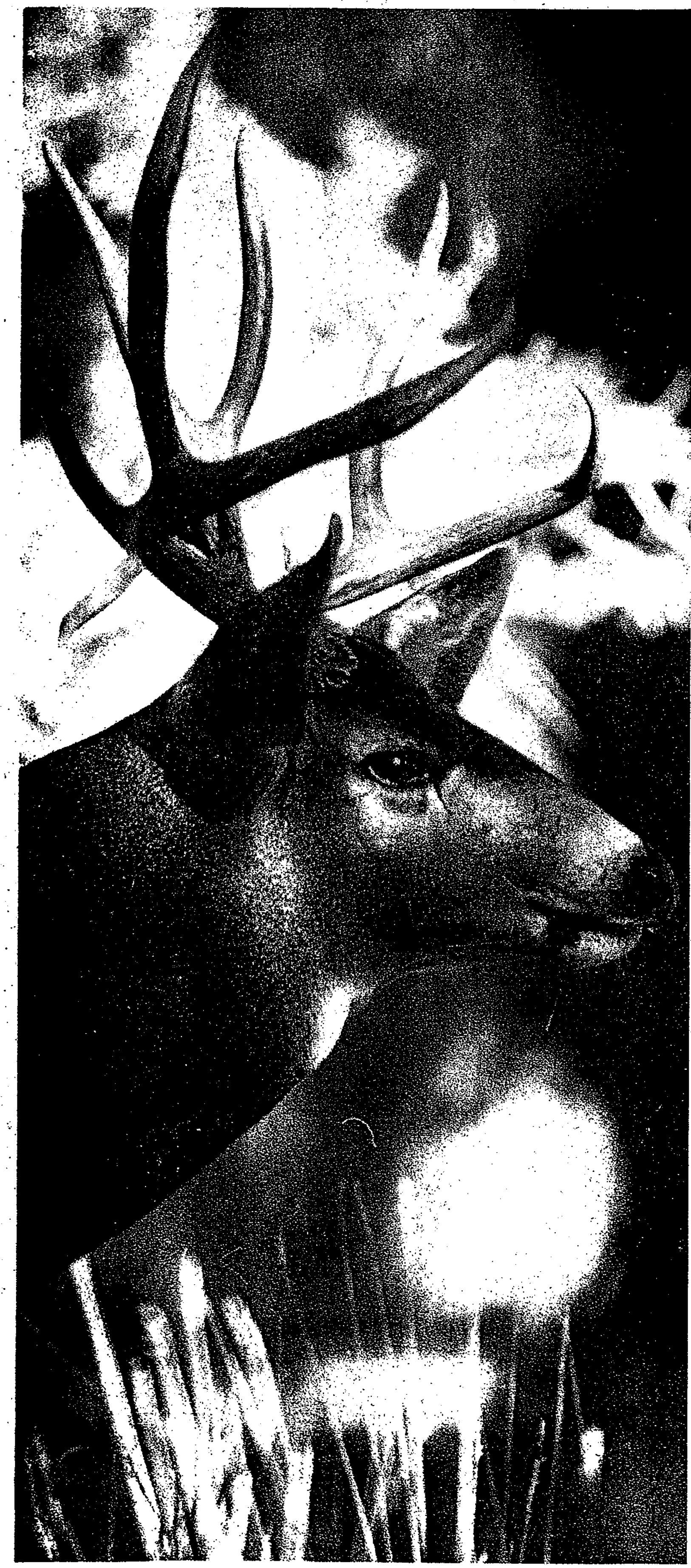
ARIZONA GAME AND FISH DEPARTMENT



RESEARCH BRANCH
TECHNICAL REPORT #29

AN EVALUATION OF ANNUAL MIGRATION PATTERNS OF THE PAUNSAUGUNT MULE DEER HERD BETWEEN UTAH AND ARIZONA

A Final Report

WILLIAM K. CARREL
RICHARD A. OCKENFELS
RAYMOND E. SCHWEINSBURG
July 1999

FEDERAL AID IN WILDLIFE
RESTORATION PROJECT

Arizona Game and Fish Department Mission
To conserve, enhance, and restore Arizona's diverse wildlife resources and habitats through aggressive protection and management programs, and to provide wildlife resources and safe watercraft and off-highway vehicle recreation for the enjoyment, appreciation, and use by present and future generations.

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William K. Carrel
Richard A. Ockenfels
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Federal Aid in Wildlife Restoration
Project W-78-R

CONTENTS

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Floyd Coles of UDWR coordinated mule deer capture efforts. Bob Lemons, Wildlife Manager for Arizona's Game Management Unit 12B, investigated mule deer mortalities in Arizona. Utah State University (USU) graduate student Paul Klimack conducted concurrent ground studies that helped define movement corridors and highway mortality. Sue Boe and Jennifer Wennerlund transformed and plotted mule deer locations, defined location parameters, and created maps using a Geographic Information System (GIS) that were essential to this study. Dr. Warren Ballard, AGFD, supervised and advised us during part of the study. Our greatest appreciation goes to Dr. Terry Messmer, Associate Professor at USU, for coordinating governmental and private organizations involved with the planning and funding of the larger study. He enlisted early AGFD participation in this interstate project.

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STUDY AREAS

Our study area was in southwestern Utah and northwestern Arizona (Fig. 1). It spanned 150 km from Utah State Route (SR) 12 south to the Kaibab Plateau south of Jacob Lake, Arizona, and 70 km from US 89 east to the Paria River. It included all of GMU 27 in Utah and portions of GMUs 12A and 12B in Arizona (Fig. 2).

The Dixie National Forest boundary generally delineates the Paunsaugunt Plateau. Bryce Canyon National Park is located on the eastern side of the Plateau and the Sevier River Valley is on the western side. The Sevier River drains north; however, 4 main drainages on the southern side of the Plateau flow south into Arizona. The latter 4 drainages are Kanab Creek, Johnson Canyon, Deer Springs Wash, and the Paria River. The Deer Springs Wash drainage changes names in lower sections; it is Kitchen Corral Wash from the Vermilion Cliffs to US 89, then Kaibab Gulch to the Paria River. Hereafter, the entire drainage will be referred to as Deer Springs Wash.

The Paunsaugunt Plateau changes in elevation from 2,450 m near SR 12 at the northern end to 2,935 m in the center to 2,700 m at its southern end. The Paunsaugunt Plateau contains high ridges with steep slopes and deep valleys with meadows. Terrain to the south is terraced and drops from 2,010 m at Skutumpah Terrace to 1,580 m at US 89 in the valley east of Kanab (Fig. 3).

The Buckskin Mountains, south of US 89, are an important portion of mule deer winter range. The Buckskin Mountains vary in elevation from 1,900 m at their northern end to 2,300 m at their southern end. This mountain range is an extension of the Kaibab Plateau.

Dominant overstory vegetation on Utah summer range includes: pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) at lower elevations, ponderosa pine (*P. ponderosa*) and Gambel oak (*Quercus gambelii*) at mid elevations, and spruce (*Picea engelmannii*), subalpine fir (*Abies lasiocarpa*), and aspen (*Populus tremuloides*) at higher elevations (Fig. 4). Sagebrush (*Artemesia* spp.) dominates the understory below the Paunsaugunt Plateau. In addition, irrigated alfalfa fields occur around Alton.

Mule deer winter range extends from the Wygaret Terrace to the Buckskin Mountains (Fig. 5), where the predominant overstory is pinyon pine and Utah juniper, with some Gambel oak, mainly in drainages. Dominant understory vegetation is big sagebrush (*A. tridentata*) and sand sagebrush (*A. filifolia*). The area which mule deer travel through between winter and summer ranges is primarily pinyon-juniper woodland and sagebrush.

At Bryce Canyon National Park, Utah (2,412 m), long-term mean maximum and minimum temperatures for January were 2.2 C and -12.8 C (Ashcroft et al. 1992, Utah Climate Center 1993). In July, mean maximum and minimum temperatures were 26.7 C and 7.8 C. Mean annual precipitation had been 39.4 cm and occurred slightly greater during July, August, and September. Mean annual snowfall was 217 cm, with most occurring from November through March.

Fredonia, Arizona (1,425 m), is 6.4 km south of the Utah-Arizona state line. It is the closest weather station and similar in elevation to winter range in the valley just east of Kanab. Historic mean maximum and minimum temperatures for January were 7.8 C and -7.2 C (Sellers and Hill 1974). In July, mean maximum and minimum temperatures were 33.9 C and 12.2 C. Mean annual precipitation had been 25.4 cm, but varied from 10 to 38 cm, with May and June being the driest months. Mean snowfall was 51 cm.

Jacob Lake, Arizona (2,414 m), is on the Kaibab Plateau at the southern end of the study area. Mean maximum and minimum temperatures for January were 4.4 C and -9.4 C (Sellers and Hill 1974). In July, mean maximum and minimum temperatures were 26.7 C and 10 C. Annual precipitation had been 48 cm, with the wettest months being July and August. Snow depths >61 cm were not uncommon.

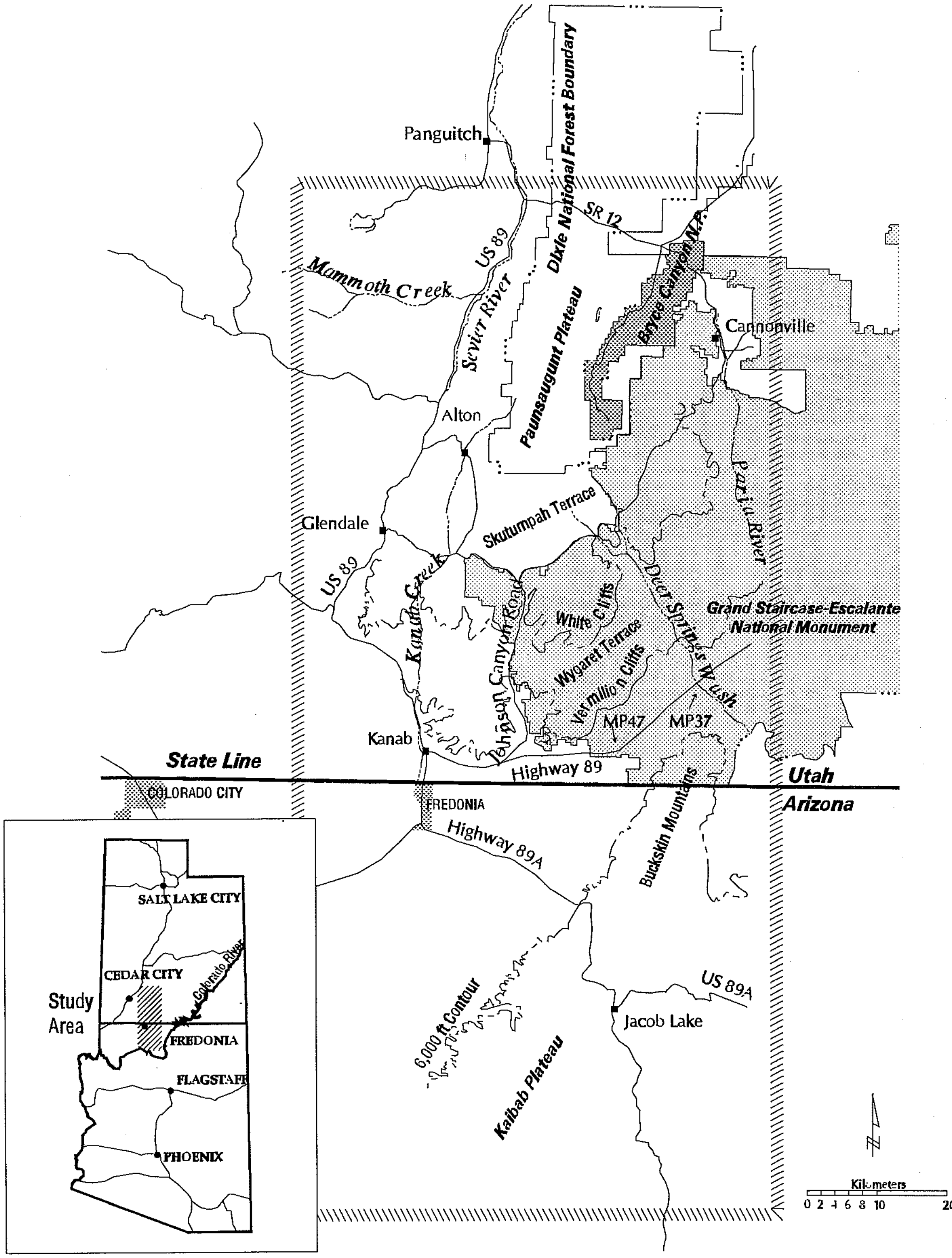


Figure 1. Location and key features of the Paunsaugunt Plateau-Buckskin Mountains study area in Utah and Arizona (MP = U.S. Highway 89 mile post).

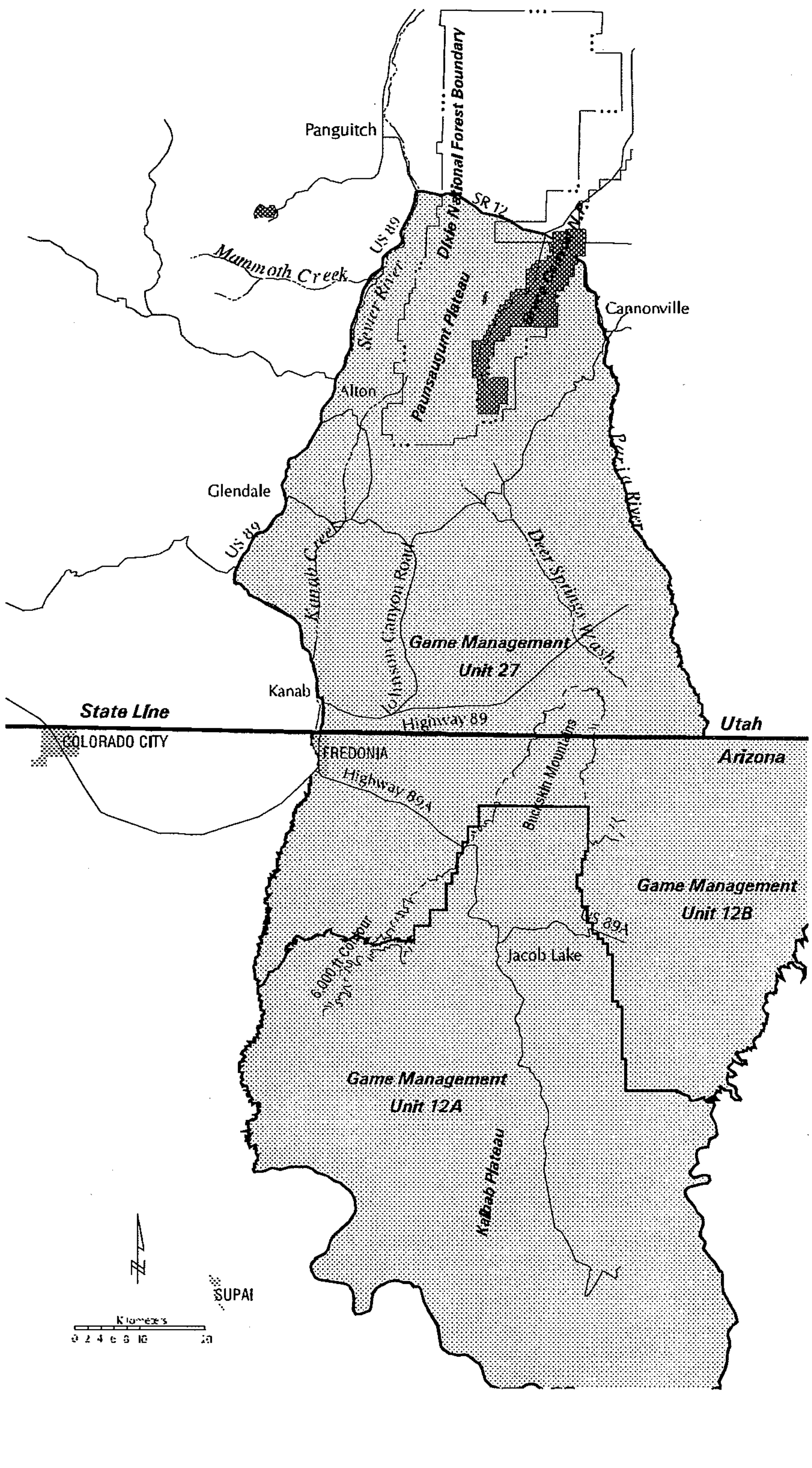


Figure 2. Game management unit (GMU) boundaries for Utah's GMU 27 and for Arizona's GMUs 12A and 12B on the Paunsaugunt Plateau-Buckskin Mountains study area.

