repel rates for 8 different treatments, spring 2002....................14

Figure 6: Repel rates in response to three different height treatments, 2002-2003....................15

Figure 7: Number of deer entering underpass per day for three different activity levels and treatments....................16

Figure 8: Percent enter and repel for width treatments....................17

Figure 9: Percent enter and repel for height treatments....................18

Figure 10: Head up and nose down behaviors in response to width modifications....................19

Figure 11: Head up and nose down behaviors in response to height modifications....................19

Figure 12: Average time between staging and entering in response to seven different treatments....................20

Figure 13: Average number of tracks per day by milepost, 2001-2002..........21

Figure 14: Average number of deer killed each year by milepost before and after underpass....................21

Figure 15: Deer mortality by migration season in Nugget Canyon...............22

LIST OF TABLES

TABLE **PAGE**

Table 1: Treatments conducted during the spring of 2002..............................6

Table 2: Treatments conducted during the fall of 2002.................................7

Table 3: Treatments conducted during the spring of 2003..............................7

Table 4: Number of approaches resulting in enter or repel for six migrations.....10

Table 5: Pronghorn use of Nugget Canyon underpass..................................13

Executive Summary

A fifteen-mile stretch of U.S. Highway 30 through Nugget Canyon between Kemmerer and Cokeville, Wyoming bisects the migration route of a subunit of the Wyoming Range mule deer herd. Consequently this highway is crossed by approximately 14,000 mule deer each fall and spring as they migrate between their winter range in Red Eye Basin and their summer range in the Wyoming Mountains. An average of 130 mule deer per year have been killed in deer-vehicle collisions since 1990. An underpass was installed in association with 8-foot-high deer-proof fence at milepost 30.5 in the summer of 2001 in an attempt to mitigate this problem.

Starting in the fall of 2001 the Wyoming Department of Transportation (WYDOT) funded the Wyoming Cooperative Fish and Wildlife Research Unit (WCFWRU) to conduct a study to evaluate mule deer activity at the underpass and to determine the optimal size and potential locations of future underpasses to be built in Nugget Canyon. We monitored the underpass using a videocamera system activated by infrared sensors to examine deer activity at the underpass. Starting in the spring of 2002, we initiated a series of trials in which we manipulated the size of the underpass using plywood dividers and gauged mule deer response to the underpass at different sizes. We collected data on the number of deer entering the underpass, the number of deer repelling from the underpass, the time needed for deer to enter the underpass, and behavioral indicators of hesitancy as deer approached the underpass. We also collected tracking data and analyzed mortality data provided by the Wyoming Game and Fish Department (WGFD) to assess deer activity in other locations between mileposts 27 – 42 in Nugget Canyon.

Based on video footage of the 2000-2003 migrations and herd estimates provided by WGFD, we found that between 8.4% and 11.0% of the mule deer crossing the highway in Nugget Canyon used the underpass at milepost 30.5. In the years the underpass was monitored the peak of fall migration occurred in December and the peak of spring migration occurred in March and April. We found that deer approaching the underpass were more likely to repel in response to smaller underpass sizes than larger. Deer were more sensitive to changes in the width of the underpass than the height. Height reductions down to 8 feet did not appear to substantially impact deer willingness to use the underpass, but reductions to 6 feet resulted in a large increase in percentage of deer repelling from the underpass. Deer crossing traffic on U.S. Highway 30 was heaviest at mileposts 35 and 36, at the east end of the deer proof fence.

We recommend that future underpasses built in Nugget Canyon be at least 20 feet wide and 8 feet tall, and have an openness ratio of at least 0.8. At least one additional underpass should be built in Nugget Canyon near mileposts 35 and 36, and the deer-proof fence extended at least 3 miles east of its current extent to prevent deer from moving around the end of the fence.

CHAPTER 1

Problem Description

U.S. Highway 30, as it passes through Nugget Canyon between Kemmerer and Cokeville, Wyoming, is the site of hundreds of deer/vehicle collisions each year as mule deer of the Wyoming Range herd cross the highway while migrating between their winter and summer ranges. In 1986, the Wyoming state legislature passed the Nugget Canyon Wildlife Migration Project Act calling for state agencies to work together in attempting to mitigate the problem of deer/vehicle collisions in this area. Several mitigation measures have been attempted in Nugget Canyon. In 1989 a seven-mile long eight-foot high deer proof fence was erected with a gap for mule deer crossings at milepost 30.5. Signs warning motorists of migratory deer crossings were installed in association with the fence, but deer mortality remained high. Swareflex reflectors were tested but were found to be ineffective in reducing deer/vehicle collisions (Reeve and Anderson 1993).

Deer mortality in Nugget Canyon is of particular concern because the Wyoming Range mule deer herd has been declining in numbers over the past few years. This mule deer herd was estimated in 2001 to consist of around 43,000 deer. The objective for the herd is 50,000 animals. Approximately 14,000 mule deer of the Red Eye Basin subunit migrate between their summer range in the Wyoming Range and their winter range in Red Eye Basin, crossing US Highway 30 in Nugget Canyon in the process (Bill Rudd, WGFD, pers. comm.). The majority of deer killed in Nugget Canyon are adult and yearling females, which could impact on herd objectives (Reeve 1986).

The risk to motorists is also an important concern. U.S. Highway 30 is a high-volume road used by many truck drivers and tourists as a cut-off from Interstate 80 to areas to the northwest of the state. Many of the motorists on the road are from outside the area and are unlikely to be familiar with the high risk of a deer/vehicle collision during peak mule deer migration times. Traditional "Deer Crossing" warning signs were found to be ineffective at causing these non-resident motorists to slow down. A system which detected deer as they moved across the road and warned motorists when deer were present was also found to be largely ineffective in causing motorists to slow down (Gordon and Anderson 2001).

During the summer of 2001, an underpass was constructed at the deer crossing at milepost 30.5 to facilitate the movement of deer safely across the highway. A WYDOT funded study evaluating this underpass commenced in the fall of 2001. We were interested in investigating patterns of deer movement through the underpass, deer response to size manipulations of the underpass, and potential future sites of underpasses in Nugget Canyon.

CHAPTER 2

Objectives

The primary objectives of this study are as follows:

1) Assess seasonal and daily patterns of movement by mule deer using the underpass.
2) Record use of the underpass by ungulate species other than mule deer.
3) Vary underpass height and width to assess deer use of the underpass at different sizes and to determine optimum size of future underpasses.
4) Assess the effects of varying underpass height and width on mule deer behavior while using the underpass.
5) Collect tracking and mortality data throughout Nugget Canyon to determine suitable locations for future underpasses.

We used video footage collected at the underpass to accomplish objectives 1-4. We completed objective 5 using tracking information collected during the fall of 2001 and the spring of 2002, and using mortality data compiled by the Wyoming Game and Fish Department. Completion of objectives 1 and 2 provided us with important background information about whether mule deer and other species in Nugget Canyon would respond well to installation of underpasses. Data gathered in execution of objectives 3 and 4 provided us with information useful in making recommendations about optimal underpass size. Completion of objective 5 allowed us to make recommendations about locations of future underpasses in Nugget Canyon.

CHAPTER 3

Task Description

Study Area

The Nugget Canyon study area is in the southwest portion of Lincoln County, Wyoming, within a major mule deer winter range complex, the Cokeville-Rock Creek (C-RC) winter range. This is one of several winter ranges used by mule deer in the Wyoming Range mule deer herd unit, consisting of approximately 43,000 animals. The Red Eye Basin subunit of this herd, numbering around 14,000 animals, crosses U.S. Highway 30 twice each year in crossing between Red Eye Basin and their summer range.

Deer-vehicle collisions primarily occur along a 15 mile segment of U.S. Hwy. 30 from milepost 27 to milepost 42. This highway segment includes the area described in the Nugget Canyon Migration Project Act (milepost 27 to milepost 39.7). The Union Pacific Pocatello, Idaho rail line parallels U.S. Hwy. 30 through the project area. Twin Creek, a tributary of the Bear River, flows through Nugget Canyon and is fed by other streams in north-south oriented drainages. Major ridges, including Boulder Ridge, Rock Creek Ridge, Dempsey Ridge, and Sellem Ridge, orient mule deer migration patterns so that they cross U.S. Hwy. 30 during spring and fall migrations.

Preliminary monitoring

In order to gather data about patterns of deer movement before the underpass was installed, we monitored the at-grade crossing in place previous to the construction of the underpass. The crossing was located at milepost 30.5 and was used by deer funneled to that location by an 8-foot-high deer proof fence that extends from milepost 28 to milepost 35. We monitored the crossing from December 2000 – May 2001 using a videocamera system designed and manufactured by ATD Northwest, Inc. The system consisted of 2 infrared cameras (ATD PATH-EMC-2000 Infrared camera with wide angle lens) and 2 lowlight cameras (ATD PATH-CCZ-32 Lowlight color camera) mounted to view the north and south side of the at-grade crossing, which spanned a width of approximately 100m. The lowlight lenses were used on the north side of the crossing, where the area was illuminated at night, and the infrared lenses were used to monitor the south side of the crossing, which lacked illumination. The lenses were associated with a VCR and splitter system (PATH-CV99MKII Color Portable Archival Traffic History) that merged the images recorded by the lenses into one split-screen display. When deer used the crossing, the cameras were activated by infrared sensors (Telonics IF-540 long range passive infrared detector) that detected the deer moving through the gap in the fence. The infrared sensors had been used in a previous study (Gordon and Anderson 2001) and were found to reliably detect deer without being prone to false hits. We collected information about the number of deer using the crossing, the seasonality of deer movement, and the number of deer that turned away from the crossing in comparison to deer that crossed the road. Because of the size of the area monitored and the lack of resolution of the images when the screen was subdivided into four parts, we were unable to discern behaviors or classify mule deer using the crossing.

