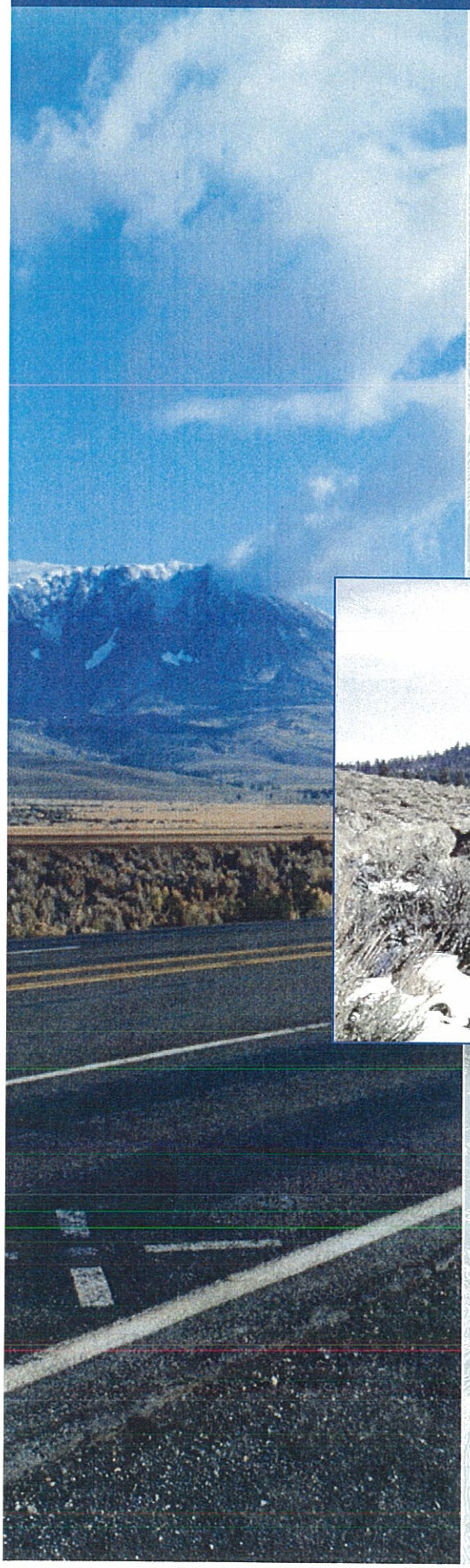

FINAL REPORT

An Assessment of the Sandhouse Project's

Effects on Mule Deer Movement and Mortality

along State Route 395 in Mono County

Submitted to:

California Department of Transportation
District 9

Submitted by:

Jones & Stokes

October1999

An Assessment of the Sandhouse Project's Effects on Mule Deer Movement and Mortality along State Route 395 in Mono County

Final Report

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Executive Summary

INTRODUCTION

The California Department of Transportation (Caltrans) proposed widening portions of State Route (SR) 395 in Mono County from two to four lanes and including a variable-width median strip. The proposed project crosses migration routes used by 1,000–1,200 mule deer (*Odocoileus hemionus*) from the Casa Diablo herd. As a condition of approval for the project, Caltrans agreed to conduct a study to determine whether inclusion of the variable-width median strip would affect the number of deer-vehicle collisions along SR 395. Jones & Stokes Associates conducted a study for Caltrans between October 1992 and November 1998 to evaluate deer movement and mortality patterns before, during, and after highway construction.

The project area is between the town of Lee Vining and SR 158 (south June Lake Loop). The project area is divided into two separate but contiguous highway expansion projects: the Sandhouse project (approximately 8 kilometers [5 miles] long) and the Rush Creek project (approximately 9.6 kilometers [6 miles] long). The variable-width median strip was constructed in the Sandhouse project area. The Rush Creek project was not constructed, so the Rush Creek project area served as the control site.

It was hypothesized that use of the variable-width median could reduce deer fatalities because with two lanes in each direction separated by a variable-width median, a driver could avoid hitting a deer without encountering oncoming traffic. In addition, the variable-width median would separate vehicle traffic, and deer would see headlights from only one direction rather than two directions when they attempted to cross the highway.

Data on deer movement and fatalities were obtained from track counts and roadside surveys. Track counts along dirt roads parallel to SR 395 were used to determine the timing and location of deer movement during spring and fall migration and summer. The dirt roads were divided into forty-two 0.3-kilometer-long (0.2-mile-long) survey segments, and the number of tracks observed in each segment was recorded. Frequent roadside surveys were used to identify the location of all deer fatalities. Traffic volumes were provided by Caltrans.

TIMING AND LOCATION OF DEER MOVEMENT

Spring Migration

The arrival of deer in the study area during spring migration varied by 1 month during the 6-year study. The variability in arrival dates was related to the persistence of snow and plant phenology in the study area. Spring migration generally peaked between the last week of May and early June and was completed by mid-June. Most deer moved at dawn and dusk. The proportion of deer moving through individual survey segments was consistent during the study, indicating high fidelity to specific movement corridors. During spring migration, deer selected survey segments that had more herbaceous vegetation than other survey segments.

Fall Migration

Fall migration started between the end of September and mid-October, often before the first significant snowfall. The initiation of fall migration was associated with several consecutive nights of subfreezing temperatures that probably reduced forage quality on summer ranges. Fall migration generally was completed

by the second week in November. During fall migration, deer moved later in the morning and earlier in the evening than during spring migration. The shift in the daily timing of movement may have been to conserve energy by avoiding movement during the colder fall nights. During fall migration, the proportion of deer moving through individual survey segments was less consistent than spring migration, and deer selected survey segments with more cover and bitterbrush compared to other survey segments.

Summer Movement

Patterns of deer movement changed during summer. There was little movement of deer during early summer. Most of the study area is used by does, and their home ranges are restricted when they are raising young fawns. In addition, movement through most survey segments was similar, suggesting little selection for specific resources. After mid-August, there was a significant increase in the number of tracks counted. The increased number of tracks probably represented increased movement by does and young fawns that were at heel and some influx of deer into the area. During late summer, deer selected to move through survey segments with more cover, bitterbrush, and water compared to other survey segments.

FACTORS AFFECTING DEER FATALITIES

A total of 149 deer fatalities caused by motor vehicles were recorded during the 6-year study. Spring migration and early summer movements resulted in few fatalities; the most fatalities generally occurred during late summer movements, followed by a reduction in fatalities during fall migration. A significant relationship ($P<0.01$, $R^2 = 0.64$) existed between seasonal deer-use days and the corresponding number of fatalities.

A significant correlation ($P>0.05$) did not exist between the amount of deer use of individual survey segments and deer fatalities. Six survey segments that accounted for 34.5% of all deer tracks counted had fewer deer fatalities than expected. When these survey segments were removed from the analysis, there was a significant relationship between the amount of deer movement through a survey segment and deer fatalities. This relationship suggested that another variable was important in contributing to deer fatalities.

Approximately 60% of all deer fatalities were associated with cutbanks, fillslopes, or guardrails. The six survey segments that accounted for most of the deer movement but had a low incidence of fatalities had no or an isolated cutbank or fillslope. These design features affect deer mortality and should be carefully evaluated during project planning.

Traffic levels varied daily, weekly, and seasonally. Nighttime traffic levels were approximately 85% lower than daytime traffic levels. Weekend traffic levels (Thursday through Saturday) were substantially higher than weekday traffic levels. There was no relationship between the number of deer fatalities and traffic levels.

EFFECTIVENESS OF THE VARIABLE-WIDTH MEDIAN STRIP

Other studies have shown that the number of deer fatalities increases substantially during the first couple of years after a new highway is available for travel. During the first summer after opening the variable-width median, most deer fatalities were young animals not experienced at crossing SR 395. The number of fatalities declined during the second summer. There was no significant difference ($P>0.05$) in the deer fatality indices between preconstruction and postconstruction of the variable-width median in the Sandhouse project area. Likewise, there was no significant difference ($P>0.05$) in the Rush Creek project area, which served as the control during the study.

Construction of the variable-width median did not increase the number of deer fatalities. The lack of a substantial increase in deer

fatalities immediately after opening the expanded highway and fewer fatalities during the second summer suggest that the variable-width median may be effective in reducing deer fatalities. Additional surveys should be implemented to monitor the effectiveness of the project, and opportunities should be identified to test the design in other locations.

Chapter 1. Introduction

INTRODUCTION

The California Department of Transportation (Caltrans) proposed widening portions of State Route (SR) 395 in Mono County from two to four lanes and including a variable-width median strip. The proposed project crosses migration routes used by 1,000–1,200 mule deer (*Odocoileus hemionus*) from the Casa Diablo herd, which winter near the California-Nevada border and summer on the east side of the Sierra Nevada (Taylor 1988). During preparation of the environmental evaluation for the SR 395 project, it was concluded that highway expansion may result in additional deer-vehicle collisions. As a condition of project approval, Caltrans agreed to conduct a study to determine whether inclusion of a variable-width median strip would affect the number of deer-vehicle collisions along SR 395. This final report describes the results of the study conducted by Jones & Stokes Associates between October 1992 and November 1998 to evaluate deer movement and mortality patterns before, during, and after highway construction.

PROJECT AREA

The project area is in Mono County between the town of Lee Vining and SR 158 (south June Lake Loop) (Figure 1-1). The project area is divided into two separate but contiguous highway expansion projects. The Sandhouse project is the southernmost project, stretching approximately 8 kilometers (5 miles) between SR 158 south and SR 120 east. The Rush Creek project, north of the Sandhouse project, extends approximately 9.6 kilometers (6 miles) between SR 120 east and Lee Vining.

PURPOSE OF AND NEED FOR THE STUDY

Recent reports have estimated that approximately 15,000 deer are killed annually along California's highways (Romin and Bissonette 1996), and highway mortality is one of the significant factors affecting California's deer population (California Department of Fish and Game 1998). Recent estimates of insurance claims resulting from deer-vehicle collisions range from $2,000 per collision (California State Automobile Association 1998) to $1,200 per collision (Romin and Bissonette 1996). Assuming an average claim of $1,600 for each collision, it is estimated that insurance companies in California could settle claims for approximately $24 million annually as a result of deer-vehicle collisions.

Numerous techniques have been developed and evaluated to reduce deer-vehicle collisions, including fencing, underpasses/overpasses, crosswalks, warning signs, highway lighting, Swarflex reflectors, ultrasonic warning whistles, and habitat alteration (Romin and Bissonette 1996, Lehnert and Bissonette 1997). It is generally concluded that fencing and underpasses/overpasses are effective in reducing deer fatalities and that highway lighting is ineffective (Romin 1994). All other techniques appear to be ineffective (Romin 1994, Groot Bruinderink and Hazebroek 1996).

The use of fencing in conjunction with underpasses was considered for the Mono County project area during the environmental evaluation. This technique was not considered a viable alternative, however, because most of the project area is within the Mono Basin Scenic

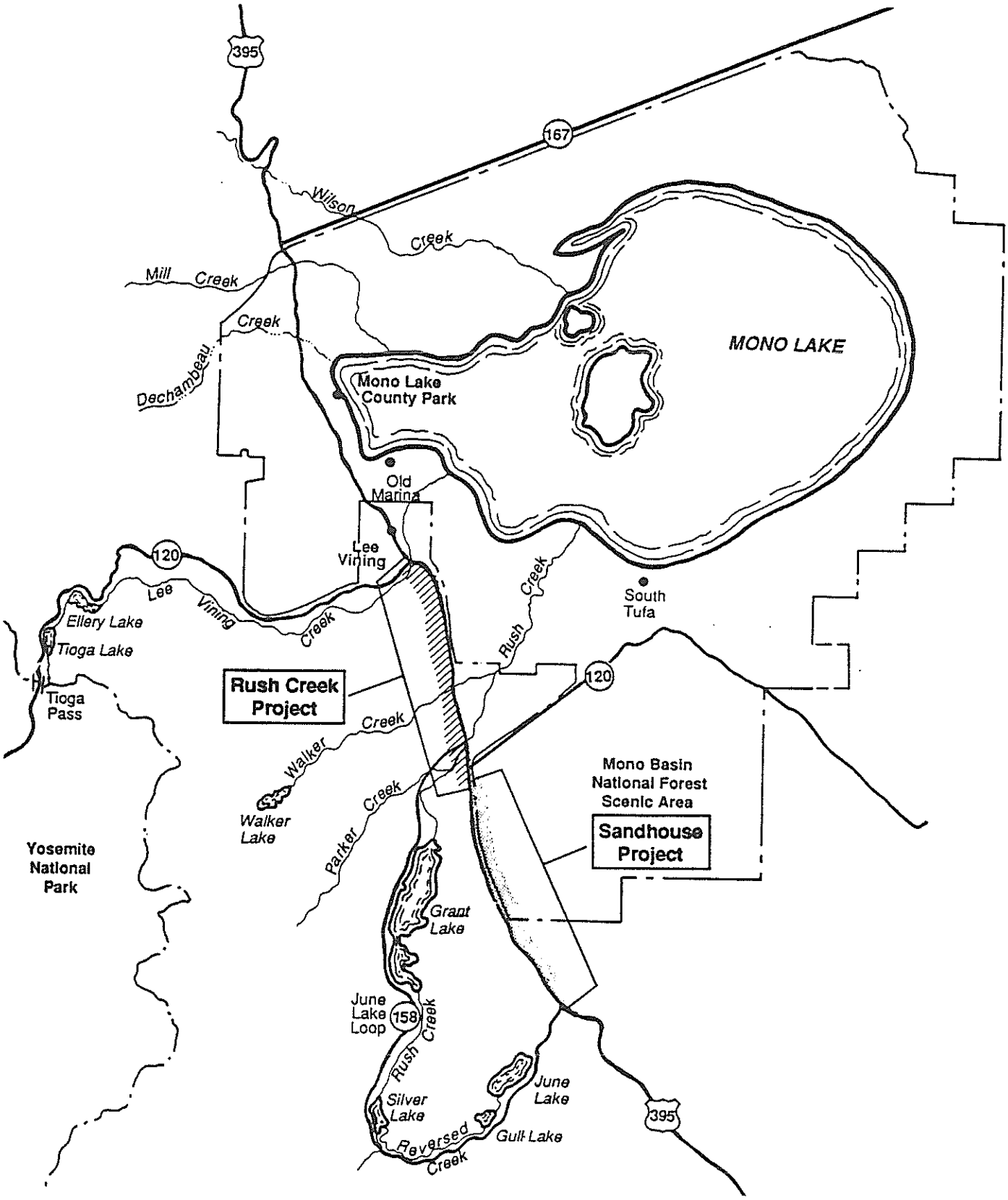

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Figure 1-1
Location of Rush Creek and Sandhouse Projects

Area and fencing would degrade the view along SR 395. A divided highway was included in the project design because use of a median was thought to have reduced deer fatalities along a section of SR 395 immediately south of the project area. It was hypothesized that the variable-width median could reduce deer fatalities because with two lanes in each direction separated by a variable-width median, a driver could avoid hitting a deer without encountering oncoming traffic (Dayak pers. comm.). Additionally, the variable-width median would separate vehicle traffic, and deer would see headlights from only one direction rather than from two directions when they attempted to cross the highway.

ORGANIZATION OF THE REPORT

Chapter 1, "Introduction", describes the project location and purpose of and the need for the study documented in this report.

Chapter 2, "Methods", describes the methods used during the study.

Chapter 3, "Description of the Study Area and Overview of the Casa Diablo Deer Herd", describes the physical features and habitat types in the study area and provides an overview of the population trends, movement patterns, and seasonal ranges used by the Casa Diablo deer herd.

Chapter 4, "Timing and Location of Spring and Fall Migration", describes the timing and location of spring and fall migration, mortality patterns, and factors associated with deer mortalities.

Chapter 5, "Timing and Location of Summer Movement", describes the timing and location of deer movement during summer.

Chapter 6, "Deer Fatalities", describes the number and location of deer fatalities in the project area and factors affecting those fatalities.

Chapter 7, "Effectiveness of the Variable-Width Median", describes the effectiveness of the median in reducing deer fatalities.

Chapter 8, "Acknowledgments", lists all who worked on this study and prepared this report.

Chapter 9, "Citations", identifies the printed materials and personal communications referenced in the study.

Chapter 2. Methods

The study area included two contiguous highway expansion projects, the Sandhouse project and the Rush Creek project. The Sandhouse project was constructed between spring 1994 and summer 1996. The Rush Creek project was not constructed during the time of the study. Movement and mortality surveys were conducted in the entire study area prior to, during, and after construction of the Sandhouse project. The schedule of surveys is shown in Table 2-1. No surveys were conducted during summer and fall 1995.

Track-Count Surveys

Track-count surveys were conducted to determine the amount, timing, and specific location of deer use within the project areas during spring and fall migration. Previous radiotelemetry studies (Taylor 1988) determined that deer migration through the project areas occurs in a generally east-west direction. The track-count survey route was established on 13.5 kilometers (8.4 miles) of dirt roads parallel to SR 395 (Figures 2-1a and 2-1b). The lack of a sufficient number of suitable dirt roads prevented establishment of tracking areas along the length of the entire survey area.

Table 2-1. Survey Periods in Relation to Construction Phases of the Sandhouse Project

Construction Phase	Surveys
Preconstruction	fall 1992; spring, summer, and fall 1993
Construction	spring, summer, and fall 1994; spring 1995; spring and summer 1996
Postconstruction	fall 1996; spring, summer, and fall 1997; spring, summer, and fall 1998

MIGRATION STUDIES

Previous studies have estimated that 1,200–2,000 migratory deer cross SR 395 at four well-defined crossings in the Sandhouse project area (Taylor 1988, 1991). Information was lacking on the migration routes in the Rush Creek project area. Track-count surveys were conducted to verify the location of movement corridors in the Sandhouse project area and to identify corridors in the Rush Creek project area.

Additionally, several small stretches of the survey area had hard, rocky substrates that provided poor tracking mediums.

Track-count surveys were conducted twice per week during each survey period. On the evening before each track-count survey was conducted , the surface of the roads was graded with a drag made from a 2-meter (6-foot) section of chain-link fence to prepare the route for counting.

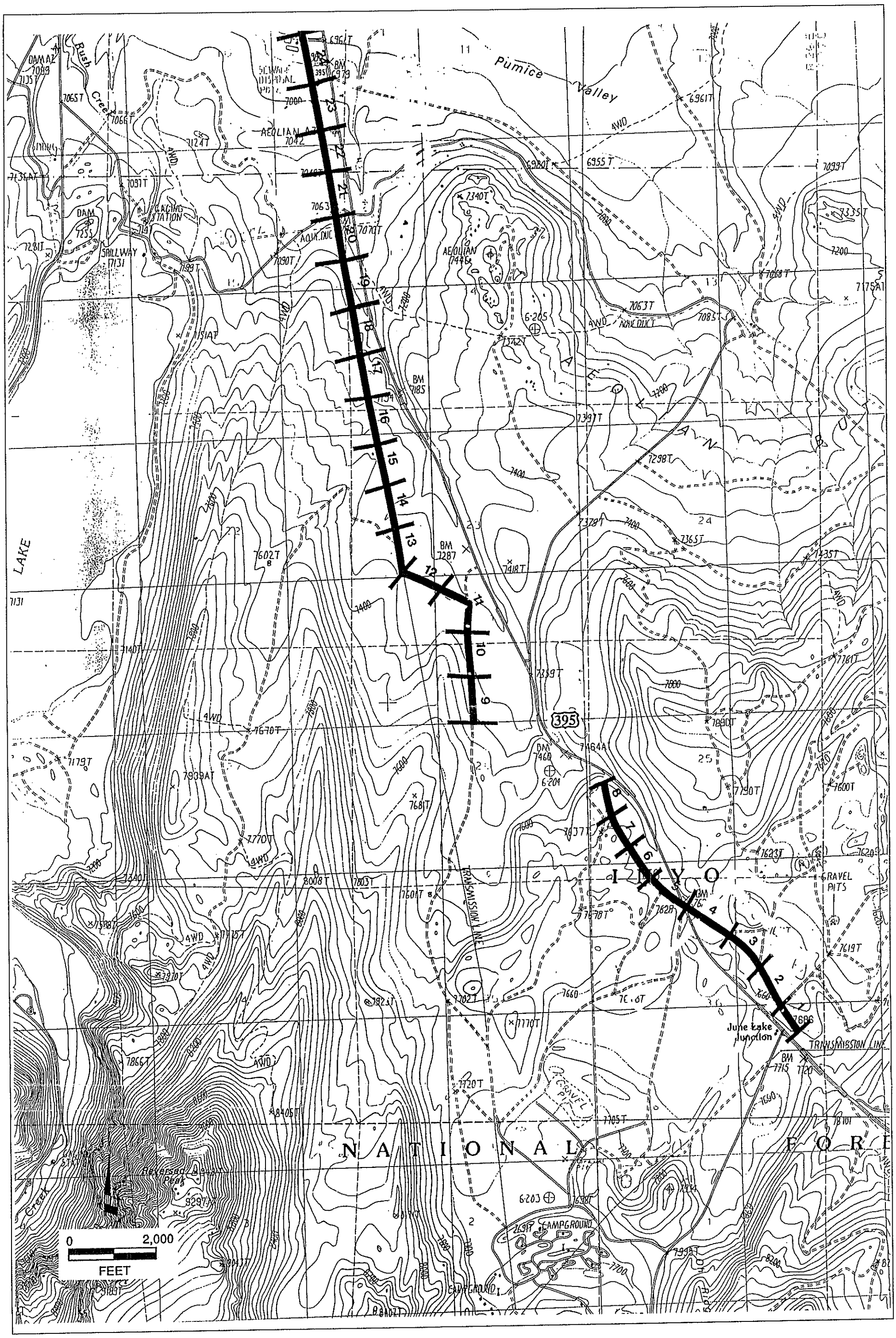

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Figure 2-1a

Location of Track Count Survey Routes in the Sandhouse Project Area

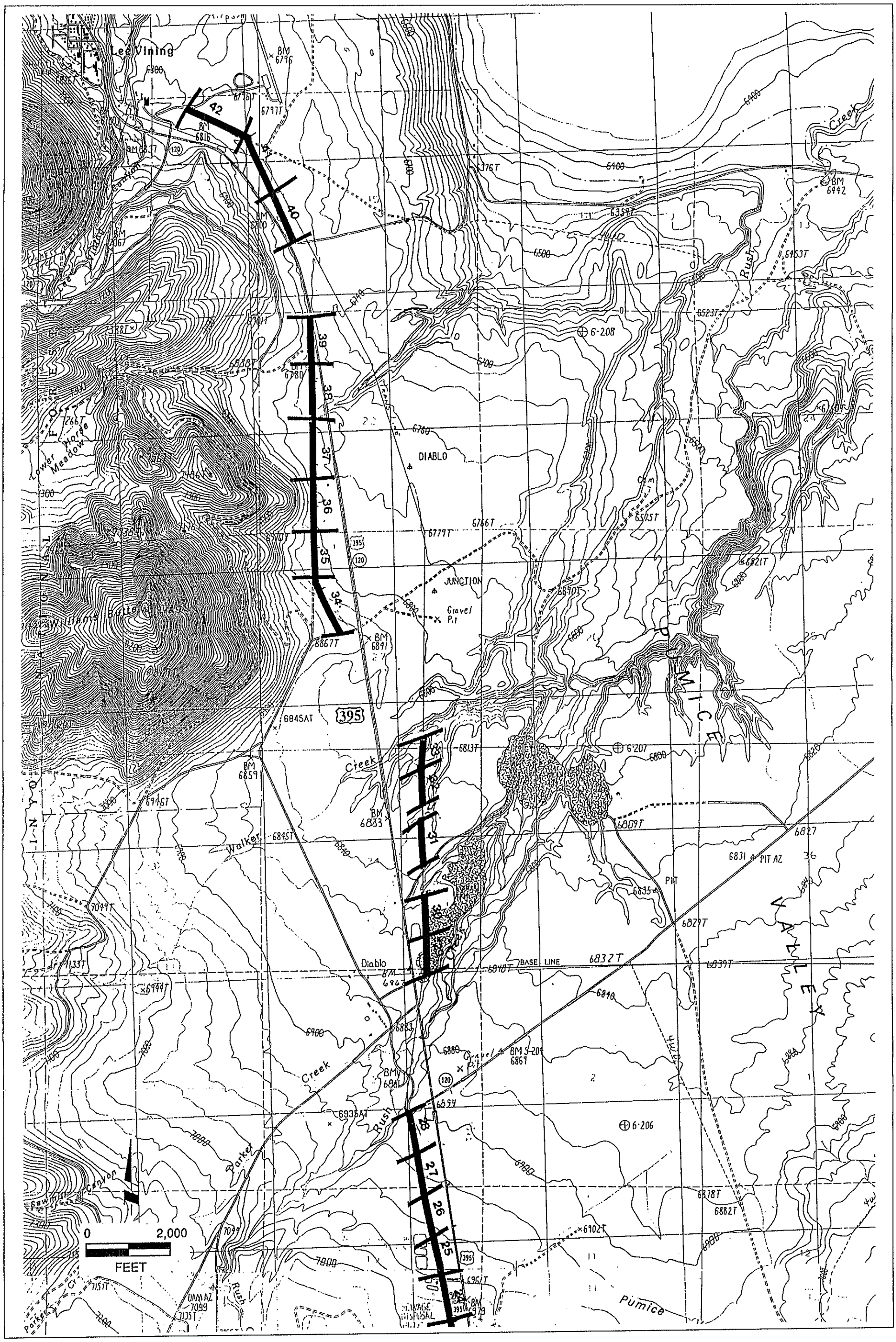

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Figure 2-1b
Location of Track Count Survey Routes in the Rush Creek Project Area

Track-count surveys were conducted between 700 and 1100 the following morning. The route was surveyed from a slow-moving vehicle and the number, location, and direction of all tracks were recorded. The locations of all tracks observed in 42 0.3-kilometer-long (0.2-mile-long) segments established along the 13.4-kilometer-long route were identified and recorded. Segments 1 to 24 were located in the Sandhouse project area between post marker (PM) 40.1 and PM 45.2. Segments 24 to 42 were located in the Rush Creek project area between PM 45.1 and SR 120 west. Segment 24 included the end of the Sandhouse project area and the beginning of the Rush Creek project area.