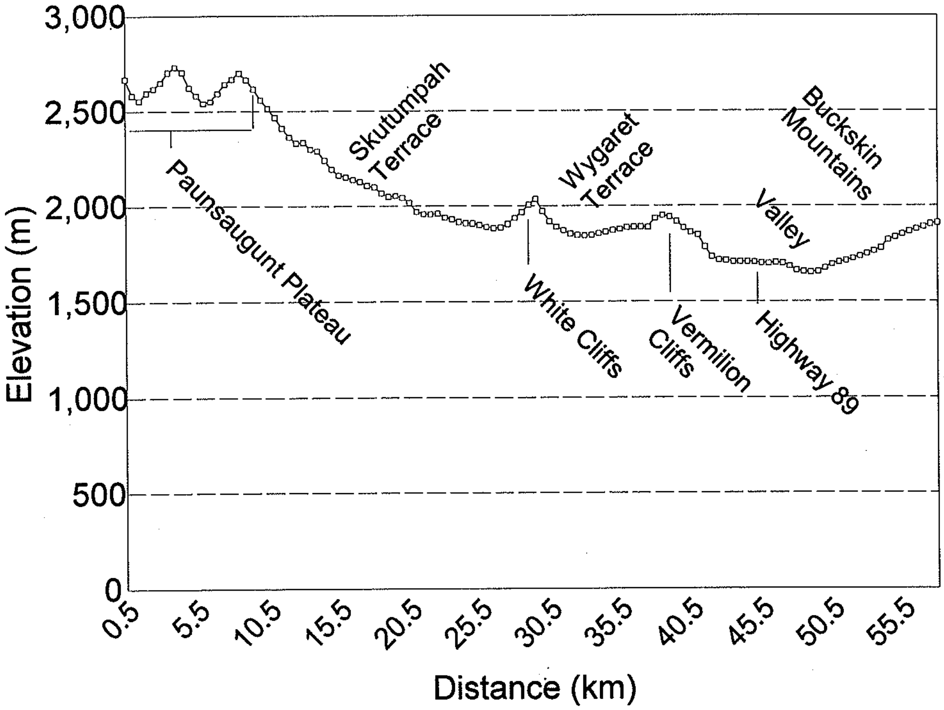


Figure 3. Elevation profile of terrain between the Paunsaugunt Plateau and the Buckskin Mountains.

Utah's GMU 27 encompasses 3,823 km^2 (Fig. 2). Bureau of Land Management (BLM) was the primary land-managing agency (63%) of GMU 27. Archery mule deer hunting began in late August, followed in September-October with a rifle season and in November with a muzzleloader season. These hunts were limited to antlered mule deer during the study. Antlerless mule deer hunts using any legal weapon were conducted occasionally in limited areas.

Arizona's GMU 12B encompasses 3,026 km^2 (Fig. 2). The BLM managed 80.5% of the land in this GMU. Our study area encompassed the central and western portion of this GMU. Archery mule deer hunting occurred from late August to mid-September. Two rifle hunts occurred from the end of October through November, and in 1998 a muzzleloader hunt was added between these hunts. This muzzleloader hunt will alternate annually between GMU 12B and subunit 12A East. These hunts were limited to any antlered deer during the study. Antlerless hunts are considered in GMU 12B when browse utilization by mule deer exceeds levels to maintain range health.

Arizona's GMU 12A encompasses 4,306 km^2 (Fig. 2). The U.S. Forest Service (USFS) managed 61% of the land in this GMU as part of the Kaibab National Forest, and the U.S. National Park Service (NPS) managed 37.5% as part of Grand Canyon National Park. Archery mule deer hunting typically occurred in mid-September through early October, except on the Park where hunting was not allowed. A 4-day muzzleloader hunt occurred in mid-October every other year in subunit 12A East. From October through November, 2 rifle hunts occurred in each of the 2 subunits of GMU 12A, 12A East and 12A West. These hunts were limited to any antlered deer during the study. Anterless hunts are considered in GMU 12A when browse utilization by mule deer exceeds levels to maintain range health.

Figure 4. Mule deer summer range on the Paunsaugunt Plateau, Utah.

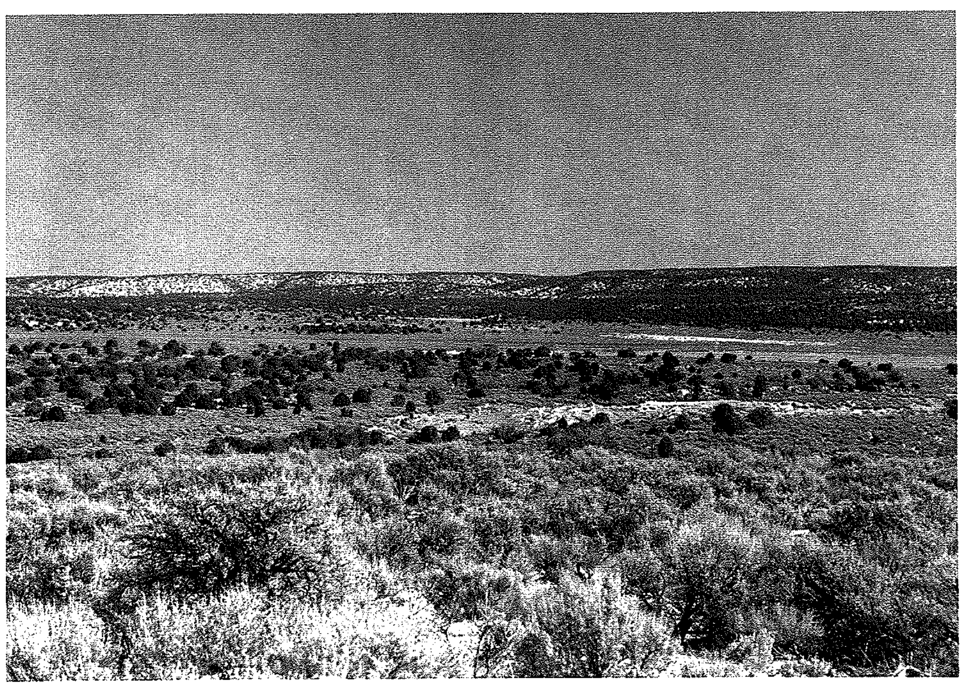


Figure 5. Mule deer winter range in the valley east of Kanab, Utah, with the Buckskin Mountains in the background.

METHODS

Capture and Telemetry

We captured adult mule deer by net-gunning from a helicopter (Smith and Horejsi 1982, Krausman et al. 1985, DeYoung 1988) in Utah during 2 summers (1994 and 1995), in Utah and Arizona during winter of 1995-96, and in Arizona during winter of 1996-97. Mule deer were ear-tagged, fitted with mortality-sensing radiocollars (Telonics, Inc., Mesa, Arizona, or Lotek Engineering Inc., Newmarket, Ontario, Canada), and released.

We located mule deer using radiotelemetry from single-engine, high-wing aircraft. We located radiomarked mule deer twice per week during 5 weeks between late-March through April and 5 weeks between October through mid-November to cover the migration periods; we located mule deer once every 2 weeks during other periods.

Aircraft used by AGFD had 2 radiotracking antenna systems. One system consisted of 2 phased, 3-element Yagi antennas, 1 on each wing strut facing forward and vertically oriented; this system was used to search for signals. The second antenna system was a 2-element, uni-directional antenna mounted horizontally on a rotatable shaft through the floor of the aircraft. This antenna, controlled by the observer, was used to locate signals by multiple signal-direction fixes as the aircraft circled above the source (Carrel 1972*a,b*). Once located, the mule deer's position was overflown and recorded on a datalogger (Omnidata® Polycorder 600) connected to the aircraft's navigational Global Positioning System (GPS) receiver (Northstar® M2 Navigator). The location was recorded as latitude and longitude coordinates in WGS84 datum, with an instrument measuring precision of 0.01 sec. Later, coordinates were downloaded to a computer, then projected to Universal Transverse Mercator (UTM) coordinates for Zone 12, North American Datum of 1927, using Arc/Info® software (Version 7.0.2, Environmental Systems Research Institute, Redlands, California). Individual animal positions were projected to a background map for each telemetry flight using Geographic Information System (GIS) software.

A left-right antenna system was used by UDWR on its aircraft for radiotracking. A 2-element antenna was mounted on each wing strut facing out along the wing and down 45 degrees in a horizontal orientation (Gilmer et al. 1981). For the first year, UDWR recorded positions manually from a **LO**ng **RA**nge **N**avigation system version **C** (LORAN-C) receiver, with an instrument measuring precision of 0.1 sec. Later, they used a GPS receiver and datalogger similar to that used by AGFD. Telemetry data obtained by UDWR were transferred to AGFD for data processing.

Migration Direction and Distance

We plotted movements of radiomarked mule deer and assigned them to 1 of 3 deer groups for analyses: mule deer that resided only in Utah (Utah mule deer); mule deer that resided in both Utah and Arizona (Interstate mule deer); and mule deer that resided only in Arizona (Arizona mule deer). Utah mule deer and Interstate mule deer when analyzed together are referred to as Paunsaugunt mule deer. Due to possible location error from use of LORAN-C (Carrel et al. 1997), only Paunsaugunt mule deer with a location more than 500 m south of the state line were considered Interstate mule deer.

We calculated a geographic center of activity (COA) of each Paunsaugunt mule deer for summer (May 19-September 11) and for winter (November 12-March 3) seasons each year. We did the same for each Arizona mule deer for summer (June 21-October 14) and for winter (December 19-April 15) seasons; season dates differed from Paunsaugunt mule deer because of different migration timing. We defined COA as the average easting and average northing UTM coordinates (Hayne 1949). We computed straight-line distances between summer COAs and the following winter COAs for mule deer, by year, using the distance equation:

$$\text{distance} = [e_1 - e_2)^2 + (n_1 - n_2)^2]^{0.5} \qquad (1)$$

where e_1 and n_1 are the easting and northing UTM coordinates for the first COA, respectively, and e_2 and n_2 are the easting and northing UTM coordinates for the second COA, respectively.

Paunsaugunt Mule Deer. For Utah and Interstate mule deer, we conducted a Kolmogorov-Smirnov one-sample goodness of fit (K-S) test to assess normality of distances between winter and summer COAs. We used Kruskal-Wallis one-way analysis of variance (K-W ANOVA) to compare distances between COAs among years. By combining years and comparing between sexes using a Mann-Whitney rank sum (M-W) test, we evaluated the null hypothesis that migration distances traveled by bucks and does did not differ. We calculated mean distance traveled between winter and summer COAs.

Arizona Mule Deer. We performed similar tests for Arizona mule deer as described for Utah and Interstate mule deer. All analyses were performed using SPSS (SPSS, Inc., Chicago, IL), with alpha set at 0.05.

Migration Timing and Duration

We calculated perpendicular distances from the state line (positive north and negative south) for all locations using GIS software. We assigned elevation (m) to locations using a GIS digital elevation model (U.S. Geological Survey 90-m Digital Elevation Model). When a flight required 2 consecutive days to locate mule deer, we assigned the date of the first day to locations for analyses. We averaged distances (km) and elevations (m) for each deer group by calendar month. We averaged distances and elevations for Paunsaugunt mule deer for each flight between September 1 and November 28 and between March 1 and May 31 for each year to quantify duration and timing of autumn and spring migrations. We did the same for Arizona mule deer to define autumn (September 1-December 24) and spring (March 1-July 8) migrations. We again changed season dates because Arizona mule deer migration timing differed from Paunsaugunt mule deer. We recorded the first location dates in Arizona during autumn migration and in Utah during spring migration for each Interstate mule deer, each year, to determine when Interstate mule deer entered and left Arizona. We recorded similar location dates for Arizona mule deer to determine when they entered and left GMU 12B.

Migration Corridors

We estimated mule deer migration routes by overlaying aerial locations on background maps and assessing specific corridors based on topographic features. Aerial locations, mule deer road-kill locations, and nighttime ground surveys conducted by USU personnel were used to determine where migrating mule deer crossed US 89.

Winter and Summer Areas

Individual radiomarked mule deer were located too infrequently during winter and summer seasons to calculate individual annual winter or summer use areas. Therefore, we generated winter and summer aggregate use areas for Paunsaugunt and Arizona mule deer by year. We calculated winter and summer use areas as 95% probability areas using the adaptive kernel method (Worton 1989) in the home range software program CalHome® (Kie et al. 1994).

Fidelity to Winter and Summer Areas

Paunsaugunt Mule Deer. We measured area overlap of 95% probability summer or winter aggregate use areas during succeeding years to examine population fidelity to these use areas. We calculated distances (Equation 1) between winter COAs of the first year (1995-1996) and winter COAs of the second year (1996-1997) to examine fidelity of individual mule deer to their winter use area, and then computed descriptive statistics. We also calculated distances between summer COAs of 1995 and 1996 to examine fidelity of individuals to their summer use areas. We tested (M-W) the null hypothesis that fidelity to seasonal ranges did not differ between genders by comparing distances between successive COAs of winter or summer ranges for bucks versus does. Last, we calculated overall mean distance between successive annual COAs for each season.

Arizona Mule Deer. We examined fidelity to winter and summer ranges for Arizona mule deer using similar analyses. However, we only calculated distances between winter COAs of the second year (1995-96) and the third year (1997-98) because only 1 mule deer was radiomarked the first year. We calculated distances between the 1996 summer COAs and the 1997 summer COAs. We then computed a mean distance between successive annual COAs for each season.

Rate of Exchange and Extent of Migration

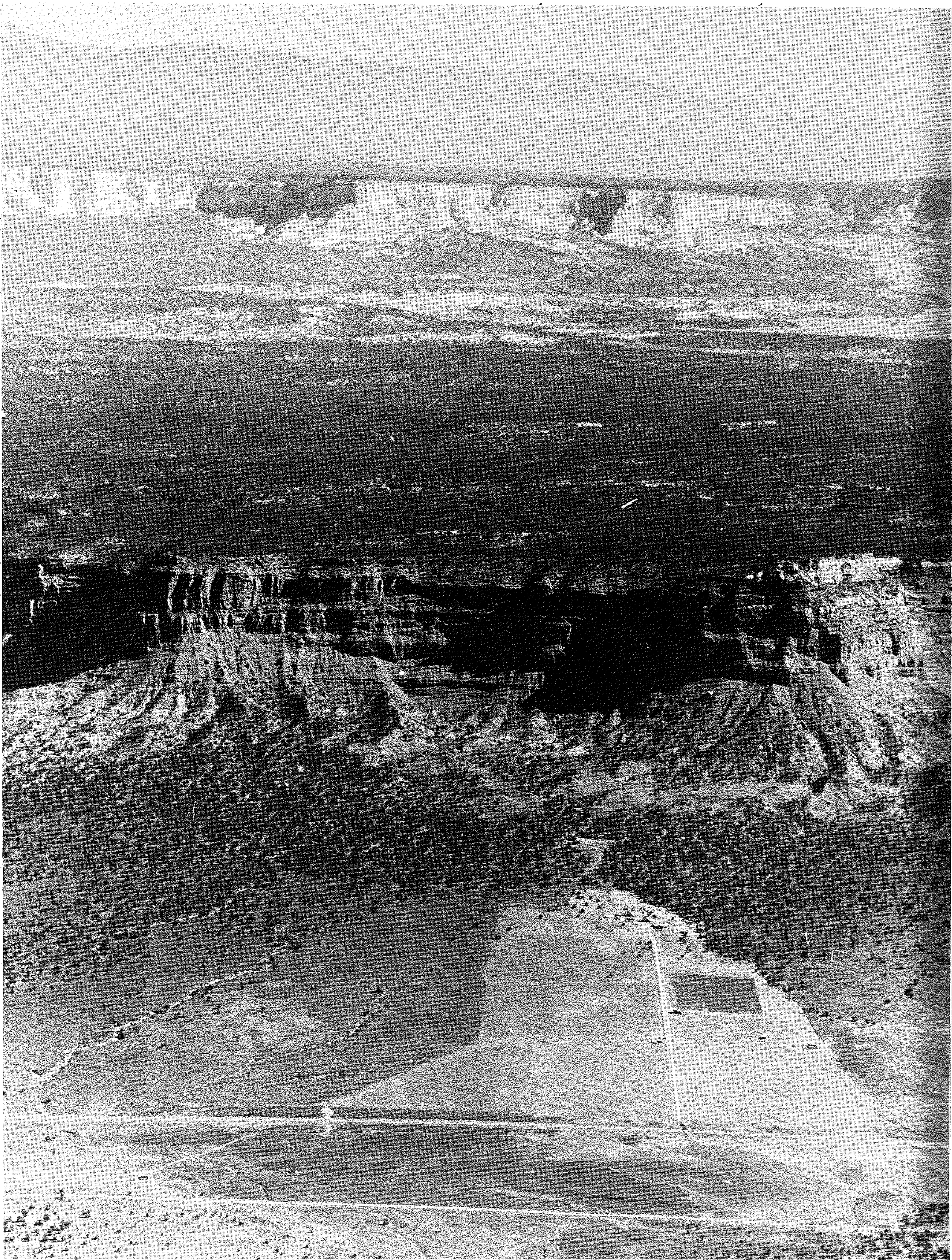
We calculated the percentage of mule deer captured on Utah summer range that migrated into Arizona to estimate the rate of exchange. We used this percentage as an initial estimate, then examined the movements of mule deer captured on winter range to further our understanding of Paunsaugunt mule deer movements into Arizona.