Underpass monitoring

During the summer of 2001, an underpass was built under U.S. Hwy. 30 to facilitate the safe passage of mule deer beneath the road. The underpass was built at milepost 30.5 at the former location of the at-grade crossing. The deer-proof fence that extends from milepost 28 to milepost 35 was modified to funnel deer into the underpass and prevent access to the road. The underpass has solid concrete walls and ceiling and a dirt floor. It measures 20 feet wide x 60 feet long and, because of the dirt floor, varies in height between 10'6" and 11'. The area adjacent to the entrance and exit of the underpass was fairly steeply graded, and as a consequence the ground inside the underpass was poorly drained and frequently muddy in the spring. Additionally, the view through the underpass appeared more constricted than it might have with more gradual grading.

In order to collect data on movement patterns of mule deer and other animals using the underpass, we installed a videocamera system to monitor animal movement. We used the same system described above for the at-grade crossing, except that we replaced the two lowlight lenses with two additional infrared lenses due to the lack of illumination at the underpass. We mounted lenses to monitor the entrance, exit, and approach areas of the underpass. The camera system was activated by four sets of the infrared scopes described above, two each located on the north and south sides of the underpass. One of these was positioned at the outermost extremity of the wings of the deer-proof fencing and the other was positioned approximately halfway along the wings of the deer proof fencing. We found that, even with infrared lenses, natural nighttime lighting at the underpass was insufficient to see all parts of the areas adjacent to the underpass entrance and exit. LED lights, visible to the infrared lenses but not to deer, were installed to improve the quality of nighttime images.

The videocamera system installed at the underpass gathered high quality footage, with a few exceptions. The lenses were prone to frosting over due to condensation. We alleviated this problem by wiping the lenses with windshield de-fogger each time we visited the underpass. Glare on the cameras from the rising or setting sun sometimes reduced visibility in the images. We constructed impromptu sunshades from plywood that partially alleviated this problem, but it was never completely remedied and as a consequence we lost a small amount of data. The VCR used to record the images malfunctioned on March 13, 2003, possibly due to moisture in the unit, and was returned to operation on April 16, 2003.

A Trailmaster TM1500 active infrared sensor was mounted inside the tunnel during the fall 2001 and spring 2002 field seasons to record times and dates of animals moving through the tunnel and to inform researchers when enough mule deer had moved through to switch to the next size manipulation treatment. Use of the Trailmaster unit was discontinued for the fall 2002 field season, since it was found that the unit was prone to frequent miscounts and false hits.

Spring 2002 Size Manipulations

To assess mule deer response to varying underpass openness, beginning in late January 2002 we modified the height and width of the underpass using a series of plywood dividers. We altered width using adjustable metal uprights that could be erected in the tunnel and secured via tension against the floor and ceiling of the underpass. These uprights were equipped with brackets from which 4' wide x 8' tall plywood panels could be suspended. Two by four supports were attached to the plywood panels horizontally at a height of 6 feet and 8 feet from the ground. In order to adjust the ceiling height, two by four "stringers" rested on the supports across the underpass at intervals of eight feet. Panels of plywood measuring 4' x 8' were laid upon the stringers in the fashion of a drop ceiling. Design of the system, construction of the metal uprights, and welding of the brackets was undertaken by Research Support at University of Wyoming and cost approximately $3,000, not including lumber.

We altered the size of the underpass according to the treatments described in Table 1. Heights and widths were chosen to represent a range of openness ratios. The openness ratio is computed using the following formula, with all measurements in meters:

$$\text{Openness} = [\text{Height (m)} * \text{Width (m)}]/\text{Length (m)}$$

When approximately 100 animals had passed through the underpass, the next treatment was initiated. Table 1 shows the underpass configurations used during the spring of 2002 and the openness ratio of each treatment. We originally planned to conduct two seven foot wide treatments, but discarded these near the end of the season as more than 70% of approaches to the underpass were resulting in deer turning away in response to the eleven foot wide treatments. We extracted data from the video footage by recording the time each animal entered the view of the video tape, the time entering the area between the wings of the underpass (referred to as the staging area), the time entering the underpass itself, and the time the animal exited the underpass. Additionally, we recorded the gait of the animal at each of the stages described above, and tallied the number of head-up and nose-down responses in the staging area as behavioral indicators of hesitancy.

Table 1: Treatments conducted during the spring of 2002.

Width	Height	Openness ratio
20 feet (unaltered; 6.098 m)	11 feet (unaltered; 3.354 m)	1.12
20 feet (dividers)	11 feet (unaltered)	1.12
20 feet	8 feet (2.439 m)	.81
20 feet	6 feet (1.829 m)	.61
15 feet (4.573 m)	11 feet	.84
15 feet	6 feet	.46
11 feet	11 feet	.61
11 feet	8 feet	.45

Fall 2002 Size Manipulations

During the fall 2002 field season, we discarded the width alterations. We based this decision on the fact that data collected during the spring 2002 indicated that alterations in width to 15 or 11 feet resulted in a repel rate of greater than 50 percent. We repeated the three different height treatments according to the schedule shown in Table 2 in an attempt to capture possible seasonal variation in repel rates in response to each treatment. Gaps between treatments are due to lapses in videotape footage, periods during which there was no deer movement, or intervals during which the underpass was being altered. The size treatment was altered approximately every two weeks during times when deer movement was minimal, and approximately once a week during the peak of migration.

Table 2: Treatments conducted during the fall of 2002.

Treatment	Date
20 x 11	10/9/02 – 10/18/02
20 x 8	10/23/02 – 10/30/02
20 x 6	11/6/02 – 11/16/02
20 x 11	11/18/02 – 11/20/02
20 x 8	11/25/02 – 12/2/02
20 x 6	12/3/02 – 12/15/02
20 x 11	12/16/02 – 12/22/02
20 x 8	12/22/02 – 12/26/02

Spring 2003 Size Manipulations

During the spring of 2003 we continued the height manipulation treatments as during the fall of 2002, until a meeting between John Eddins (WYDOT), Bill Rudd (WGFD) and Kelly Gordon (WCFWRU) in early March. At this meeting it was decided that the 6' height manipulation would be discontinued, as it consistently resulted in high repel rates. Table 3 shows the treatment schedule for spring 2003. Unfortunately, a malfunction in the VCR used to record video footage resulted in lost footage between March 13, 2003 and April 16, 2003.

Table 3: Treatments conducted during the spring of 2003.

Treatment	Date
20 x 11	12/30/02 – 1/7/03
20 x 6	1/8/03 – 1/21/03
20 x 8	1/22/03 – 2/3/03
20 x 11	2/8/03 – 2/23/03
20 x 6	2/26/03 – 3/10/03
20 x 11	3/11/03 – 3/13/03
20 x 11	4/16/03 – 4/30/03
20 x 8	4/30/03 – 5/20/03

Tracking Data Collection

During the fall of 2001 and spring of 2002, we assessed mule deer crossing traffic on U.S. 30 in Nugget Canyon by tallying the total number of deer tracks in each ½ mile segment along the shoulder of U.S. Hwy 30 between mileposts 25 and 44, excluding the fenced section from mileposts 28 to 35. Track surveys were conducted by driving slowly along the shoulder of the highway and scanning for tracks. Counts were completed each morning that a researcher was present at the site and snow conditions were suitable for tracking. Tracks were obscured after counting to ensure that they were not counted twice.

Due to lack of consistent snow cover, no tracking data was collected during the 2002-2003 field season.

Data Analyses

Using footage collected by the video system, we examined seasonal and daily patterns of mule deer movement by tallying the number of approaches by deer that resulted in the deer passing across the road crossing or through the underpass (enters) and the number of approaches by deer that resulted in deer turning away from the road crossing or underpass and refusing to cross (repels). We tallied approaches rather than actual number of deer because it was impossible to distinguish whether an individual deer repelling from the crossing later returned and successfully crossed. However, during migration periods deer traffic across highway 30 was almost exclusively in the direction of migration, so once a deer crossed the road or moved through the underpass it was unlikely to return until the following migration. Therefore, we can be fairly certain that the number of enters we tallied are close to representative of the number of deer crossing the highway during each migration. We summarized enter and repel data by season (fall and spring migrations), month, and time of day to determine patterns of mule deer movement at the site. We also examined the relationship between snowfall and deer movement through the underpass for the fall of 2001, during which time no underpass size manipulations were taking place. We downloaded snowfall and other weather data from the National Weather Service's weather station at Fossil Butte, WY, 15 miles from the site and examined whether snowfall and snow depth impacted deer activity at the underpass.