The direction of travel for all tracks was recorded as north, south, east, or west. A track headed down the road was followed until the track turned off the road, and the direction where it turned off was recorded as its direction of travel. The direction of travel was recorded to differentiate localized back-and-forth movements of holdover and resident deer from migratory movements.

Analyses of the Location of Deer Movement

The location of deer movement was analyzed to determine whether individual survey segments were used in proportion to their availability or more or less than their availability. The analysis was performed similar to other analyses of utilization-availability (Neu et al. 1974, Byers et al. 1984). A chi-square analysis of the total number of tracks counted each season was used to determine whether the observed pattern of use was similar to the expected pattern. The expected pattern was based on the assumption that all survey segments were used equally. Bonferroni confidence intervals (alpha = 0.05) were calculated for the number of tracks observed in each segment to determine whether individual survey segments were utilized equally, more, or less than expected. Study area boundaries can affect inferences from utilization-availability analyses (Porter and Church 1987); therefore, study area boundaries and movement patterns were closely evaluated.

Schooley (1994) identified annual shifts in habitat selection resulting from changes in resource availability. We analyzed the track-count data to determine whether shifts in selection of movement corridors occurred before, during, and after highway construction.

The total numbers of tracks observed during the three time periods (before, during, and after construction) during spring migration, fall migration, and early summer and late summer movements were used during the analysis. Seasonal comparisons of utilization were made between the spring and fall migration periods and between early and late summer. No comparisons were made between migration periods and summer because of ecological differences between the two periods. Migration represented traditional movement by a large portion of the deer herd as it moved through the area, whereas summer movement represented movement by individuals within their traditional home ranges.

Estimate of the Number of Deer Moving through the Study Area

The number of tracks in each cardinal direction of travel was recorded during each survey. In fall, tracks headed east were in the direction of fall migration, and in spring, tracks headed west were in the direction of spring migration. The total number of deer using the project areas during migration was calculated as the total of the number of deer that migrate through the area plus the number of deer that use it as a holding area.

Migrating Deer. To estimate the number of migrating deer observed during surveys, the number of tracks headed in the direction of migration was subtracted from the number of tracks headed in the opposite direction. The total number of deer migrating through the project areas was calculated by dividing the number of migrating deer observed during surveys by the proportion of days that were

sampled during the entire sampling period of migration.

Holdover Deer Use. Holdover deer may spend more than 1 day in the project areas; therefore, track counts may represent one animal for 1 day or one animal staying in the areas for several days. Therefore, estimates of numbers of individual deer cannot be calculated; instead, use by holdover animals was calculated as deer-use days (the amount of use by one deer over a 24-hour period).

Holdover deer use was calculated by subtracting the number of tracks moving in the direction of migration from the total number of tracks and dividing the difference by 2 to account for animals that move back and forth in the project areas. The total number of holdover deer-use days was then calculated by dividing the number of holdover deer by the percentage of time the area was surveyed during migration.

Total Deer-Use Days. The total number of deer-use days was calculated by adding the number of migrant and holdover deer observed and dividing by the proportion of time that areas were surveyed during migration. This assumes that one migrant deer is equal to one deer-use day.

Duration of Spring Migration. The end of spring migration was determined by evaluating the number of tracks recorded during each survey and the presence of deer at a known holding area along the Owens River, south of the study area.

The study area is at the lower elevation of the summer range and serves as a holding area for migrating deer that use higher elevation summer habitats. Other studies have shown that deer delay migration by staying in holding areas until snow recedes and high-quality forage is available at higher elevation summer ranges (Kucera 1992, Loft et al. 1989, Bertram and Rempel 1977). We assumed that there would be a large "pulse" of deer migrating through the study area at the end of spring migration and that the timing of this movement would be affected by the amount of snow on higher elevation summer ranges. Therefore, the end of spring migration was determined by identification of the survey date with the largest percent decline in tracks counted from the previous survey date. The results found using this technique were consistent with expected delays in migration caused by snow.

Duration of Fall Migration. We determined previously that fall migration in the Casa Diablo herd was not always initiated by snowstorms (Jones & Stokes Associates 1997). Instead, it was determined that fall migration was associated with there being a succession of nights with temperatures below freezing; on these nights with freezing temperatures, forage was desiccated on the summer range, initiating fall migration (Jones & Stokes Associates 1995). The beginning of fall migration was determined by identification of a succession of nights with temperatures below freezing followed by a substantial increase in the number of deer tracks recorded, with more than 50% of the tracks counted in each subsequent survey headed east, toward the winter range.

Data Analysis. Spearman's rank correlation was used to test the relationship between the Julian calender date of arrival of deer in the study area during spring migration and the amount of snow that fell the previous winter. The Kolmogorov-Smirnov test was used to determine whether there were differences in the distribution of dates of arrival and completion of spring migration. The Mann-Whitney test was used to determine whether there were differences in the duration of spring and fall migration.

Verification of Track-Count Survey Accuracy. Track-count surveys may not provide an accurate measure of the number of deer crossing a particular area (Salwasser 1976, Connolly 1981, Ford pers. comm.). In areas where several deer cross the same portion of the survey route and tracks overlap, it is often difficult to estimate the number of deer crossing and determine their direction of travel. An infrared-sensor monitoring device (Trail Master

1500) and 35-mm camera were used to count the actual number of deer crossing a portion of the track-count route.

Accuracy of the track counts was evaluated by comparing the number of deer estimated by track counts with the number of deer recorded by the cameras. Data from spring 1993 and fall 1993 were used in the evaluation. A chi-square analysis and regression analysis were used to determine the relationship between the Trail Master and track-counting techniques. Different regression models were evaluated to determine the line of best fit. Additionally, the slope was compared with a 1:1 relationship, which assumes that track counts are as accurate as direct observation. These data are presented in Appendix A.

Estimating the Daily Timing of Movement through the Project Area

Trail Master units were used to determine the time of day when deer passed through the study area. Units were placed in locations that had well-defined travelways recently used by deer. Four to six units were used during each migration period. The distance between the transmitter and receiver was approximately 10 meters (30 feet) for each Trail Master unit. The Trail Master units were usually set for a 2- to 3-day period; information on the number of deer crossing through the beam was collected during each track survey. A chi-square analysis was used to determine whether there were differences in the hourly frequency of movement between spring and fall migration.

Mortality Surveys during Migration

To estimate deer mortality, SR 395 was surveyed for deer carcasses and areas adjacent to SR 395 were surveyed for deer that had been hit by vehicles but died in the area adjacent to the highway.

Deer Mortality Surveys along SR 395

The data collected during mortality surveys were used to estimate weekly mortality rates for the project areas. Information collected by Caltrans on deer mortality was also used to supplement the data on weekly mortality rates within the project area.

The Rush Creek and Sandhouse project areas were surveyed to determine the number and locations of deer mortalities. Mortality studies were conducted in the morning for a minimum of four days each week during migration. To determine weekend mortality, sampling was conducted on two days selected from Friday, Saturday, and Sunday; to determine weekday mortality, surveying was conducted on two randomly selected days during the remainder of the week. This sampling strategy was used so that weekend mortality rates could be compared with weekday mortality rates.

The surveyors located deer carcasses along the highway by slowly driving along the shoulder of the road. Information collected on dead deer included the date, location (to the nearest 0.1 PM), sex, age, physical condition, traffic lane of collision, and proximity of topographic and cultural features (cutbanks, fill slopes, ditches, or guard rails). The age of the animal was estimated by examination of tooth replacement patterns or evaluation of cementum characteristics of an extracted tooth. Extracted teeth were sectioned and ages assigned by Matson's Laboratory (Montana). Information on weather and road conditions (e.g., wet, icy, dry) was also recorded during the survey. Deer carcasses were removed from the road and flagged to prevent double counting.

Surveys for Deer That Were Hit along SR 395 but Died in the Surrounding Area

The number of deer that were hit along SR 395 but that moved away from the highway and died in the surrounding brush was estimated through sampling of a series of transects perpendicular to the highway during fall migration 1992 and 1993 and spring migration 1993 and 1994. Two sampling areas were established within the Sandhouse project area based on work previously conducted by Taylor

(1988, 1991). One survey area was established in a crossing used by a large number of deer located between PM 44.9 and PM 45.4. The second survey area was located in a crossing used by few deer, located between PM 40.4 and PM 40.9 (immediately north of the south June Lake Loop junction).

Barriers to migration were absent in the high- and low-use survey areas. The west side of the high-use survey area borders the Rush Creek diversion canal, but this waterway was not considered a barrier to deer movement because numerous tracks were found entering and exiting the canal.

Rectangular sampling areas 0.8 kilometer (0.5 mile) long and 0.64 kilometer (0.4 mile) wide were established on both sides of SR 395 for the high- and low-use areas (Figure 2-2). Each sampling area was divided into five subareas 0.16 kilometer (0.1 mile) wide. In the high-use deer-crossing area, two transects were walked in each 0.16-kilometer-wide (0.1-mile-wide) subarea. In the low-use deer-crossing area, one transect was walked in each 0.16-kilometer-wide (0.1-mile-wide) subarea. The stratified design allowed for more intensive sampling in the high-use area, where more deer were expected to be located. Dividing the survey areas into five subareas ensured that transects were established throughout the sample area.

The starting point of each transect was randomly selected daily. Pedometers were used to determine the starting location of transects, and compass bearings were taken periodically while the transects were walked to maintain straight lines perpendicular to SR 395.

Each transect was approximately 10 meters (30 feet) wide; ten transects were walked on both sides of SR 395 in the area of high deer use, and five transects were walked on each side of SR 395 in the area of low deer use. Sampling was conducted during peak migration and was performed on one weekend day and two weekdays. This survey approach provided information on the distribution of mortalities throughout the week and allowed for comparison between weekday and weekend mortality.

Deer carcasses located during transect surveys were recorded only if they appeared to have been present for less than 1 month. Bleached bones from previous years were not recorded because most of the bone deposits did not contain skulls and the surveyors could not determine whether the bones were those of deer or domestic sheep (*Ovis airies*), which also use the project area. Information that was collected on deer mortalities included transect number, distance from the road (determined by the pedometer), date, age, and sex.

Data Analysis

To calculate weekend and weekday mortality rates, the total number of fatalities that occurred on weekends or weekdays was divided by the total number of days available during a period of movement. The Mann-Whitney test was used to test for differences in weekday and weekend mortality rates. Correlation analysis was used to test the relationship between seasonal traffic levels and seasonal fatalities and the relationship between the use of movement corridors and fatalities associated with movement corridors. Regression analysis was used to test the relationship between deer-use days and fatalities.

Summer Surveys

Summer surveys were used to determine the locations of deer use and estimated deer mortality during summer along SR 395.

Track-Count Surveys

Track-count surveys were conducted once every 2 weeks between late June and late September.

Deer Mortality Surveys along SR 395

Mortality surveys were conducted weekly in the Rush Creek and Sandhouse project areas

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Figure 2-2
Diagram of Sampling Plots to Estimate the Number of Deer that Die In and Adjacent to State Route 395

between late June and late September. Weekend mortality was determined through sampling of one day selected from Friday, Saturday, and Sunday, and weekday mortality was determined through surveys on one or two randomly selected days during each week.

Data Analysis

Data analysis was similar to the analysis used for spring and fall migration.

Demographic Parameters

Data from the post-hunting season and spring herd composition counts were provided by the California Department of Fish and Game.

Habitat Mapping

Habitat types were described in a 2.4–4.8 km (1.5–3.0 mile) corridor along SR 395. Color aerial photographs (1:24,000 scale) were used to determine the boundaries of habitats in the study area. Habitats were then delineated on 7.5-minute topographic maps, and the habitat types and their boundaries were verified in the field. Habitat types were described following the wildlife habitat relationships classification system (Mayer and Laudenslayer 1988).

Vehicle Traffic

Information on SR 395 hourly traffic volume was collected by Caltrans. Sufficient data were available for analysis of all four periods of deer movement in 1993 and 1994; early summer, late summer, and fall 1996; fall 1997; and spring, late summer, and fall 1998. Only nighttime traffic levels were used to evaluate deer fatalities because most deer are hit at night (Schafer and Penland 1985, Groot Bruinderink and Hazebroek 1996, Hughes et al. 1996).

Weather Data

Daily weather data (maximum and minimum temperatures and precipitation) were provided by the U.S. Forest Service, Mammoth Lakes Ranger District (District). The District also provided data on fuel moisture (sagebrush [*Artemesia tridentata*]), which was used as a surrogate for forage moisture.

Chapter 3. Description of the Study Area and Overview of the Casa Diablo Deer Herd

This chapter describes the study area and provides an overview of the Casa Diablo deer herd. The overview of the Casa Diablo deer herd has been summarized from a previous study (Taylor 1988) and our analysis of recent population changes. More detailed descriptions of movement and mortality patterns observed during this study are provided in Chapters 4, 5, and 6.

DESCRIPTION OF THE STUDY AREA

The study area is an approximately 17.6-kilometer-long (11-mile-long) corridor along SR 395 between the town of Lee Vining and south June Lake Loop (SR 158). Most of the study area is on lands administered by the Inyo National Forest. The northern end of the study area is approximately 2,266 meters (6,800 feet) in elevation, and the southern end is approximately 2,633 meters (7,900 feet) in elevation. Average daytime temperatures during spring, summer, and fall are 17°C (63°F), 26°C (80°F), and 11°C (52°F), respectively.

Physical Features

The terrain along the highway is generally flat; the eastern escarpment of the Sierra Nevada is immediately west of SR 395 and the Mono Craters are east of SR 395. The Glass Mountain Range extends east of the study area to the town of Benton.

Lee Vining Creek crosses SR 395 immediately north of the Rush Creek project area. Walker Creek, Rush Creek, and Parker Creek cross SR 395 in the Rush Creek project area; no creeks cross SR 395 in the Sandhouse project area. The Los Angeles Department of Water and Power (LADWP) aqueduct and a regional sewage treatment facility are at the junction of the Rush Creek and Sandhouse projects.

Habitat Types

Habitat types characteristic of the Great Basin are found in the study area. The six dominant habitat types are pasture, low sage, big sagebrush, antelope bitterbrush, montane riparian habitat, Jeffrey pine forest, and pinyon-juniper woodland.

Distribution and Abundance

The distribution and abundance of the habitat types in the study area are shown in Figures 3-1a and 3-1b and Table 3-1. Habitat types were mapped in a corridor that ranged from approximately 1.7 to 3.0 kilometers (1.1 to 1.9 miles) wide. The width of the corridor was arbitrary but included all survey areas and the expansion project. The Rush Creek project area is dominated by big sagebrush, pasture, and antelope bitterbrush, followed by pinyon-juniper woodland and montane riparian habitat. The Sandhouse project area is dominated by big sagebrush, followed by antelope bitterbrush, low sage, and Jeffrey pine forest habitat. Each habitat type is briefly described below.

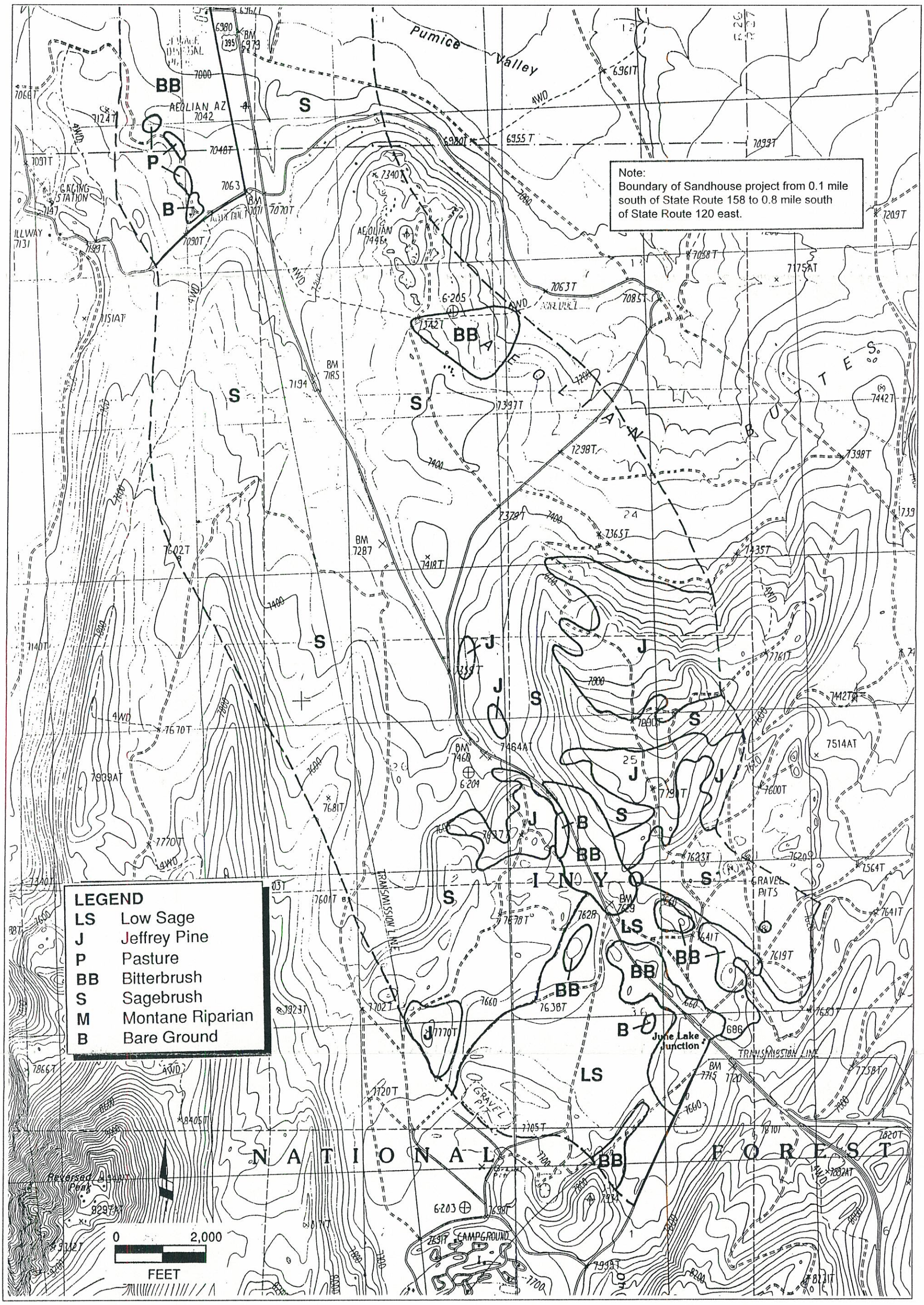

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Figure 3-1a
Habitat Types in the Sandhouse Project Area

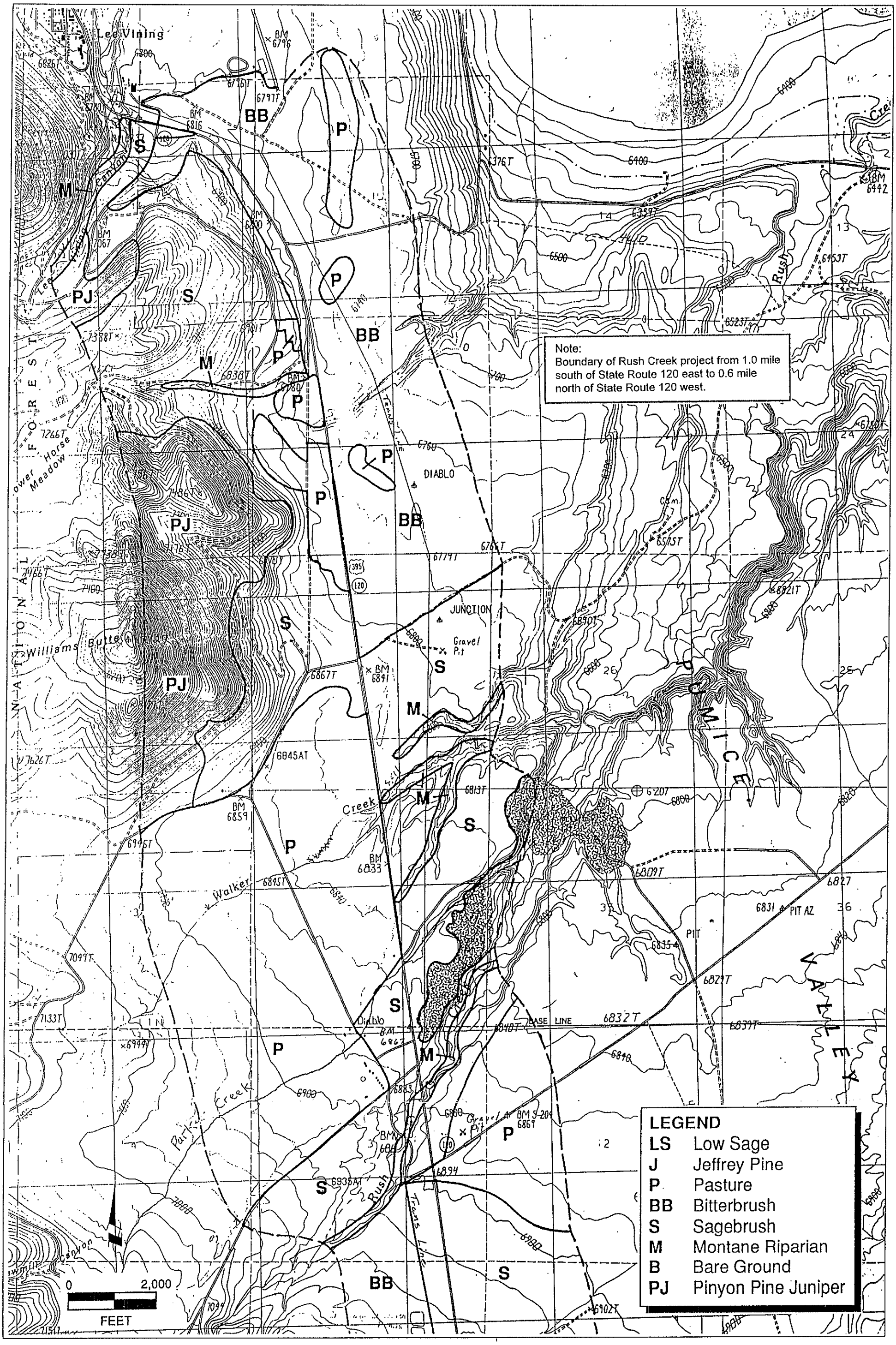

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Figure 3-1b
Habitat Types in the Rush Creek Project Area

exigua), wild rose (*Rosa woodsii*), and snowberry (*Symphoricarpus vacciniodes*).