To measure the extent of movements into Arizona, we used distances (km) of Interstate mule deer locations in Arizona from the state line to calculate individual mean distances. Then, we calculated a mean distance (±SE) of Interstate mule deer movements into Arizona. We mapped mule deer locations in Arizona by deer group to visually show the extent of Interstate mule deer movements into Arizona and winter range overlap with Arizona mule deer.

Mortality

We investigated mule deer mortalities as quickly as possible to document time and cause of death. We examined sites and/or carcasses, assigned cause if possible, and recovered radiocollars. We calculated cause-specific mortality as a simple percentage, by gender, when appropriate.

We used Kaplan-Meier survival analysis (SPSS, Inc., Chicago, IL) to calculate annual survivorship for Paunsaugunt and Arizona does. Because of the small sample size for Arizona bucks, we only calculated annual survivorship for Paunsaugunt bucks.



RESULTS

Capture, Telemetry, and Important Movements

From August 1994 to February 1996, 83 mule deer (71 F, 12 M) were captured and radiocollared during 4 captures; 2 occurred on winter range and 2 on summer range (Table 1; Appendix 1). During the first capture, 12 mule deer, 2 at each of 6 locations, were captured on summer range west and southwest of the Paunsaugunt Plateau in the vicinity of Alton (Appendix 2a). In autumn of 1994, these mule deer migrated south, most to the Buckskin Mountains. Only 2 of these mule deer crossed into Arizona.

In the second capture, February 1995, 34 mule deer were captured on winter range along the Utah-Arizona state line, 18 in Utah and 16 in Arizona (Appendix 2b). Only 1 mule deer (#35) did not return to summer range in Utah in spring of 1995; apparently it was an Arizona mule deer because it migrated south to the Kaibab Plateau.

During the third capture, July 1995, 12 mule deer were captured west, southwest, and south of the Paunsaugunt Plateau (Appendix 2a). Two of these mule deer crossed into Arizona in autumn of 1996. One other mule deer (#53) did not migrate during autumn of 1995, but was forced to move 17 km south between December 20, 1996, and January 30, 1997, because of heavy snowfall. Mule deer #53 returned to its summer range by March 17, 1997.

During the fourth capture, February 1996, 25 mule deer were captured on winter range in Arizona along the eastern and western sides of the Buckskin Mountains (Appendix 2c). In spring of 1996, 5 of these mule deer returned north to summer range in Utah; whereas 18 mule deer moved south to summer range on the Kaibab Plateau; 2 died prior to spring migration.

From April 1995 to December 1997, 4,516 locations were obtained during 99 telemetry flights. AGFD completed 50 of the flights and UDWR completed 49.

Migration Direction and Distance

Paunsaugunt Mule Deer. Although 2 Paunsaugunt mule deer migrated northwest, most of them migrated south or southeast to winter range. We found no difference (X^2 = 0.055, n = 94, P = 0.973) in distance traveled by mule deer between seasonal ranges among years (Table 2, Appendix 3). Therefore, we combined years and found no difference (Z = 0.203, n = 94, P = 0.839) between bucks and does for

Table 1. Capure and residency data for Utah (Paunsaugunt herd), Interstate (Paunsaugunt herd), and Arizona (Kaibab herd) mule deer, 1994-96.

Capture season-year	Date	Number of mule deer	Sex	I.D.	Capture state		State residence[a]			
					Utah	Arizona	Utah	Inter-state	Arizona	Unk
Summer 1994	8/16/94	12	1M 11F	1-12	12		8	2		2
Winter 1995	2/17/95	34	10M 24F	13-46	18	16	12	17	1	4
Summer 1995	7/21/95	12	12F	47-58	12		10	2		
Winter 1996	2/13/96	25	1M 24F	59-83		25		5	18	2
Total		83	12M 71F		42	41	30	26	19	8

[a] Utah = mule deer that reside only in Utah.
Interstate = mule deer that reside in Utah and Arizona.
Arizona = mule deer that reside only in Arizona.
Unk = mule deer that died before residency could be determined.

Table 2. Mean distance (km) traveled by Paunsaugunt (Utah and Interstate) mule deer[a] migrating from Utah summer range south towards winter range along the Utah-Arizona state line, based on individual winter and summer centers of activity.

Year	*n*	$\bar{x}$	SE	Min	Max
1995	44	50.7	2.3	14.8	72.2
1996	32	51.2	2.5	16.3	70.6
1997	18	51.1	3.0	30.7	72.0

[a] Excludes mule deer #53, a nonmigrant, and 2 mule deer (#49 and #54) that migrated to the northwest.

distance traveled between seasonal ranges. The distance traveled between winter and summer COAs varied from 14.8 to 72.2 km during 3 years and averaged 50.9 km ($n = 94$, SE = 1.5).

Arizona Mule Deer. All Arizona mule deer migrated south to summer range on the Kaibab Plateau. We found no difference ($Z = -0.843$, $n = 26$, $P = 0.399$) between years in distance traveled by mule deer between seasonal ranges (Appendix 4). Thus, with the 2 years combined, distance varied from 8.8 to 58.3 km and averaged 22.6 km ($n = 26$, SE = 3.4). However, 4 of 16 mule deer traveled 38-58 km south to near the northern boundary of the Grand Canyon National Park. When these 4 mule deer were excluded, the average distance for the remaining 12 mule deer only varied from 8.8 to 23.1 km and averaged 13.2 km ($n = 19$, SE = 1.0). None of the Arizona mule deer migrated to winter range in Utah.

Migration Timing and Duration

By visually assessing plotted locations for individual mule deer and reviewing capture and mortality locations, we assigned 30 individuals as Utah mule deer and 26 as Interstate mule deer (Table 1). Combined, these 56 mule deer represented the Paunsaugunt herd.

We assigned 19 mule deer as Arizona mule deer, because they did not occur in Utah, but shared Arizona winter range with Interstate mule deer. Eight mule deer did not survive long enough for us to determine which group they represented.

We saw a similar pattern in mean distance from the Utah-Arizona state line by month for the Utah and Interstate segments of the Paunsaugunt herd, but a slightly different pattern by Arizona mule deer (Fig. 6a). The Arizona mule deer did not move as far from the state line as did the Utah and Interstate mule deer. Nonetheless, the general pattern was similar among the 3 groups. Mean distance to the state line increased during March-May as mule deer returned to their summer ranges, stabilized during June-September as mule deer remained on summer range, then decreased during September-November as mule deer migrated back to winter range.

Changes in mean elevation by month also showed similar timing of movements among the groups (Fig. 6b). Generally, these 2 patterns of data (changes in elevation and distance) indicated that spring migration for the 3 groups tended to occur from March through May, whereas autumn migration tended to occur from September through November.

Paunsaugunt Mule Deer. Mule deer movements during autumn and spring migrations were illustrated by changes in average distance of mule deer locations from the state line over time and by changes in average elevation of mule deer locations over time (Figs. 7 and 8). We interpreted that autumn migration began in late September-early October, when the mean elevation or mean distance began decreasing, and migration ended by early November when these same parameters stabilized. Mean elevation or mean distance began increasing in late March, indicating the beginning of spring migration. These parameters stabilized by mid-May, indicating an end to spring migration. Autumn and spring migrations appeared to last 6-7 weeks. Individual mule deer usually were located only once or twice between seasonal ranges during migration periods, indicating completion of migration by individual mule deer within 1-2 weeks.

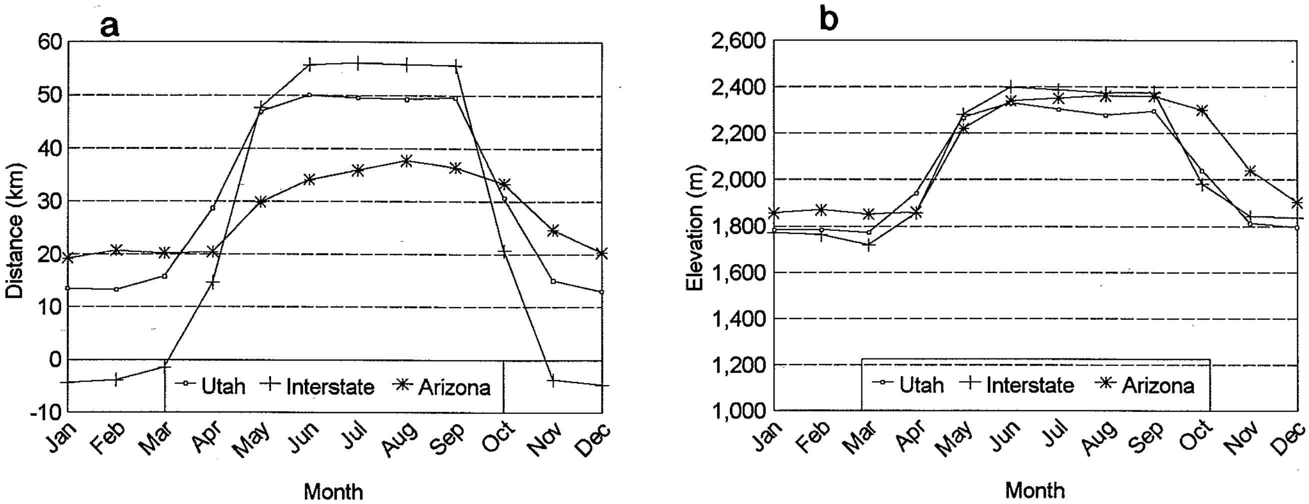


Figure 6. Migration timing and duration of deer groups (Utah, Interstate, and Arizona) by a) average distance from the Utah-Arizona state line (negative distances south of the state line for Arizona deer are shown as positive distances for convenience of comparison) and b) average elevation, 1995-97.

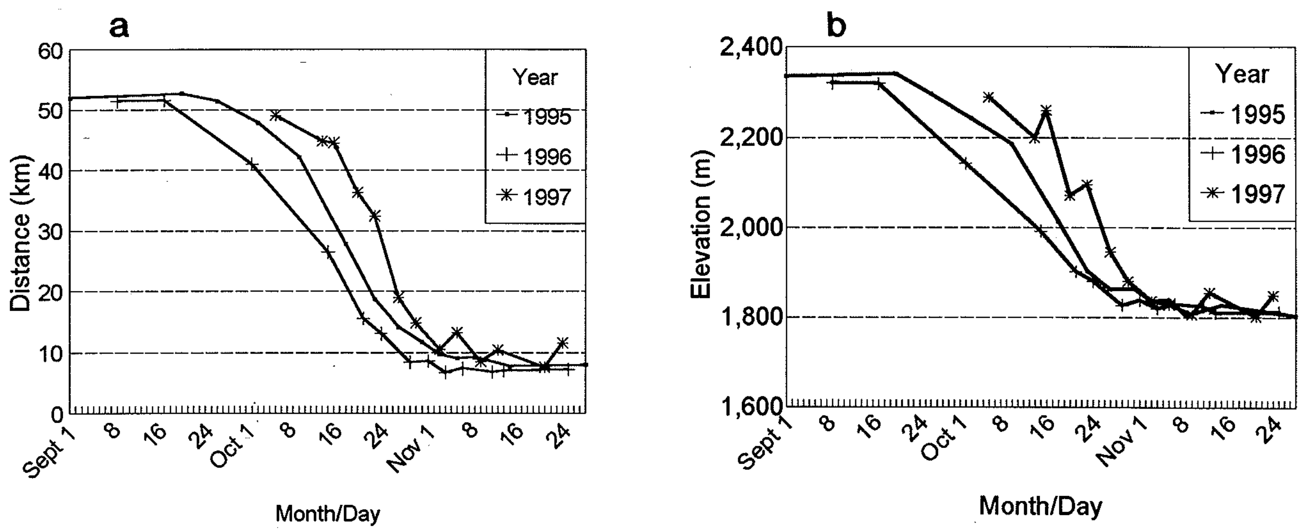


Figure 7. Autumn migration timing and duration of Paunsaugunt (Utah and Interstate) mule deer by a) average distance from the Utah-Arizona state line and b) average elevation, 1995-97.

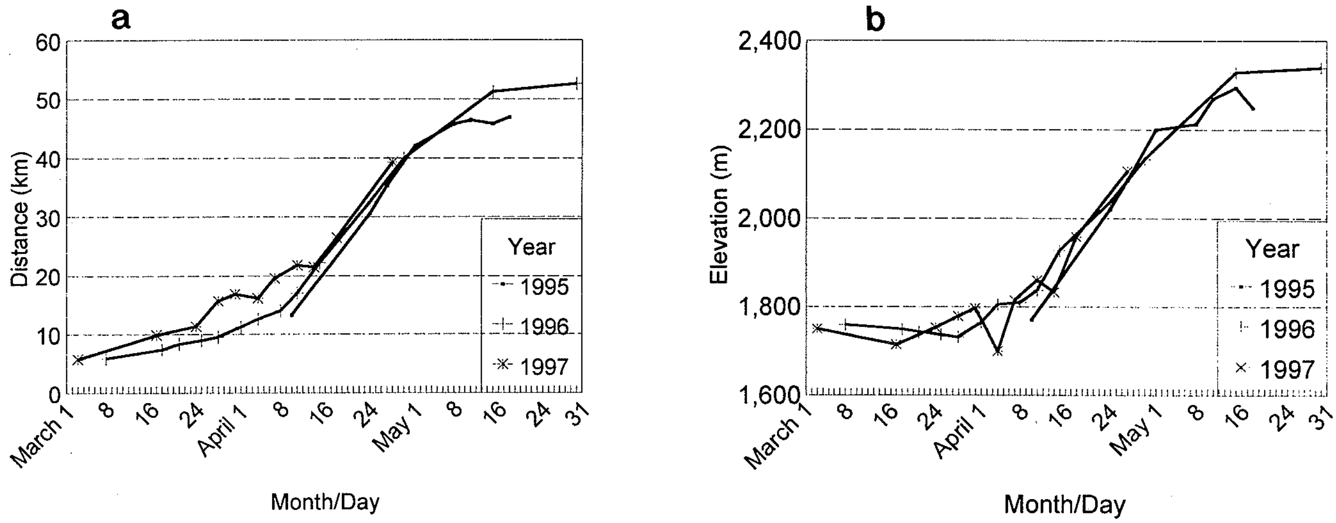


Figure 8. Spring migration timing and duration of Paunsaugunt (Utah and Interstate) mule deer by a) average distance from the Utah-Arizona state line and b) average elevation, 1995-97.