In addition to mule deer, the underpass was used by antelope, elk, and other species. We summarized use by other species in terms of enters and repels as described above, by date, and by association with mule deer during crossing.

We evaluated mule deer willingness to use the underpass at different openness ratios by examining enter and repel data in response to varying size manipulations of the underpass. We performed a simple linear regression on the spring 2002, fall 2002, and spring 2003 data looking at the effect of openness on percentage of repels for each treatment. We were also interested in whether changes in height or width had more impact on deer willingness to use the underpass, so we performed chi squared tests of independence on the distribution of enters and repels in response to three height manipulations and three width manipulations. Over the course of the study we realized that the proportion of repels to enters may be inflated by deer that approach the underpass several times before finally moving through the underpass. We were interested in the number of deer that eventually move through the underpass in response to a given size manipulation, as opposed to seeking an alternate route across the highway. In order to address this question, we stratified the fall 2002 and spring 2003 data for the three height manipulations into data collected during low activity times, medium activity times, and high activity times based on the total number of approaches to the underpass during two week periods ranging from October 2002 to May 2003. For each of the height manipulations we computed the average number of deer passing through the underpass per day during each of these activity periods. This enabled us to determine whether fewer deer are willing to pass through the smaller sized underpass given a certain level of activity at the underpass.

We also analyzed the effect of underpass size on deer behavior. We recorded the number of head up behaviors, in which the deer looks up at the ceiling of the underpass, and nose down behaviors, in which the deer sniffs the ground, for each deer approaching the underpass. We computed average head up and nose down behaviors for each of the height and width manipulations and computed 95% confidence intervals in order to discern significant differences. We also examined the relationship between underpass size and the number of seconds before entering spent in the area directly in front of the underpass entrance between the concrete wings, which we referred to as the staging area.

We used the tracking data gathered during the 2001-2002 field season and mortality data gathered by WYDOT and WGFD to assess mule deer crossing traffic patterns in Nugget Canyon. We examined number of deer mortalities by milepost before and after the construction of the current underpass, and summarized tracking data by milepost to determine which locations in Nugget Canyon had the most deer activity. Additionally, we summarized deer mortalities per year in Nugget Canyon to illustrate interyear variation in number of deer-vehicle collisions.

CHAPTER 4

Findings and Conclusions

Seasonal and daily patterns of movement

Table 4 shows the dates during which data was collected for each migration during the course of the study and the number of enters and repels at the at-grade crossing and the underpass.

Table 4: Number of approaches resulting in enter or repel for six migrations.

	Fall 2000	Spring 2001	Fall 2001	Spring 2002	Fall 2002	Spring 2003
Crossing	Road	Road	Underpass	Underpass	Underpass	Underpass
Dates	12/5/00 – 1/31/01	2/1/01 – 5/19/01	11/6/01 - 1/31/02	2/1/02 - 5/14/02	10/9/02 - 1/31/03	2/1/03 - 3/13/03, 4/16/03 - 5/20/03
Enter	543	1754	1453	1186	1534	608
Repel	327	663	577	2359	3802	665

Unfortunately, large gaps in the monitoring data for fall of 2000 and spring of 2003 prevent us from directly comparing the road and underpass crossing data. The spring 2002 underpass migration is considerably smaller than the spring 2001 road crossing migration, which may indicate that a portion of deer that formerly crossed at the road crossing sought an alternate route rather than use the underpass. However, there is a great deal of variation in the overall migration of the Wyoming Range mule deer herd depending on weather, herd size, and other variables, which may impact activity at the crossing site at milepost 30.5. Herd size has been declining in recent years, which may account for a reduction in the migration over time (Bill Rudd, WGFD, pers. comm.). Without long-term historic crossing data, it's impossible to determine whether the construction of the underpass reduced the number of mule deer crossing the highway at this site. We did find that repels in response to the road crossing (Spring 2001; 27.4% of deer approaching repel) were comparable to repels in response to the unaltered underpass (Fall 2001; 28.4% of deer approaching repel). Higher numbers of repels during the spring and fall of 2002 are due to the fact that we were conducting underpass size manipulations during these periods. Many of the animals approaching the underpass at this time may have either sought alternate crossing points or taken several attempts before successfully using the underpass. It is estimated that around 14,000 mule deer cross Highway 30 in Nugget Canyon during each migration to and from the Red Eye Basin winter range. If this is the case, then the mule deer crossing at the site of the underpass represent between 8.4% and 11.0% of the total migration in Nugget Canyon.

Figure 1 shows the average number of deer crossing at the site per day for the months between October and May for each of the 2000-2001, 2001-2002, and 2002-2003 migrations. Data is missing for months of October and November for the 2000-2001 seasons, and for the months of October and May for the 2001-2002 season. Peaks of migration occurred in December and in March and April of these years.

Figure 1: Average number of deer passing per day by month for three migrations.

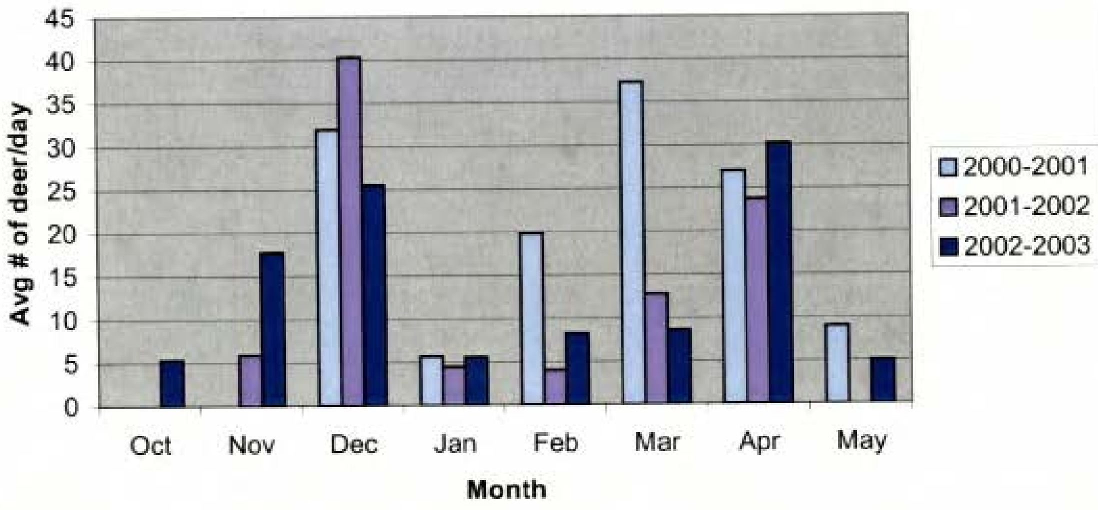
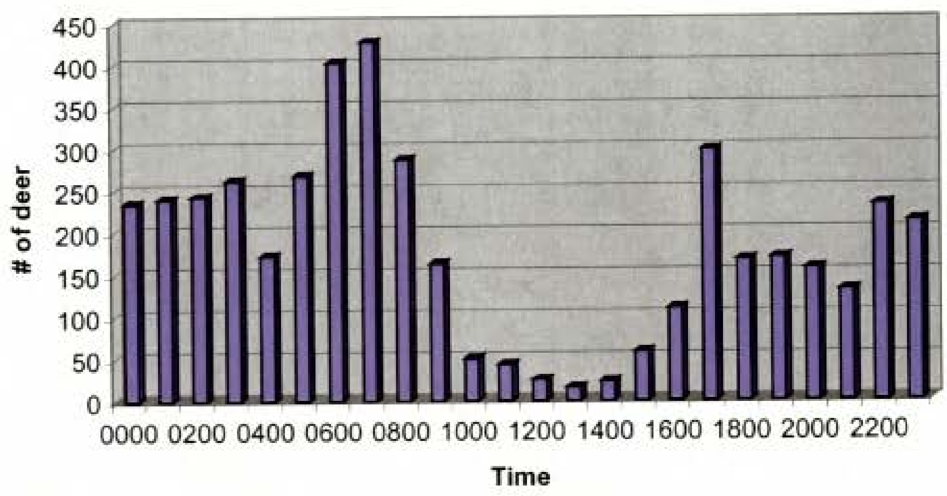


Figure 2 illustrates patterns of deer movement at the underpass during the migrations of 2001-2002 and 2002-2003 by time of day. Movement peaks at dawn and dusk, with a lull in deer activity between 1200 and 1400. Daily deer activity patterns were similar at the road crossing during 2000-2001.

Figure 2: Number of deer using the underpass by time of day.



Deer migration seemed to be prompted during the fall by severe weather events. Figure 3 depicts the number of deer moving through the underpass daily during the fall of 2001, during which time no underpass size manipulations were being conducted. Daily snowfall in centimeters is shown on the graph as well. Pulses of deer movement seem to occur within a few days of significant snowfall. The lag time may be due to movement being initiated in the Wyoming Range a few days' travel away.

Figure 3: Daily snowfall and number of deer entering underpass, fall 2001.