Jeffrey Pine Forest. Jeffrey pine forest is found at the southern end of the Sandhouse project area, where elevations range from 2,530 to 2,630 meters (7,600 to 7,900 feet). The stands are characterized by mature trees (30–50 centimeters [12–20 inches] diameter at breast height) with an understory of big sagebrush, antelope bitterbrush, rubber rabbitbrush, and snowberry.

Pinyon-Juniper Woodland. Pinyon-juniper woodland habitat is found west of SR 395, at the north end of the Rush Creek project area. One large stand is on Williams Butte and another is near the junction of SR 395 and SR 120 west. These stands are dominated by pinyon pine (*Pinus monophylla*) and western juniper (*Juniperus occidentalis*) with an understory that is similar to that of the Jeffrey pine forests.

State Route 395

Lane Configuration

Prior to construction of the Sandhouse project in spring 1994, there was approximately 2.1 kilometer (1.3 mile) of four-lane highway between survey segment 32 and the southern portion of survey segment 37 (Figure 2-1a); the remainder of SR 395 in the study area was a two-lane highway. Construction of the Sandhouse project resulted in two northbound and southbound lanes, separated by a variable-width median, between Old West Portal Road and approximately the south loop of SR 158 (Figure 3-2). At the widest point, the northbound and southbound lanes are approximately 560 meters (1,680 feet) apart. No construction occurred on the Rush Creek project during the study documented in this report.

Traffic Patterns

Traffic patterns are influenced by the number of recreationists traveling to Mammoth Mountain and June Lake, which are destination resort areas near the study site. Average daily (24-hour) traffic levels varied substantially between the beginning of spring migration and completion of fall migration (Figure 3-3). Between mid-April and mid-May, daily traffic in the northbound lane totaled approximately 1,500 vehicles per day. Traffic levels increased during summer to approximately 3,600 vehicles per day in early August, then declined to approximately 1,100 vehicles per day in early November.

Nighttime traffic levels (1900–0800) were substantially lower than total daily traffic levels. Between mid-April and mid-May, traffic levels averaged approximately 275 vehicles per night. Traffic levels increased and averaged approximately 500 vehicles per night between July 1 and August 31, then declined to approximately 200 vehicles per night by early November.

Traffic levels also vary by day of the week, with weekend levels being substantially higher than weekday levels. The highest nighttime traffic levels occur Thursday through Saturday, when people are traveling to their recreation destinations, and the lowest nighttime levels occur Sunday through Wednesday. During spring, weekend traffic levels may increase 95% over weekday levels. During summer, weekend nighttime traffic levels may increase 60% in early summer and 100% during late summer over weekday levels. Nighttime weekend traffic levels increase 40% over weekday levels during fall.

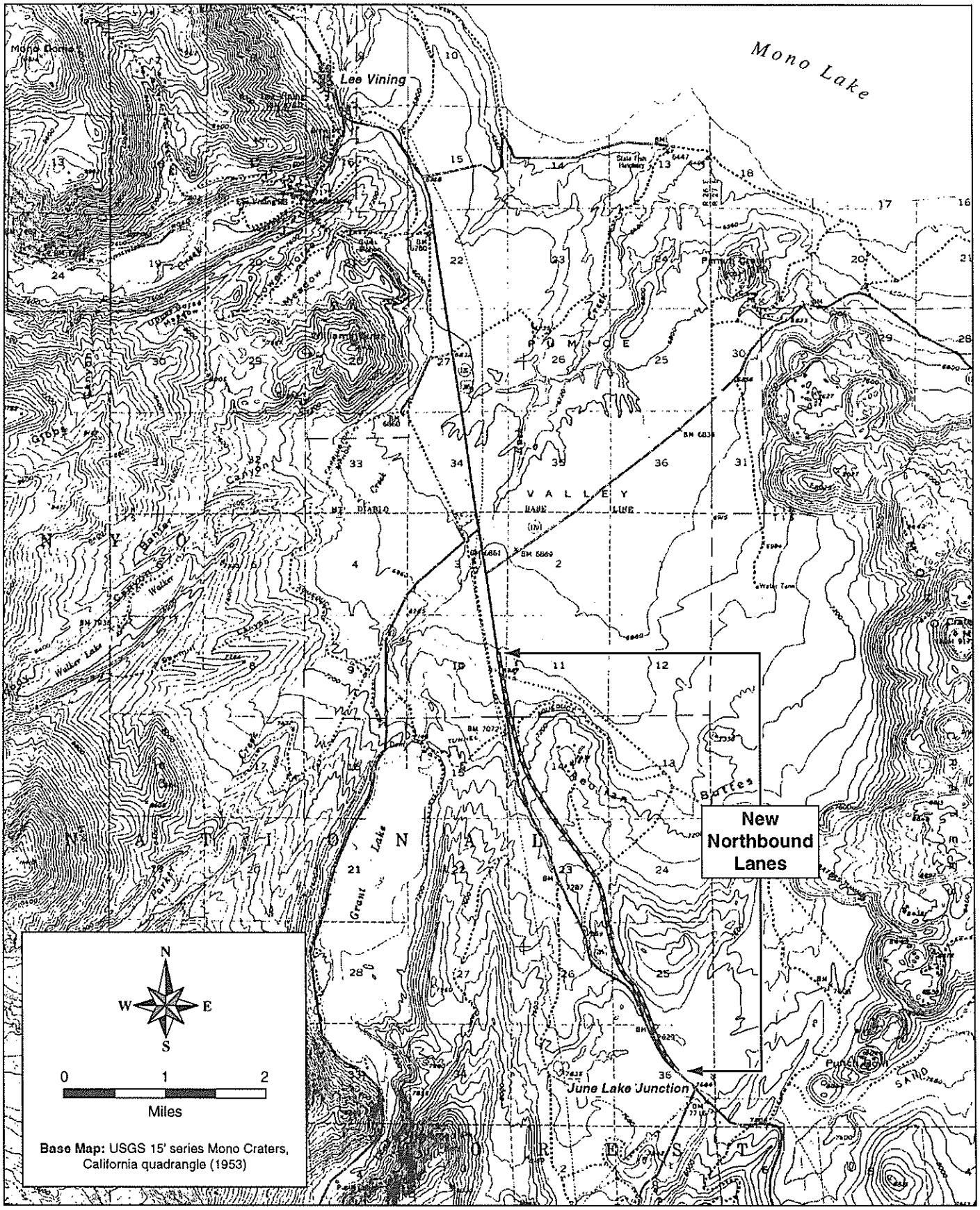

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Figure 3-2
Location of New Northbound Lanes and Variable-Width Median in the Sandhouse Project Area

Table 3-1. Abundance of Habitat Types in the Study Area

Habitat Type	Acres in Sandhouse Project Area	Acres in Rush Creek Project Area	Total Number of Acres
Pasture	10	1,410	1,420
Low sage	430	0	430
Big sagebrush	3,555	1,920	5,385[a]
Antelope bitterbrush	530	1,080	1,550[b]
Montane riparian habitat	0	120	120
Jeffrey pine forest	400	0	400
Pinyon-juniper woodland	0	480	480
Lava flow	0	85	85

Notes: [a] 90 acres overlap between the two project areas.
[b] 50 acres overlap between the two project areas.

Description of Habitat Types

Pasture. Pasture is a dominant habitat type in the Rush Creek project area. This habitat type is dominated by dry meadow sedge (*Carex douglassi*), Nebraska sedge (*C. nebraskensis*), bromegrass (*Bromus tectorum*) and bluegrass (*Poa pratensis*). Pastures are grazed extensively by domestic sheep.

Big Sagebrush and Low Sage. Big sagebrush is the most common habitat type in the study area. Throughout most of the study area, this habitat type is dominated by an association of big sagebrush, antelope bitterbrush (*Purshia tridentata*), and rubber rabbitbrush (*Chrysothamnus nauseosus*). At the southern end of the study area, some associations of this habitat type are dominated by low sage (*A. arbuscula*). In this study area, individual plants range in height from 0.5 meter to 1.5 meters (1.5 feet to 4.5 feet). This habitat type provides cover and forage for deer; however, the habitat value as cover is lower than that of the woodland or forests and the value as forage is lower than that of habitat dominated by antelope bitterbrush.

Antelope Bitterbrush. Antelope bitterbrush habitat is present in several locations throughout the study area and is most abundant in the Rush Creek project area. This habitat type is dominated by antelope bitterbrush with scattered big sagebrush and rubber rabbitbrush. Antelope bitterbrush habitat tends to be composed of dense stands with individual plants ranging from 1 to 2.6 meters (3 to 8 feet) tall. The density and height of these stands provide security and thermal cover for deer. Additionally, antelope bitterbrush is recognized as important mule deer forage because it is highly digestible and contains high levels of crude protein (Neal 1988).

Montane Riparian Habitat. Montane riparian habitat is found in the project area along the stream courses and as extensive stands on the summer range. This habitat type is dominated by quaking aspen (*Populus tremuloides*) with scattered coyote willow (*Salix*

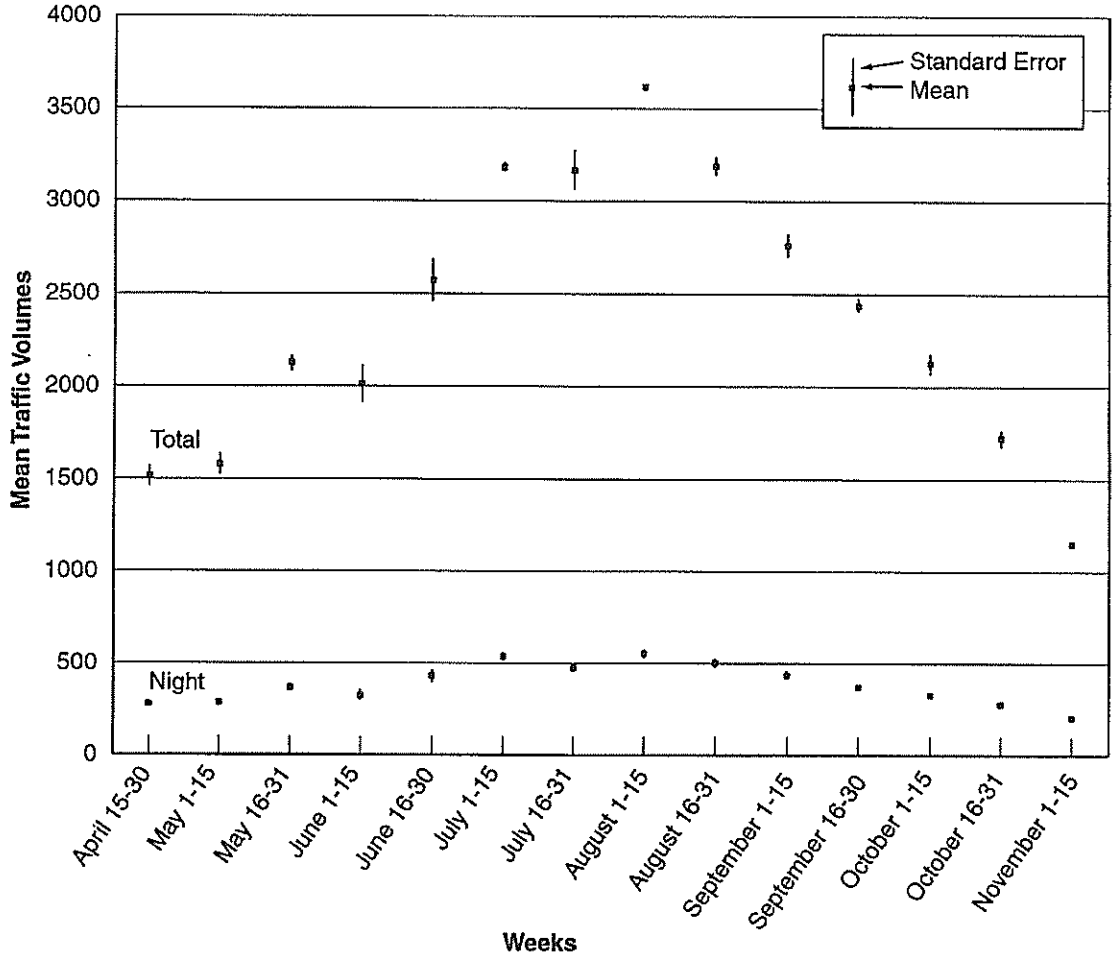

Figure 3-3
Means and Standard Errors of Daily Traffic Volumes

DESCRIPTION OF THE CASA DIABLO HERD

Population Characteristics

General Population

The Casa Diablo deer herd is a migratory population within Mono County. In the late 1940s, approximately 6,000 deer were in the population (Longhurst et al. 1952). In 1988, an estimated 1,500 deer remained in this herd (Taylor 1988). Recent population estimates for this deer herd are not available. There was probably a sharp population decline in the Casa Diablo herd during winter 1992–1993, similar to that of other herds on the east side of the Sierra Nevada (Bleich and Taylor 1998). Deer in these herds were in poor physical condition as a result of six consecutive years of drought, and mortality was high following the harsh winter of 1992–1993, in which snowfall was 120% of the normal level. Following 1993, the population has probably continued to decline at a slow rate, as has that of other migratory deer herds on the east side of the Sierra Nevada (California Department of Fish and Game 1998). Current studies indicate that fawn mortality is high on summer ranges and adult mortality occurs primarily on winter ranges (California

Department of Fish and Game 1998). Mountain lion (*Felis concolor*) predation is the dominant agent of mortality affecting adult does on this winter range (Bleich and Taylor 1998).

Fawn Recruitment

Fawn recruitment can influence annual population fluctuations. Recruitment rates have been low in this population; however, improved fawn recruitment in 1995 and 1998 may have resulted in slight increases in the population (Table 3-2).

sites along migration routes that are used by deer before they move to other seasonal ranges (Bertram and Rempel 1977). More than 70% of the deer from HA-1 migrated north, around the south end of the Mono Craters. The majority of these deer crossed SR 395 near the Aeolian Buttes and moved to another holding area, HA-2, north of SR 158, before moving to their summer ranges or another holding area, HA-3, north of Mono Lake. We concluded during the current study that some proportion of deer that crossed SR 395 south of the Aeolian Buttes used a new holding area near Reversed Peak (HA-4)

Table 3-2. Fawn Recruitment Rates in the Casa Diablo Herd, 1993-1998

Year	Fawn Recruitment Rates (Fawns per 100 Does)
1993	21
1994	22
1995	35
1996	15
1997	32
1998	47

Patterns of Deer Movement and Seasonal Ranges

Winter range for the Casa Diablo herd is near Benton, along the eastern border of California, and approximately 22.4 kilometers (14miles) from SR 395 (Figure 3-4). Spring migration generally begins during the second week of April, with deer moving west along the north and south flanks of the Glass Mountain Range. Approximately 86% of radio-collared deer have been documented moving along the south side of the Glass Mountains and using a holding area east of SR 395 along the upper portion of the Owens River (HA-1) (Taylor 1988). Holding areas are important foraging

or moved directly to lower elevation summer ranges. Spring migration is generally completed by mid-June.

Summer range is on the east slope of the Sierra Nevada at 2,195–3,050 meters (6,585–9,150 feet) in elevation (Taylor 1988). Most of the summer range is west of SR 395; however, a small number of deer summer east of SR 395. Areas of high deer concentrations include the area within and adjacent to SR 158, the June Lake Loop.

Fall migration generally begins the first week in October as deer move to lower elevations. The study area and the Owens River

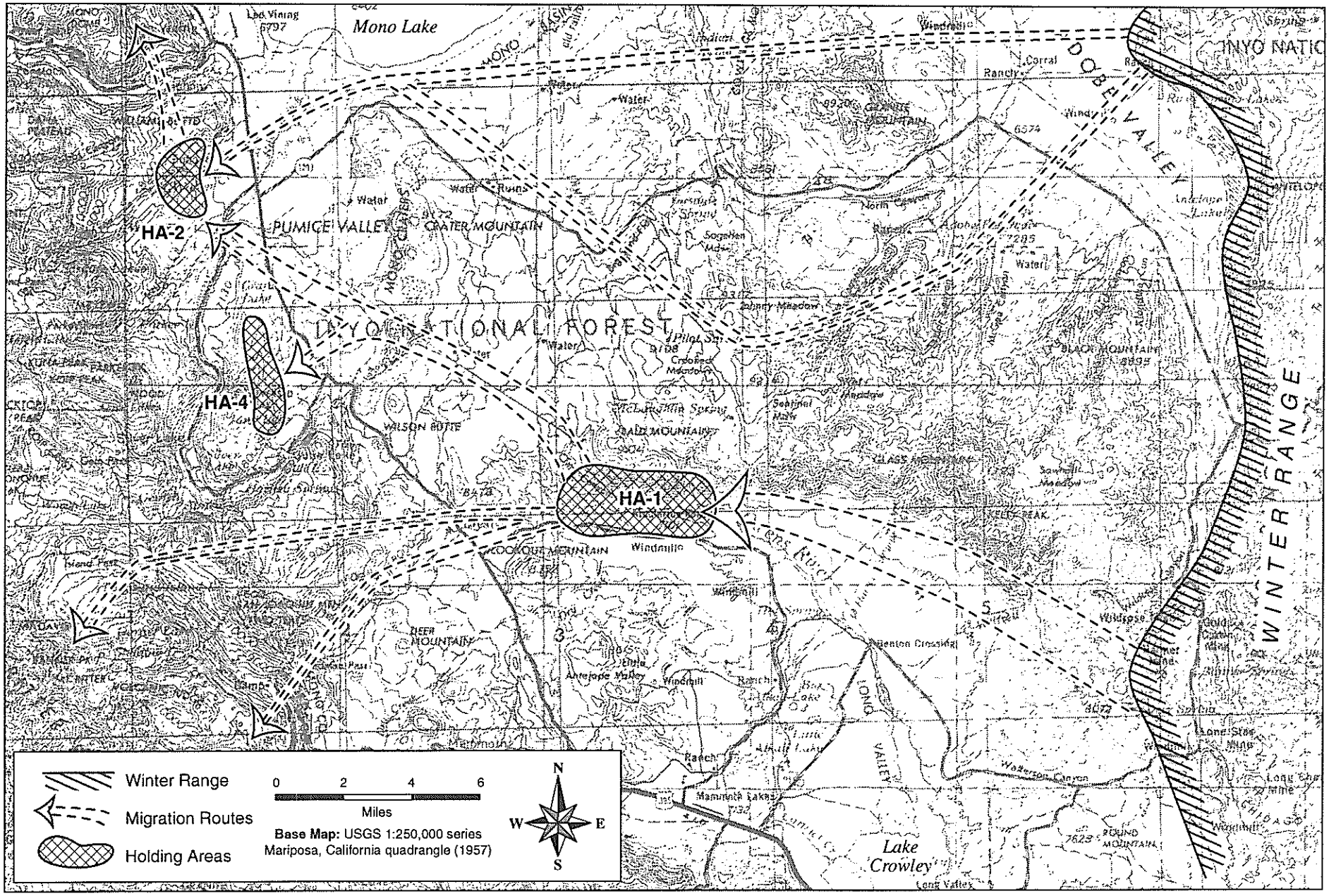

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Figure 3-4
Location of Winter Range, Major Migration Routes, and Holding Areas for the Casa Diablo Deer Herd

are holding areas where deer may delay fall migration prior to moving to the winter range. Deer generally leave the study area by the second week of November.

Chapter 4. Timing and Location of Spring and Fall Migration

This chapter describes the seasonal timing of spring and fall migration; the daily timing of movement; the use of movement corridors in the study area; and changes in the use of movement corridors before, during, and after realignment of SR 395.