Some Interstate mule deer entered Arizona as early as October 10 and most (88.2%, Table 3, Appendix 5) entered by November 3. Some Interstate mule deer left Arizona as early as March 3 and most (87.9%, Table 4; Appendix 5) left by April 27. Thus, Interstate mule deer stayed in Arizona about 25 weeks each year.

Arizona Mule Deer. Using the same methods, we illustrated Arizona mule deer movements; we interpreted that autumn migration began in late October and ended in early December (Fig. 9), whereas spring migration began in late April and ended in early June (Fig. 10). Autumn and spring migrations for Arizona mule deer also appeared to last 6-7 weeks.

During 2 years, only 27.3% of the Arizona mule deer entered GMU 12B by November 4 and only 51.2% by December 15 (Table 5, Appendix 6). Although some Arizona mule deer (30.4%) left GMU 12B by April 24, most (78.3%) left by May 15 (Table 6, Appendix 6).

Migration Corridors

Paunsaugunt mule deer seemed to use the same migration corridors during autumn and spring when moving to or from winter range in the Buckskin Mountains (Fig. 11). Mule deer movements were likely restricted to limited breaks in the almost vertical White Cliffs that separate the Skutumpah and Wygaret terraces; further, movements likely occurred through limited breaks in the precipitous Vermilion Cliffs that separate Wygaret Terrace from the valley to the south. Main drainages through these cliffs provide the easiest access. Thus, we suspect Johnson Canyon and Deer Springs Wash were primary routes through the White Cliffs for mule deer traveling to and from winter range. Deer Springs Wash seemed the primary route through the Vermilion Cliffs. For mule deer that migrated to and from Wygaret Terrace just north of Kanab, we suspect Kanab Creek was their route through the White Cliffs.

Approximately 90% of mule deer that migrated across US 89 did so between mile markers 39-42 and 49-51 (P. W. Klimack and T. A. Messmer, USU, pers. commun.). Those Paunsaugunt mule deer on winter range south of US 89 seemed to use an area west of Deer Springs Wash between US 89 and the Vermilion Cliffs as a staging area during spring migration, before continuing on to summer range.

Winter and Summer Areas

Paunsaugunt Mule Deer. Comparing area overlap of winter and summer 95% probability use areas (all mule deer combined) for each of 3 years (Fig. 12), we found that the 1996-97 and 1997-98 winter ranges encompassed 78.9% and 83.1% of the base 1995-96 winter range, respectively. Likewise, 1996 and 1997 summer ranges enclosed 99.9% and 76.3% of the base 1995 summer range, respectively.

Table 3. Cumulative percentage of Interstate mule deer entering Arizona during autumn migration by date.

Date		1995	1996	1997	All years combined
October	10	14.3	0	0	5.9
	15	14.3	38.5	0	20.6
	18	28.6	38.5	0	26.5
	21	28.6	58.3	0	32.3
	24	57.1	76.9	0	52.9
	27	71.4	76.9	57.1	70.6
	30	78.6	92.3	71.4	79.4
November	3	85.7	92.3	85.7	88.2
	15	100.0	92.3	100.0	97.1
December	19	100.0	100.0	100.0	100.0
No. marked		14	13	7	34
Begin hunt[a]		Oct. 26	Oct. 25	Oct. 31	

[a] Beginning date of first rifle hunt for any antlered deer in Game Management Unit 12B.

Table 4. Cumulative percentage of Interstate mule deer leaving Arizona during spring migration by date.

Date		1995	1996	1997	All years combined
March	8	0	17.6	28.6	12.5
	4	0	29.4	57.1	28.1
April	8	0	35.3	57.1	31.3
	1	0	41.2	57.1	34.4
	5	0	52.9	57.1	40.6
	8	0	52.9	71.4	43.8
	4	37.5	76.5	71.4	65.6
	8	75.0	76.5	85.7	78.1
May	1	75.0	82.4	85.7	81.3
	8	87.5	82.4	85.7	84.4
	5	100.0	94.1	85.7	93.8
	1	100.0	100.0	85.7	96.9
No. marked		8	17	7	32

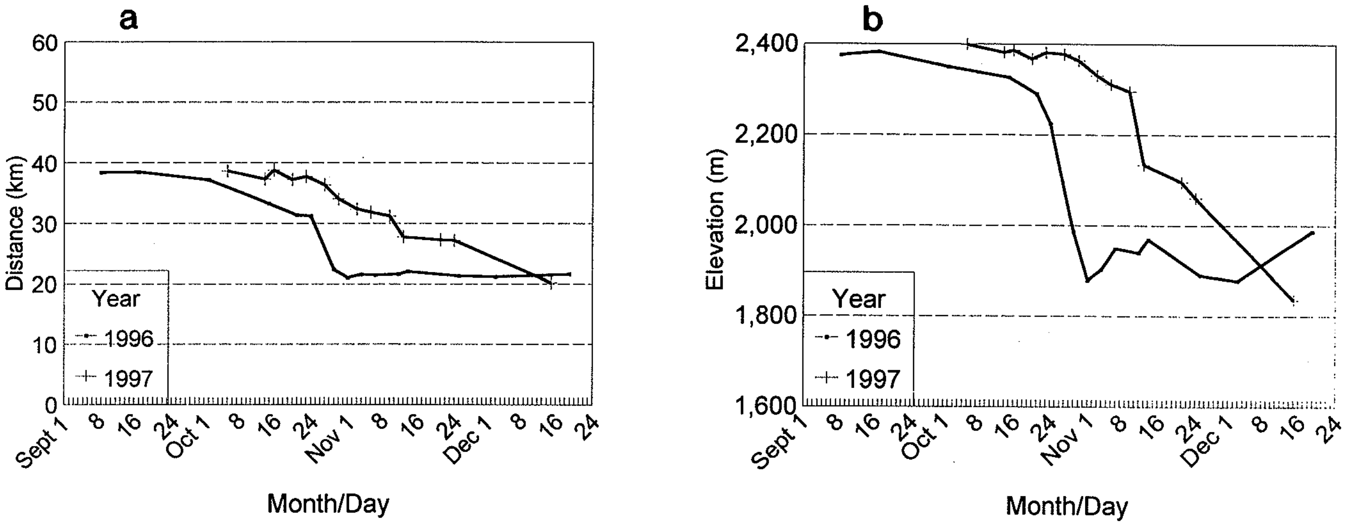


Figure 9. Autumn migration timing an duration of Arizona mule deer by a) average distance from the Utah-Arizona state line and b) average elevation, 1996-97.

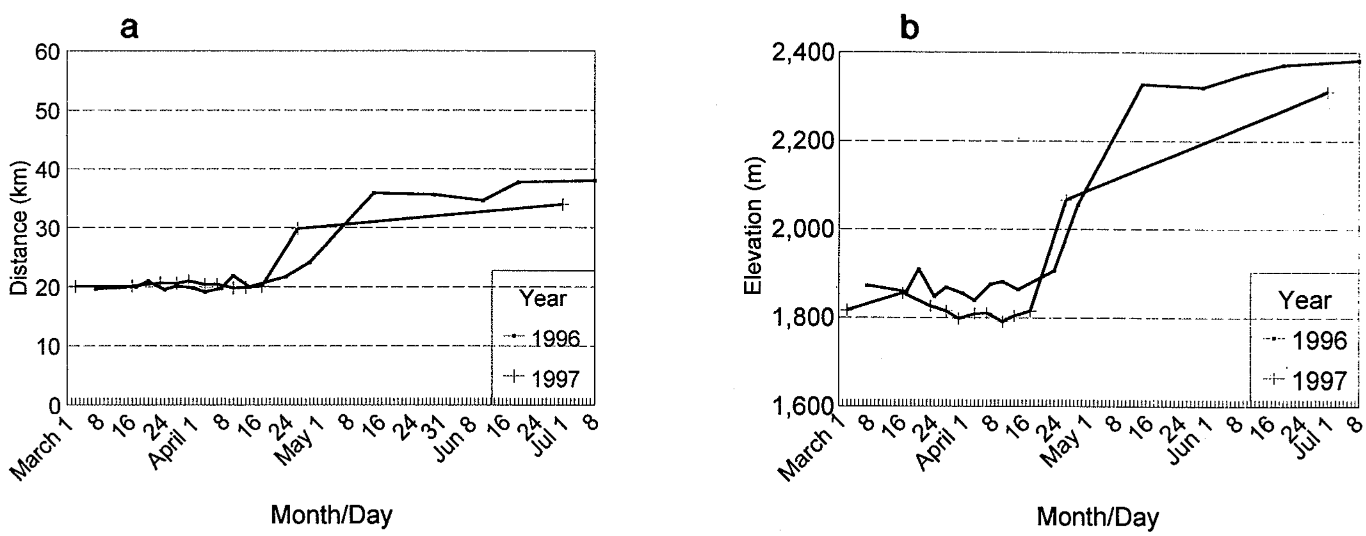


Figure 10. Spring migration timing and duration of Arizona mule deer by a) average distance from the Utah-Arizona state line and b) average elevation, 1996-97.

Table 5. Cumulative percentage of Arizona mule deer entering Game Management Unit 12B during autumn migration by date.

Date		1996	1997	Both years
October	22	45.5	0	22.8
November	4	54.5	0	27.3
	13	54.5	14.3	34.4
	21	54.5	28.6	41.6
	24	54.5	42.9	48.7
December	15	54.5	71.4[a]	61.1
January	30	63.6		
February	3	72.7		
	25	90.1		
No. marked		11	7	
Begin hunt		October 25	October 31	

[a] Location flights were not conducted beyond December 15, 1997, during the 1997-98 winter.

Table 6. Cumulative percentage of Arizona mule deer leaving Game Management Unit 12B during spring migration by date.

Date		1996	1997	Both years
March	22	7.1	0	4.3
April	11	14.3	10.1	13.0
	14	14.3	20.2	17.4
	15	21.4	20.2	21.7
	24	35.7	20.2	30.4
	28	35.7	66.7[a]	47.8
May	1	57.1	66.7	60.9[b]
	15	85.7	66.7	78.3[b]
June	11	100.0	66.7	87.0[b]
No. marked		14	9	

[a] Location flights were not conducted between April 28 and July 1 in 1997.

[b] Minimum estimates using last known value from 1997.

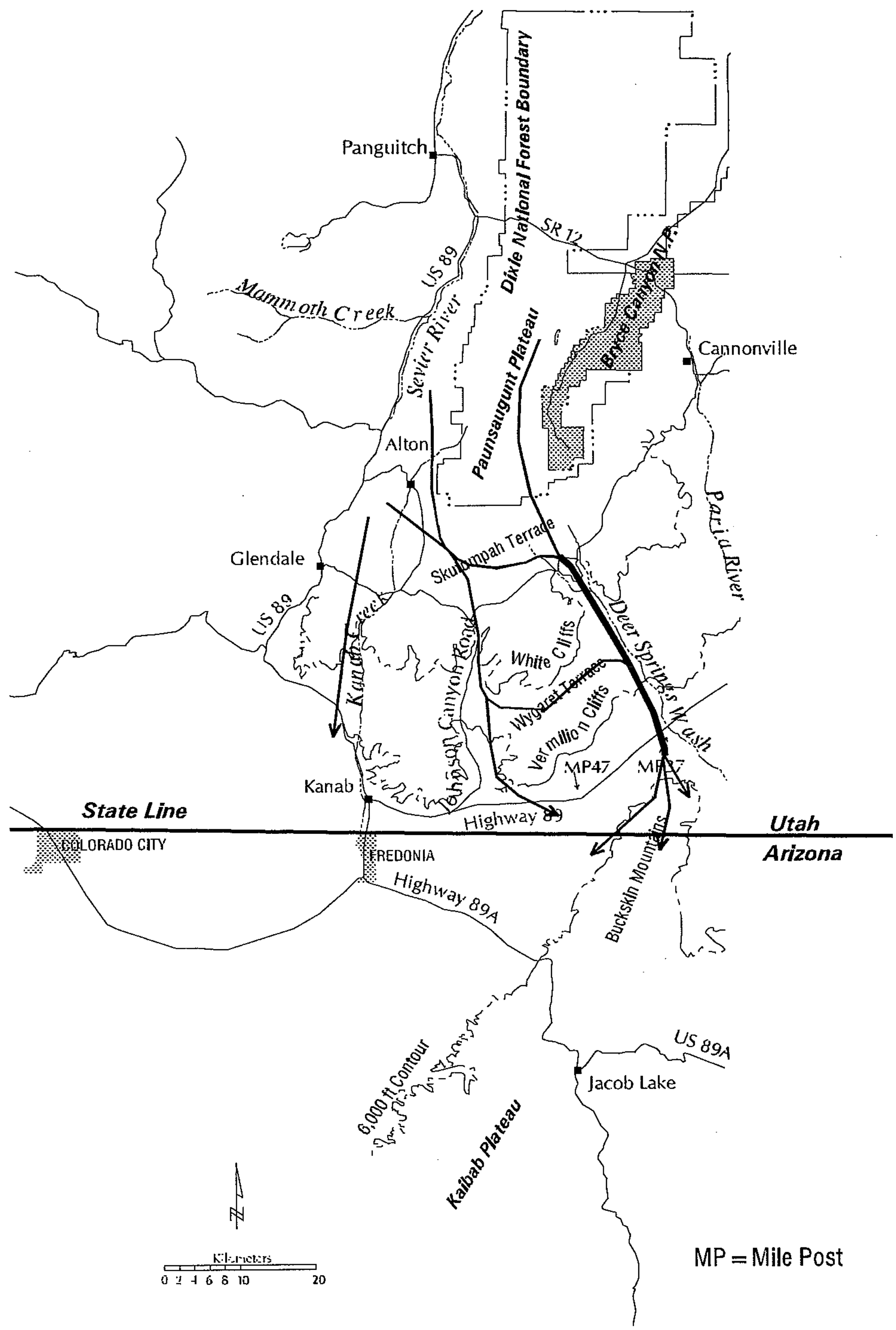


Figure 11. Estimated migration corridors used by Paunsaugunt (Utah and Interstate) mule deer to move between summer range on and around the Paunsaugunt Plateau and winter range on the Wygaret Terrace, along the Utah-Arizona state line, or on the Buckskin Mountains, 1995-97.