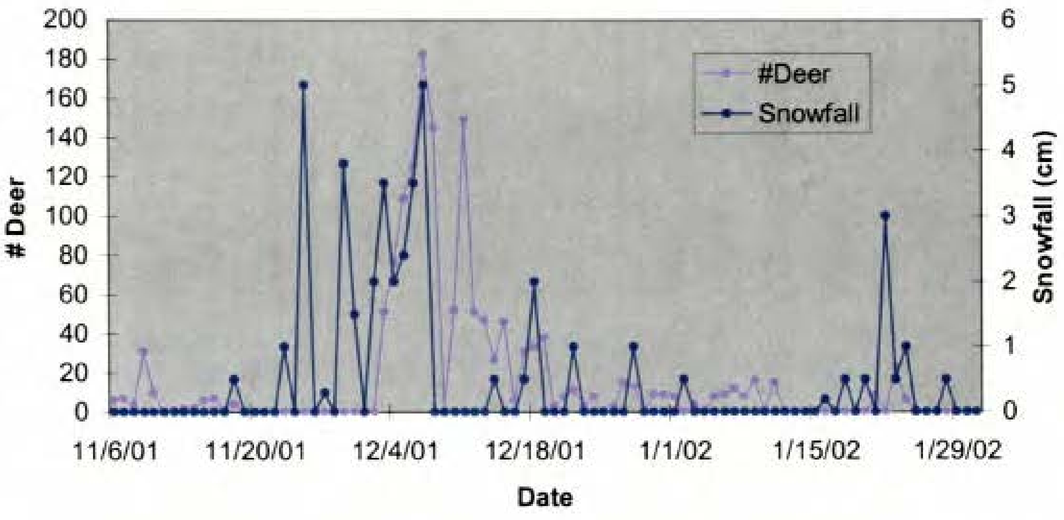


Figure 4 illustrates the effect of snow depth on the percentage of mule deer that repel at the underpass during the fall of 2001. Average daily repel rates and average daily snow depths were computed for each one week period during the fall migration. Early in the season, when snow depths were low, mule deer were more hesitant to enter the underpass and repel rates were higher. Repel rates decreased later in the season as snow accumulated and mule deer were more driven to seek forage on their winter range.

Underpass use by other species

We were interested in recording the use of the underpass by other ungulate species. Pronghorn use in particular was of interest because, to our knowledge, use of underpasses by pronghorn has not been previously documented. We found that pronghorn use the Nugget Canyon underpass incidentally. Pronghorn use occurred on 7 December and 12 December 2001, and on 4 March, 31 March, 4 April, and 16 April 2002. A total of 70 pronghorn were observed passing through the underpass (Table 5). An additional 19 pronghorn approached the structure but repelled before entering. Group size ranged from 1 to 57 animals. All but 2 usages occurred at dusk or pre-dawn. Nearly all of the successful passages occurred in the presence of mule deer and were in the prevailing direction of migration at the time.

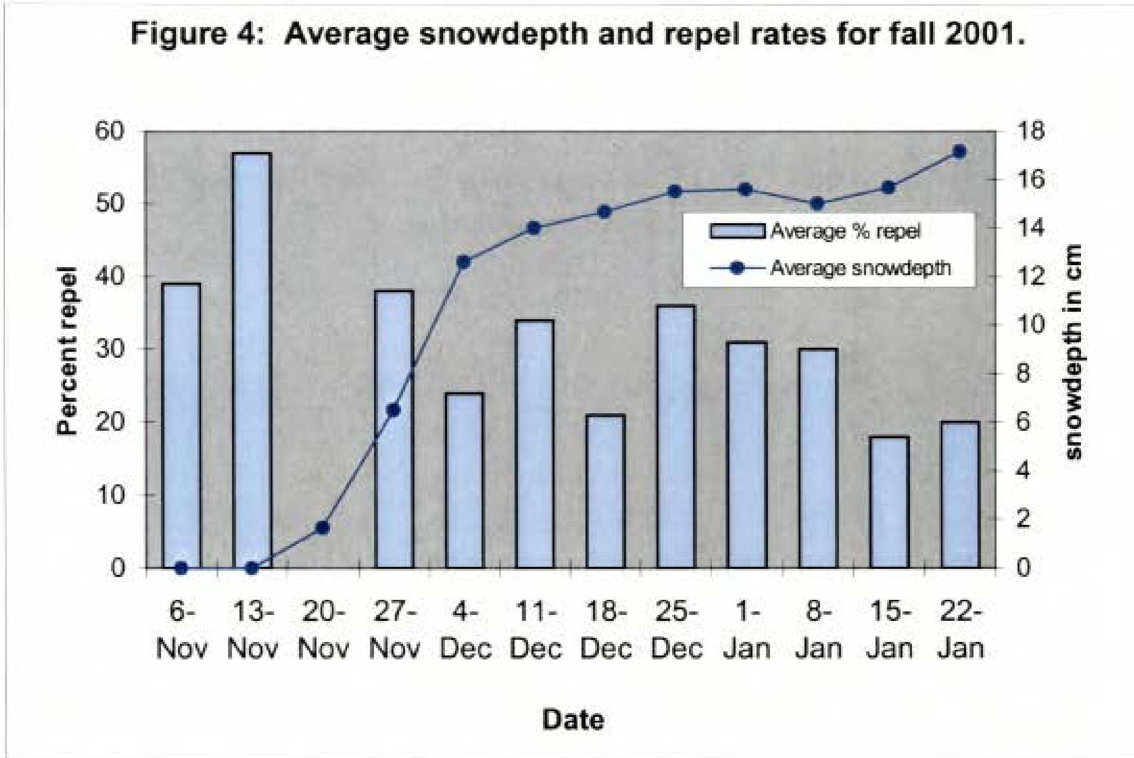


Table 5: Pronghorn use of the Nugget Canyon underpass.

Group	Group Size	Date	Time	Pass/Repel[a]	MD[b]	Direction
1	57	7 Dec	0340	56P/1R	+	South
2	1	7 Dec	1652	1R	+	South
3	8	7 Dec	1715	8P	+	South
4	4	12 Dec	1452	1P/3R	+	South
5	4	4 Mar	1700	4P	+	South
6	4	31 Mar	0902	1P/3R	-	North
7	1	4 Apr	1559	1R	-	North
8	5	4 Apr	1620	5R	-	North
9	2	4 Apr	1647	2R	-	North
10	2	4 Apr	[c]	2R	-	North
11	1	16 Apr	1926	1R	-	North

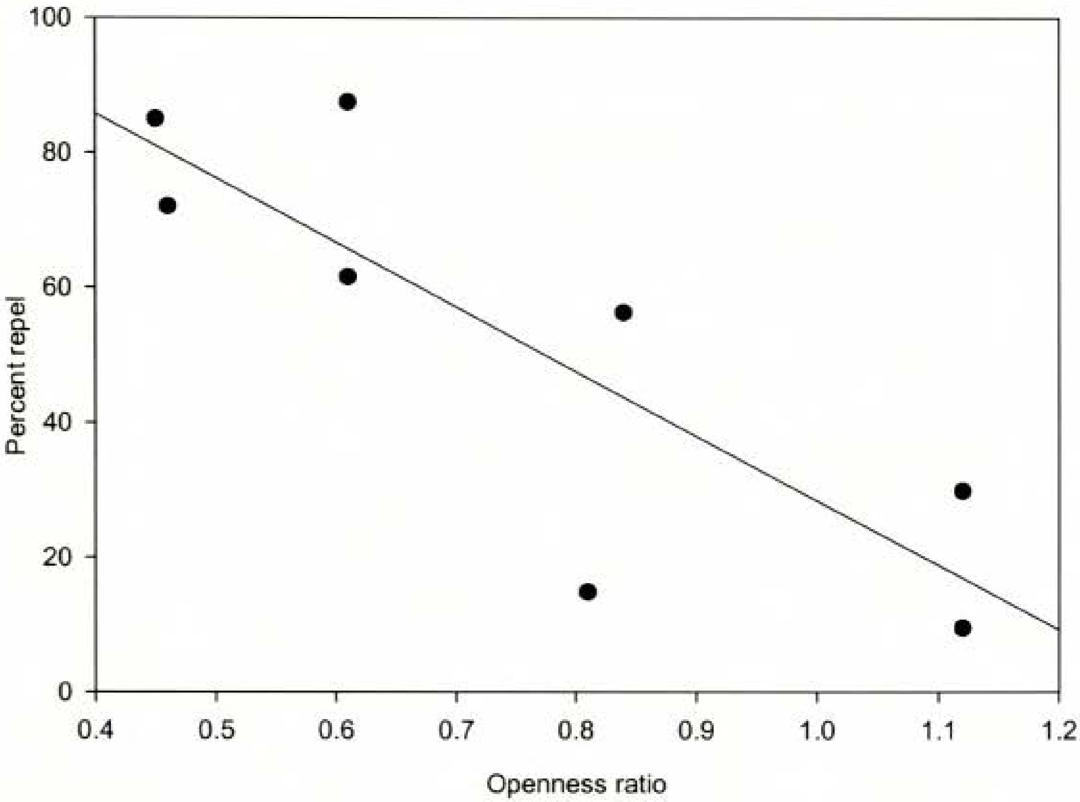
[a] Distinguishes between individuals passing through underpass (P) or being repelled (R).
[b] Denotes the presence of mule deer within 10 minutes of pronghorn use.
[c] Time of day was obscured by glare on cameras.