RESULTS

Timing and Intensity of Migration

Spring Migration

The date of the arrival of migratory deer in the study area during spring migration varied by one month during the 6-year study period (Figure 4-1). The earliest date when deer arrived in the study area was April 4 and the latest arrival was May 4. Snowfall of the previous winter from 1992 through 1997 was as follows: 1992—120%, 1993—50%, 1994—150%, 1995—110%, 1996—100%, and 1997—131 % of normal, respectively. The data suggest that arrival dates in the study area were affected by the previous winter's snowfall because the earliest arrival dates were in 1994 and 1997, when there was the least amount of snowfall (50% and 100%) and the latest arrival dates occurred when snowfall exceeded 100% of normal. However, the relationship between

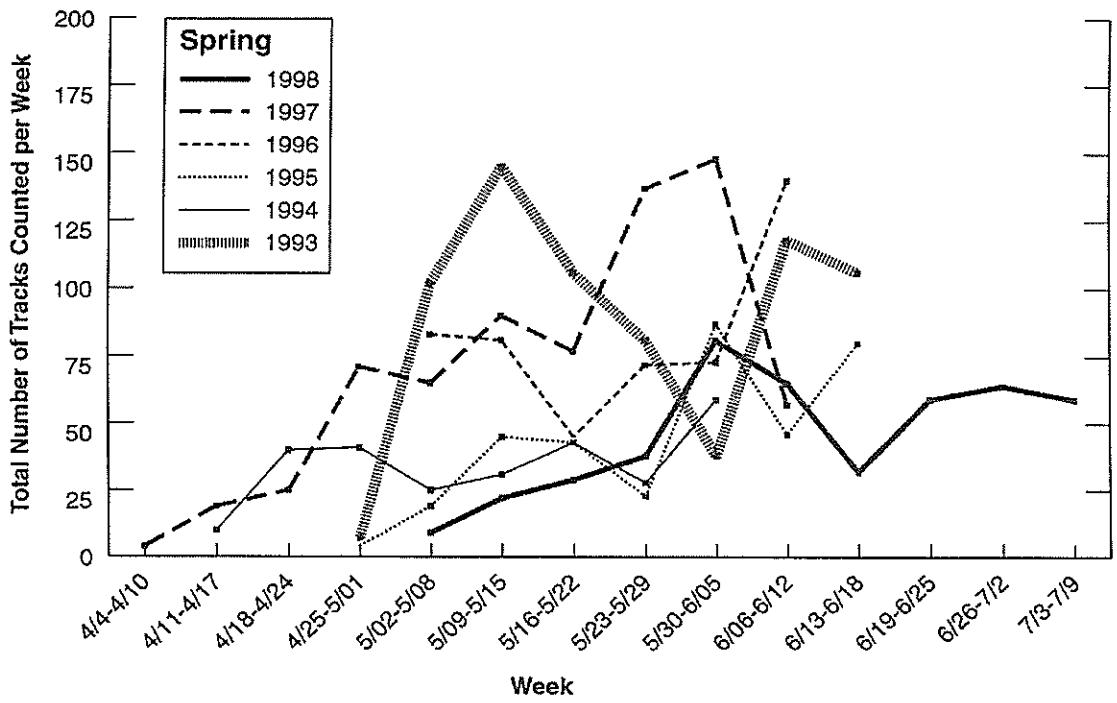


Figure 4-1
Tracks Counted Per Week during Spring

the arrival of deer in the study area and snowfall the previous winter was not statistically correlated (Spearman rank $r_s = 0.829$, $P > 0.05$).

The pattern of spring migration was similar between most years; the number of deer migrating through the area gradually increased, then peaked between the last week of May and early June, then declined rapidly. The relationship between the peak of migration and amount of snowfall was similar to the relationship between the start of migration and amount of snowfall. The latest peak occurred June 25–July 8, 1998, after a winter when snowfall was 131% of normal. The peak was June 6–12 in 1995 and 1996, when snowfall was 150% and 110% of normal; the peak was May 25–June 5 in 1994 and 1997, when snowfall was 50% and 100% of normal. The exception to this pattern was 1993, when the peak occurred May 8–22 and snowfall was 120% of normal.

Spring migration was generally completed by mid-June. The exception was spring 1998, when migration was not completed until July 8, approximately three weeks later than in previous years. Spring migration lasted 47.7 ± 5.79 days (X ± S.E.) from 1993 through 1996; however, it lasted more than 65 days in 1997 and 1998. The distribution of dates when spring migration was completed was less variable than that of the arrival of deer in the study area; however, the difference was not statistically significant (Kolmogorov-Smirnov, $P = 0.441$) because of the small sample size.

Reconnaissance surveys in the upper Owens River holding area (HA-1) also were used to determine the end of spring migration. In every year except 1998, very few deer were observed in the holding area in mid-June, and we concluded that migration had been completed and that most deer were on the summer range. In late June 1998, many individual adult does were observed in the holding area; these does were widely separated from the other individual animals.

Fall Migration

Fall migration started between September 29 and October 14 during the six years of observation. This 15-day timeframe (Figure 4-2) for fall migration was shorter than the 30-day period of the arrival of deer during spring migration. Fall migration was also initiated before the first snowfall in four out of the six years of observation; mean minimum temperatures in September and October were -0.5°C (31°F) and -3.8°C (25°F), respectively. In 1992, less than 0.25 centimeter (0.1 inch) of snow had fallen by October 29. In 1993, only 1 centimeter (0.4 inch) of snow had fallen by October 31, after most of the deer had passed through the study area. Similarly, in 1996, most of the deer had passed through the study area by October 26, when 12 centimeters (3 inches) of snow had fallen.

Fall migration was generally characterized by a peak in movement between the second and third week of October, followed by a gradual decline in the number of deer moving through the study area. Snowfall can affect deer movement during migration. On October 5, 1994 approximately 14 centimeters (6 inches) of snow fell in the southern end of the study area, at the highest elevation, and 75% of the tracks counted the next day were recorded in survey segments 5–8; few tracks were observed in the other survey segments. Apparently, the localized snowfall at higher elevations in the southern portion of the study area did not affect deer that summered at lower elevations in the northern portion of the study area. Fall migration was generally completed by the second week in November and lasted 35.3 ± 4.22 (X ± S.E.) days from 1992 to 1998, a significantly shorter duration (Mann-Whitney $P = 0.037$) than that of spring migration.

Daily Timing of Deer Migration

Peak periods of daily movement during spring ($n = 207$ deer) and fall ($n = 281$ deer) migration occurred at dawn and dusk (Figure 4-3); however, there were significant

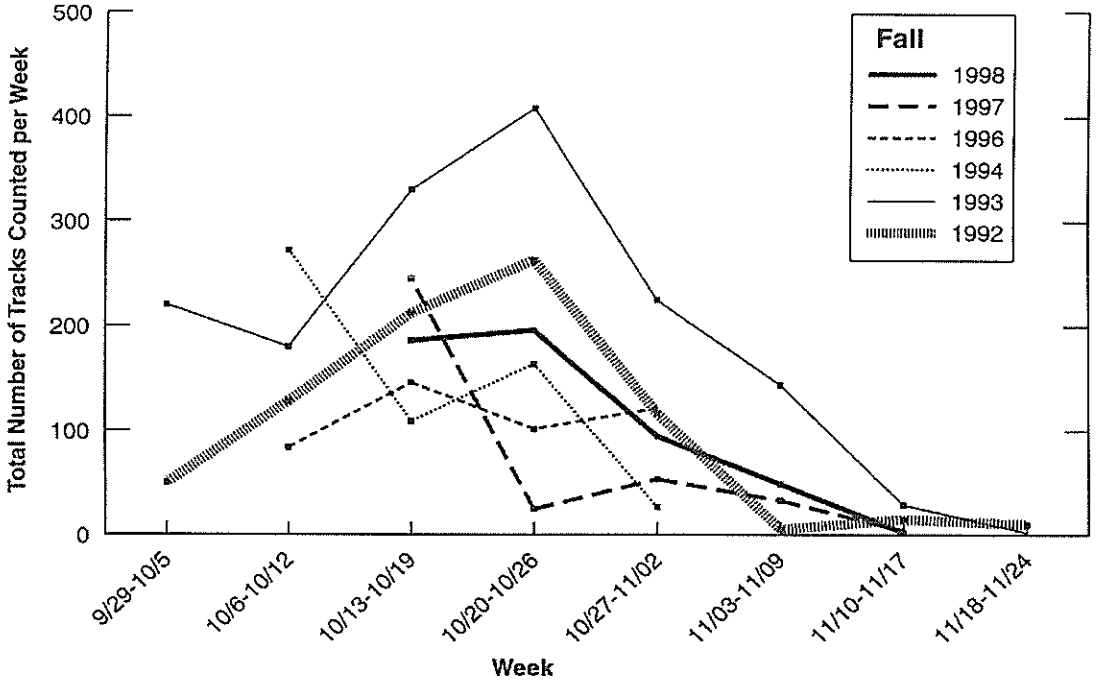


Figure 4-2

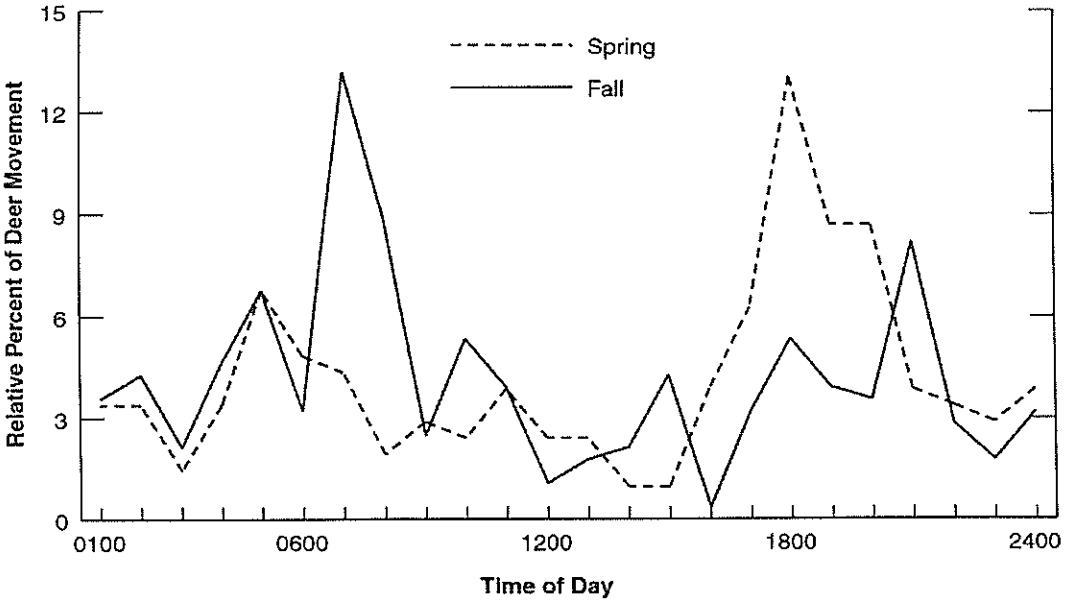


Figure 4-3
Daily Activity Levels of Deer during Spring and Fall Migrations

differences (P<0.01) between seasons in the time of day when movement occurred. During spring, most movement occurred between 0500 and 0759 and again between 1800 and 2059. During fall, most movement occurred between 0700 and 0859 and again at 1800 and 2000. Examination of Figure 4-3 also shows that more deer movement occurred during the day during fall migration than during spring migration.

Location of Deer Migration

Overview

During spring migration, 76.6% of the deer tracks (n = 2,973) were recorded in the Sandhouse project area (survey segments 1–24) and during fall migration, 72.6% of the deer tracks (n = 4,366) were recorded in this area. Further examination of tracks showed that 91% of the tracks were recorded between segments 5 and 29 during spring migration and 93.9% were recorded between these segments during fall migration (Figure 4-4). The low number of tracks counted in the majority of the Rush Creek project area is consistent with earlier results (Taylor 1988). Porter and Church (1987) showed that the location of study area boundaries could affect inferences about habitat utilization when habitats or patterns of use were aggregated. Therefore, the study area boundaries were adjusted to include only segments 5–29 for the analysis of movement among the survey segments.

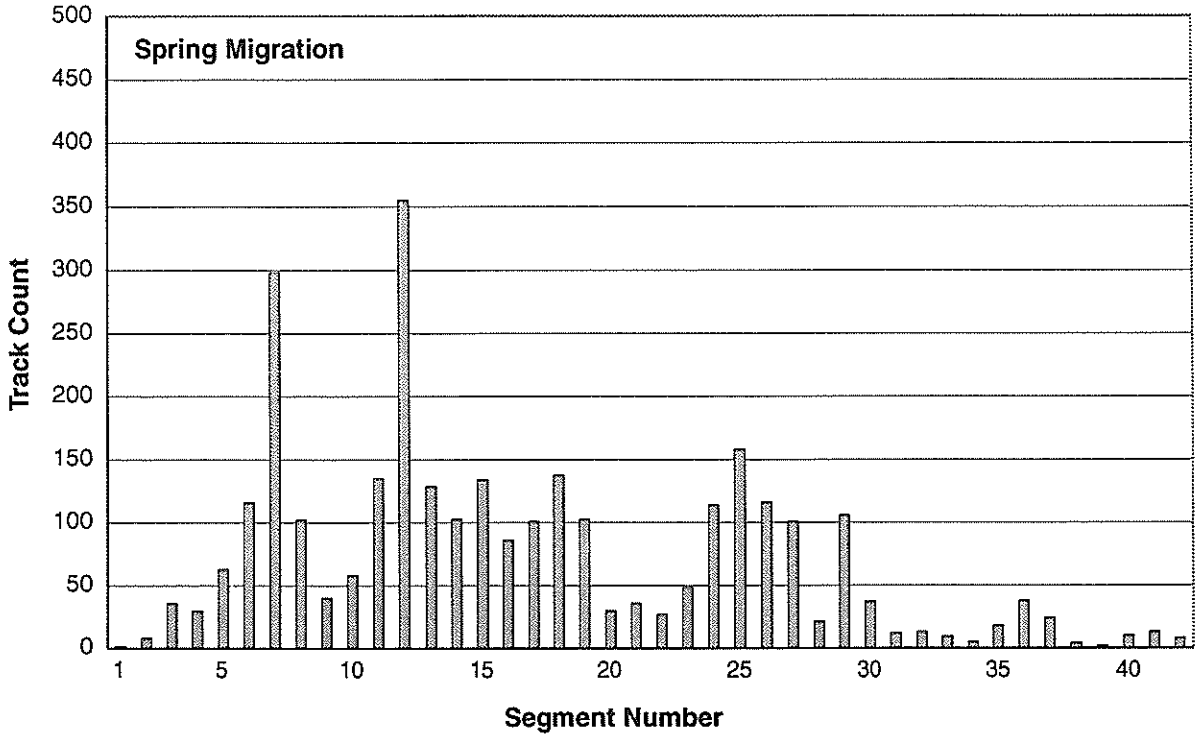
Distribution of Deer Movement in Migration Corridors

The distribution of deer tracks in each survey period during spring and fall migration was significantly different (P<0.01) than expected. Deer movement through survey segments 5–29 before, during, and after realignment of SR 395 during spring and fall migration is summarized in Table 4-1. Deer utilization of each survey segment is described as greater than the segment's availability (+), equal to its availability (=), or less than its availability (-). Availability refers to the width of the survey segment (0.32 kilometer [0.2 mile]). Bonferroni confidence intervals for each segment and survey period are provided in Appendix B.

Spring Migration. During spring migration, deer utilization of each survey segment was consistent 72% of the time during the three survey periods. For instance, deer utilization of segment 6 was always equal to its availability, while deer utilization of segment 7 was always greater than its availability. There were changes in utilization in seven segments during the three periods and in five of those (segments 5, 8, 10, 12, and 18), utilization changed during construction. In three segments, deer movement increased during construction (e.g., utilization in segment 8 changed from avoidance to no preference). Changes in segments 25 and 29 occurred after construction. Additionally, when a change in use occurred in a segment, there were no reciprocal changes in adjacent segments, suggesting that deer use did not move to those segments.

During spring migration, deer utilization of survey segments 7 and 12 was greater than their availability. These segments are located in Jeffrey pine and sagebrush habitats, and our observations indicate that herbaceous vegetation was more abundant in these segments than in others. Utilization of segments 5, 9,10, 20–23, and 28 was lower than their availability. Segment 5 was located in low sagebrush habitat; segments 9, 10, and 20 were in big sagebrush habitat, and segments 23 and 28 were in bitterbrush habitat. The remaining 15 segments were used in proportion to their availability, and most were located in sagebrush habitat.

Fall Migration. During fall migration, deer utilization of each survey segment during the three periods was consistent 56% of the time. There were changes in 11 segments, and 54% of those changes occurred during construction (in segments 5, 10, 20–22, and 25). In five of those segments, deer use declined during construction (e.g., segment 5 changed from preference to use in proportion to its availability). However, there



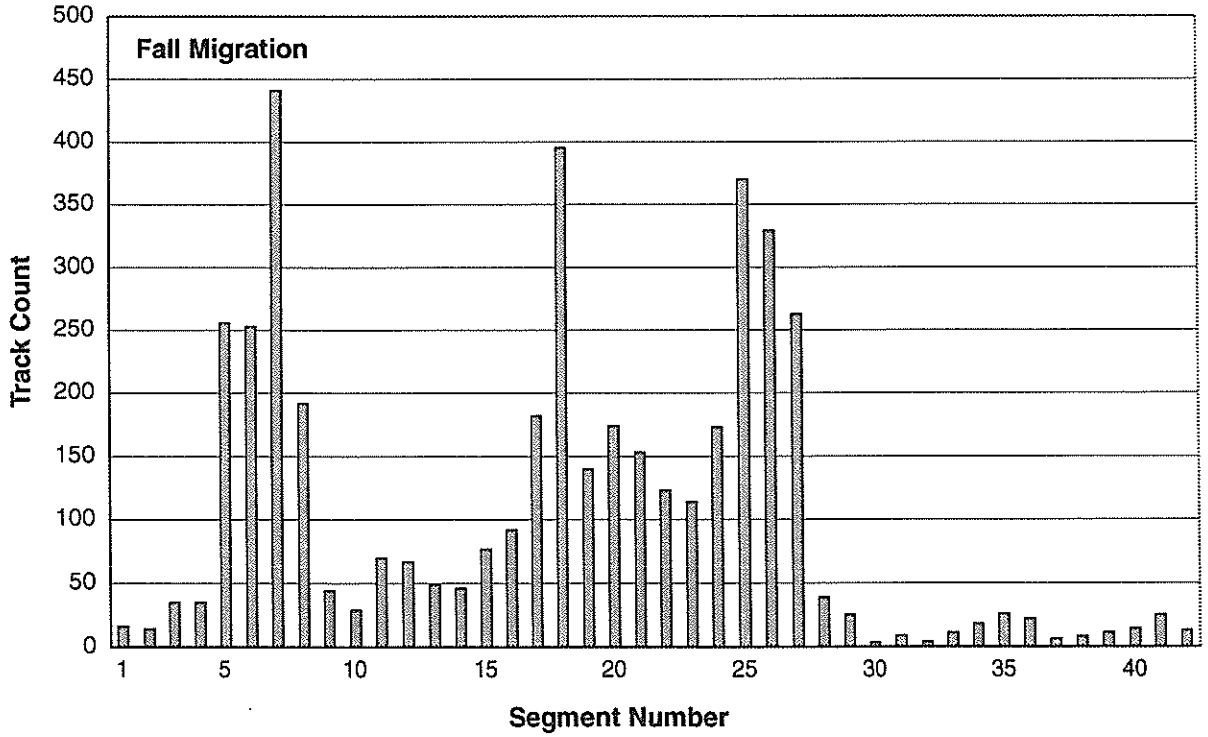


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Figure 4-4
Cumulative Track Summary for Sandhouse and Rush Creek Project Areas, 1992-1998

Table 4-1. Utilization of Survey Segments during Spring and Fall Migration before, during, and after Realignment of SR 395

Survey Segment	Spring Migration			Fall Migration			Habitat
	Before	During	After	Before	During	After	
5	=	-	-	+	=	=	low sagebrush
6	=	=	=	+	+	=	bitterbrush
7	+	+	+	+	+	+	Jeffrey pine
8	-	=	=	=	=	=	Jeffrey pine
9	-	-	-	-	-	-	sagebrush
10	-	=	-	-	=	-	sagebrush
11	=	=	=	-	-	-	sagebrush
12	=	+	+	-	-	-	sagebrush
13	=	=	=	-	-	-	sagebrush
14	=	=	=	-	-	-	sagebrush
15	=	=	=	-	-	=	sagebrush
16	=	=	=	-	-	-	sagebrush
17	=	=	=	=	=	=	sagebrush
18	+	=	=	+	+	+	sagebrush
19	=	=	=	=	=	-	sagebrush
20	-	-	-	=	-	=	sagebrush
21	-	-	-	=	-	=	bitterbrush
22	-	-	-	=	-	-	bitterbrush
23	-	-	-	-	-	=	bitterbrush
24	=	=	=	=	=	-	bitterbrush
25	=	=	+	+	=	+	bitterbrush
26	=	=	=	+	+	+	bitterbrush
27	=	=	=	+	+	+	bitterbrush
28	-	-	-	-	-	-	bitterbrush
29	=	=	-	-	-	-	sagebrush

Notes: + Utilization is greater than availability.
= Utilization is in proportion to availability.
- Utilization is less than availability.

were no reciprocal changes in utilization patterns in segments adjacent to 5, 10, and 25, indicating that deer did not move to those segments.

The utilization of survey segments by deer during fall migration was different from their utilization during spring migration. During fall, utilization of survey segments 6, 7, 18, and 25–27 was greater than their availability. Segment 7 was in Jeffrey pine habitat, segment 18 was in big sagebrush habitat, and segments 6 and 25–27 were in bitterbrush habitat. The utilization of segments 9–16, 22–23, and 28–29 was less than their availability. All of these segments crossed through sagebrush except segments 23 and 28, which crossed through bitterbrush. The remaining seven segments were used in proportion to their availability.

DISCUSSION

Timing and Intensity of Migration

Spring Migration

During this study, migrating deer arrived in the study area between early April and early May. These observations are consistent with those of the earlier study of the Casa Diablo herd that determined that deer started leaving the winter range, 22.4 km (14 miles) east of the study area, as early as the end of March but that most deer left between early April and mid-May (Taylor 1988). Arrival dates in the study area are also in the range of dates described by Kucera (1992) and Taylor (1997) for other migratory deer herds that initiate their spring migration from the base of the eastern Sierra Nevada.

The arrival of deer in the study area and the peak period of movement varied substantially among the six years of observation, with a trend of later arrival dates and later peak periods of movement following years of heavy winter snowfall. For instance, in 1997, following a winter of 100% of normal snowfall, deer began arriving in the study area April 4, and peak migration occurred between May 27 and June 3. In 1998, following 131% of normal snowfall, deer began arriving May 4, and peak migration occurred between May 31 and June 8 and again between June 25 and July 8.

This observation is similar to those of numerous other studies of migratory deer (Leopold et al. 1951, Bertram and Rempel 1977, Garrott et al. 1987, Loft et al. 1989, Taylor 1997). These studies concluded that annual weather patterns affect plant phenology and forage quality, which influence deer movement during spring. The combination of dry winters and warm spring temperatures results in early departures and early peak periods of movement during migration; the combination of wet winters and cool spring temperatures results in later arrival dates and migrations of longer duration. Plant phenology, as influenced by annual weather patterns, probably has a greater effect on the start and peak period of spring migration than on its completion. There was not a significant statistical correlation between the arrival of deer during spring migration and the previous winter's snowfall; however, the analysis did not evaluate changes in plant phenology.

Kucera (1992) concluded that spring migration of deer that wintered south of the Casa Diablo herd was not influenced by the previous winter's snowfall. This study demonstrated that the timing and duration of spring migration was similar from year to year, even though winter precipitation varied between years. However, the deer population studied by Kucera migrated over the crest of the Sierra Nevada to its traditional summer ranges on the west slope of the mountain range. Deer in the Casa Diablo herd are responding to plant phenology on migration corridors and summer ranges on the east slope of the Sierra Nevada.