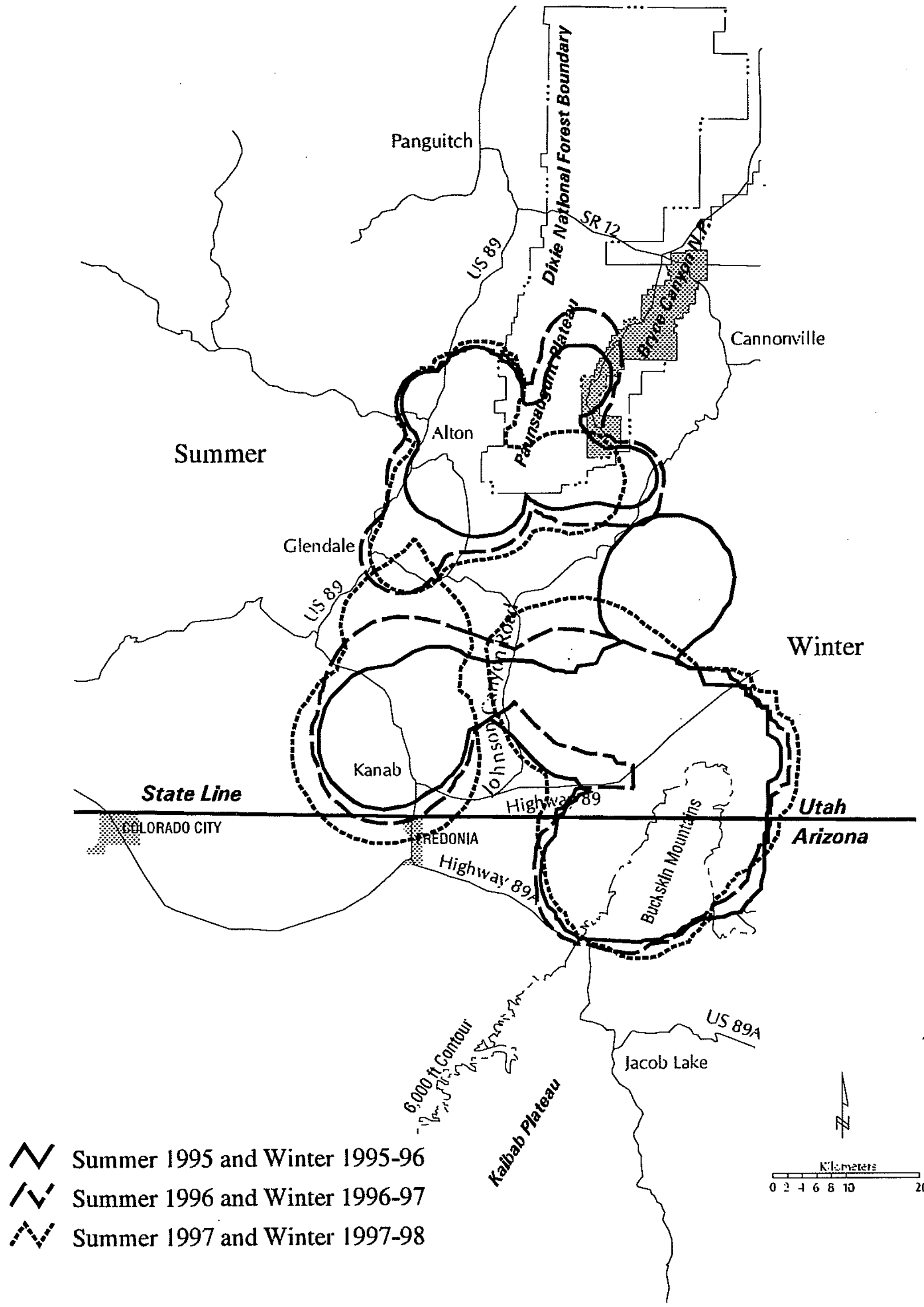


Figure 12. Summer and winter ranges of the Paunsaugunt (Utah and Interstate) mule deer based on 95% probability areas calculated from aerial telemetry locations using the adaptive kernel method, 1995-97.

Seven (31.8%) of the 22 Paunsaugunt mule deer captured on summer range migrated only as far as the Wygaret Terrace. The rest continued south to winter range in the valley or on the Buckskin Mountains.

Arizona Mule Deer. Comparing area overlap of winter and summer 95% probability use areas of 2 years, we found that 1997-98 winter range encompassed 87.5% of the base 1996-97 winter range on the eastern side of the Buckskin Mountains and 82.5% on the western side (Fig. 13). Likewise, 1997 summer range enclosed 100% of the base 1996 summer range on the area around Jacob Lake and 85.6% on the area to the south near the Grand Canyon National Park boundary (Fig. 13).

Fidelity to Winter and Summer Areas

Paunsaugunt Mule Deer. Distances between 1995-96 winter COAs and 1996-97 winter COAs for mule deer (excluding nonmigratory mule deer #53) varied from 0.1 to 11.2 km and averaged 2.0 km ($n = 35$, SE = 0.4; Appendix 3). Distances between 1995 summer COAs and 1996 summer COAs varied from 0.3 to 7.9 km and averaged 1.2 km ($n = 38$, SE = 0.2). We could not detect a difference between sexes for distance between winter COAs ($Z = -1.244$, $n = 35$, $P = 0.213$) or summer COAs ($Z = -0.756$, $n = 38$, $P = 0.450$). For both comparisons, our sample for males was small (winter $n = 4$, summer $n = 5$; respectively). Also, data from the third year were insufficient to calculate reliable COAs for either season.

Arizona Mule Deer. Distances between 1996-97 winter COAs and 1997-98 winter COAs varied from 0.3 to 19.6 km and averaged 2.7 km ($n = 13$, SE = 1.4; Appendix 4). However, 1 mule deer (#67) did not return to the same winter use area in 1997, resulting in a large distance of 19.6 km between winter COAs for this mule deer and an inflated average distance between winter COAs for Arizona mule deer. When we excluded mule deer #67, the distance varied from 0.3 to 3.6 km and averaged 1.2 km ($n = 12$, SE = 0.3). Distances between 1996 summer COAs and 1997 summer COAs varied from 0.3 to 4.3 km and averaged 1.4 km ($n = 10$, SE = 0.4).

Rate of Exchange and Extent of Migration

The use of mule deer captured on winter range would bias estimates of what proportion of the Paunsaugunt herd entered Arizona. Since most of the Interstate mule deer were captured on winter range, we had to rely only on mule deer captured on Utah summer range for an initial estimate. However, mule deer were not captured randomly across summer range; thus, this estimate would also be biased; it only provided us a starting point.

Of 24 mule deer captured on Utah summer range, 22 lived long enough to determine whether they were either Utah (18, 81.8%) or Interstate (4, 18.2%, Table 1) mule deer. Although 4 of these mule deer entered Arizona, only 2 had winter COAs in Arizona.

Based on our knowledge of the capture locations and movements of mule deer from the winter range, we believe that between 20 and 30% of the mule deer in the Paunsaugunt herd were Interstate mule deer.

The distance that Interstate mule deer ranged into Arizona varied from 0.5 to 21.5 km and averaged 7.1 km ($n = 529$, SE = 0.2; Appendix 7). The most northerly location of the 19 radiomarked Arizona mule deer was 3.9 km south of the state line on winter range and the most southerly location was 73.6 km from the state line on summer range. Thus, Interstate mule deer use of Arizona winter range overlapped with use by Arizona mule deer (Fig. 14).

Our best estimate of the area of overlap for winter habitat use by Interstate and Arizona mule deer is an east-west band across the Buckskin Mountains, beginning 4 km south of the state line and extending 9 km south into Arizona. We defined this area of overlap because 95% of the Interstate mule deer locations in Arizona were within 13 km of the state line (Fig. 14), and the closest Arizona mule deer location to the state line was about 4 km south. The unit boundary between GMUs 12A and 12B is about 10.5 km south of the state line (Fig. 14); therefore, this area of overlap extended into GMU 12A.

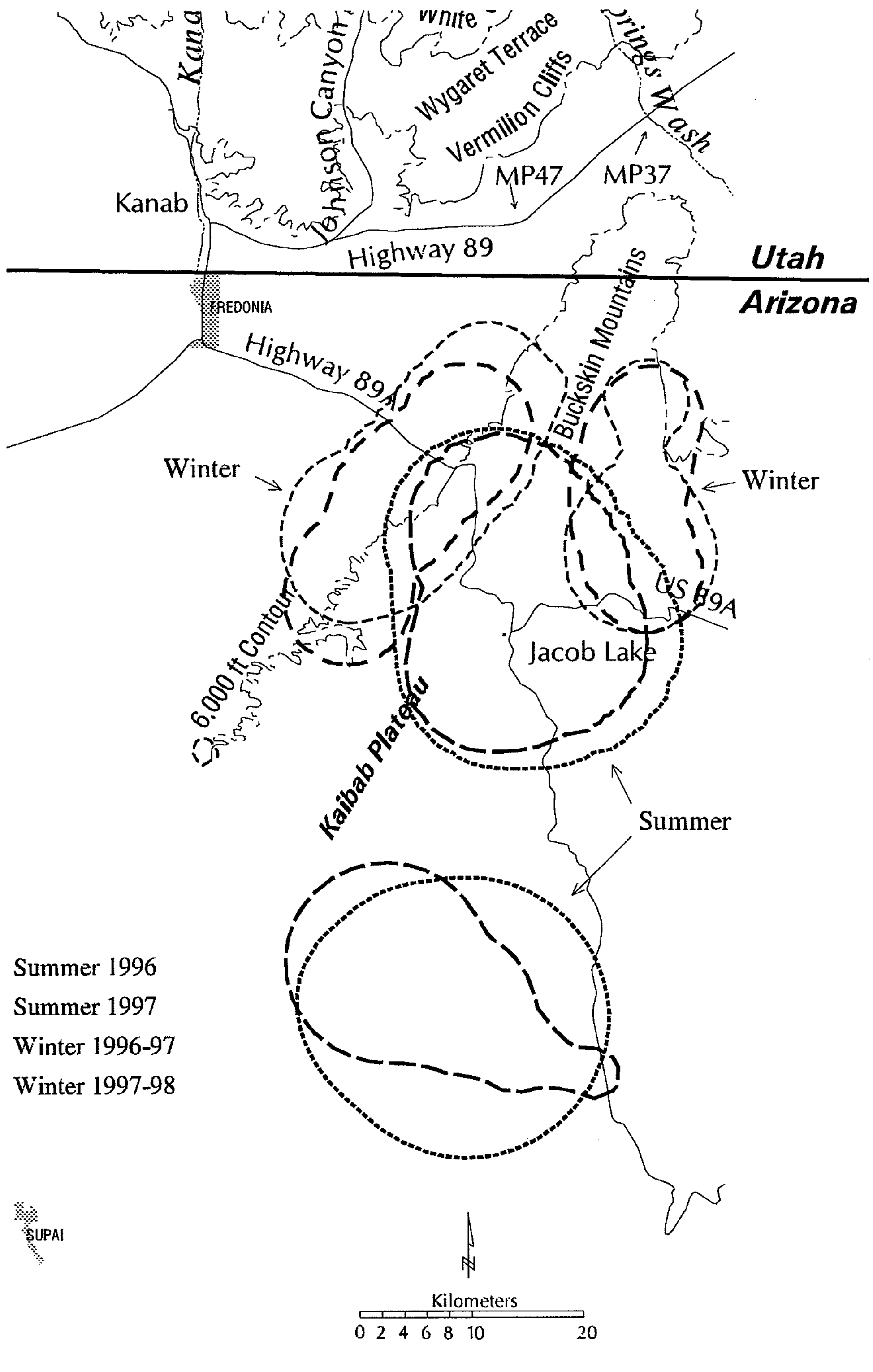


Figure 13. Summer and winter ranges for Arizona (Kaibab herd) mule deer that winter on the Buckskin Mountains, based on 95% probability areas calculated from aerial telemetry locations using the adaptive kernel method, 1995-97.

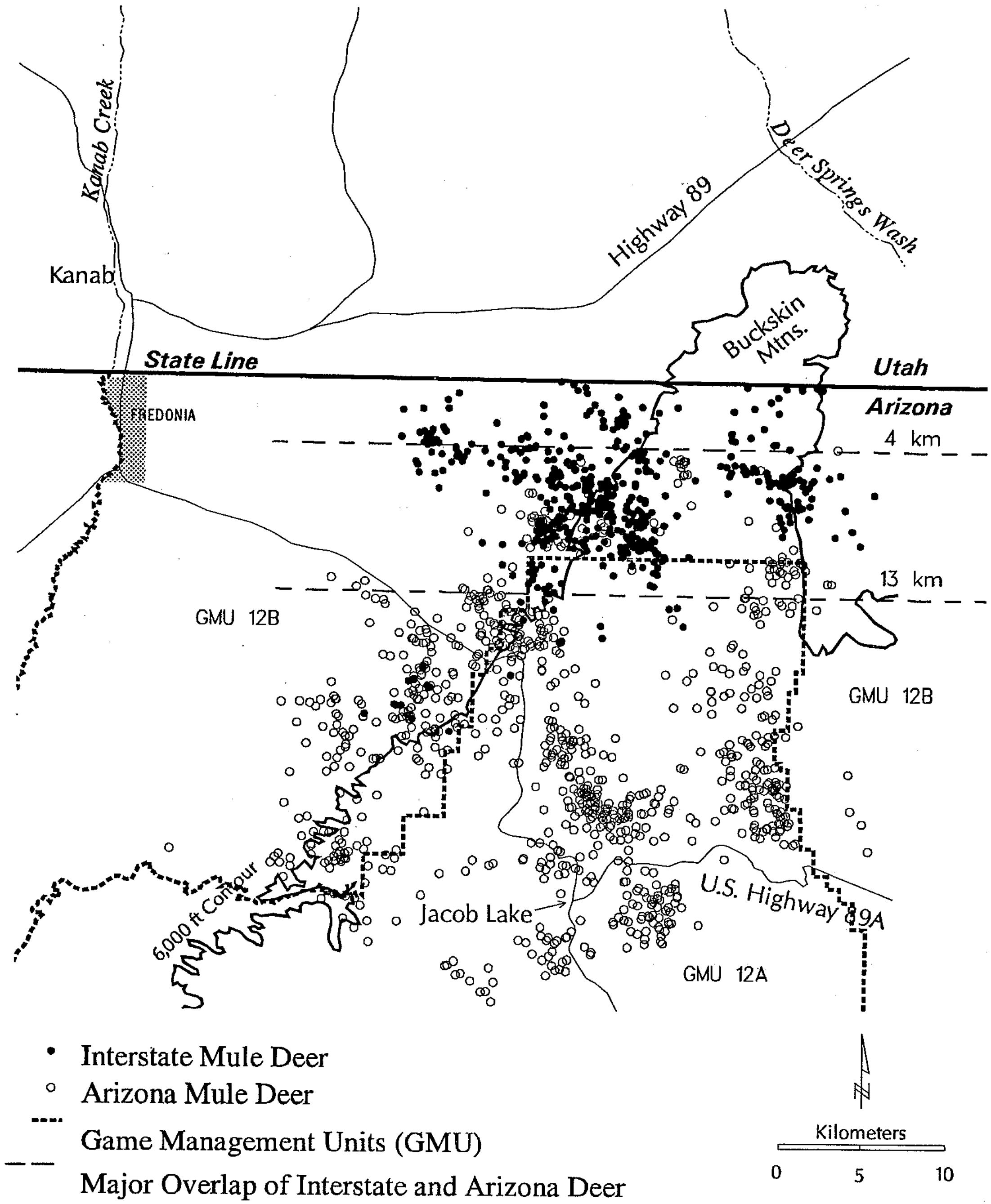


Figure 14. Overlap of winter range use by Interstate (Paunsaugunt herd) and Arizona (Kaibab herd) mule deer that winter on the Buckskin Mountains, from aerial telemetry locations south of the Utah-Arizona state line, 1995-97.

Nonmigratory and Unusual Movements

Mule deer are usually considered migratory when their summer and winter ranges do not overlap. By this definition, only 1 (4.5%) of 22 Paunsaugunt mule deer captured on summer range did not migrate each year. Mule deer #53, residing at an elevation of 1,990 m about 15 km SSW of Alton, had a small winter use area (95% probability, 1995-96, 835 ha) that was entirely within its summer use area (95% probability, 1996, 4,919 ha). However, this mule deer apparently was forced by weather and snowfall to migrate 17 km south during the 1996-97 winter.

Two mule deer (#49 and #54), captured on summer range around Alton, migrated northwest instead of south. Mule deer #49 died in a collision with a vehicle on a highway about 60 km northwest, near Parowan, Utah. Mule deer #54 was still alive and last located near Parowan, Utah in August 1998. Another mule deer (#31), captured on winter range in Arizona in 1995, returned to summer range that was 42 km north of Alton, Utah. This mule deer was later killed by a Utah hunter in October 1995.

Four mule deer, captured on summer range around Alton, migrated south down Kanab Creek each autumn to winter range in an area on the Wygaret Terrace just north of Kanab (Fig. 11). Three other mule deer traveled only as far as Johnson Canyon and Wygaret Terrace to spend their winters.

Mortality

We investigated 31 radiomarked mule deer mortalities that occurred during the 3-year study. Of these deaths, 14 (45.2%) were due to unknown causes, 6 (19.4%) were due to mountain lion (*Puma concolor*) predation, 2 (6.5%) were due to other predators, 4 (12.9%) were due to deer-vehicle collisions, 3 (9.7%) were due to legal hunting, and 2 (6.5%) were due to poaching.

Of the 8 radiomarked bucks that died, 3 (37.5%) were killed by legal hunting; 2 were harvested in Utah and 1 in Arizona. One (12.5%) buck died from a deer-vehicle collision, 1 (12.5%) was killed by a mountain lion, 1 (12.5%) died from unknown predation, and 2 (25.0%) deaths were unknown.

Of the 33 Paunsaugunt does that crossed US 89 during the study, 3 (9.1%) died from highway deer-vehicle collisions.