Other species recorded using the underpass included elk and fox. Video footage showed 15 elk approaching the underpass over the course of the 2001-2002 and 2002-2003 seasons, 4 of which passed through, and 3 approaches by fox, of which 2 passed through.

Underpass size manipulations

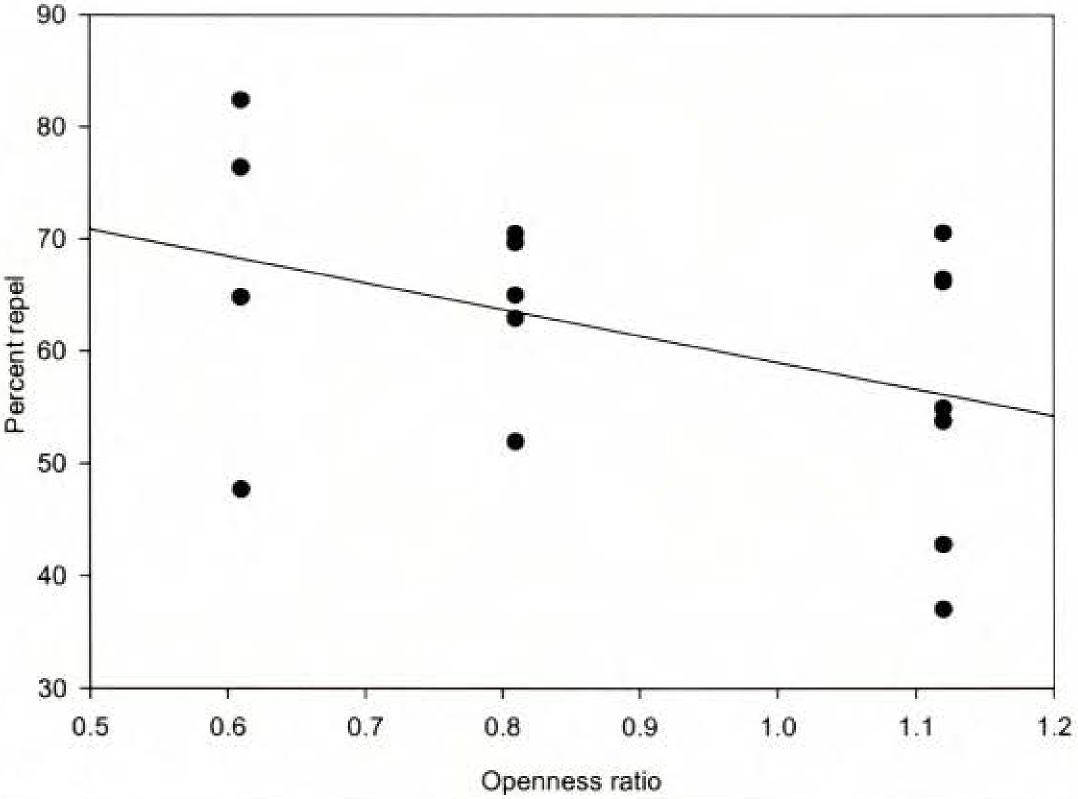
During the spring of 2002 we initiated manipulations of the width and height of the underpass to simulate a range of different openness ratios. We performed a simple linear regression on openness ratio against percentage of repels and found a significant relationship between the two variables (Adj. R^2 =0.650, p = 0.0096). Figure 5 shows a scatterplot of the openness ratios and percentage of repels for eight different treatments performed during spring 2002.

Figure 5: Openness ratio and repel rates for 8 different treatments, spring 2002.



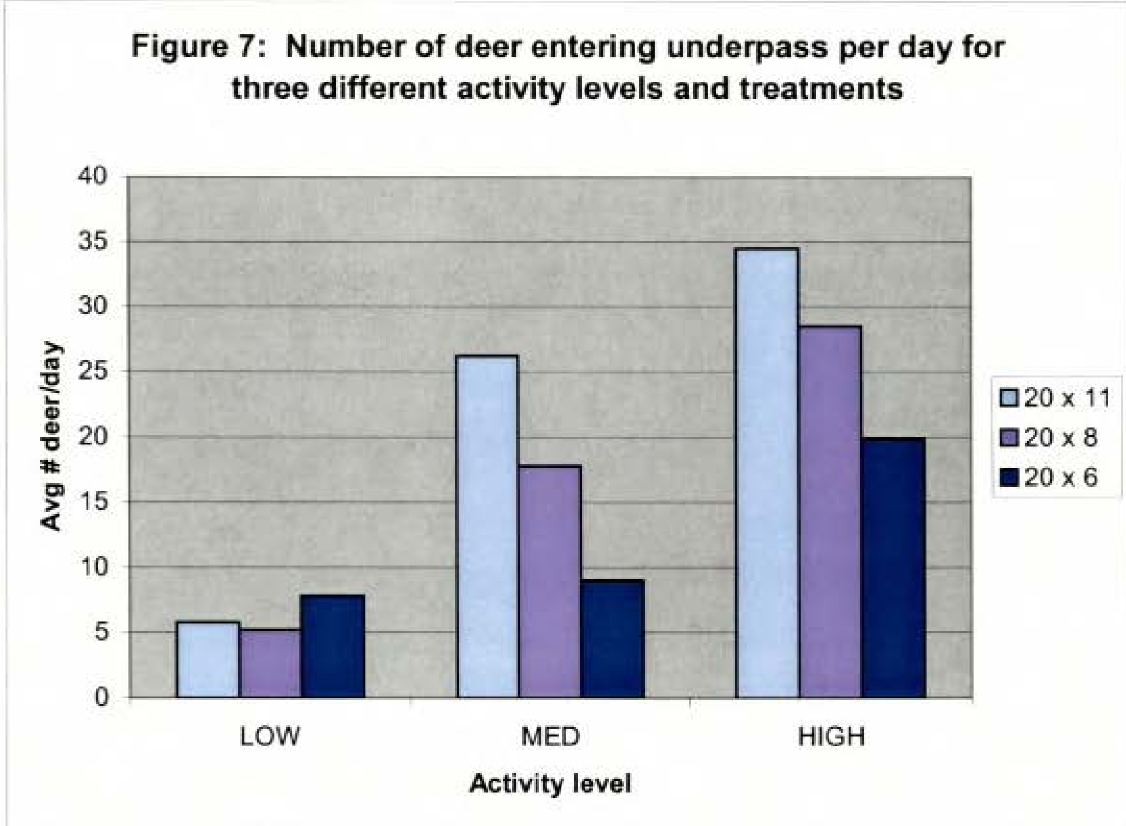
We repeated this analysis on data collected during the fall of 2002 and the spring of 2003, during which time we conducted several trials of three different size manipulations, all of which involved altering the height of the underpass but not the width. We found no significant relationship between openness ratio and percentage of repels for these trials (Adj. R^2 = 0.117, p = 0.1059). All three trials had high repel percentages, although the 6' ceiling treatment was the highest. Figure 6 shows a scatterplot of the trials performed during fall 2002 and spring 2003.

Figure 6: Repel rates in response to three height treatments, 2002-2003.



During the spring of 2002, the 20' x 11' and 20' x 8' treatments (openness ratios 1.12 and 0.81 respectively) had extremely low percentages of repels, ranging from 10% to 30%. During the fall of 2002 and the spring of 2003 when these treatments were repeated the percentages of repels ranged from 37% to 71%. It is not clear why the percentage of repels for these treatments increased during the 2002-2003 field season. If a higher number of deer are actually refusing to use the underpass in its second year, this may be cause for concern, especially since one would expect that deer would become more willing to use the underpass since many of them had been exposed to it in the previous year. Increased human activity at the site during the 2002-2003 field season may have left increased odor and sign of disturbance, causing mule deer approaching the underpass to be more hesitant to use it. Additionally, weather during the 2002-2003 field season was much milder than in past years. We have seen that snowcover impacts the percentage of repels of deer approaching the underpass (Figure 4). Perhaps the reduced snowcover during the 2002-2003 field season resulted in mule deer being less motivated to pass through as they approached the underpass.