Spring migration of the Casa Diablo herd was usually completed by mid-June. This allowed does to become established on traditional home ranges prior to fawning, which occurs between mid-June and the end of July, with a peak in early July in the Casa Diablo herd. The exception was in 1998, when

migration was not completed until early July. In late June 1998, many isolated does were observed in the upper Owens River holding area. Their distribution and behavior were similar to those described for does prior to fawning (Dasmann and Taber 1956, Geist 1981). The El Niño event in winter 1998 and cool spring temperatures delayed spring migration, and some deer may have been forced to give birth in the holding areas, as described also by Loft et al. (1989). Thus, holding areas are important components of migration routes because they allow deer to obtain the highest quality forage available during migration (Bertram and Rempel 1977) and they may also be used as fawning areas during years of persistent snow.

Fall Migration

On the west side of the Sierra Nevada, migratory deer initiate fall migration in response to snowfall, which affects forage quality/ quantity (Leopold et al. 1951, Bertram and Rempel 1977, Loft et al. 1989, Kucera 1992). However, previous studies of migratory deer on the east side of the Sierra Nevada demonstrated that fall migration was not always initiated by fall storms (Taylor 1988, 1997). The current study indicates that fall migration was initiated before the first snowfall in four out of the six years of the study, supporting Taylor's earlier reports. In Colorado, Garrott et al. (1987) observed that migratory deer initiated fall migration before the first snowfall or freezing temperatures on the summer range. These authors hypothesized that deer moved in response to changes in photoperiod and that migration allowed deer to take advantage of higher quality forage on winter ranges.

Deer in the Casa Diablo herd often initiated fall migration before the first snowfall during the study. Mean minimum temperatures in September and October were below 0°C (32°F), and after several consecutive days of subfreezing weather, a large number of deer tracks was always observed in the study area, and we identified this as the initiation of fall migration. The initiation of fall migration occurred during a very short timeframe compared with the timeframe of the arrival of deer during spring migration. Additionally, most deer movement during fall migration generally occurred at the beginning of migration, rather than the end of migration as in spring. The exception was 1993, when deer delayed fall migration in the study area prior to moving to their winter ranges. It was concluded that in response to immediate changes in forage quality resulting from subfreezing temperatures, deer move off the summer range and through the study area quickly, seeking better forage on lower elevation and warmer winter ranges.

Daily Timing of Deer Migration

Deer movement during spring and fall migration occurred primarily at dawn and dusk. However, deer were more active later in the morning, during the day in general, and earlier in the evening during fall migration than during spring migration. Crepuscular peaks in deer movement and seasonal shifts in peak movement are well documented (Kammermeyer and Marchinton 1977, Beier and McCullough 1990, Hayes and Krausman 1993). Changes in the daily periods of activity between spring and fall migration may be influenced by temperature, forage quality, and/or human recreation activities. Deer restrict their activity during cold periods to conserve energy (Moen 1976, Beier and McCullough 1990). During fall, forage quality is substantially reduced compared with spring conditions (Taylor 1997), and deer spend more time foraging when forage quality/quantity is reduced (Kammermeyer and Marchinton 1977, Kie et al. 1991). Therefore, because temperatures are frequently below freezing at night, deer become more active during the day, when it is warmer, to acquire the additional forage necessary to maintain their nutritional plane. Additionally, the hunting season for this herd generally takes place from mid-September through the first week of October. Disturbance by the large number of hunters in the study area on weekends could also be affecting deer behavior during early migration (Puglisi et al. 1974, Romin 1994).

Location of Deer Migration

Overview

More than 70% of the deer migrating through the study area moved through the Sandhouse project area; Taylor (1988) reported a similarly large proportion of radio-collared deer moving through this area. The use of survey segments 5–29 is disproportionately high because of the location of migration routes entering the study area, the location of holding areas, and habitat conditions in the project area. More than 85 % of the radio-collared deer from the Casa Diablo deer herd migrated along the southern side of the Glass Mountain Range to the upper Owens River holding area. From there, 72% of the deer moved north and west, crossing SR 395 in the project area (Taylor 1988), to use holding areas on Reversed Peak and north of the June Lake Loop road. Few deer cross SR 395 in the southern extreme of the Sandhouse project area, where the habitat is dominated by low sagebrush. Because these plants are short, they do not provide adequate cover for deer, and sagebrush is not important forage during spring migration (Taylor 1997).

Few deer cross through the Rush Creek project area because only 14% of the radio-collared deer migrate along the northern side of the Glass Mountain Range. Also, most of the northern portion of the Rush Creek project area consists of large polygons of pasture habitat, which does not provide suitable cover for migratory deer. The pastures in this study area were not along the shortest and easiest route between winter and summer ranges, as observed by Bertram and Rempel (1977), and Brown (1992) has observed that migratory deer may avoid agricultural areas within sagebrush habitats.

The distribution of deer observed along SR 395 was not uniform and also varied seasonally. These findings are similar to those of other studies (Bellis and Graves 1971, Mansfield and Miller 1975, Carbaugh et al. 1975, Feldhamer et al. 1986, Romin 1994) that conclude that the distribution depends on different resource requirements.

Distribution of Deer Movement in Migration Corridors

It is widely accepted that deer use traditional migration corridors to move between winter and summer ranges (Leopold et al. 1951, Gruell and Papez 1963, Bertram and Rempel 1977, Garrott et al. 1987, and Brown 1992). Leopold et al. (1951) found that the widths of migration corridors ranged from 0.8 kilometers (0.5 mile) to several meters (yards). Bertram and Rempel (1977) found that the width of migration corridors ranged from 1.2 kilometer (0.75 mile) to narrower corridors that are influenced by topography. In the present study, the deer were observed to select and avoid corridors that are as little as 0.32 kilometers (0.2 mile) wide (segment 7) up to 1 kilometer (0.6 mile) wide (segments 25–27). The corridors may be narrower or wider than we identified; however, to refine the measurements, it would be necessary to differentiate between an individual trail and the minimum number of trails that, when aggregated, could be termed a corridor.

Spring Migration. Deer movement through the survey segments was very consistent during spring migration. There were changes in deer movement in five segments during construction; however, deer use increased in three of those segments. Additionally, there was no change in segments adjacent to those five segments indicating that deer shifted their movement in response to construction activities. The potential for disturbance from construction during spring migration is minimized because the least amount of deer movement occurred during the day, when construction activities were being conducted. There is little evidence to suggest that construction activities during spring migration caused deer to alter their use of movement corridors.

During spring migration, deer utilization of survey segments 7 and 12 was greater than their availability. Both of these corridors would

provide the shortest route to the Reversed Peak holding area (HA-4) and HA-2, north of the June Lake Loop road.

These migration corridors were in Jeffrey pine and big sagebrush habitat. Jeffrey pine forest is found in only 8% of the area studied for deer movement, and Eberhardt et al. (1984) indicated that mule deer appeared to be attracted to trees in sagebrush-dominated habitat. However, the utilization of half of this habitat type in the project area was equal to its availability. Deer also avoided sagebrush habitat, and its utilization was equal to its availability. Field observations indicated that grasses and herbaceous vegetation were more abundant in the corridors defined by survey segments 7 and 12. Deer on the east side of the Sierra Nevada increase their intake of grasses and herbaceous vegetation during spring (Leach 1956, Taylor 1997). Loft et al. (1984) also concluded that deer migrate in response to the phenology of grasses and forbs, rather than phenology of browse species. Therefore, corridors 7 and 12 provided the forage and cover sought by deer during spring migration.

Segments 9 and 10 may have been avoided because of local topographic features. There is a rock cliff along SR 395, immediately south and east of these segments. Deer moving from the east would move beyond the cliff, crossing SR 395 north of segments 9 and 10. It is not clear why deer avoided segments 20–23. These segments would provide direct access to HA-2 and they cross through big sagebrush and bitterbrush, habitat types for which, in general, utilization was equal to availability. These segments, however, do lack topographic features that could provide deer with additional cover. Segment 28 was probably avoided because it was at the northern extreme of the movement area, where there is less deer movement.

Fall Migration. During fall migration, 54% of the changes in the use of movement corridors occurred during the construction period, and most of those changes were a reduction in use compared with use during the preconstruction period. The reduction in use of segment 5 also occurred during spring migration. However, there were no changes in the use of corridors adjacent to segment 5 that would suggest that deer movement switched to an adjacent corridor. There was less use in segment 25 during construction; however, no construction occurred in segment 25. Therefore, it does not appear that construction activities affected deer movement in segment 5 or segment 25.

Changes in the pattern of movement in segments 20–22 was different than in segments 5 and 25. These segments were adjacent to each other, and the reduction in use in segments 20 and 21 occurred only during fall migration. Additionally, more deer movement occurred during the day, when construction activities were occurring. These data indicate that construction activities could affect deer movement; however, the impacts were restricted to these corridors and were temporary.

During fall migration, deer selected two survey segments (6 and 7) dominated by bitterbrush and Jeffrey pine at the southern end of the study area; segment 18 in the middle of the study area, which is dominated by big sagebrush; and survey segments 25–27 at the northern end, which is dominated by bitterbrush. Segment 7 is the same segment selected by deer during spring migration, where the Jeffrey pine habitat provides excellent cover. Survey segment 18 crosses sagebrush; although this habitat type does not provide the best cover in the study area, this segment was also identified as an important movement corridor by Taylor (1988). There is a small drainage in the segment, and in some areas deer follow drainages and low points, using them as cover (Gruell and Papez 1963). The bitterbrush in segments 25–27 is an important forage species for deer during late summer and fall (Leach 1956, Taylor 1997) and, because of its height, bitterbrush provides better cover than sagebrush. Additionally, the sewage treatment ponds and LADWP aqueduct appear to be important water sources in the study area.

Segments dominated by sagebrush generally are avoided by deer during fall. Sagebrush is

shorter than the conifer stands and bitterbrush, and it does not provide the cover that is apparently preferred by deer during fall. It appears that the deer selected habitat types that provide excellent cover during fall. This would be advantageous because deer in the Casa Diablo herd are more active during the day in fall than in spring.

Comparison of Spring and Fall Migration. Deer movement through the survey segments was more consistent across the three observation periods during spring migration than during fall migration. However, construction activities may have temporarily disrupted deer movement in three survey segments during fall migration. If this disturbance had not affected deer movement, consistency of movement during the three observation periods would have been very similar between spring migration (72%) and fall migration (68%).

Seasonal differences in habitat utilization by migrating deer appear to be related to differences in habitat requirements and changes in resource availability between seasons. During spring migration, deer gradually move to higher elevations seeking the best available forage. They selected two segments that appeared to provide more abundant herbaceous vegetation than other segments. Approximately 60% of the segments were used in proportion to their availability because forage quality is high throughout most of the migration corridor.

Fall migration begins in response to rapidly declining forage quality, and deer feed during the day during fall migration because the nights are cold and deer decrease their activity in response to cold. During fall migration, the deer seek Jeffrey pine stands and bitterbrush because bitterbrush provides excellent forage and both habitats provide better cover than sagebrush. During fall migration, the deer avoided segments with poor cover and forage or selected segments that provided cover, forage, and, in some cases, water; therefore, utilization of only 32% of the segments was equal to their availability.

Chapter 5. Timing and Location of Summer Movement

This chapter describes the timing and location of summer deer movements and identifies factors that may affect those movements.

RESULTS

Timing and Intensity of Summer Movement

Summer movement is divided into two periods based on changes in the number of tracks counted. Early summer begins when spring migration is completed and generally lasts 8–10 weeks. The exception was in 1998, when this period lasted only 5 weeks (Figure 5-1). During early summer, the mean number of tracks counted was 37%–66% lower than the mean number of tracks counted during peak spring migration for the same year.

The late summer period was characterized by a sharp increase in the number of tracks counted and generally lasted from August to the initiation of fall migration. The peak number of tracks during late summer was generally counted between August 21 and September 16;

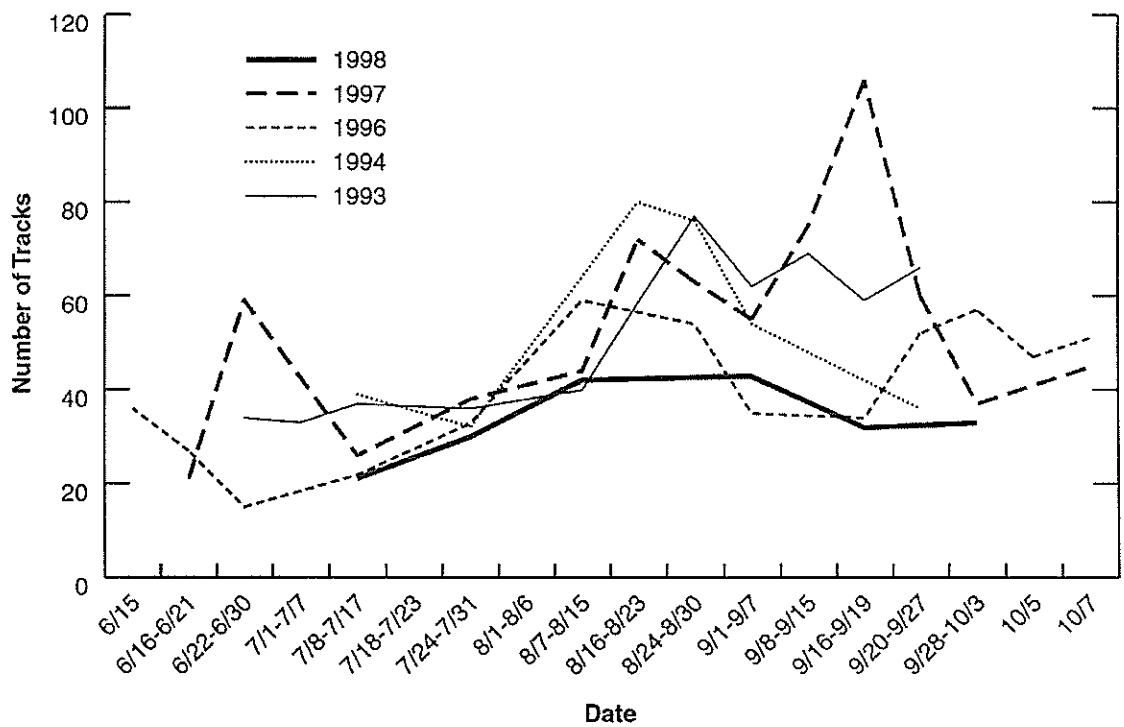


Figure 5-1
Timing and Intensity of Deer Movement during Summer

however, the peak number of tracks counted in 1996 was on August 9. The number of tracks counted declined after the late summer peak until the initiation of fall migration.

Location of Summer Movement

During early summer, 681 deer tracks were counted in the study area, and 71.8% were recorded in the Sandhouse project area (survey segments 1–24); during late summer, 1,696 deer tracks were recorded in the study area, and 68.7% were counted in the Sandhouse project area. Further examination of the data showed that 89.4% of the tracks were recorded in segments 5–29 during early summer and 95.6% were recorded in these segments during late summer (Figure 5-2). These data are similar to those gathered during migration; therefore, this study evaluated movement only through segments 5–29 during the summer period.

Early Summer

There was a significant difference ($P<0.01$) in the distribution of tracks counted in the survey segments in early summer, indicating that deer did not use the survey segments equally. Deer utilization of each survey segment was consistent during the three survey periods 32% of the time (Table 5-1). There were changes in 17 segments, and 70% of these occurred during construction. Eight of the changes observed during construction consisted of increased use, while changes in four segments consisted of decreased use. Less use occurred in segments 9, 16, 21, and 23. There was no change in use in segment 10, indicating that deer did not switch their movement to segment 10. There was an increase in use in segment 8. It is not clear whether the changes in use between segments 8 and 9 are related, however, because there is a gap of approximately 0.9 kilometers (3,000 feet) between these two segments. Use increased in segment 15, suggesting that deer avoided segment 16 by increasing their use of segment 15. No reciprocal changes in use were observed in segments adjacent to 21 and 23.

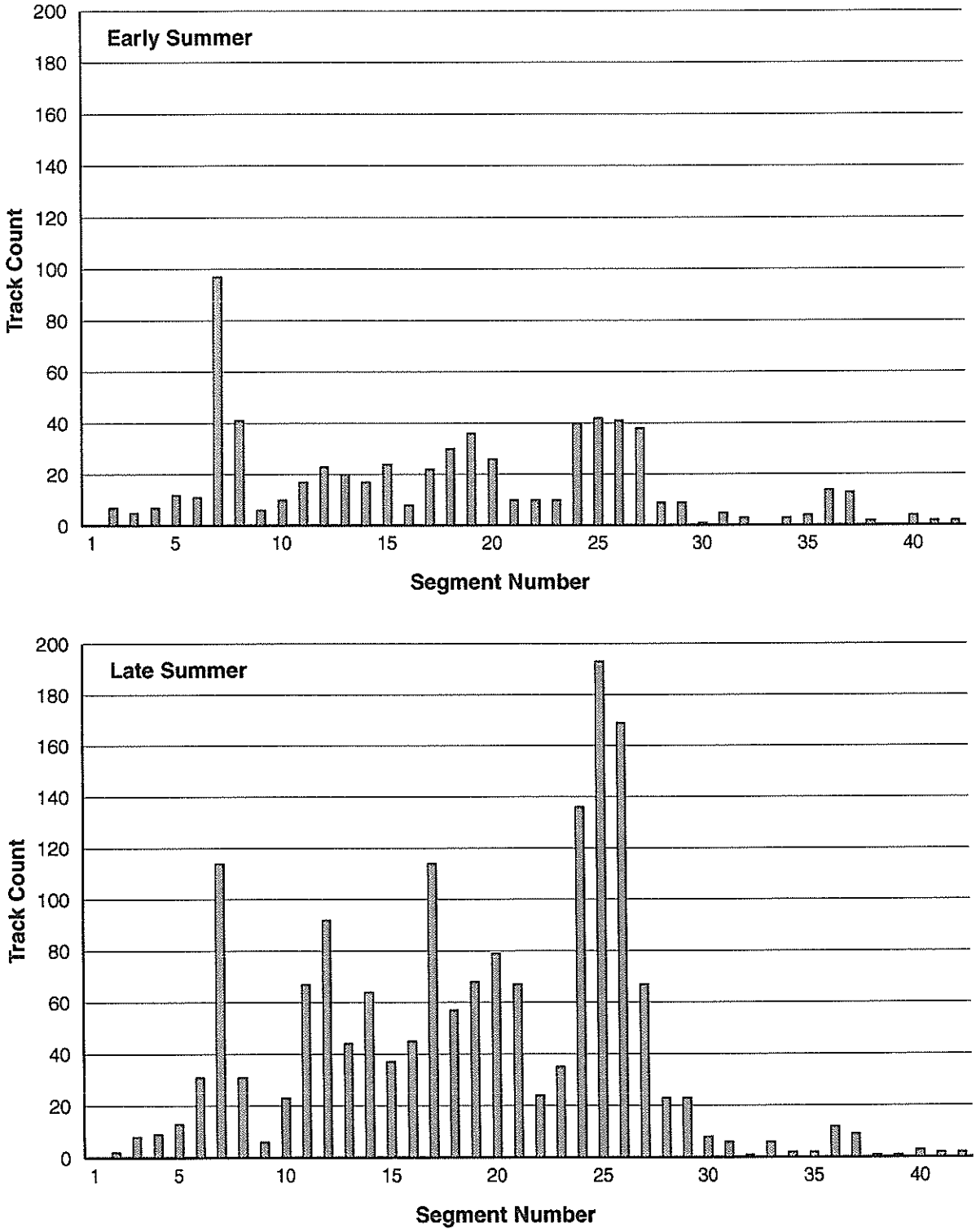
Four of the five changes in use that occurred after construction (in segments 10, 11, 12, and 13) consisted of less use. In each case, deer avoided use of these segments after construction was completed.

During early summer, deer utilization of segment 7 was greater than its availability. This segment is in a stand of Jeffrey pine and its utilization is greater than its availability during spring and fall migration. Deer utilization of segments 5, 6, 10, 21, 22, 28, and 29 was less than their availability. Segment 5 crossed low sagebrush, and segments 10 and 29 crossed through big sagebrush, and the remaining segments crossed through bitterbrush. Utilization of the remaining 17 segments, most of which were in big sagebrush and bitterbrush, was equal to their availability.

Late Summer

Deer did not use the survey segments equally in late summer; the difference in distribution was significant ($P<0.01$). During late summer, deer utilization of each survey segment was consistent during the three survey periods 56% of the time. There were changes in 11 segments, and 54.5% of these occurred during construction. Five of the changes observed during construction consisted of more use, and the change in one segment, segment 22, consisted of less use. Use did not change in segments adjacent to 22, indicating that deer did not avoid segment 22 by increasing use in adjacent segments. Two of the five changes in use that occurred after construction consisted of less use (in segments 13 and 24).

During late summer, deer utilization of segments 7 and 24–26 was greater than their availability. Segment 7 is in a stand of Jeffrey pine and its utilization is greater than its availability during all other seasons. Segments 24–26 cross through bitterbrush. Deer utilization of segments 5, 6, 8, 9, 10, 15, 23, 28, and 29 was lower than their availability. Segment 5 crosses low sagebrush; segments 6, 23, and 28 cross bitterbrush; segment 8 crosses Jeffrey pine; and all other segments cross big



Jones & Stokes Associates, Inc.

Figure 5-2
Cumulative Track Summary for Sandhouse and Rush Creek Project Areas, 1993-1998

Table 5-1. Utilization of Survey Segments during Early and Late Summer Movement before, during, and after Realignment of SR 395

Survey Segment	Early Summer Movement			Late Summer Movement			Habitat
	Before	During	After	Before	During	After	
5	-	-	=	-	-	-	low sagebrush
6	-	=	-	-	=	-	bitterbrush
7	=	+	+	-	+	+	Jeffrey pine
8	-	=	+	-	-	=	Jeffrey pine
9	=	-	-	-	-	-	sagebrush
10	=	=	-	-	-	-	sagebrush
11	=	=	-	=	=	=	sagebrush
12	=	=	-	=	=	=	sagebrush
13	=	=	-	=	=	-	sagebrush
14	-	=	-	=	=	=	sagebrush
15	-	=	=	-	-	=	sagebrush
16	=	-	=	-	=	=	sagebrush
17	=	=	=	=	=	+	sagebrush
18	=	=	=	=	=	=	sagebrush
19	=	=	=	=	=	=	sagebrush
20	=	=	=	=	+	-	sagebrush
21	=	-	-	=	=	=	bitterbrush
22	-	-	-	=	-	=	bitterbrush
23	=	-	=	-	-	-	bitterbrush
24	=	=	=	+	+	=	bitterbrush
25	=	=	=	+	+	+	bitterbrush
26	=	=	=	+	+	+	bitterbrush
27	-	=	=	=	=	=	bitterbrush
28	-	=	-	-	-	-	bitterbrush
29	-	=	-	-	=	-	sagebrush

Notes: + Utilization is greater than availability.
= Utilization is in proportion to availability.
- Utilization is less than availability.

sagebrush habitat. Utilization of the remaining 12 segments, most of which are in big sagebrush, was equal to their availability.

Segments 24–26 accounted for approximately 31% of all tracks counted in segments 5–29 during late summer. Segments 24–26 are near the sewage treatment ponds and LADWP aqueduct, which provide the only water in the Sandhouse project area. The preference for segments near water is also associated with a decline in the moisture content of big sagebrush (Figure 5-3). We used the moisture content of big sagebrush as a surrogate for forage moisture. In 1993, 1994, and 1996, the surveys in which most deer tracks were counted coincided with times when the moisture content of big sagebrush was between 115% and 84%. Information on the moisture content of big sagebrush was not available during the survey when the most tracks were counted in 1997 or 1998. Assuming that the trend in moisture content was similar in 1997 and 1998 to that of previous years, the moisture content when most tracks were counted in 1998 would have been between 115% and 85%. The peak count in 1997 would have occurred when moisture was below 84%.