Mortalities occurred each month of the year (Appendix 1), except during July, with a peak in October-November, the autumn migration and hunting season; 8 mortalities occurred in this period. Of these 8, 3 were the bucks harvested during hunts, 2 died from deer-vehicle collisions, 1 was killed by a mountain lion, and 2 died from unknown causes. June and August also had ≥ 3 mortalities.

Female annual survivorship for the Paunsaugunt herd was 0.745 (SE = 0.076, n = 33) during 1994-97. For Arizona does, annual survivorship was 0.596 (SE = 0.131, n = 14). For Paunsaugunt bucks, annual survivorship was 0.512 (SE = 0.176, n = 8).

DISCUSSION

Migration Patterns

Most Paunsaugunt mule deer migrate south to lower elevation winter range on either the Wygaret Terrace, the valley east of Kanab, or along the Buckskin Mountains bisected by the Utah-Arizona state line. In spring, these mule deer return to summer range on or around the higher elevation Paunsaugunt Plateau. Thus, the migration pattern exhibited by the Paunsaugunt herd best fits the uni-directional patterns described by Garrott et al. (1987) and Thomas and Irby (1990), as opposed to complex patterns reported by Gruell and Papez (1963), Brown (1992), and Matthews and Coggins (1998). However, exceptions to the general pattern did occur in our study; 2 (3.6%) radiomarked Paunsaugunt mule deer migrated north-northwest towards Panquitch and 1 (1.8%) mule deer did not migrate. Although mule deer were not captured on top of the Paunsaugunt Plateau, because of difficulty of net-gun capture within its dense overstory, some mule deer captured on the winter range returned to summer range on top of the Plateau. Thus, we believe we have a general overview of migration from this Plateau.

The Arizona mule deer were from the Kaibab herd. An earlier study of Kaibab mule deer herd migration (Haywood et al. 1987) showed a somewhat more complex pattern in that most Kaibab mule deer migrated to winter range on either the eastern or western sides of the Kaibab Plateau. We believe most of the winter range for the Kaibab mule deer herd is on the western side of the Plateau. Data from this study and those of Haywood et al. (1987) indicate Kaibab mule deer actually migrate east, west, and north from summer range to lower elevation winter range, with only a small portion of the Kaibab mule deer herd using the Buckskin Mountains for winter range.

We found no difference in migration distance by Paunsaugunt males and females, as also reported by Carpenter et al. (1979), Thomas and Irby (1990), and Brown (1992) for other mule deer herds. Basically, we believe migration for the Paunsaugunt herd is similar for bucks and does. Haywood et al. (1987) also found no gender-related difference in the Kaibab herd's migration.

If there are resident mule deer on the Buckskin Mountains winter range, they are apparently low in number. Few mule deer are typically observed and tracks are infrequent around water tanks on the Buckskin Mountains during summer (Bob Lemons, AGFD, pers. commun.). Furthermore, all mule deer captured on winter range migrated from the area. Mule deer that migrated north were from the Paunsaugunt herd in Utah; those that migrated south were from the Kaibab herd in Arizona.

For Paunsaugunt mule deer to migrate to southern portions of their winter range, then return to summer range, they must cross US 89. These mule deer are vulnerable to collisions with vehicles during these migrations. Over the 3 years Paunsaugunt mule deer were monitored, nearly 10% of the radiomarked does died from collisions. Approximately 100 mule deer annually died from vehicle collisions during the same period (P. W. Klimack and T. A. Messmer, USU, pers. commun.). This may be a substantial impact on the Paunsaugunt herd, particularly on the interstate portion.

Migration Timing and Duration

Earlier researchers believed that snowfall was the primary factor initiating autumn migration, however, Garrott et al. (1987) reported that it did not account for the consistency in timing of autumn migration in Colorado mule deer. They proposed photoperiod as the primary factor. Based on our general observations from 3 years of aerial radiotracking mule deer, snowfall was not the key reason for initiating autumn migration in Paunsaugunt or Kaibab mule deer herds; mule deer initiated migration whether substantial snowfall was present or absent.

We also do not believe photoperiod is the overriding factor in initiating migration. Migration timing varied during all 3 years of our study. In the third year of our study, Paunsaugunt mule deer held off migrating to winter range until the last 3 weeks of their "normal" 6-7 week period, based on the previous 2 years of data. Then, most mule deer moved rapidly to winter range and completed their migration at about the same time as the previous 2 years. Furthermore, Arizona mule deer did not initiate migration at the same time as Paunsaugunt mule deer.

Garrott et al. (1987) reported the average start of autumn migration for mule deer as the previous 2 years. Furthermore, Arizona mule deer did not initiate migration at the same time as Paunsaugunt mule deer.

Garrott et al. (1987) reported the average start of autumn migration for mule deer as the beginning of October in Colorado. We interpreted the average beginning of migration for Paunsaugunt mule deer as late September-early October and for Arizona mule deer as late October. For photoperiod to be the overriding factor, migration initiation for mule deer in Arizona, Colorado, and Utah should be similar; in fact, they are separated by nearly a month in initiation of migration. Further, the annual variation we observed in initiation of autumn and spring migrations during the 3 years of our study also indicates photoperiod is not the only or ultimate factor.

Haywood et al. (1987) determined that the average date for initiation of autumn migration by Kaibab mule deer was October 29, and migration ended on December 9, lasting 6 weeks. Whereas the average date for initiation of spring migration was April 23, and migration ended on June 3, again lasting 6 weeks. Our findings suggest movements of Arizona mule deer to and from the Buckskin Mountains to the north varies among years. Autumn migration period in 1 year of our study, 1997, mimicked findings of Haywood et al. (1987), whereas the previous year, 1996, showed a slightly earlier and more rapid migration. Still, our findings and those of Haywood et al. (1987) indicate Arizona mule deer migrate about 4 weeks later than Paunsaugunt mule deer during both spring and autumn. We cannot explain this observed difference.

There seemingly is no difference in migration timing between males and females for Paunsaugunt mule deer, the same as reported for Kaibab mule deer by Haywood et al. (1987). Movements of individual mule deer between seasonal ranges for Paunsaugunt and Arizona mule deer occur within 1-2 weeks. Matthews and Coggins (1998) reported that movements by individual mule deer in Oregon, over a mean distance of 25.3 km to summer range, normally occurred within 1 week. If snowfall or photoperiod were overriding factors initiating migration, all mule deer should have migrated within the same 1-2 week period, rather than 6-7 weeks. A combination of proximate or ultimate stimuli may be the triggering mechanism of migration, including snowfall and photoperiod. More research is warranted.

Timing of migration by Paunsaugunt mule deer versus Arizona mule deer is important to management in Arizona because of hunting season dates. Season dates in Arizona are based on statewide guidelines, not migration timing of mule deer in a particular area. Since most Interstate mule deer arrive in Arizona's GMU 12B before the first general rifle hunt at the end of October, Interstate bucks are subject to harvest by Arizona hunters during 2 traditional rifle hunts and a recently added muzzleloader hunt.

Most Arizona mule deer are not on winter range, at least in the Buckskin Mountains, during the first rifle hunt in GMU 12B; this hunt includes the largest number of mule deer permits and harvested bucks for GMU 12B. During our study (1995-97), 77% ($\bar{x}$ = 149.0) of bucks harvested in GMU 12B have been from the first rifle hunt. Within GMU 12B, most hunters (estimated 80%; Bob Lemons, AGFD, pers. commun.) hunt on and around the Buckskin Mountains during the first rifle hunt. Thus, it is likely that the majority of the unit harvest is taken from the Buckskin Mountains portion of GMU 12B. If earlier arriving Interstate mule deer comprise a substantial proportion of the Buckskin Mountains wintering herd, then Interstate bucks may also comprise a considerable proportion of the GMU 12B Buckskin Mountains harvest. Hunt pressure on Interstate mule deer in later hunts would decline with the arrival of the Arizona mule deer.

Unfortunately, we could not estimate what percentage of the harvest is Interstate mule deer; further, it was beyond the scope of our study to determine what percentages of the mule deer on the Buckskin Mountains winter range were Interstate or Arizona mule deer. More research is needed to determine if Interstate mule deer are being substantially impacted by current hunt strategies.

Winter and Summer Areas and Fidelity to These Areas

Most of Utah's Paunsaugunt herd migrates south to winter range; over half winter on or along the Buckskin Mountains and perhaps a third winter on the Wygaret Terrace. The Wygaret Terrace is important winter range in Utah for the Paunsaugunt herd. Thus, winter range for Paunsaugunt mule deer is much larger than the valley along the Utah-Arizona state line and the Buckskin Mountains as originally suspected. Mule deer wintering on the Wygaret Terrace are not exposed to highway mortality along US 89 nor are they vulnerable to hunting in Arizona.

The small average difference between COAs for winter and summer ranges during succeeding years by both Paunsaugunt and Arizona mule deer indicates strong fidelity to seasonal areas by individuals of both herds. Thus, population-wide, both herds exhibit strong fidelity to seasonal ranges. This strong fidelity results in the same segment of each herd returning to Arizona's GMU 12B each autumn.

Because of this strong fidelity to winter range, in order for Arizona and Utah wildlife managers to cooperatively manage the Interstate mule deer, they must be aware that any reduction in mule deer through uncoordinated harvest will not be mitigated by substantial immigration of mule deer from other areas. Mule deer not harvested, preyed upon, or killed in highway deer-vehicle collisions during previous years and the recruitment of fawns, led by their mothers to winter range in Arizona, will be those available for harvest in succeeding years.

Rate of Exchange and Extent into Arizona

Only a portion (likely 20-30%) of the Paunsaugunt herd are Interstate mule deer that cross the state line into Arizona's GMUs 12B and 12A and depend on winter range in Arizona. Based on traditional hunt seasons in Utah and Arizona, this proportion of the Paunsaugunt herd is vulnerable to hunting in both states during autumn of each year. Thus, most bucks in the Paunsaugunt herd are subject to hunts only in Utah.

Although a few Interstate mule deer extend far enough into Arizona to be in GMU 12A, most winter in GMU 12B. Management decisions regarding harvest in GMU 12B impact Interstate mule deer, but decisions for 12A are probably not an issue for cooperative management of the Paunsaugunt herd. Similarly, those Arizona mule deer that cross into GMU 12B from 12A are also subject to multiple hunts in Arizona.

Land Status Change

On September 18, 1996, a proclamation by President Clinton created the Grand Staircase-Escalante National Monument (GSENM) on the Colorado Plateau in the canyonlands of south-central Utah, west of the Colorado River (BLM*a*, unpublished mimeo).

The western part of this new 688,000-ha national monument (Fig. 1) encompasses much of the winter range within Utah for the Paunsaugunt mule deer herd and a large portion of the country through which they migrate between seasonal ranges.

Existing uses under federal or state laws, such as hunting, camping, traveling, hiking, backpacking, and other recreational activities, can continue on GSENM. Utah responsibilities and authorities regarding wildlife management, including management of fishing and hunting, within the monument were unaffected by the proclamation. Grazing activities under existing leases and permits were also unaffected. However, federal lands within GSENM were withdrawn from entry, location, selection, sale, leasing, or other disposition under the public land laws, including among others the mineral leasing and mining laws (BLM*b*, unpublished mimeo).

Thus, creation of GSENM precludes coal mining expansion and averts possible increases in mule deer deaths on US 89 from additional mining truck traffic. Mule deer winter range and migration corridors seem relatively secure for the present.

Mortality

The determination of mule deer mortality was not a primary objective. Due to infrequent locations throughout most of each year and the inaccessibility of many sites, exact cause of death for many radiomarked mule deer could not be determined. However, identified causes of mortality of radiomarked mule deer over the

3 years provides some insight into population dynamics of the Paunsaugunt and Kaibab herds. Apparently, there are 3 main causes of mule deer mortality: 1) predation by mountain lions, 2) deaths of Paunsaugunt mule deer (including Interstate mule deer) from deer-vehicle collisions, and 3) harvest of bucks during fall hunts. These factors had been identified in previous studies of the Kaibab herd (Barlow and McCulloch 1984, McCulloch and Brown 1986).

None of the identified factors seemed high enough to limit the population of the Paunsaugunt herd. The estimate of survivorship of 75% for Paunsaugunt does was comparable to rates found in mule deer herds from other states (Connolly 1981, White et al. 1987, Wood et al. 1989, Matthews and Coggins 1998). With an annual mortality rate of 25%, fawn recruitment of 50:100 does will maintain a stable population. Fawn recruitment for the Paunsaugunt herd during the study period exceeded 60:100 (UDWR, unpubl. data), which more than compensated for estimated mortality. Although the sample size for Paunsaugunt bucks was small, survivorship of 51% was comparable to other hunted mule deer populations (Connolly 1981, Wood et al. 1989, Matthews and Coggins 1998).

Our estimate of 59.6% annual survivorship for Arizona does may be reason for concern. However, the 95% confidence interval around our point estimate is wide enough (31.3-87.9%) to include declining, stable, or increasing situations. Mortality studies on the Kaibab herd indicated that annual survivorship for adult females as low as 67.5% can result in a population decline of 9.1% per year (Barlow and McCulloch 1984). When survivorship is nearer 80% for adult females, the population typically increases (McCulloch and Brown 1986). If our estimate, based on a small sample size of radiomarked does over less than a 2-year period, is correct, the portion of the Kaibab herd migrating to the Buckskin Mountains should have been declining. We do not believe this was the case. Survey data in GMUs 12A and 12B indicated sufficient recruitment for 70-75% annual adult female survivorship.

Highway deer-vehicle collisions may impact a portion of the Paunsaugunt herd, but seemingly are of little consequence to Arizona mule deer. Highway 89 in southern Utah has open, straight routes that allow vehicles to travel at high speed, whereas US 89A, crossed by some Arizona mule deer on their migration to and from GMU 12B, winds through more rugged terrain, restricting vehicle speeds. Because Interstate mule deer must cross US 89 to travel to and from winter range, ways to mitigate deer-vehicle collisions could be a point of discussion for cooperative management of the Paunsaugunt herd.

MANAGEMENT IMPLICATIONS

Since mule deer migration timing and fidelity to winter range cannot be influenced by Arizona and Utah resource managers, they will have to concentrate on other factors directly affecting mule deer population dynamics, such as mortality factors, buck:doe ratios, age structure, and population levels. Under certain conditions, predators can be a major cause of mule deer mortalities in this region (Barlow and McCulloch 1984, McCulloch and Brown 1986). However, predator control is not typically considered when mule deer population levels are at or above carrying capacity of the rangeland. History of the Kaibab mule deer herd has shown that predator control can lead to overpopulation of mule deer, habitat destruction, and a massive mule deer die-off.

A number of techniques have been proposed to mitigate mortality from deer-vehicle collisions. These techniques could be reviewed cooperatively by Arizona and Utah resource managers to determine if any are feasible for use on the Paunsaugunt herd migration corridors, particularly the 2 main corridors between US 89 mileposts 39-42 and 49-51. This will require coordination with UDOT.

Given the lack of resident mule deer in GMU 12B, hunting and other recreational opportunities are limited to the influx of either Paunsaugunt or Arizona mule deer. Any management action or human perturbation that lessens migration of mule deer into GMU 12B impacts future hunting opportunities in Arizona.

The impact of Arizona hunters on the Paunsaugunt herd is likely not significant, as only a small to moderate portion of the herd ever enters Arizona. However, the interstate portion of this herd is more subject to harvest because of 3 primary factors:

1) Paunsaugunt and Kaibab herds both demonstrate strong fidelity to winter use areas, thus the same portion of each herd are hunted each year in GMU 12B;
2) the traditional timing and permit levels of Arizona in GMU 12B promote the highest harvest during the first rifle hunt rather than during the second rifle hunt or muzzleloader hunt; and
3) the difference in migration timing between Paunsaugunt and Kaibab mule deer herds indicates that most Interstate bucks and few Arizona bucks are available for harvest during the first rifle hunt in Arizona.

The winter range overlap zone in GMU 12B for Arizona mule deer and Interstate mule deer is an important area for habitat protection. This area is more likely to receive habitat damage than any other areas because:

1) a greater number of mule deer are likely to concentrate in this area since it receives mule deer from 2 herds on different summer ranges;
2) the mule deer occupy this area longer due to differences in migration timing; and
3) cattle also use this area for winter range and can compete with mule deer for forage during periods of deep snow.