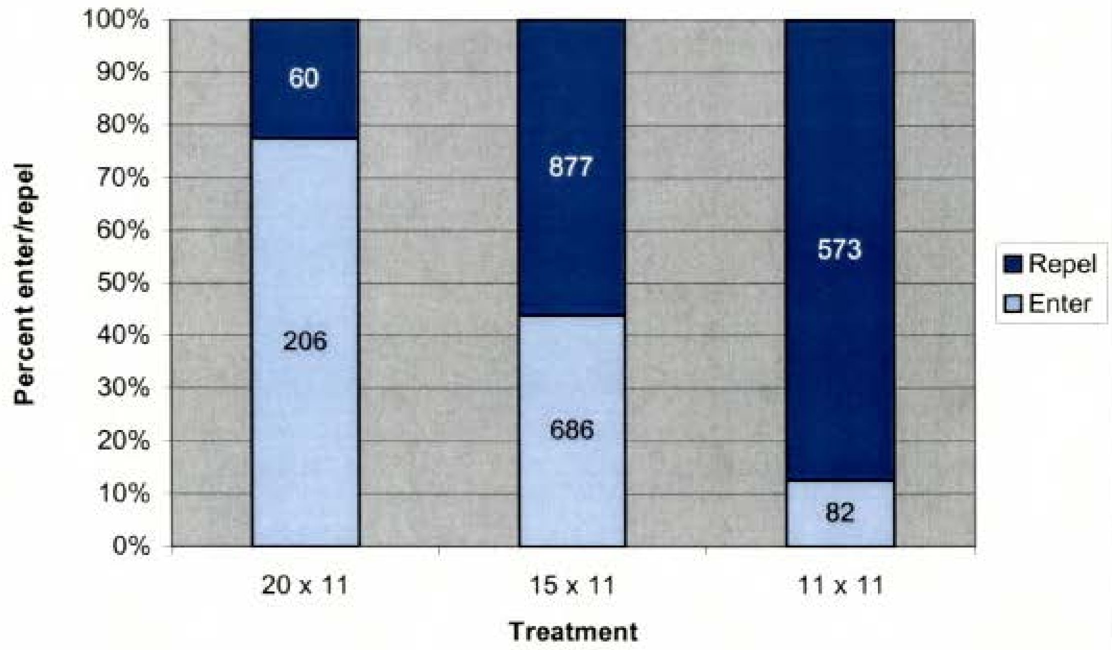
If a large number of deer approach the underpass several times before finally moving through the underpass, this could result in an inflated percentage of repels despite the fact that most deer are ultimately using underpass. It is important to distinguish between a situation in which deer approach the underpass several times and then move through and a situation in which deer approach the underpass and then turn away, seeking an alternate route across the highway. Figure 7 shows the average number of deer passing through the underpass per day during low, medium, and high periods of deer activity for the three different height treatments during the spring of 2002, fall of 2002, and spring of 2003.



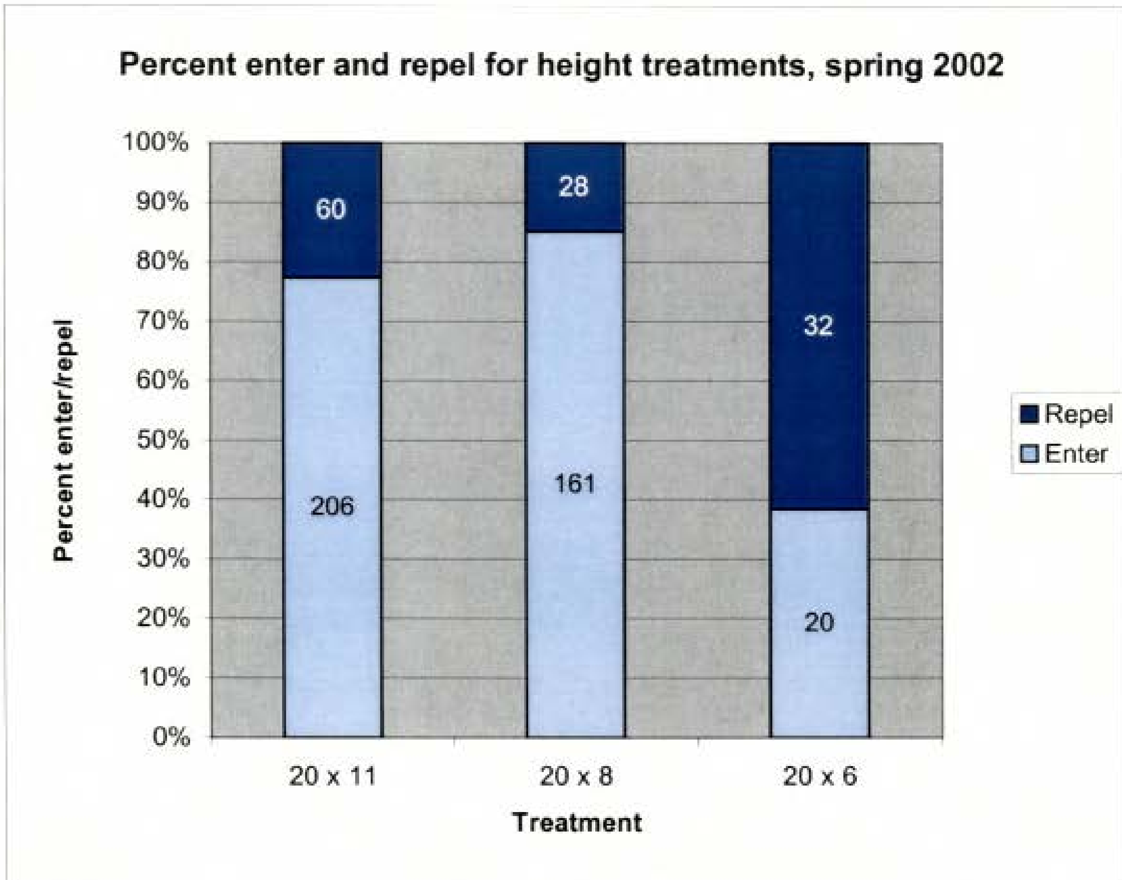
During periods of low activity, there was little difference between the number of deer entering the underpass per day for each of the three treatments. However, during periods of medium and high activity, the number of deer entering the underpass per day decreased as the size of the underpass decreased. Presumably many deer that may have entered the larger sized underpass were seeking alternate ways of moving across the highway at those times when the underpass was smaller in size.

We were also interested in determining whether deer were more sensitive to decreases in the width of the underpass or decreases in the height of the underpass. We used data gathered during the spring of 2002, since both height and width manipulations were conducted during this migration. We compared deer percentages of repels for the 20', 15', and 11' widths at the full underpass height (11'). The number of deer entering and repelling from the underpass as a function of the three different width treatments is shown in Figure 8.

Figure 8: Percent enter and repel for width treatments, spring 2002



The percentage of repels increased dramatically as the width of the underpass decreased. We performed a chi-squared test of independence and found that deer response to the underpass was significantly different between the three treatments [$X^2 = 405.5$ (df= 2; N= 2484); $p < 0.0001$]. Figure 9 shows deer response to the underpass at the full underpass width with three different height treatments. The percentage of repels is approximately the same for the 20' x 11' treatment and the 20' x 8' treatment, but increased drastically for the 20' x 6' treatment. A chi-squared test of independence revealed significant differences in deer response to the three treatments ($X^2 = 43.02$ (df = 2, n=507); $p < 0.0001$). Repels by deer increase in response to any of the reductions in width attempted in this study, but it would appear that a reduction in height from 11' to 8' does not result in any significant increase in percentage of repels.



We were interested in determining whether behaviors associated with hesitancy varied in response to variation in underpass width and height. Using data collected during the spring of 2002, we computed the average number of head up and nose down responses per approach to the underpass for three width treatments (20' x 11', 15' x 11', and 11' x 11') and three height treatments (20' x 11', 20' x 8', and 20' x 6'). We also computed 95% confidence intervals for each of these categories. Results of these analyses are shown in Figures 10 and 11. Bars on the figures indicate 95% confidence intervals. Head up and nose down behaviors increased as width of the underpass decreased, although differences between the 20' and 15' treatment were not significant. Head up and nose down responses showed no pattern in relation to height of the underpass. These results also indicate that mule deer appear to be more sensitive to smaller underpass widths than heights.

Figure 10: Head up and nose down behaviors in response to width modifications.