DISCUSSION

Timing and Intensity of Movement

During early summer, substantially fewer tracks were counted than at the peak of spring migration. The reduction in tracks counted was expected because the tracks represent movement of animals at the lower elevation of the summer range and not movement on the entire summer range. Additionally, this period coincides with

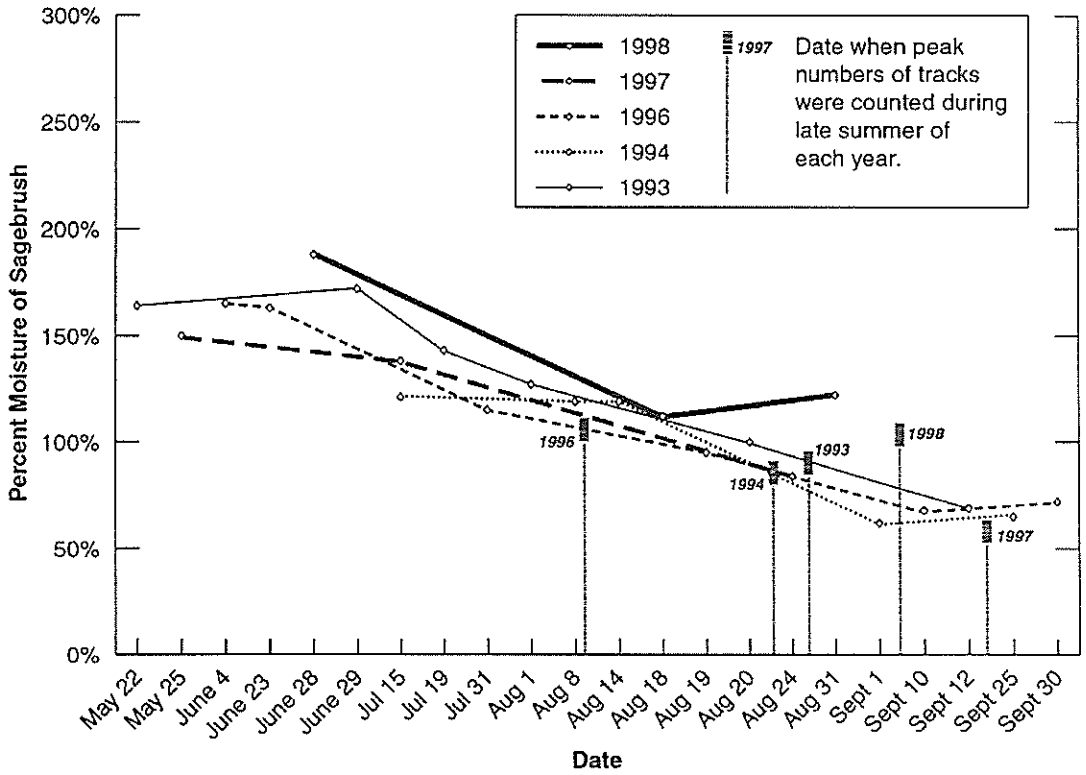


Figure 5-3
Moisture Content of Sagebrush during May–September

fawning (mid-June to the end of July) and does and neonate fawns have restricted movement during this period. The number of tracks counted during late summer was approximately 150% higher than the number counted during early summer. Some of these tracks represent increased movement by does and young fawns that are at heel and some may represent an influx of additional deer into the area.

Location of Summer Movement

Most deer movement during summer occurred in the Sandhouse project area, and the majority of deer moved in survey segments 5–29, as during migration. During construction, most of the changes in the use of survey segments were positive, which indicates that deer did not avoid construction areas because of disturbance from construction activities.

Early Summer

Deer movement was less consistent between survey periods during early summer than during the other seasons. Additionally, utilization of most segments was proportional to their availability, indicating that there was little preference or avoidance of geographic areas or habitat types. We hypothesize that most of the movement during this period is by younger animals who have not established traditional home ranges. We believe that the matriarchal does are less active because of fawning and the younger animals are moving on their own, rather than with an older doe.

It is not clear why deer avoided segments 10–13 after construction ended. Segment 10 is generally avoided during spring and fall migration and late summer because a cliff along SR 395 restricts movement in that area. Segments 11–13 are not avoided during spring migration and late summer. These segments, however, are avoided during fall migration, apparently because of the lack of cover provided by big sagebrush.

Late Summer

The consistency of deer movement between survey periods during late summer was identical to that of fall migration. Deer selected survey segment 7 as they had during all other seasons. They also showed preferences for movement through segments 24–26, which crossed through a bitterbrush stand. Bitterbrush is probably an important forage species for animals that summer on lower elevation summer ranges (Taylor 1997). However, the deer observed in the present study avoided or showed no preference for other segments that crossed bitterbrush habitat; thus, it is probable that they were attracted to other resources in segments 24–26.

Segments 24–26 are adjacent to the only free-standing water in the Sandhouse project area, and the peak number of deer tracks counted during late summer was associated with declining forage moisture content. These observations and the high number of tracks counted in these segments lead us to hypothesize that some deer movement in late summer is in response to declining moisture content in forage. We do not believe deer are moving in response to high summer temperatures, which increase the need for water to balance water losses caused by evaporative cooling. Mean daily temperatures in August are 28°C (83°F), and studies of desert mule deer have shown that they do not increase their intake of water until ambient temperatures exceed 35°C (95°F) (Hervert and Krausman 1986).

It is not clear whether the increase in the number of tracks counted during late summer represents a large influx of animals into the study area in search of water. Ashcraft (1961) suggested that deer migrated in response to the drying of water sources; however, more recent studies have indicated that deer may make only temporary movements to obtain water (Hervert and Krausman 1986, Boroski and Mossman 1996) instead of migrating.

Our hypothesis about the need for water can be easily tested. Additional water developments have been planned for this project area. These developments should not be spaced more than 3.2 kilometers (2 miles) apart (Boroski and Mossman 1996). Track counts could be used to monitor changes in deer use in segments 24–26, and infrared sensors and cameras could be used to monitor use of the new water developments.

Chapter 6. Factors Affecting Deer Fatalities

This chapter describes the numbers, timing, and distribution of deer fatalities and evaluates factors that could affect those fatalities caused by motor vehicles in the study area.

RESULTS

Deer Fatalities

Overview

The number of deer that may have been hit along SR 395 but that died in the surrounding area was estimated from 41 surveys conducted during four migratory periods between fall 1992 and spring 1994. One deer was found in 1992, approximately 6.7 meters (20 feet) east of SR 395. Both front legs of the animal were broken, which suggested that it had been hit by a vehicle and either crawled from the highway or had been pulled away from the highway by a passing motorist. No other deer were found.

It is unlikely that additional deer were missed by the sampling effort. Big sagebrush was the dominant plant in the survey area and the height and density of plants would not have prevented detection of a deer carcass in the 10-meter-wide (30-foot-wide) transects that were surveyed. The transects were distributed throughout the study area, and approximately 10% of the Sandhouse project area was searched during each survey. Additionally, the presence of ravens *(Corvus corax)* and magpies *(Pica pica)* was also used to locate deer carcasses during roadside surveys, and no birds that were observed during the surveys exhibited the behaviors associated with feeding on deer carcasses.

A total of 149 deer fatalities caused by motor vehicles were recorded during the 6-year study. The number of deer killed by motor vehicles varied annually and seasonally throughout the study period (Figure 6-1). The highest number of fatalities (n = 25) occurred during fall 1993 migration, and the fewest fatalities (n = 1) occurred during fall migration 1997. Except in 1993, deer fatalities followed a similar cyclical pattern each year of the survey. Spring migration and early summer movements resulted in few fatalities; the most fatalities generally occurred during late summer movements, followed by a reduction in fatalities during fall migration.

The number of fatalities during spring migration 1993 were higher than the number of fatalities during spring migration in 1994, 1995, 1996, and 1997. Spring migration 1998 had the most fatalities of all spring migrations. Deer fatalities during late summer were very similar in 1993, 1994, 1996, and 1997, but were lower in 1998.

Sex Ratio and Age Structure

The sex ratio of all deer greater than 1-year old that were killed (n=118) during the 6-year period was 46 bucks:100 does. The sex ratio of fawns was 60 bucks:100 does (n = 16), and the sex of 15 fawns recovered along SR 395 could not be determined because the carcasses were so badly dismembered.

The distribution of age classes assigned using cementum characteristics and those assigned using tooth replacement and wear were significantly different ($P<0.05$). Figure 6-2 shows the age distribution of 16 fawns and 44 adult deer assigned using cementum characteristics. The oldest female recorded was 12 years old. No males older than 5 years of age were detected in this sample or in the other sample of deer aged using tooth replacement

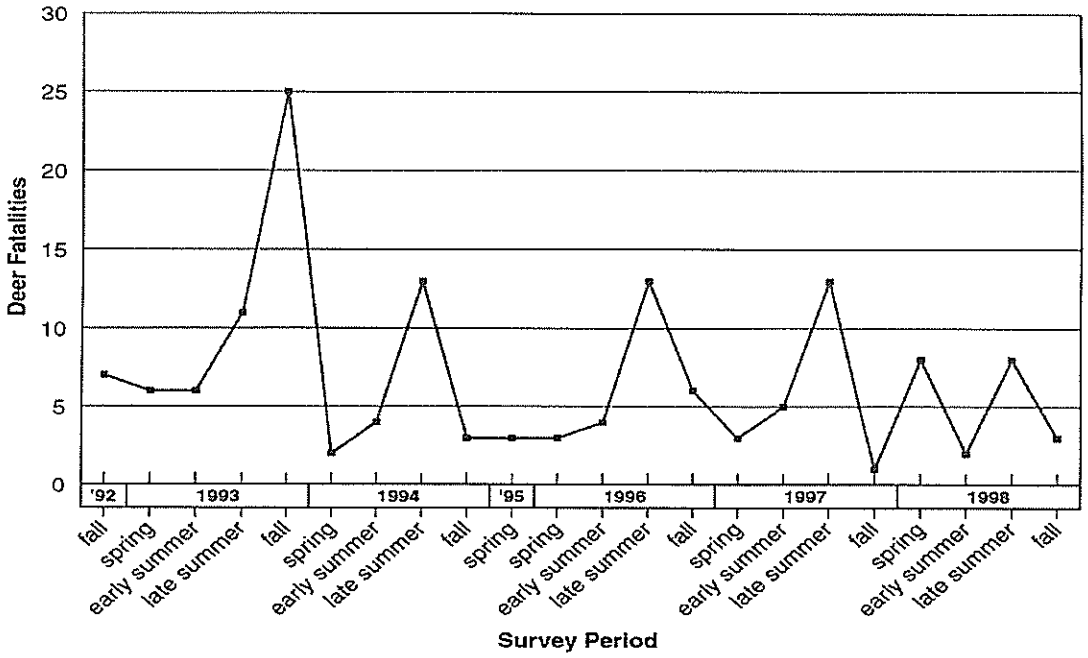


Figure 6-1
Seasonal Deer Fatalities along State Route 395, Fall 1992-Fall 1998

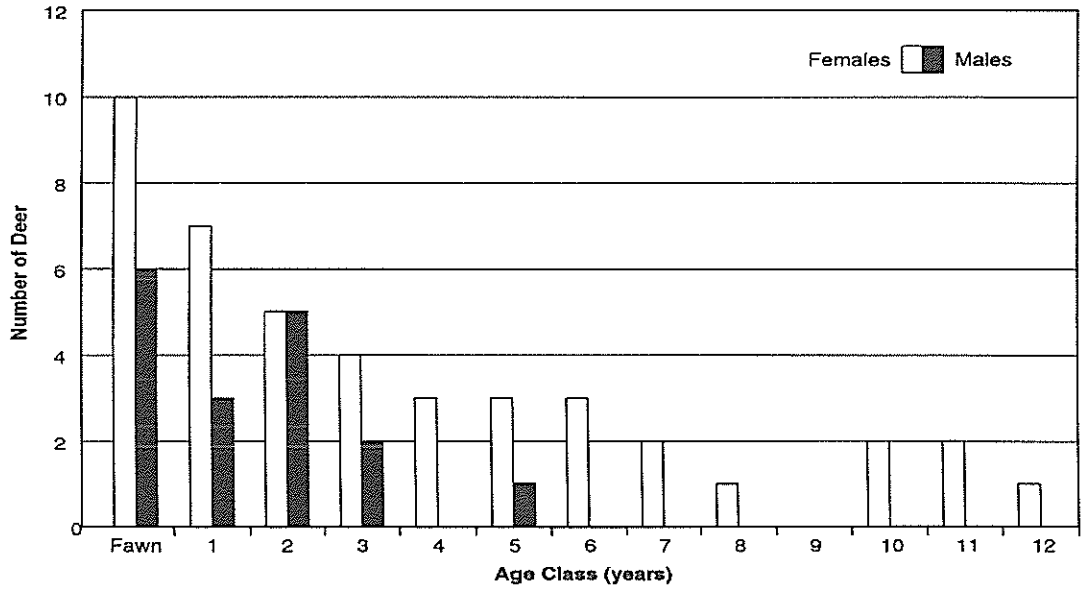


Figure 6-2
Age Distribution of Deer Recovered along State Route 395

and wear (n = 16). The total number of deer in different age classes that were killed also varied seasonally (Figure 6-3). Spring migration was characterized by few fatalities, with the fatalities dominated by adult deer. The number of fatalities declined in early summer. The most fatalities occurred during late summer movements and fawn fatalities were greater than those of yearlings. Fatalities in all age classes declined slightly during fall migration; however, they were still higher than during spring migration.

seasonal deer-use days and the corresponding number of fatalities (Figure 6-4).

Use of Movement Corridors

Deer use of the movement corridors, as indicated by total track counts in survey segments 5–29, ranged from 950 tracks in survey segment 7 to 92 tracks in survey segment 28. There was no correlation ($r = 0.385$, $P > 0.05$) between the total number of tracks in a movement corridor and the total number of deer

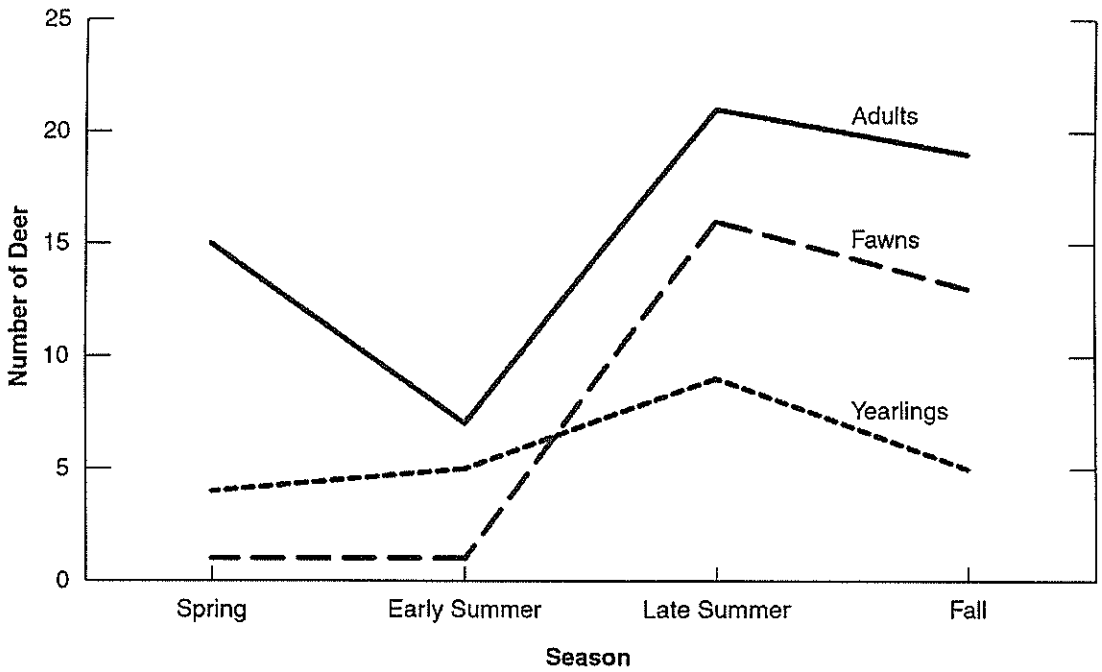


Figure 6-3
Sex and Age Ratios of Deer Fatalities

Effect of Deer Use in the Study Area

The cyclical pattern of deer fatalities shows that deer use in the project area may affect the number of fatalities. There was a significant relationship ($P<0.01$, $R^2 = 0.64$) between

fatalities (Figure 6-5). Survey segments 7, 12, 25, 26, and 27, which account for 34.5% of all tracks counted, had substantially fewer fatalities compared with the other movement corridors. When data for these movement corridors were removed, there was a positive and significant correlation ($r = 0.677$, $P<0.01$) between total deer movement in a corridor and total number of fatalities in that corridor. The fact that there

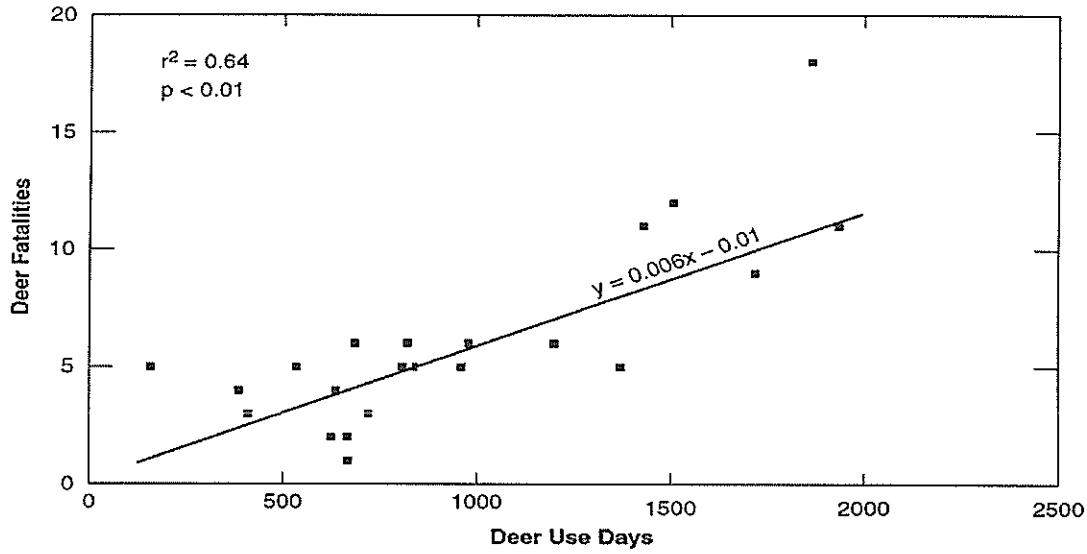


Figure 6-4
Relationship between Deer Use Days and Deer Fatalities

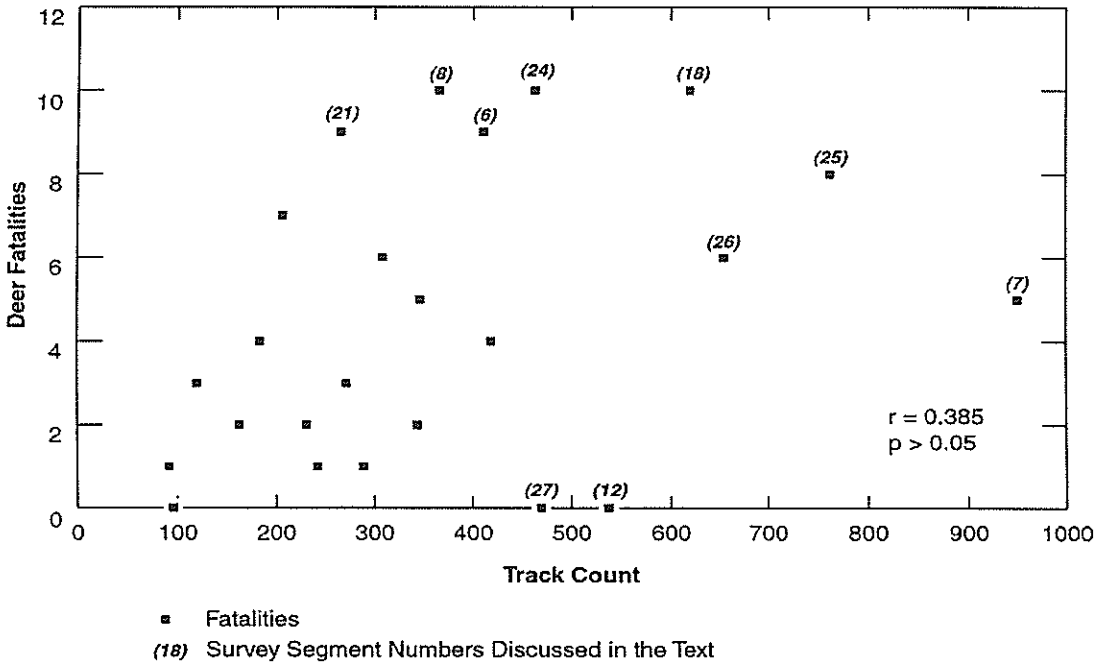


Figure 6-5
Relationship between Tracks and Fatalities by Segment

were fewer fatalities than expected in segments 7, 12, and 25–27 suggested that additional factors affected deer fatalities.

Topographic and Cultural Features

Approximately 60% of all deer fatalities in the study area were associated with cutbanks, fillslopes, or guardrails. The number of guardrails in the study area is minimal, and only one deer fatality was associated with this cultural feature. Segments 6, 8, 18, 21, and 24 accounted for the majority (n = 48) of the deer fatalities. Fillslopes or cutbanks were present along the length of segments 6 and 8 and the majority of segments 18, 21, and 24. Cutbanks and fillslopes were present along the northbound and southbound lanes through segment 7; however, the slopes were not high and angles were gentle. There were no cutbanks of fillslopes in segments 12 or 27. One isolated fillslope existed along the northbound lane in segment 25 and along the southbound lane in segment 26.

Effect of Traffic Levels

Nightly traffic levels were substantially higher on weekends (Thursday through Saturday) than on weekdays (Sunday through Wednesday) during the four movement periods. Mean ± S.E. daily mortality rates on weekends and weekdays for the four periods are described in Table 6-1. There were no significant differences ($P>0.05$) between mean weekend and weekday mortality rates.

Mean nightly traffic levels also varied seasonally and during the 6-year period ranged from a mean of 257 vehicles in fall 1996 to 528 vehicles in early summer 1996. The correlation was not significant ($r = 0.033$, $P > 0.05$) between mean nightly traffic levels and total number of seasonal fatalities (Figure 6-6). Mean nightly traffic levels were transformed to a logarithmic scale to determine whether there was a nonlinear relationship; however, the correlation was determined not to be significant ($r = 0.038$, $P > 0.05$).