Habitat management could focus on protecting and enhancing the browse plant component (e.g., establishing vegetation exclosures for monitoring livestock-versus-deer use, stimulating decadent browse plants, and conducting antlerless mule deer harvest if overuse of browse by mule deer occurs).

Both states share a common goal of providing a quality hunt experience and the opportunity to harvest an older-aged mule deer. Arizona and Utah have recently developed mule deer management plans, but the plans do not have common objectives to achieve that goal. Such goals and objectives could be standardized and written into a joint management plan for the interstate portion of the Paunsaugunt herd (i.e., manage the age of bucks in the same proportions, set the same parameters for post-hunt buck:doe ratios, implement antlerless hunts based on the same habitat protection thresholds). This would still allow flexibility for the states to set permit numbers independently and establish coordinated management since overall mule deer population parameters would be standardized. Managers from Arizona and Utah could also exchange survey results and harvest information annually to coordinate common objectives and formulate plans for future research of this shared resource.

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APPENDIXES

Appendix 1. Capture, residency, and mortality data of 83 radiomarked mule deer, by animal identification number (ID).

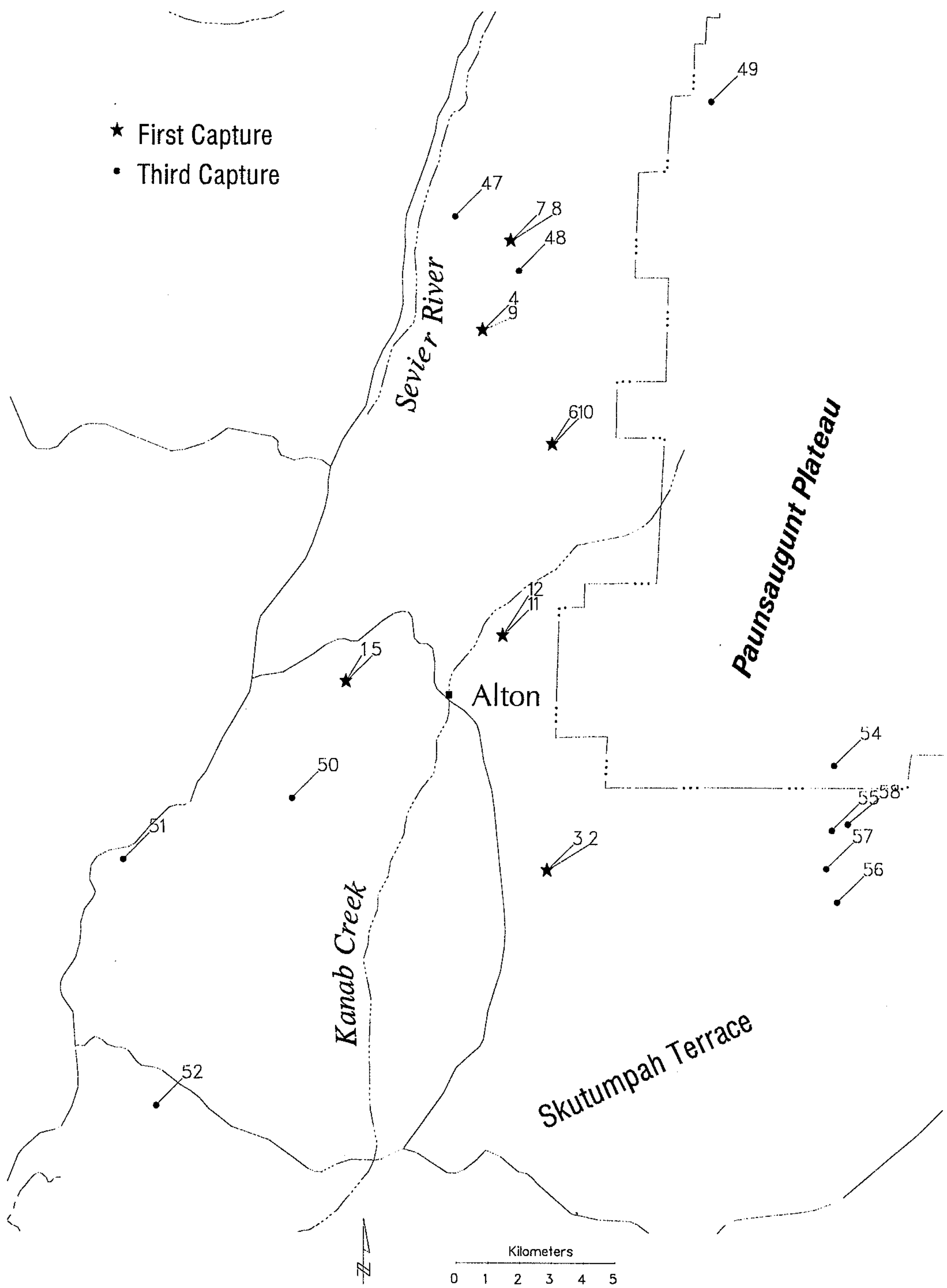
Capture						Mortality	
ID	Sex	Month	Year	State	Group	Date	Cause
1	F	8	94	UT	Utah		
2	F	8	94	UT	Utah		
3	F	8	94	UT	Utah		
4	F	8	94	UT	Unknown	12/19/94[a]	Mtn. lion
5	F	8	94	UT	Utah		
6	F	8	94	UT	Utah		
7	F	8	94	UT	Utah		
8	F	8	94	UT	Utah	3/3/97[a]	Road kill
9	F	8	94	UT	Utah		
10	M	8	94	UT	Interstate	09/07/95	Unknown
11	F	8	94	UT	Interstate		
12	F	8	94	UT	Unknown	12/19/94[a]	Mtn. lion
13	F	2	95	UT	Utah		
14	F	2	95	UT	Utah	03/03/97	Unknown
15	F	2	95	AZ	Interstate		
16	F	2	95	AZ	Interstate	01/03/96	Unknown
17	M	2	95	UT	Utah	11/08/96	Utah hunter kill
18	F	2	95	AZ	Interstate		
19	F	2	95	AZ	Interstate	6/21/95[a]	Predation
20	F	2	95	UT	Unknown	4/18/97[a]	Unknown
21	F	2	95	UT	Interstate		
22	M	2	95	UT	Interstate		
23	F	2	95	AZ	Interstate		
24	M	2	95	UT	Utah		
25	M	2	95	AZ	Interstate	11/12/95	Arizona hunter kill
26	M	2	95	UT	Utah	11/28/96	Road kill
27	M	2	95	UT	Unknown	05/17/95	Mtn. lion
28	F	2	95	AZ	Interstate	08/08/96	Mtn. lion
29	M	2	95	UT	Utah		
30	M	2	95	AZ	Interstate	01/03/96	Unknown
31	M	2	95	AZ	Interstate	10/21/95	Utah hunter kill
32	F	2	95	UT	Utah		
33	M	2	95	AZ	Interstate		
34	F	2	95	AZ	Interstate		
35	F	2	95	AZ	Arizona		
36	F	2	95	UT	Utah		
37	F	2	95	AZ	Interstate		
38	F	2	95	UT	Utah		
39	F	2	95	UT	Utah		
40	F	2	95	UT	Utah	12/95	Road kill

[a] Last date mule deer was located alive, based on the mortality sensor in radiocollar.

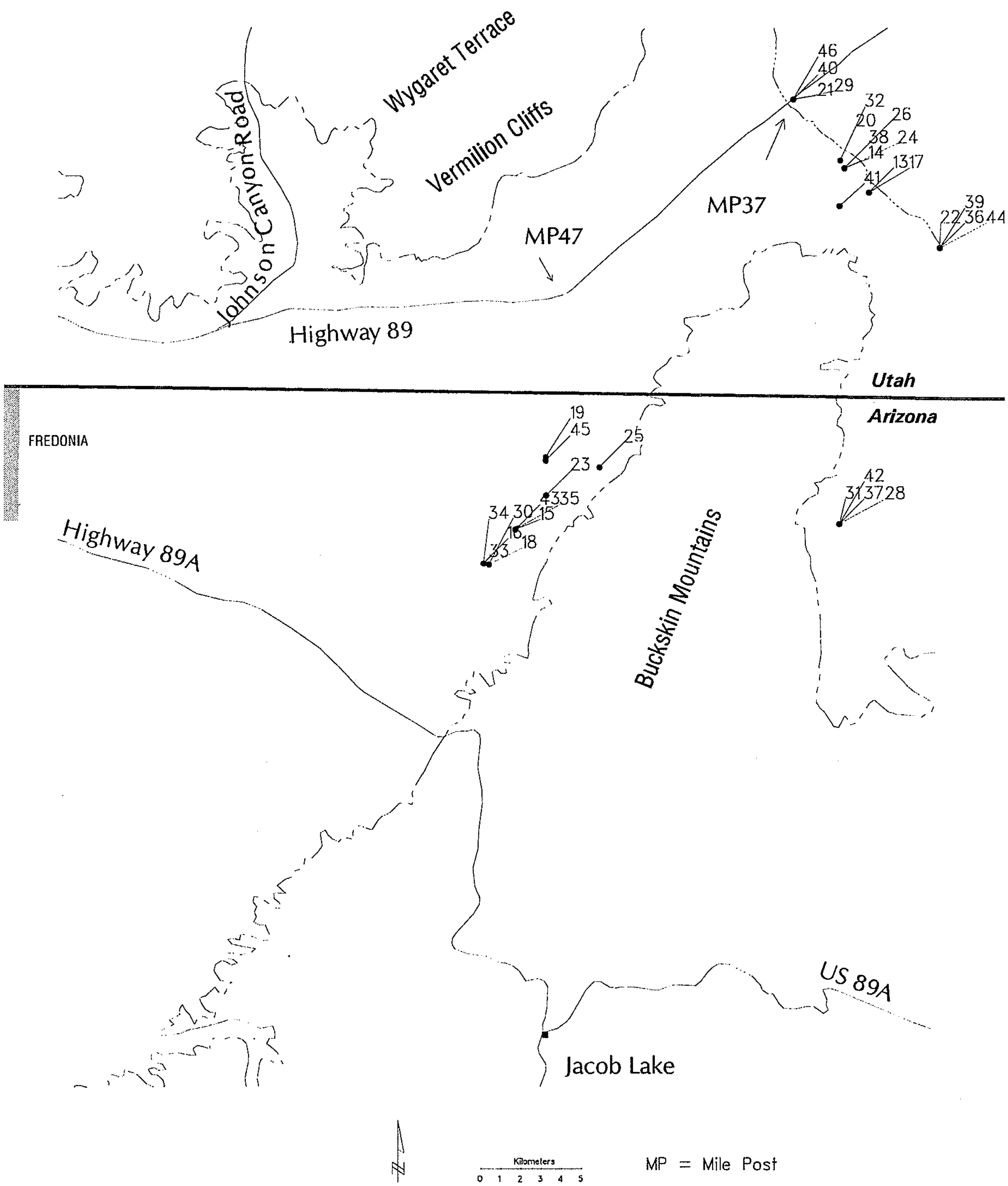
Appendix 1. (continued) Capture, residency, and mortality data of 83 radiomarked mule deer, by animal identification number (ID).

Capture						Mortality	
ID	Sex	Month	Year	State	Group	Date	Cause
41	F	2	95	UT	Unknown	2/17/95	Road kill
42	F	2	95	AZ	Interstate	10/19/96[a]	Illegal kill
43	F	2	95	AZ	Interstate		Unknown
44	F	2	95	UT	Utah		
45	F	2	95	AZ	Interstate	06/02/95	Unknown
46	F	7	95	UT	Unknown		
47	F	7	95	UT	Utah		
48	F	7	95	UT	Utah		
49	F	7	95	UT	Utah	10/04/96	Road kill
50	F	7	95	UT	Interstate		
51	F	7	95	UT	Interstate		
52	F	7	95	UT	Utah		
53	F	7	95	UT	Utah		
54	F	7	95	UT	Utah		
55	F	7	95	UT	Utah		
56	F	7	95	UT	Utah		
57	F	7	95	UT	Utah		
58	F	2	95	UT	Utah		
59	F	2	96	AZ	Arizona		
60	F	2	96	AZ	Interstate	10/29/96	Mtn. lion
61	F	2	96	AZ	Arizona		
62	F	2	96	AZ	Interstate		
63	F	2	96	AZ	Interstate		
64	F	2	96	AZ	Unknown	03/21/96	Unknown
65	F	2	96	AZ	Arizona		
66	F	2	96	AZ	Arizona		
67	F	2	96	AZ	Arizona		
68	F	2	96	AZ	Interstate	09/20/96	Unknown
69	F	2	96	AZ	Arizona		
70	F	2	96	AZ	Arizona	08/25/97	Poached
71	F	2	96	AZ	Arizona		
72	F	2	96	AZ	Arizona		
73	F	2	96	AZ	Arizona		
74	F	2	96	AZ	Interstate	02/03/97	Unknown
75	F	2	96	AZ	Arizona		
76	F	2	96	AZ	Arizona	06/15/96	Unknown
77	M	2	96	AZ	Unknown	04/10/96	Predation
78	F	2	96	AZ	Arizona	06/11/96	Unknown
79	F	2	96	AZ	Arizona	06/11/96	Mtn. lion
80	F	2	96	AZ	Arizona		
81	F	2	96	AZ	Arizona	11/17/96	Unknown
82	F	2	96	AZ	Arizona	08/21/96	Unknown
83	F	2	96	AZ			

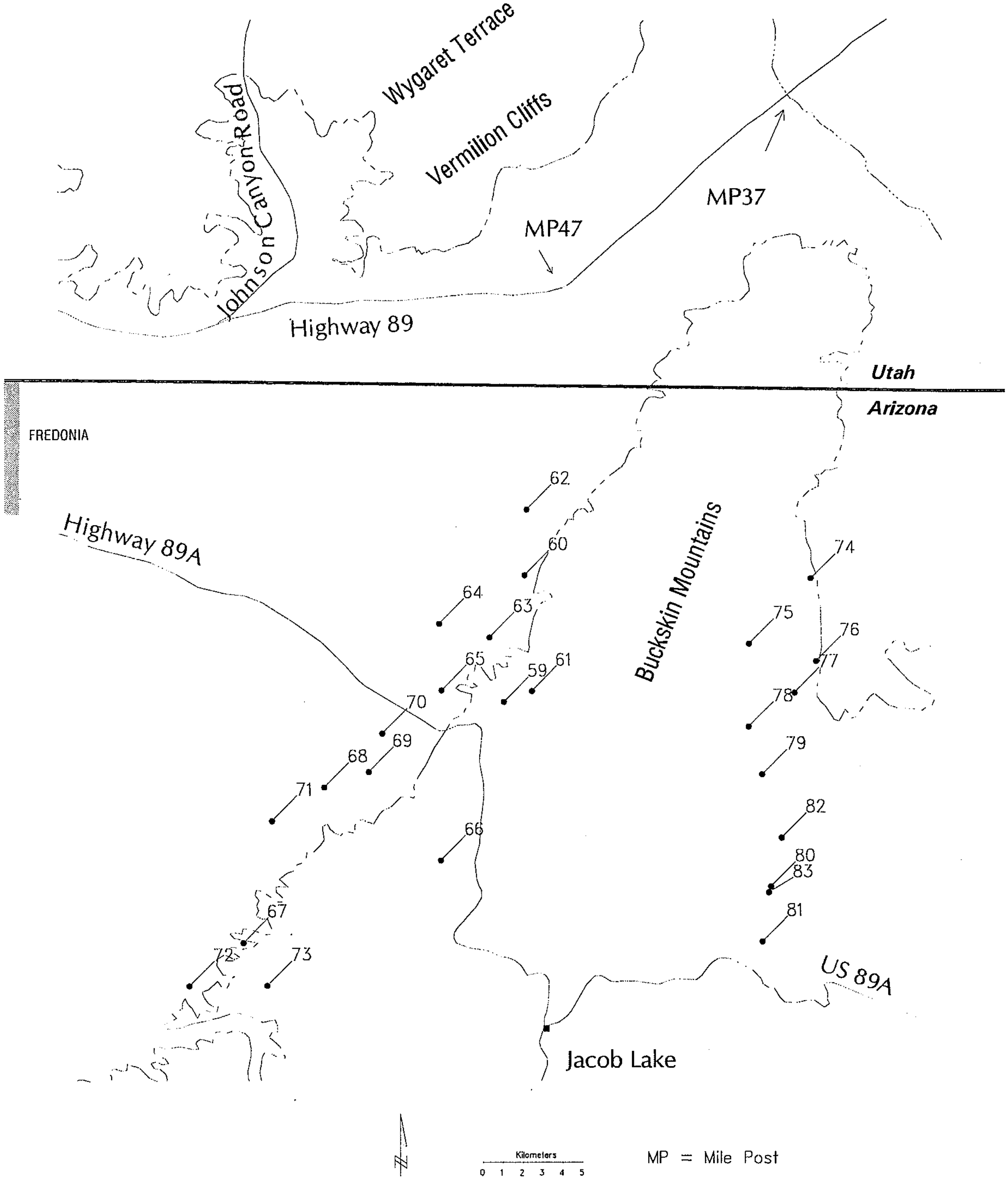
[a] Last date mule deer was located alive, based on the mortality sensor in radiocollar.