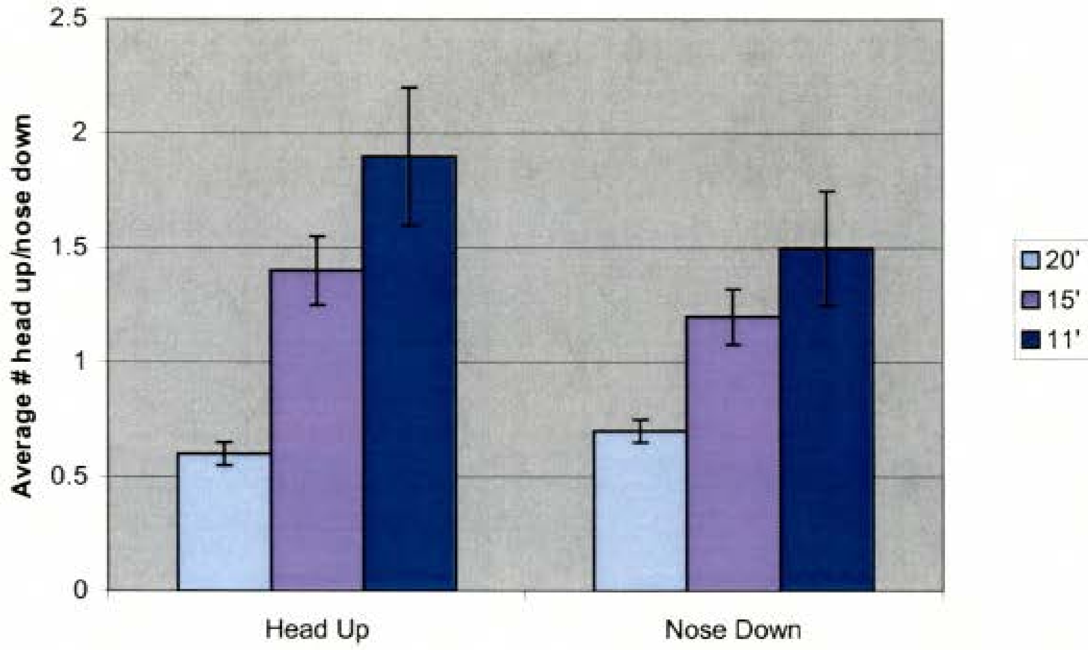
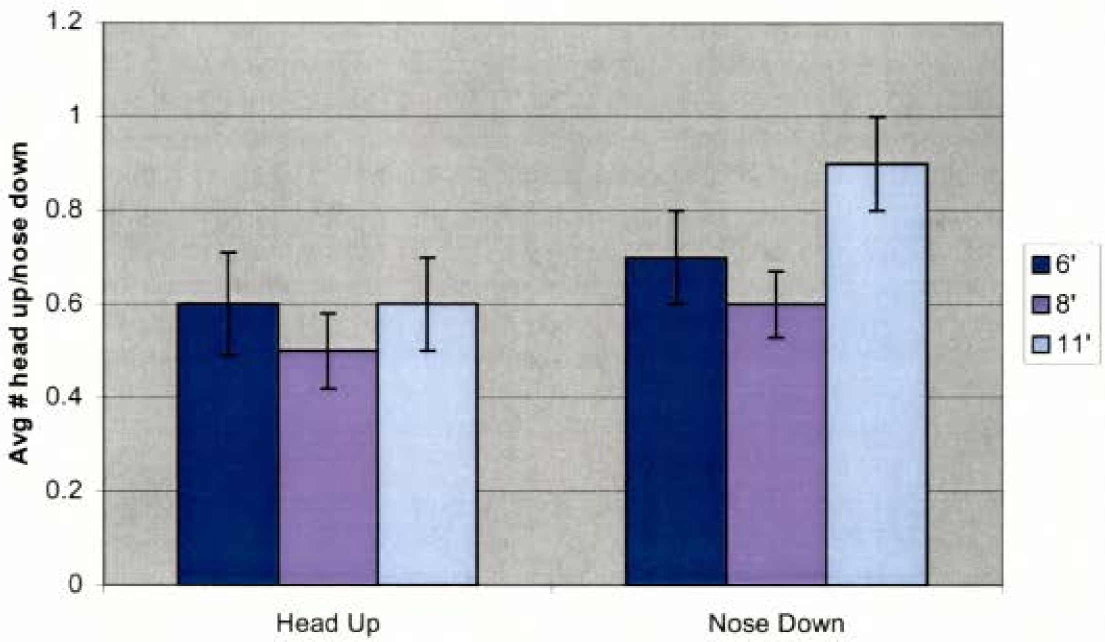
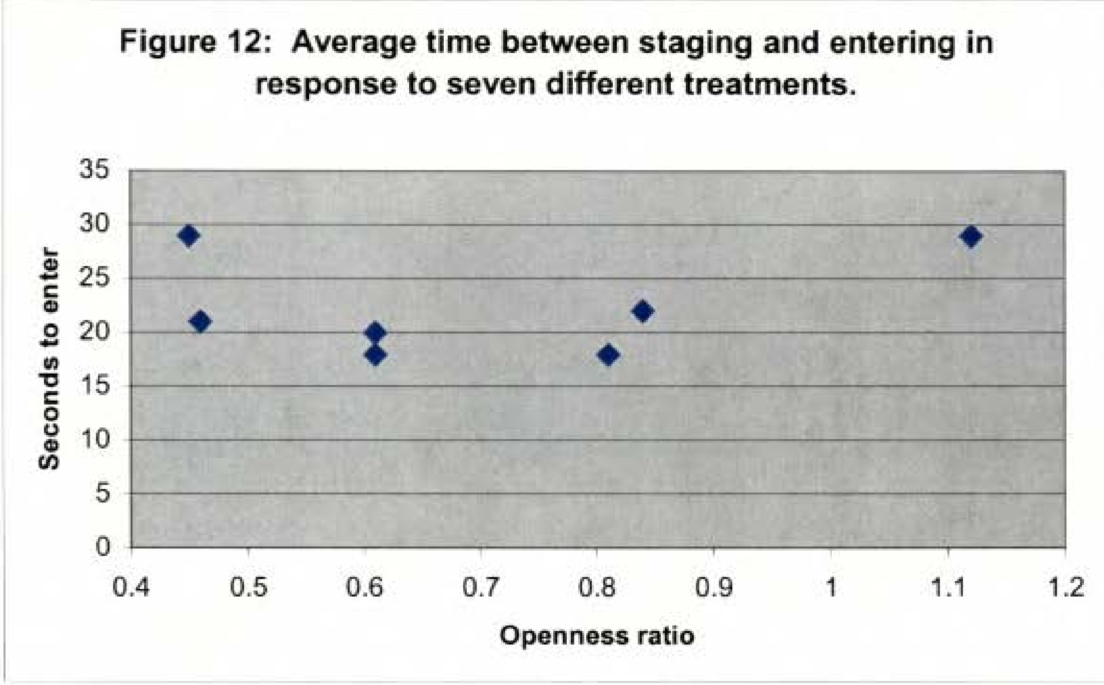


Figure 11: Head up and nose down behaviors in response to height modifications



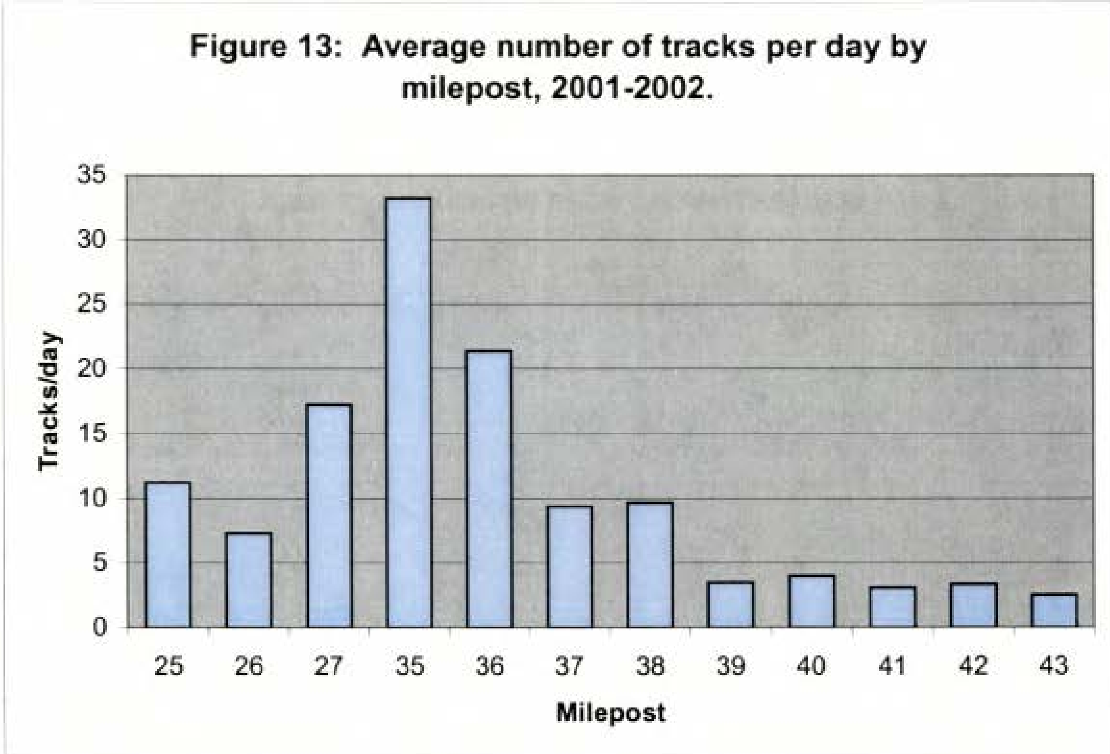
Time required to move out of the staging area and enter the underpass may also be an indicator of hesitancy. Figure 12 shows a scatterplot of average number of seconds required by approaching deer to enter the underpass from the staging area graphed against openness ratio.