Effect of Construction Activities

A small number of sampling periods was scheduled for before and during construction of the Sandhouse project (Table 6-2). Deer fatalities were found to be higher in spring, early summer, and fall before construction than during construction.

Table 6-1. Mean ± S.E. Seasonal Mortality Rates on Weekends and Weekdays

Season	Weekend Mortality Rates	Weekday Mortality Rates
Spring (n = 6)*	0.07 ± 0.08	0.08 ± 0.04
Early Summer (n = 5)	0.08 ± 0.03	0.06 ± 0.05
Late Summer (n = 5)	0.16 ± 0.07	0.24 ± 0.09
Fall (n = 6)	0.16 ± 0.15	0.22 ± 0.2

Note: n = the number of sampling periods.

DISCUSSION

Deer Fatalities

Overview

The lack of deer carcasses found in the area surrounding SR 395 was not surprising. Vehicles are generally traveling at high speeds

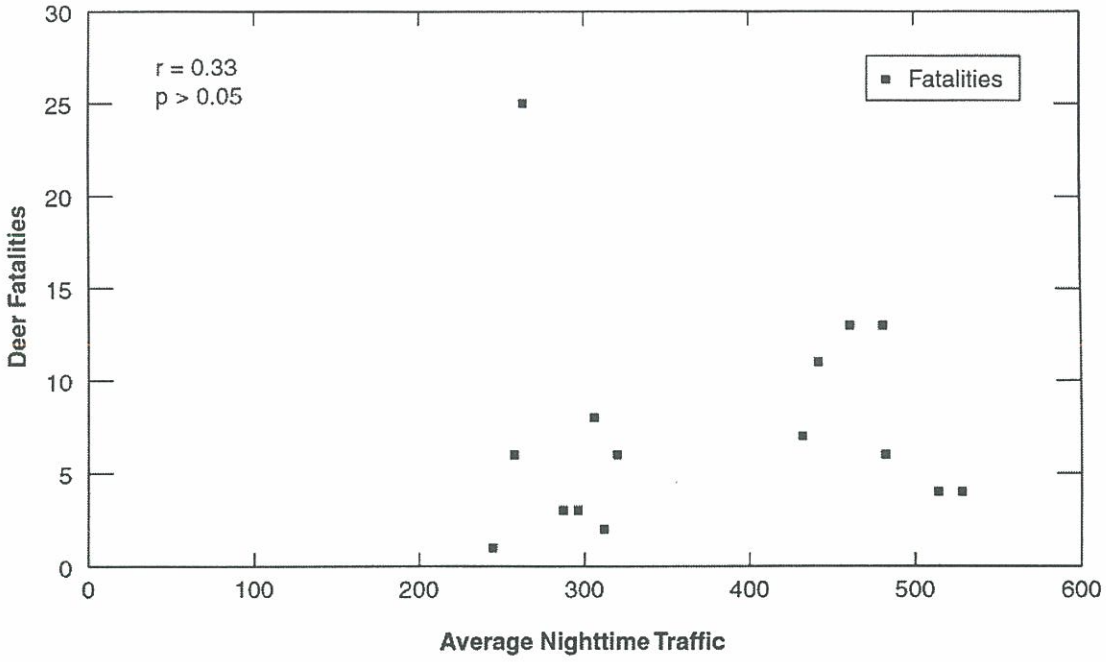


Figure 6-6
Relationship between Mean Seasonal Nighttime Traffic and Deer Fatalities

Table 6-2. Mean and Number of Sampling Periods (n) of Seasonal Fatalities before and during Construction in the Sandhouse Project Area

Season	Before Construction	During Construction
Spring	4 (n=1)	2 (n = 3)
Early summer	4 (n = 1)	2 (n = 2)
Late summer	4 (n = 1)	11 (n = 2)
Fall	14 (n = 2)	2 (n = 1)

(greater than 96 kilometers per hour [60 miles per hour]). When a deer is hit by a motor vehicle, the trauma is sufficient to kill the animal instantly; in many cases, we could not even determine the sex of animals killed by vehicles. It is possible that a small percentage of deer may survive a vehicle collision; however, the number would be so small that it would not substantially affect the results of the surveys.

The number of deer fatalities in other studies appears to correspond to large population fluctuations (McCaffery 1973, Puglisi et al. 1974, Reilly and Green 1974, Romin 1994). The survey data did not indicate

that the numbers of deer fatalities followed any long-term population trend; however, they did appear to follow the annual population cycle. The population declined substantially during winter 1992–1993, but the highest number of fatalities was recorded in fall 1993. Additionally, the number of fatalities during late summer was very consistent between 1994 and 1997, even though the population probably declined through this period, as described in Chapter 3.

Sex Ratios and Age Structure

The adult sex ratio of fatalities (46 bucks:100 does) was higher than the herd composition count ratio of 21 bucks: 100 does observed during the past six years. Romin (1994) also observed a higher sex ratio in a road-kill sample. The sex ratio of road fatalities should be higher than the herd composition count ratio because the largest contribution to the sample was obtained prior to hunting season and the herd composition count ratio represents the population after bucks were removed by hunting.

The distribution of female age classes in our sample seems reasonable for a large ungulate population. It is not clear whether the lack of males older than 5 years in the survey data is representative of the entire Casa Diablo deer herd or just the animals that move through the study area.

Few studies have been conducted comparing the age distribution of deer killed by vehicles and those in the living population. One study evaluated the age distribution of animals killed by vehicles during winter and concluded that the sample included so many diseased, injured, and malnurished animals that it was not representative of the population (O'Gara and Harris 1988, Pierce 1999). Our sample was obtained during spring, summer, and fall, when deer are in better physical condition. Romin (1994) compared the age structure of road-kill samples with buck harvest records and noted that both samples described a population dominated by young animals; however, there were no data to compare with the true population.

The low number of fatalities during spring migration is consistent with the annual population cycle of a deer herd because it is at its cyclical low following winter and before the addition of the next cohort during fawning. The number of fatalities likely remained low during early summer because this period coincides with fawning and most adult does have restricted their activities by this time of year. Romin (1994) also observed a small number of fawn fatalities during fawning in Utah. We had expected to observe a larger increase in the number of fatalities in the yearling age class; however, either this increase did not occur or the sample size was too small for a change to be detected. During late summer, there is a substantial increase in the number of fatalities in all age classes because the deer herd population is at its cyclical high and there may be an influx of animals into the study area searching for water. Fatalities decline during fall migration because the size of the herd has declined as a result of summer mortality and hunting.

Effect of Deer Use in the Study Area

A significant relationship was found between the number of deer fatalities and deer-use days during each season. Other studies have also found a significant relationship between site-specific estimates of deer abundance and fatalities (Bellis and Graves 1971, Carbaugh et al. 1975, Romin 1994). Local estimates of deer abundance may be a better independent variable than population size because they represent the occurrence of deer in the project area and most likely are proportional to the number of times deer cross the highway. For instance, the large number of fatalities during fall 1993 occurred because deer delayed their migration and spent more time than usual in the study area. Spring migration 1998 had the highest number of spring fatalities because the harsh winter prolonged spring migration. The spring migrations in 1994–1996 were shorter and had less fatalities than the spring migrations of 1993 and 1998.

Use of Movement Corridors

The analysis in Chapter 4 demonstrated that deer select, avoid, or use movement corridors in proportion to their availability. After allowances were made for topographic features, it was determined that there was a positive relationship between the amount of movement in a corridor and the number of deer fatalities. In many cases, the most fatalities occurred in corridors that were selected for movement by deer because of seasonal resource requirements. Bellis and Graves (1971) and Carbaugh et al. (1975) did not find a relationship between the number of deer observed in 61- meter-wide survey segments and deer fatalities; however, Feldhamer et al. (1986) determined there was a significant correlation between the number of deer observed in 160-meter-wide survey segments and fatalities. Deer often move along the shoulder of a road prior to crossing the highway (Bellis and Graves 1971); therefore, the narrow survey segments used in these studies did not necessarily coincide with the locations where deer attempted to cross the road.

The correct identification of movement corridors that are selected by deer is important when the location of a new highway is being sited or an existing highway realigned. The use of these corridors is very consistent historically (Puglisi et al. 1974) and this consistency provides a mechanism for subsequent generations of deer to move successfully between seasonal ranges. Highway alignments that interrupt important movement corridors or create a barrier can have long-lasting effects on a deer herd. Because deer have high fidelity to a movement corridor, the loss of that corridor could result in the loss of important summer or winter ranges and, ultimately, carrying capacity (Reilly and Green 1974). Minimizing the amount of highway that crosses an important movement corridor can reduce deer fatalities. Where highways cross migration routes, as in this study, other highway design factors may be necessary to reduce deer fatalities.

The relationship between deer use and fatalities does not accurately predict movement corridors that may be selected by deer. Deer selected survey segments 6, 7, 12, 18, and 24–27 for movement during at least one season. Survey segment 6 had nine fatalities and segments 18 and 24 had 10 fatalities each; however, the other five corridors that deer selected had substantially fewer fatalities than expected compared with all others.

Effects of Topographic Features

Approximately 60% of the deer fatalities in the study area were associated with topographic features (fillslopes and cutbanks). Most fatalities occurred in corridors that deer selected for movement where topographic features were present along most of the corridor.

Feldhamer et al. (1986) and Puglisi et al. (1974) did not find a relationship between topographic features and deer fatalities. Carbaugh et al. (1975) reported that most deer observed along roadsides were on slopes, and others have determined that most deer fatalities were associated with topographic features (Bellis and Graves 1971, Romin 1994). Topographic features may act as funnels that direct deer movement along the right-of-way and onto the highway. They also reduce the visibility of deer along roadsides and affect the ability of drivers to anticipate the movement of deer onto the road.

Deer also selected movement corridors 7, 12, and 25–27, which had a minimal amount of or no topographic features and fewer fatalities than expected. These data suggest that visibility of deer to drivers may affect deer fatalities. Deer that move along the downslope side of a cutbank or along the trough between a fill slope and elevated roadway are not visible to motorists. If deer move quickly onto the roadside from these area, drivers may not have sufficient time to recognize deer and avoid hitting them.

Effect of Traffic Levels

The relationship between traffic levels and wildlife fatalities is not well documented in the literature. In some previously reported studies, the correct data were not available for the relationship to be evaluated (Mansfield and Miller 1975), no relationship could be identified (Groot Bruinderink and Hazebroek 1996), or no relationship was quantified, but it was concluded that there was a relationship (McCaffery 1973). Puglisi et al. (1974) and Romin (1994) determined, however, that there was a direct relationship between traffic levels and deer fatalities.

In our study, nightly traffic levels varied during the week and seasonally, but there was little change during the 6-year period in the range of traffic levels measured. The minimum nightly traffic level averaged 244 vehicles in fall 1997, and there was one fatality during this period. Deer fatalities did increase as nightly traffic levels increased to approximately 500 vehicles; however, the relationship varied too much to be statistically significant. Within the range of traffic levels observed, changes in traffic levels were not statistically correlated with changes in deer fatalities.

It is logical to conclude that an increase in traffic levels will result in an increase in deer fatalities. If there were no traffic on the highway, there would be no deer fatalities, and as traffic levels increased, so would deer fatalities. Traffic levels and deer fatalities could continue to increase until they became so high that deer could not successfully cross the highway and the road would become a barrier to movement (Reilly and Green 1974).

Effect of Construction Activities

The data comparing deer fatalities before and during highway construction indicated that construction activities had little effect on deer fatalities. The conclusion based on these limited data is also supported by the data on the location of deer movement before and during construction during three seasons. The seasonal data on deer movement led us to conclude that there may have been some avoidance of movement corridors during fall migration, when more deer are moving during the day.

Highway construction took approximately three construction seasons, 1994–1996. During construction, there were no periods when much equipment was operating at any one time and there were extensive periods of limited operation. Other than the fall migration data, little data were collected that support the conclusion that construction activities significantly disrupted deer movement, leading to increased fatalities. The results may have been different if a larger, more active crew had completed the highway realignment project over a shorter timeframe.

Chapter 7. Effectiveness of the Variable-Width Median

This chapter evaluates the effectiveness of the variable-width median in reducing deer mortality resulting from vehicle-deer collisions in the study area along SR 395.

RESULTS

Topographic Features

As discussed in Chapter 6, topographic features affected the number of deer fatalities. The number of deer fatalities in the Sandhouse project area before and after construction of the variable-width median was evaluated to determine whether changes in topographic features affected the number of fatalities (Table 7-1). There was a significant difference ($P < 0.05$) in the distribution of fatalities after construction of the median. The proportion of the total number of fatalities that occurred in areas without topographic features was higher following construction than before construction of the median. The 12 fatalities occurred between segments 10 and 24; of these, 75% occurred in the southbound lane and 58% occurred during late summer 1997. Two of the fatalities were adults more than 5 years old, four were yearlings, and two were fawns. The age and sex could not be determined for four animals.

Table 7-1. Distribution of Deer Fatalities in the Sandhouse Project Area before and after Construction of the Variable-Width Median

	Topographic Features Present	Topographic Features Absent
Without median	50	23
With median	14	12

Effectiveness of the Variable-Width Median

As indicated in Chapter 6, we determined that construction activities had little effect on deer behavior and did not affect deer fatalities. Therefore, we combined the results from preconstruction and construction surveys. We also determined there was a significant relationship between the number of deer-use days and the number of fatalities during each season. Based on this relationship, a deer fatality index, calculated as the number of deer fatalities per 1,000 deer-use days in each survey period, was determined for both project areas before and after construction of the Sandhouse project (Table 7-2). The deer fatality index was lower in the Sandhouse project area than in the Rush Creek project area. This does not indicate that fewer fatalities occurred in the Sandhouse project area; in fact, more deer were killed in the Sandhouse project area. However, the deer fatality index reflects the ratio of fatalities to deer-use days, and proportionately more deer cross SR 395 in the Sandhouse project area.

There was no significant difference ($P>0.05$) in the deer fatality indices between preconstruction and postconstruction of the variable-width median in the Sandhouse project area. Likewise, there was no significant difference ($P > 0.05$) in the Rush Creek project area, which served as the control during our surveys.

Table 7-2. Mean ±S.E. of the Deer Fatality Index in the Sandhouse and Rush Creek Project Areas during Seasonal Survey Periods, before and after Construction of the Sandhouse Project

Seasonal Survey Period	Sandhouse Project Area	Rush Creek Project Area
Without median (n = 13)	5.44±2.95	10.43±9.67
With median (n = 9)	7.79±7.31	12.34±12.48

DISCUSSION

Topographic Features

Prior to construction of the variable-width median, a higher proportion of deer fatalities was associated with topographic features. After construction of the Sandhouse project, a higher proportion of fatalities was recorded where topographic features did not exist. Indeed, the majority occurred along the southbound lanes, which were realigned only slightly during construction of the new northbound lanes. Most these fatalities occurred during the first summer the new highway was opened, and six out of eight fatalities were young animals that were inexperienced in crossing the highway. The number of fatalities declined the second summer (1998) the divided highway was opened. These results suggest that deer fatalities may decline in the future and demonstrate that the variable-width median is effective in reducing deer fatalities.

Effectiveness of the Variable-Width Median

The small sample sizes and high variability reduced the power of the statistical test. However, the similarities in the means and S.E. between construction periods in both project areas do not indicate there were substantial differences in the number of fatalities. There was an unexpected increase in deer fatalities in the Sandhouse project area during the first summer after opening the divided highway. However, there was no substantial increase in the number of deer fatalities immediately after the second set of lanes was opened, as reported by others.

In Michigan, highway fatalities in a population of white-tailed deer *(Odocoileus virginianus)* increased substantially the first and second year following construction of a new expressway next to an existing two-lane highway, then gradually declined by the fifth year. Additionally, traffic levels did not increase during this study (Reilly and Green 1974). Of the studies reported, this one is most similar to our study because a new highway was opened next to an existing highway and traffic levels did not differ during the study periods. In Utah, mule deer fatalities increased the first and second year and began declining the third year after realignment and construction of a new highway. Additionally, the population of that deer herd declined substantially during the study (Romin 1994). The Casa Diablo herd declined during the study period, but we do not think the decline exceeded the 62% reported by Romin (1994). Highway fatalities of white-tailed deer in Pennsylvania increased the first year, then declined through the second year after construction of a new highway (Bellis and Graves 1971).

The similarity in deer fatalities between the preconstruction and postconstruction periods and the lack of a substantial increase in deer fatalities after the opening of the variable-width median demonstrates that the variable-width median did not result in additional deer fatalities. If deer fatalities in the Sandhouse project area decline in future years, as in other studies, the variable-width median may be an effective way to reduce deer fatalities. Few methods are available to reduce the number of deer-vehicle collisions; therefore, if the variable-width median is effective in reducing

fatalities, opportunities should be identified to test this design in other locations.

Monitoring

The current study was the first effort to evaluate the effectiveness of a variable-width median. Implementation of an effective monitoring plan could determine whether additional studies in the current project area would be useful for evaluating the effectiveness of the variable-width median. The monitoring plan should not be designed to answer all the questions and changes that may be observed over the next several years. The monitoring plan should be:

- simple and inexpensive to implement,
- designed to determine whether a change in deer-vehicle collisions has occurred, and
- used to develop a hypothesis that can be tested.

The extensive baseline data and initial results from the current study suggest that the variable-width median may be effective in reducing the number of deer-vehicle collisions. This and other studies have indicated that the number of deer-vehicle collisions is affected by large-scale changes in the amount of traffic, the size of the deer herd, or both (see Chapter 6).

The California Department of Fish and Game and Caltrans collect regional data on the size of deer populations and traffic patterns. Personnel from Caltrans, California Highway Patrol, California Department of Fish and Game, and Mono County Sheriff's Department collect data on deer fatalities along SR 395. The annual collation and analysis of these data can be used as an effective monitoring tool to determine whether additional, focused studies could be used to evaluate the effectiveness of the variable-width median in reducing the number of deer-vehicle collisions.

Most of the Casa Diablo deer herd crosses SR 395 in the Sandhouse project area, and the number of deer fatalities from vehicle collisions varies seasonally. Table 7-3 presents the mean number of seasonal deer fatalities in this area based on the current size of the deer population, traffic levels, and approximate dates of movement. Deviations from these values and comparison to regional estimates of deer population sizes and traffic levels should be used to develop hypotheses and signal the need for additional studies that capitalize on the current information to test the effectiveness of the variable-width median.

Table 7-3. Approximate Dates of Seasonal Movement and Expected Number of Deer Fatalities in the Sandhouse Project Area

	Spring Migration (April 15 to June 15)	Early Summer (June 16 to July 31)	Late Summer (August 1 to September 30)	Fall Migration (October 1 to November 15)
Expected range of deer fatalities	0–2 (n = 6)	1–2 (n = 5)	4–7 (n = 5)	1–5 (n = 5)*

* The high value obtained in 1993 was not used to prepare this estimate; the number of fatalities in 1993 (15) was substantially higher than in the other years.

Chapter 8. Acknowledgments

Steve Holl was principal-in-charge of the project documented in this report. Tim Taylor was project manager and responsible for collecting the majority of the field data, organizing and analyzing data, and preparing all the interim reports. Steve Avery and George Visger assisted with the collection of field data. Jennifer Haire assisted with data organization and preliminary analyses. Dr. Gerrit Platenkamp assisted with the statistical analyses. Dr. Vernon Bleich, DFG, and Stan Ford, recently retired Caltrans wildlife biologist, reviewed the draft of this report. Roberta Childers and Jim Merk edited the final report. Tim Messick prepared the graphics. Tom Dayak, Caltrans project manager, provided support and encouragement throughout the study.

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PERSONAL COMMUNICATIONS

Dayak, T. Environmental planner. California Department of Transportation, Bishop, CA. Various dates - conversations with project manager.

Ford, Stan. Wildlife biologist. California Department of Transportation, Sacramento, CA. February 7, 1992 - meeting.

Appendix A. Accuracy of Track Counts

Appendix A. Accuracy of Track Counts

The current study relied on track counts to identify the locations of deer use areas and estimate the timing of migration and the number of deer migrating through the project areas. The technique may underestimate deer numbers because tracks can be missed and not counted, and when a large number of deer pass through an area, tracks of individual deer cannot be discerned.

During spring and fall 1993, 47 estimates of deer numbers based on track counts were compared with the number of deer photographed as they passed through the track survey areas. A chi-square analysis showed there was no significant difference ($P = 0.99$) between the number of deer photographed and the number of deer estimated by track counts. A linear regression analysis provided a reasonably good fit and explained 86% of the variation (Figure A-1a). Predictions using the linear model determined that track counts provide consistently accurate estimates when fewer than five deer pass through a counting station.

A nonlinear model explained 88% of the variation, slightly higher than that explained by the linear version (Figure A-1b). Predictions using the nonlinear model determined that track counts provide accurate estimates when fewer than seven deer pass through a counting station.

Both regression models demonstrate that track counts can accurately estimate the number of deer when groups are small. The accuracy of track counts declines when the groups of deer are larger because more tracks overlap and the numbers of deer are underestimated.

Group size had little effect on estimates of deer numbers during preconstruction surveys. Of the 44 groups of deer observed in the project areas, 86% had six or fewer deer (Figure A-2). Therefore, track counts during preconstruction surveys provided a reasonably accurate estimate of deer passing through the project areas.

Figure A-1a

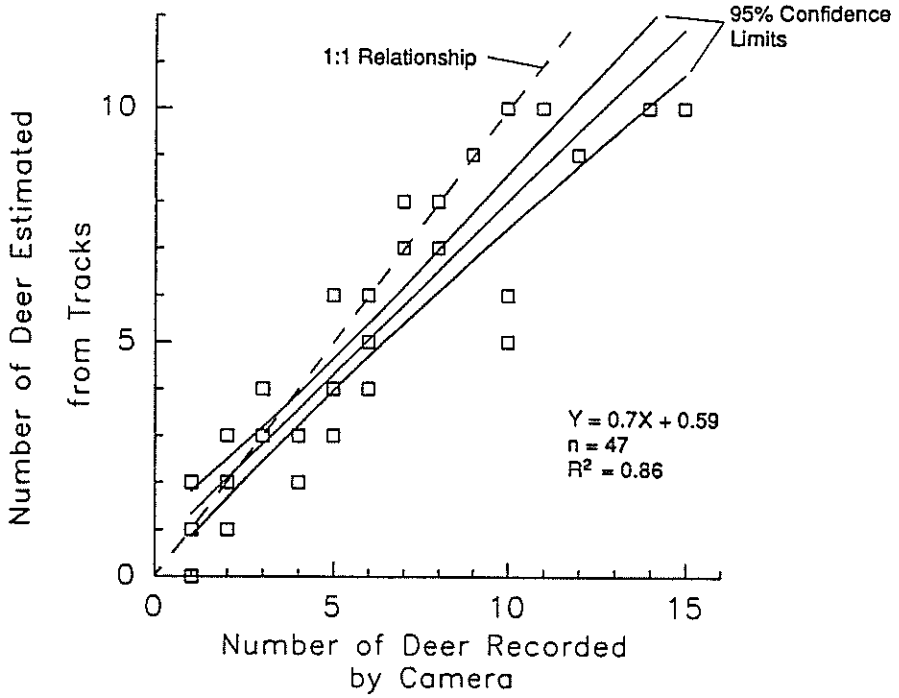
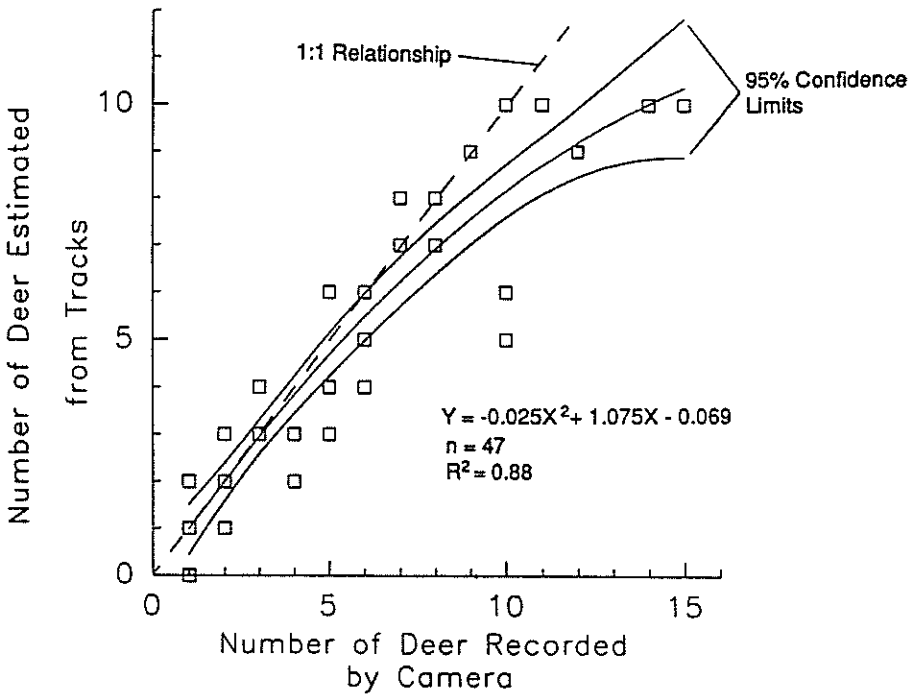


Figure A-1b



Note: Several data points represent multiple observations.