Appendix 2a. Capture locations of 24 Paunsaugunt mule deer (12 on August 16, 1994, and 12 on July 21-22, 1995) on summer range, by animal identification number (ID).



Appendix 2b. Capture locations of 34 (33 Paunsaugunt and 1 Arizona, #35) mule deer on the winter range, north or south of the Utah-Arizona state line on February 17-18, 1995, by animal identification number (ID).



Appendix 2c. Capture locations of 25 (5 Paunsaugunt, 18 Arizona, and 2 of unknown group status) mule deer on winter range along the eastern or western sides of the Buckskin Mountains in Arizona on February 13, 1996, by animal identification number (ID).

The Paunsaugunt mule deer herd of southwestern Utah occupies summer habitat on and around the Paunsaugunt Plateau and was believed to be migratory; however, little was known about its movements. Utah wildlife managers assumed that mule deer that crossed US 89 towards Arizona were from this herd. Like the adjacent Kaibab mule deer herd in Arizona, this herd was known for its trophy-sized bucks. Thus, hunting permits for these mature bucks were highly desirable and sought locally, nationally, and internationally.

Utah issued 2 types of mule deer hunting permits (normal draw and landowner). In 1998, 311 permits were issued to public-land mule deer hunters in Utah for the Paunsaugunt unit (GMU 27). Private landowners around Alton, Utah, a small ranching community in northern GMU 27, were issued an additional 43 hunting permits as part of the Cooperative Wildlife Management Unit (CWMU) system. The CWMU program is a Utah effort to reimburse private landowners for providing habitat for big game animals by allowing them to sell permits to clients for hunts on private land. Under a similar program, members of the Paunsaugunt Landowner's Association were allowed to sell another 35 hunting permits in GMU 27, excluding the Alton CWMU area (J. Grandison, Utah Division of Wildlife Resources [UDWR], pers. commun.). These landowner permits generated more than $400,000 annually. Consequently, UDWR and Utah landowners viewed the Paunsaugunt mule deer herd as a sustainable, valuable resource and UDWR managed the herd for the production of mature bucks.

Information was also lacking on mortality factors influencing the population dynamics of this herd. Resource managers suspected substantial mortality occurred from deer-vehicle collisions on US 89 east of Kanab, Utah, because this highway was believed to bisect the Paunsaugunt herd's migration route. Utah Department of Transportation (UDOT) predicted an increase in deer-vehicle collisions on US 89 between Page, Arizona, and Kanab, Utah, due to an expected 60% increase in traffic volume by the year 2015. In addition, proposed development of a new coal mine north of Big Water, Utah, in 1999 was expected to greatly add to existing traffic volume. Defining migration corridors across this highway was essential for devising means to reduce deer-vehicle collisions.

In autumn 1994, Utah State University (USU) investigators documented southward migration of 12 Paunsaugunt mule deer captured on summer range around Alton, Utah; 2 of these mule deer entered Arizona (P. W. Klimack and T. A. Messmer, USU, pers. commun.). Thus, it seemed likely that a portion of this mule deer herd was a shared resource between states. Information on the movements of the interstate portion of the Paunsaugunt mule deer herd could be the basis for an interstate management plan; therefore, a cooperative study was begun in January 1995 involving USU, UDWR, and Arizona Game and Fish Department (AGFD). This report documents the results of AGFD's portion of the study.

Study Objectives

To address concerns raised by both states, our study objectives were to:

- Determine direction, distance, timing, and duration of migration for Paunsaugunt mule deer that use the Buckskin Mountains winter range;
- Define migration corridors, primarily across US 89;
- Identify summer and winter use areas and mule deer fidelity to these areas;
- Identify the proportion of the Paunsaugunt herd that winters within Arizona;
- Ascertain how far Paunsaugunt mule deer migrate into Arizona; and
- Secondarily, determine time and cause of deaths for radiomarked mule deer to estimate annual survivorship.

AN EVALUATION OF ANNUAL MIGRATION PATTERNS OF THE PAUNSAUGUNT MULE DEER HERD BETWEEN UTAH AND ARIZONA

William K. Carrel, Richard A. Ockenfels, and Raymond E. Schweinsburg

Abstract: We studied the migration of the Paunsaugunt mule deer (*Odocoileus hemionus*) herd from 1995 to 1997 to aid in its cooperative management by Utah and Arizona. Our objectives were to determine the direction, distance, timing, and duration of migration; movement corridors; fidelity to winter and summer use areas; and proportion and extent of mule deer movement into Arizona. Secondarily, we also sought to determine causes of radiomarked mule deer mortality. We captured and radiomarked 83 (71 F, 12 M) adult mule deer and monitored their movements over 3 years. Twenty-four mule deer were captured on summer range in Utah, whereas 59 were captured on winter range in Utah and Arizona. In autumn, most mule deer that occupied summer habitat on and around the Paunsaugunt Plateau migrated an average 50.9 km south-southeast to winter near or on the Buckskin Mountains in Utah and Arizona. Autumn migration began in late September-early October and ended by early November. Spring migration began in late March and was completed by mid-May. Arizona mule deer tended to migrate about 4 weeks later than Paunsaugunt mule deer, arriving in the Buckskins later in autumn and returning to summer range later in spring. Autumn and spring migration periods lasted 6-7 weeks for both herds. Based primarily on movements of mule deer captured on Utah summer range, we believe that only 20-30% of the Paunsaugunt herd uses winter range in Arizona. Mule deer that moved from Utah to Arizona (Interstate mule deer) typically ranged ≤ 13 km ($\bar{x} =$ 7.1 km) into Arizona. Interstate mule deer were hunted in Utah prior to and during migration. Most Interstate mule deer entered Arizona before the end of October, and these Interstate bucks were also hunted in Arizona during late October and November. A portion of the Paunsaugunt herd and Arizona mule deer shared the Buckskin Mountains winter range in Arizona and showed strong fidelity to winter use areas. Of the radiomarked mule deer captured on the winter range of the Buckskin Mountains, none were resident mule deer. All ($n = 26$) radiomarked Paunsaugunt mule deer using Arizona's Buckskin Mountains winter range migrated north to Utah and all ($n = 19$) radiomarked Arizona mule deer sharing this winter range moved south to the Kaibab Plateau summer range. Predation, deer-vehicle collisions, and sport hunting were the 3 most common sources of mortality. Annual female survivorship for the Paunsaugunt herd was 0.745, whereas annual male survivorship was 0.512. Genetic interchange likely occurs between the Paunsaugunt and Arizona herds because they are sympatric during the breeding season. Arizona winter range is important to a portion of the Paunsaugunt mule deer herd. Cooperative programs by Utah and Arizona would optimize management of the interstate portion of the Paunsaugunt mule deer herd.

Key Words: Arizona, interstate, Kaibab, migration, mortality, movements, mule deer, *Odocoileus hemionus*, Paunsaugunt, summer range, Utah, winter range.

INTRODUCTION

From observations, Utah landowners, sportsmen, and resource managers suggested that mule deer crossed U.S. Highway (US) 89 into the Buckskin Mountains in Utah and Arizona during autumn and the reverse during spring. They expressed concern that a reduction of mature bucks in the herd might occur due to harvest by Arizona hunters, thus reducing the number and value of permits available to hunters in Utah. Further, Arizona wildlife managers needed to know herd boundaries of mule deer using winter range in the Buckskin Mountains of Arizona to properly manage mule deer in game management units (GMUs) 12A and 12B. Managers in both states were concerned that multiple, uncoordinated hunts on interstate mule deer could result in overharvest of bucks.

Most mule deer in the Rocky Mountain/ Intermountain region (from central Arizona and New Mexico to northern Alberta and British Columbia) are migratory (Wallmo and Regelin 1981). Although mule deer herds in this region have exhibited diverse migratory patterns, they showed strong fidelity to seasonal ranges (Gruell and Papez 1963, Russo 1964, Haywood et al. 1987, Garrott et al. 1987, Brown 1992). Mule deer move between summer and winter ranges in response to climatic and seasonal changes, such as snow cover, temperature extremes, and forage availability (Wallmo and Regelin 1981).

Migration as a survival strategy is a learned behavior; fawns born on summer range are led by does to winter range in autumn, thereby passing on specific movement behavior to the next generation (Nelson 1979).

Appendix 3. Distance (km) between centers of activity (COA) of summers (sum) and winters (win) within years and between years, 1995-98, for 47 Paunsaugunt mule deer.

ID	95 sum/ 95-96 win[a]	96 sum/ 96-97 win	97 sum[b]/ 97-98 win[c]	95 sum/ 96 sum	95-96 win/ 96-97 win
1	33.9	32.9	30.9	1.8	0.4
2	36.6	35.7	38.9	0.6	1.2
3	36.7	36.7	37.7	0.7	0.6
5	31.2	33.6	31.2	0.7	2.1
6	39.6	40.2	39.9	0.6	1.0
7	59.5	61.5	58.2	0.9	3.3
8	61.9	61.5		1.2	1.5
9	62.5	61.6	58.6	1.2	0.5
11	59.4	61.8	59.6	0.4	2.1
13	14.8	24.6		1.6	11.2
14	40.6	40.0		0.5	0.1
15	66.0	66.7		0.4	0.5
16	71.4				
17	56.0			0.9	
18	58.7			1.8	
21	56.9	57.1		0.5	0.1
22	48.8	57.4		1.2	7.9
23	58.7	62.5	63.2	1.0	4.1
24	36.4	35.5	38.5	1.2	0.7
26	46.2	41.3		0.5	6.0
28	68.5			0.3	
29	34.5				
30	61.0				
32	54.0	54.9	47.5	0.8	2.8
33	67.8	68.0	69.6	1.0	1.2
34	71.5	69.7	72.0	0.9	1.2
36	47.9	47.8		1.1	1.4
37	68.0	67.6		0.4	0.6
38	44.6			0.4	
39	55.0	55.5		0.5	0.3
40	56.6				
42	68.3			0.5	
43	72.2	70.6		0.4	1.8
44	55.0	55.5		0.6	1.1
47	60.8	59.6	60.9	0.5	0.8
48	55.9	60.1	59.5	7.9	0.3
49	54.9				
50	49.1	51.1	50.2	1.1	1.6
51	59.8	61.0	59.3	0.9	0.7
52	15.6	16.3		0.9	1.7
54				3.8	
55	41.6	42.9		4.1	2.4
56	25.3				
57	45.9	45.8	43.8	1.3	0.9
58	19.4				
62		62.9			2.8
63		72.9			2.1
74		73.9			1.9

[a] Distance between the COA for 1995 summer and the COA for 1995-96 winter. Other column headings are similar.
[b] Summer 1997 COA was based on only 2 locations, instead of 6-8 locations for other years.
[c] Winter 1997-98 COA was based on only 3 locations, instead of 7-9 locations for other years

Appendix 4. Distance (km) between centers of activity (COA) of winters (win) and summers (sum) within years and between years, 1995-97, for 16 Arizona (Kaibab herd) mule deer.

ID	95-96win/ 96 sum[a]	96-97win/ 97 sum	95-96win/ 96-97 win	96 sum/ 97 sum
35	17.1	16.8	0.8	0.3
59	58.3	55.7	0.3	2.5
61	54.2	57.9	0.6	4.6
65	43.9		0.7	
66	11.4	12.8	3.6	1.0
67	38.3	27.5	19.6	0.7
69	9.8	8.8	1.0	0.9
70	9.7		2.4	
71	15.0	15.2	1.5	1.1
72	11.3			
73	13.8	14.5	1.8	0.5
75	22.1	23.1	1.1	0.7
80	8.8	10.1	0.5	1.5
81	9.0			
82	12.3			
83	9.4		0.6	

[a] Distance between the COA for 1995-96 winter and the COA for the summer of 1996. Other column headings are similar.

Appendix 5. Earliest autumn and latest spring dates during which 23 Interstate mule deer were located in Arizona each year, by animal identification number (ID). Each mule deer entered Arizona before the autumn date and left Arizona after the spring date.

	1995		1996		1997		
I.D.	Spring	Autumn	Spring	Autumn	Spring	Autumn	Comments
11		10/27	3/19	10/15	3/24	10/30	
15	5/18	10/18	5/1	10/15			Died 3/3/97
16		10/18					Died 12/21/95
18	4/24	10/10	4/24				
19	5/8						Died 7/15/95
21		11/15					
22				12/19			
23			3/18	10/29	3/17	10/27	
28	4/27	10/23	4/11				Died 8/8/96
30	4/24	10/10					Died12/21/95
31	4/27						Died 10/21/96
33	4/24	10/23	4/15	10/15	7/1[a]	10/27	
34		10/23	3/25	10/15	4/18	10/27	
37	4/27	11/3	4/24	10/29			
42		10/31	4/15				Died 10/19/96
43		10/27	3/25	10/21	3/17	11/3	
50		10/23	5/15	10/24	4/28	10/27	
51		11/15	3/18	10/15		11/10	
60			4/8				Died 10/15/96
62			5/15	10/21	3/24		
63			4/24	10/24			
68			5/31				Died 9/20/96
74			4/25	10/24			Died 2/3/97
Totals	8	14	17	13	7	7	

[a] Location flights were not conducted between 4/28 and 7/1 in 1997.

Appendix 6. Earliest dates that 14 Arizona mule deer were located in game management unit (GMU) 12B during autumn migration by year and earliest dates that these mule deer were located in GMU 12A during spring migration by year, by animal identification number (ID). Each mule deer entered GMU 12B before the autumn date and left GMU 12B before the spring date.

	1996		1997		
I.D.[a]	Spring	Autumn	Spring	Autumn	Comments
35	5/15	10/29	4/28	12/15	
59	5/1	2/25	8/13	(not by 12/15)[b]	
61	4/24	2/25	4/28		Last located 8/13/97
65	4/15	2/3	4/11		Last located 4/28/97
66	5/15	10/29	4/28	12/15	
67	5/15		(did not enter GMU 12B again by 12/15/97)		
69	6/11	11/4	7/1[c]	11/24	
70	6/11	10/29			Last located 4/28/97
71	5/1	10/29	4/28	11/13	
72	4/24				Last located 9/17/96
73	5/1	10/29	7/1[c]	11/21	
75	4/11	1/30	4/14	(not by 12/15)	
76	3/22				Last located 6/11/96
81	5/15				Last located 11/14/96
Totals	14	10	9	7	

[a] 5 Arizona mule deer (I.D. nos. 78, 79, 80, 82, and 83) were never located in GMU 12B.
[b] Location flights were not conducted beyond 12/15/97 during 1997-98 winter.
[c] Location flights were not conducted between 4/28 and 7/1 in 1997.

Appendix 7. Mean distance (km) of Interstate mule deer locations from the Utah-Arizona state line for 4 winters (1994-97) and an overall average distance.

Winter	*n*	$\bar{x}$	SE	Min	Max
1994-95	30	5.8	0.4	0.5	11.4
1995-96	278	7.4	0.2	0.0	21.5
1996-97	179	7.0	0.2	0.3	15.6
1997-98	42	5.9	0.5	0.2	10.8
All	529	7.1	0.2	0.0	21.5

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