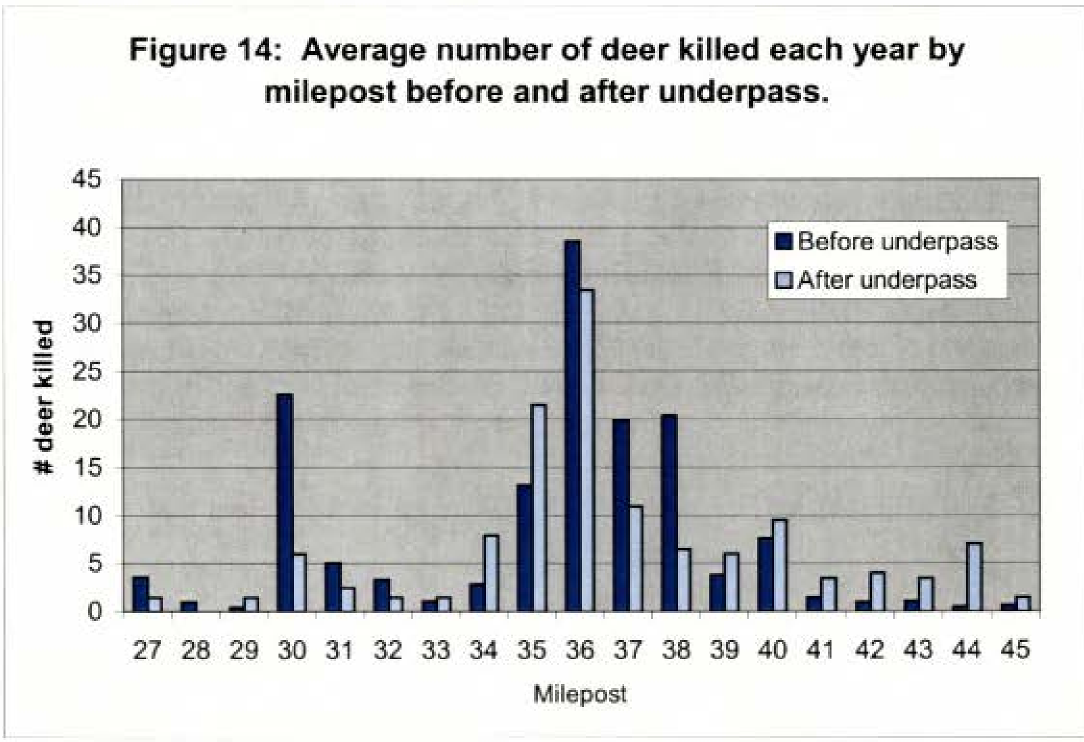
There appears to be no relationship between openness ratio and amount of time required to enter the underpass. Furthermore, no pattern was discerned when treatments were broken down by height or width modifications.

Tracking and mortality data

We collected tracking data during the 2001-2002 field season to determine areas in Nugget Canyon that received high amounts of deer crossing activity. Figure 13 shows average number of track sets per day that tracking data was collected by milepost. Data was collected between mileposts 25 and 43 excluding the fenced area stretching from milepost 28 to 35. Tracking data illustrates that the greatest amount of crossing activity occurred at mileposts 35 and 36, at the eastern end of the deer proof fence. This is likely to be due to a combination of factors. Deer movement may have been altered since the building of the fence. Additionally, the mouth of a small canyon opens in that area which may guide deer movement to that location. There is a smaller peak in deer crossing activity at milepost 27 at the western fence end as well.

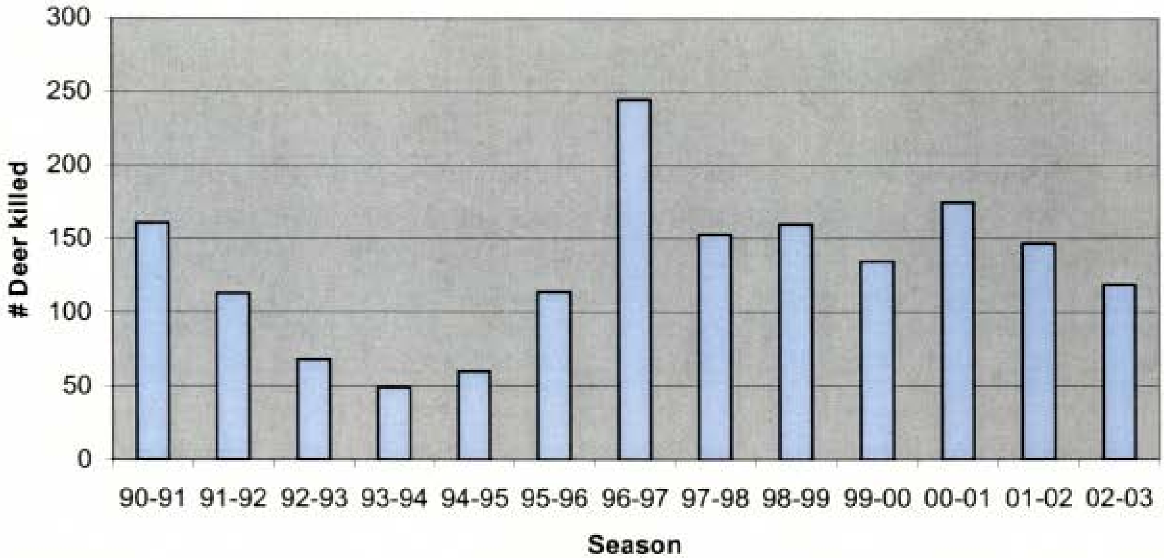


Patterns in vehicle-caused deer mortality in Nugget Canyon are similar to those revealed by the tracking data. Figure 14 shows average deer mortality by milepost for migratory seasons spanning 1990 –2001, before the underpass was built, and for the 2001-2002 and 2002-2003 migrations occurring after the underpass was built.



The largest peaks in vehicle caused mortality occur in the vicinity of mileposts 35 and 36. Mortality before the underpass was built peaks at milepost 30 as well, but has sharply declined since the building of the underpass. However, overall mortality in Nugget Canyon has declined slightly since the late 1990's (Figure 15), so this decrease may be partially attributable to overall declines in mortality due to decreased migration, increased motorist vigilance, or some other confounding factor.

Figure 15: Deer mortality by migration season on U.S. Hwy 30 mileposts 27 - 42.



CHAPTER 5
Implementation Recommendations

1.) Openness ratios of future underpasses built in Nugget Canyon should be 0.8 or greater.

A sharp increase in percentage of repels was seen in response to underpass treatments with openness ratios of less than 0.8 during the spring of 2002 in this study. Additionally, the number of deer passing through the underpass during medium and high periods of activity was much lower for the 0.61 openness ratio treatment compared to the 0.81 and 1.12 openness ratio treatments. Another study has recommended an openness ratio of 0.6 or better (Reed et al. 1979), but this study was conducted in a situation where deer may have had higher motivation to cross and stipulates that deer with light to moderate motivation may require larger structures. Data gathered during this study consisted of crossings only and did not address the number of deer approaching the structure and then turning away. Deer motivation in Nugget Canyon is likely to vary seasonally, and early, less motivated migrators may seek alternate routes across the highway rather than use a smaller underpass. Additionally, this study primarily considered deer behaviors rather than deer enters and repels in determining a recommendation for underpass size.

2.) Future underpasses built in Nugget Canyon should be at least 20 feet wide.

Our data indicate that any decrease in the width of the underpass resulted in a substantially higher percentage of repels. During the spring of 2002, the percentage of repels for the 20 x 11 foot treatment was 22.5%, whereas the percentage of repels for the 15 x 11 foot treatment was 56.3%. Behaviors indicating hesitancy also increased in response to decrease in width of the tunnel.

3.) Future underpasses built in Nugget Canyon should be at least 8 feet tall.

Percentages of repels during the spring of 2002 were both in the 20% range for the 20 x 11 foot treatment and the 20 x 8 foot treatment, whereas the percentage of repels for the 20 x 6 foot treatment was 61.5%. During the fall of 2002 and the spring of 2003 the percentage of repels increased for the 20 x 11 and 20 x 8 treatments, but higher numbers of mule deer passed through the underpass at these sizes than at the 20 x 6 treatment during medium and high periods of activity. Frequency of behaviors indicating hesitancy did not seem to change in response to underpass height.

4.) One underpass should be built near milepost 35 or 36 of U.S. Highway 30.

The highest frequency of track sets and vehicle-caused mortalities of mule deer occurred near mileposts 35 and 36 near the eastern fence end. This site should be seriously considered in the construction of a future underpass in Nugget Canyon. Optimally the current fence would be extended by 3 miles or more eastward to prevent deer from moving to the fence ends.

5.) Future underpasses should be graded gradually to alleviate drainage problems and to increase apparent openness.

The steep grading at the entrance and exit of the underpass at milepost 30.5 may contribute to drainage problems that result in mud and pooling of water during the spring. The grading also lowers the apparent openness of the underpass by reducing the amount of visible sky in the view through the underpass. Foster and Humphrey (1995) suggest that a view of the sky, horizon, and terrain beyond the underpass is important in determining whether wildlife are willing to use underpasses.

6.) Research into minimizing traffic noise and screening views of traffic may result in a higher usage of future underpasses.

Although we did not collect data on these factors, we observed that deer frequently seemed startled away from using the underpass by the noise and sight of traffic passing overhead. Screens along the highway that shield the view of passing traffic and measures to minimize noise both inside and adjacent to the underpass may result in increased underpass usage. Clevenger and Waltho (2000) found that decibel level inside underpasses in Banff National Park was a significant predictor of deer use of underpasses.

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