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Figure A-1
Regression Models of Deer Recorded by Trail Master Cameras and Deer Estimated from Track Counts

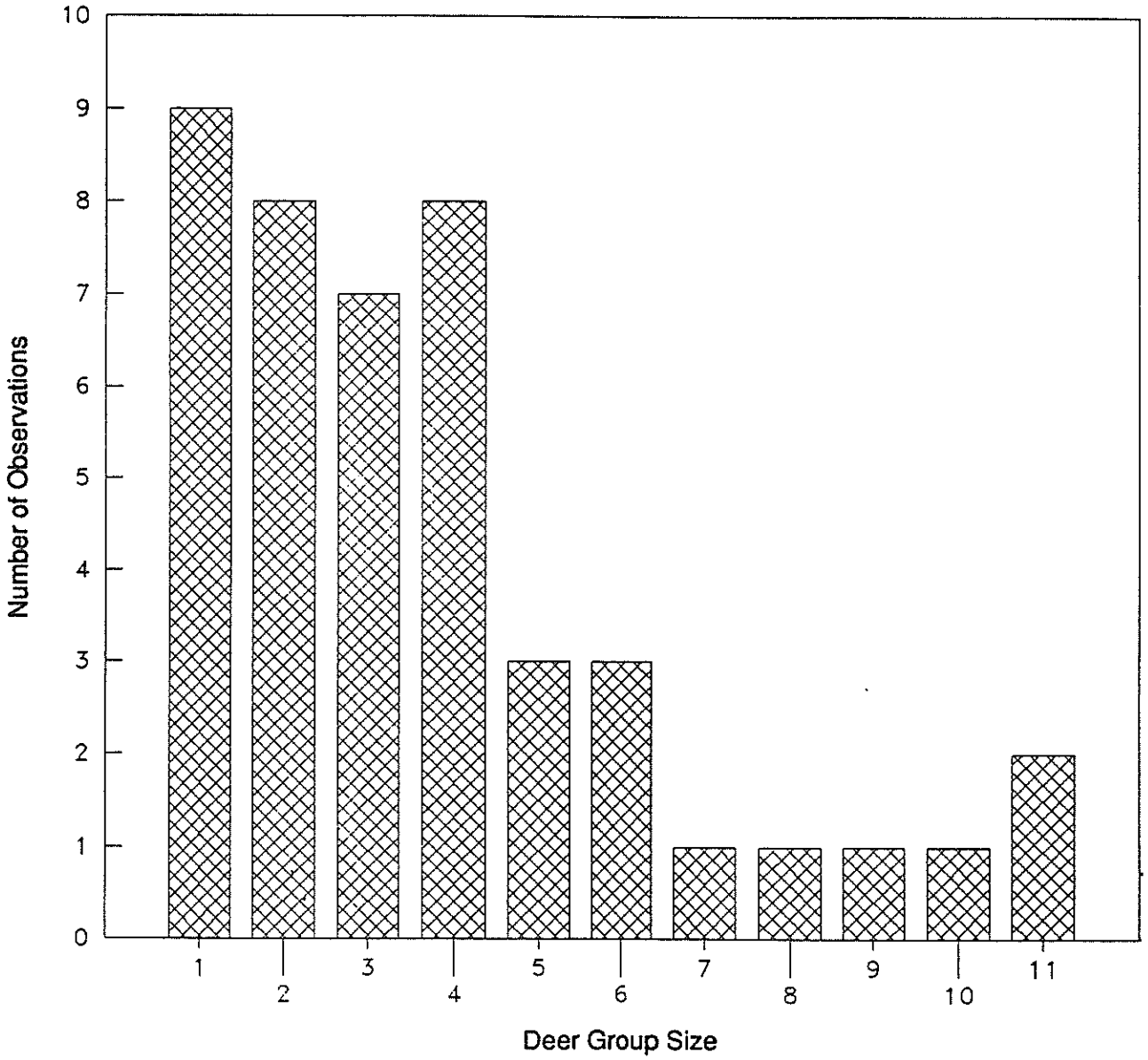

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Figure A-2
Observations of Deer in the Project Areas by Group Size

Appendix B. Bonferroni Confidence Intervals for Utilization of Movement Corridors

Spring Migration

	Pre-Construction			During Construction			Post-Construction		
Segment	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval
5	23	0.037	0.014≤ P ≤ 0.060	14	0.014	0.003≤ P ≤ 0.025	26	0.024	0.010≤ P ≤ 0.039
6	35	0.056	0.028≤ P≤ 0.085	47	0.046	0.026≤ P ≤ 0.066	34	0.032	0.015≤ P ≤ 0.048
7	52	0.084	0.050≤ P≤ 0.118	144	0.140	0.107≤ P ≤ 0.174	102	0.095	0.068≤ P ≤ 0.122
8	14	0.023	0.004≤ P≤ 0.041	42	0.041	0.022≤ P ≤ 0.060	46	0.043	0.024≤ P ≤ 0.062
9	11	0.018	0.002≤ P≤ 0.034	18	0.018	0.005 ≤ P ≤ 0.030	11	0.010	0.001≤ P ≤ 0.020
10	14	0.023	0.004≤ P≤ 0.041	34	0.033	0.016≤ P ≤ 0.050	10	0.009	0.000≤ P ≤ 0.018
11	33	0.053	0.026≤ P≤ 0.081	51	0.050	0.029≤ P ≤ 0.071	51	0.048	0.028≤ P ≤ 0.067
12	41	0.066	0.036≤ P≤ 0.097	129	0.126	0.094≤ P ≤ 0.158	185	0.172	0.137≤ P ≤ 0.208
13	38	0.061	0.032≤ P≤ 0.091	46	0.045	0.025≤ P ≤ 0.065	45	0.042	0.023≤ P ≤ 0.061
14	20	0.032	0.011≤ P≤ 0.054	51	0.050	0.029≤ P ≤ 0.071	32	0.030	0.014≤ P ≤ 0.046
15	25	0.040	0.016≤ P≤ 0.064	65	0.063	0.040≤ P ≤ 0.087	44	0.041	0.022≤ P ≤ 0.060
16	18	0.029	0.008≤ P≤ 0.050	34	0.033	0.016≤ P ≤ 0.050	34	0.032	0.015≤ P ≤ 0.048
17	39	0.063	0.033≤ P≤ 0.093	31	0.030	0.014≤ P ≤ 0.047	31	0.029	0.013≤ P ≤ 0.045
18	54	0.087	0.052≤ P≤ 0.122	55	0.054	0.032≤ P ≤ 0.075	29	0.027	0.012≤ P ≤ 0.042
19	22	0.035	0.013≤ P≤ 0.058	40	0.039	0.021≤ P ≤ 0.058	41	0.038	0.020≤ P ≤ 0.056
20	13	0.021	0.003≤ P≤ 0.039	8	0.008	-0.001≤ P ≤ 0.016	9	0.008	0.000≤ P ≤ 0.017
21	5	0.008	-0.003≤ P≤ 0.019	8	0.008	-0.001≤ P ≤ 0.016	23	0.021	0.008≤ P ≤ 0.035
22	7	0.011	-0.002≤ P≤ 0.024	9	0.009	0.000≤ P ≤ 0.018	11	0.010	0.001≤ P ≤ 0.020
23	8	0.013	-0.001≤ P≤ 0.027	14	0.014	0.003≤ P ≤ 0.025	26	0.024	0.010≤ P ≤ 0.039
24	35	0.056	0.028≤ P≤ 0.085	37	0.036	0.018≤ P ≤ 0.054	42	0.039	0.021≤ P ≤ 0.057
25	26	0.042	0.017≤ P≤ 0.067	28	0.027	0.012≤ P ≤ 0.043	104	0.097	0.069≤ P ≤ 0.125
26	21	0.034	0.012≤ P≤ 0.056	30	0.029	0.013≤ P ≤ 0.045	65	0.061	0.038≤ P ≤ 0.083
27	17	0.027	0.007≤ P≤ 0.047	42	0.041	0.022≤ P ≤ 0.060	42	0.039	0.021≤ P ≤ 0.057
28	12	0.019	0.002≤ P≤ 0.036	3	0.003	-0.002≤ P ≤ 0.008	6	0.006	-0.001≤ P ≤ 0.013
29	37	0.060	0.031≤ P≤ 0.089	45	0.044	0.02≤ P ≤ 0.063	24	0.022	0.009≤ P ≤ 0.036

P = proportion of total tracks observed.

Fall Migration

	Pre-Construction			During Construction			Post-Construction		
Segment	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval
5	167	0.074	0.057≤ P ≤ 0.090	56	0.059	0.036≤ P ≤ 0.083	33	0.039	0.019≤ P ≤ 0.060
6	152	0.067	0.051≤ P ≤ 0.083	71	0.075	0.049≤ P ≤ 0.101	30	0.036	0.016≤ P ≤ 0.055
7	159	0.070	0.054≤ P ≤ 0.083	184	0.195	0.155≤ P ≤ 0.234	98	0.117	0.083≤ P ≤ 0.151
8	102	0.045	0.032≤ P ≤ 0.051	36	0.038	0.019≤ P ≤ 0.057	54	0.064	0.038≤ P ≤ 0.090
9	18	0.008	0.002≤ P ≤ 0.014	15	0.016	0.003≤ P ≤ 0.028	11	0.013	0.001≤ P ≤ 0.025
10	22	0.010	0.003≤ P ≤ 0.018	1	0.001	-0.002≤ P ≤ 0.004	6	0.007	-0.002≤ P ≤ 0.016
11	40	0.018	0.009≤ P ≤ 0.027	20	0.021	0.007≤ P ≤ 0.036	10	0.012	0.000≤ P ≤ 0.023
12	46	0.020	0.011≤ P ≤ 0.029	7	0.007	-0.001≤ P ≤ 0.016	14	0.017	0.003≤ P ≤ 0.030
13	39	0.017	0.009≤ P ≤ 0.025	2	0.002	-0.002≤ P ≤ 0.007	8	0.010	-0.001≤ P ≤ 0.020
14	33	0.015	0.007≤ P ≤ 0.022	7	0.007	-0.001≤ P ≤ 0.016	6	0.007	-0.002≤ P ≤ 0.016
15	31	0.014	0.006≤ P ≤ 0.023	14	0.015	0.003≤ P ≤ 0.027	32	0.038	0.018≤ P ≤ 0.058
16	48	0.021	0.012≤ P ≤ 0.035	24	0.025	0.010≤ P ≤ 0.041	20	0.024	0.008≤ P ≤ 0.040
17	112	0.049	0.035≤ P ≤ 0.068	37	0.039	0.020≤ P ≤ 0.059	33	0.039	0.019≤ P ≤ 0.060
18	200	0.088	0.070≤ P ≤ 0.100	98	0.104	0.073≤ P ≤ 0.134	97	0.116	0.082≤ P ≤ 0.150
19	81	0.036	0.024≤ P ≤ 0.050	39	0.041	0.021≤ P ≤ 0.061	20	0.024	0.008≤ P ≤ 0.040
20	119	0.052	0.038≤ P ≤ 0.065	20	0.021	0.007≤ P ≤ 0.036	33	0.039	0.019≤ P ≤ 0.060
21	96	0.042	0.029≤ P ≤ 0.054	16	0.017	0.004≤ P ≤ 0.030	41	0.049	0.026≤ P ≤ 0.072
22	81	0.036	0.024≤ P ≤ 0.045	24	0.025	0.010≤ P ≤ 0.041	18	0.021	0.006≤ P ≤ 0.037
23	48	0.021	0.012≤ P ≤ 0.033	4	0.004	-0.002≤ P ≤ 0.011	26	0.031	0.013≤ P ≤ 0.049
24	86	0.038	0.026≤ P ≤ 0.058	61	0.065	0.040≤ P ≤ 0.089	17	0.020	0.005≤ P ≤ 0.035
25	236	0.104	0.084≤ P ≤ 0.122	61	0.065	0.040≤ P ≤ 0.089	73	0.087	0.057≤ P ≤ 0.117
26	186	0.082	0.064≤ P ≤ 0.097	67	0.071	0.045≤ P ≤ 0.097	76	0.091	0.060≤ P ≤ 0.121
27	137	0.060	0.045≤ P ≤ 0.066	64	0.068	0.043≤ P ≤ 0.093	62	0.074	0.046≤ P ≤ 0.102
28	15	0.007	0.001≤ P ≤ 0.011	10	0.011	0.000≤ P ≤ 0.021	14	0.017	0.003≤ P ≤ 0.030
29	13	0.006	0.001≤ P ≤ 0.006	6	0.006	-0.002≤ P ≤ 0.014	6	0.007	-0.002≤ P ≤ 0.016

P = proportion of total tracks observed.

Early Summer Movement

	Pre-Construction			During Construction			Post-Construction		
Segment	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval
5	4	0.005	-0.011≤ P ≤ 0.022	3	0.014	-0.010≤ P ≤ 0.038	5	0.024	-0.009≤ P ≤ 0.057
6	1	0.070	0.013≤ P ≤ 0.128	10	0.046	0.002≤ P ≤ 0.089	0	0.000	0.000≤ P ≤ 0.000
7	13	0.022	-0.011≤ P ≤ 0.054	37	0.169	0.091≤ P ≤ 0.246	47	0.229	0.139≤ P ≤ 0.319
8	4	0.011	-0.012≤ P ≤ 0.034	11	0.050	0.005≤ P ≤ 0.095	26	0.127	0.056≤ P ≤ 0.198
9	2	0.032	-0.007≤ P ≤ 0.072	3	0.014	-0.010≤ P ≤ 0.038	1	0.005	-0.010≤ P ≤ 0.020
10	6	0.027	-0.009≤ P ≤ 0.064	4	0.018	-0.009≤ P ≤ 0.046	0	0.000	0.000≤ P ≤ 0.000
11	5	0.076	0.016≤ P ≤ 0.135	10	0.046	0.002≤ P ≤ 0.089	2	0.010	-0.011≤ P ≤ 0.031
12	14	0.043	-0.003≤ P ≤ 0.089	8	0.037	-0.002≤ P ≤ 0.075	1	0.005	-0.010≤ P ≤ 0.020
13	8	0.022	-0.011≤ P ≤ 0.054	12	0.055	0.008≤ P ≤ 0.102	0	0.000	0.000≤ P ≤ 0.000
14	4	0.011	-0.012≤ P ≤ 0.034	10	0.046	0.002≤ P ≤ 0.089	3	0.015	-0.011≤ P ≤ 0.040
15	2	0.011	-0.012≤ P ≤ 0.034	13	0.059	0.010≤ P ≤ 0.108	9	0.044	0.000≤ P ≤ 0.088
16	2	0.032	-0.007≤ P ≤ 0.072	1	0.005	-0.009≤ P ≤ 0.019	5	0.024	-0.009≤ P ≤ 0.057
17	6	0.076	0.016≤ P ≤ 0.135	4	0.018	-0.009≤ P ≤ 0.046	12	0.059	0.008≤ P ≤ 0.109
18	14	0.065	0.009≤ P ≤ 0.120	7	0.032	-0.004≤ P ≤ 0.068	9	0.044	0.000≤ P ≤ 0.088
19	12	0.027	-0.009≤ P ≤ 0.064	15	0.068	0.016≤ P ≤ 0.121	9	0.044	0.000≤ P ≤ 0.088
20	5	0.032	-0.007≤ P ≤ 0.072	7	0.032	-0.004≤ P ≤ 0.068	14	0.068	0.014≤ P ≤ 0.122
21	6	0.032	-0.007≤ P ≤ 0.072	2	0.009	-0.011≤ P ≤ 0.029	2	0.010	-0.011≤ P ≤ 0.031
22	6	0.005	-0.011≤ P ≤ 0.022	2	0.009	-0.011≤ P ≤ 0.029	2	0.010	-0.011≤ P ≤ 0.031
23	1	0.081	0.020≤ P ≤ 0.142	2	0.009	-0.011≤ P ≤ 0.029	7	0.034	-0.005≤ P ≤ 0.073
24	15	0.092	0.027≤ P ≤ 0.157	7	0.032	-0.004≤ P ≤ 0.068	18	0.088	0.027≤ P ≤ 0.148
25	17	0.092	0.027≤ P ≤ 0.157	11	0.050	0.005≤ P ≤ 0.095	14	0.068	0.014≤ P ≤ 0.122
26	17	0.108	0.038≤ P ≤ 0.178	13	0.059	0.010≤ P ≤ 0.108	11	0.054	0.005≤ P ≤ 0.102
27	20	0.005	-0.011≤ P ≤ 0.022	13	0.059	0.010≤ P ≤ 0.108	5	0.024	-0.009≤ P ≤ 0.057
28	1	0.000	0.000≤ P ≤ 0.000	7	0.032	-0.004≤ P ≤ 0.068	1	0.005	-0.010≤ P ≤ 0.020
29	0	1.000	1.000≤ P ≤ 1.000	7	0.032	-0.004≤ P ≤ 0.068	2	0.010	-0.011≤ P ≤ 0.031

P = proportion of total tracks observed.

Late Summer Movement

	Pre-Construction			During Construction			Post-Construction		
Segment	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval	Observed	P	Bonferroni Interval
5	1	0.003	-0.006≤ P ≤ 0.012	4	0.006	-0.003≤ P ≤ 0.015	8	0.012	-0.001≤ P ≤ 0.026
6	1	0.003	-0.006≤ P ≤ 0.012	20	0.031	0.010≤ P ≤ 0.051	10	0.016	0.001≤ P ≤ 0.030
7	1	0.003	-0.006≤ P ≤ 0.012	51	0.078	0.046≤ P ≤ 0.110	62	0.096	0.061≤ P ≤ 0.132
8	5	0.015	-0.006≤ P ≤ 0.036	8	0.012	-0.001≤ P ≤ 0.025	18	0.028	0.008≤ P ≤ 0.048
9	2	0.006	-0.007≤ P ≤ 0.019	3	0.005	-0.003≤ P ≤ 0.013	1	0.002	-0.003≤ P ≤ 0.006
10	6	0.018	-0.004≤ P ≤ 0.041	10	0.015	0.001≤ P ≤ 0.030	7	0.011	-0.002≤ P ≤ 0.023
11	23	0.071	0.027≤ P ≤ 0.114	18	0.028	0.008≤ P ≤ 0.047	26	0.040	0.017≤ P ≤ 0.064
12	16	0.049	0.013≤ P ≤ 0.086	42	0.064	0.035≤ P ≤ 0.094	34	0.053	0.026≤ P ≤ 0.080
13	7	0.022	-0.003≤ P ≤ 0.046	28	0.043	0.019≤ P ≤ 0.067	9	0.014	0.000≤ P ≤ 0.028
14	7	0.022	-0.003≤ P ≤ 0.046	21	0.032	0.011≤ P ≤ 0.053	36	0.056	0.028≤ P ≤ 0.084
15	3	0.009	-0.007≤ P ≤ 0.025	10	0.015	0.001≤ P ≤ 0.030	24	0.037	0.014≤ P ≤ 0.060
16	5	0.015	-0.006≤ P ≤ 0.036	24	0.037	0.014≤ P ≤ 0.059	16	0.025	0.006≤ P ≤ 0.044
17	15	0.046	0.011≤ P ≤ 0.082	34	0.052	0.025≤ P ≤ 0.079	65	0.101	0.065≤ P ≤ 0.137
18	13	0.040	0.007≤ P ≤ 0.073	21	0.032	0.011≤ P ≤ 0.053	23	0.036	0.013≤ P ≤ 0.058
19	11	0.034	0.003≤ P ≤ 0.065	26	0.040	0.016≤ P ≤ 0.063	31	0.048	0.022≤ P ≤ 0.074
20	15	0.046	0.011≤ P ≤ 0.082	53	0.081	0.048≤ P ≤ 0.114	11	0.017	0.001≤ P ≤ 0.033
21	17	0.052	0.015≤ P ≤ 0.090	19	0.029	0.009≤ P ≤ 0.049	31	0.048	0.022≤ P ≤ 0.074
22	7	0.022	-0.003≤ P ≤ 0.046	0	0.000	0.000≤ P ≤ 0.000	17	0.026	0.007≤ P ≤ 0.046
23	5	0.015	-0.006≤ P ≤ 0.036	15	0.023	0.005≤ P ≤ 0.041	15	0.023	0.005≤ P ≤ 0.042
24	31	0.095	0.046≤ P ≤ 0.145	70	0.107	0.070≤ P ≤ 0.144	35	0.054	0.027≤ P ≤ 0.082
25	50	0.154	0.093≤ P ≤ 0.215	76	0.116	0.078≤ P ≤ 0.155	67	0.104	0.067≤ P ≤ 0.141
26	50	0.154	0.093≤ P ≤ 0.215	55	0.084	0.051≤ P ≤ 0.117	64	0.100	0.063≤ P ≤ 0.136
27	23	0.071	0.027< P < 0.114	19	0.029	0.009≤ P ≤ 0.049	25	0.039	0.016≤ P ≤ 0.062
28	5	0.015	-0.006≤ P ≤ 0.036	11	0.017	0.001≤ P ≤ 0.032	7	0.011	-0.002≤ P ≤ 0.023
29	6	0.018	-0.004≤ P ≤ 0.041	16	0.024	0.006≤ P ≤ 0.043	1	0.002	-0.003≤ P ≤ 0.006

P = proportion of total tracks observed.