SUMMER HABITAT USE AND MIGRATION MOVEMENTS OF THE PAUNSAUGUNT PLATEAU MULE DEER HERD

Final Report

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by

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Executive Summary

The Paunsaugunt Plateau, located in South-Central Utah is well known as home to one of North America's premier trophy mule deer (*Odocoileus hemionus*) herds. The Utah Division of Wildlife Resources (UDWR) Paunsaugunt Plateau Deer Management Unit (DMU) encompasses 285,263 ha of the Plateau located in Garfield and Kane counties. Approximately 40% of the DMU consists of mule deer summer range. Although UDWR and Arizona Game and Fish Department (AGF) wildlife biologists, local landowners, and hunters believed that the Paunsaugunt Plateau mule deer herd was shared by both states, little else was known about the ecology of the herd. In particular, no data were available regarding seasonal habitat use patterns, migration movements, causes of mortality, and general herd health. If this herd crosses state lines during seasonal migrations, information regarding the timing, duration, and extent of these movements would be needed to develop an inter-state management plan to preserve herd integrity and regional socio-economic benefits associated with current recreational opportunities.

To obtain this information, wildlife biologists from the UDWR, AGF, and Utah State University (USU) captured and radio-collared 83 mule deer (73 does, 10 bucks) over a two year period (August 1995 to February 1996). Field personnel monitored the portion of the study population that established home ranges in Utah during 1995-96 to determine herd summer macro-habitat use, production, herd composition, and densities relative to landownership. We used radio-telemetry data obtained by aircraft to plot on-the-ground animal temporal and spatial locations during 1995-97 migration periods to

determine the timing, duration, and extent of herd movements between seasonal ranges. Study animals that died during this study period were relocated by field personnel to determine the cause of death. Additionally, we compared the efficiency of using aerial telemetry techniques to roadside transects for delineating migration corridors used by mule deer to cross a highway.

In 1996, we collected blood samples from 18 animals captured on the winter range. These blood samples were analyzed to assess herd health. Captured animals also were examined by a veterinarian to determine general body condition.

Sixty-two of the 83 mule deer monitored (75%) during this study occurred in Utah. This population was considered to represent the Paunsaugunt Plateau mule deer herd. Two of these animals died before completing a seasonal migration. Twenty-seven of the remaining 60 Paunsaugunt mule deer (45%) crossed state lines during seasonal migrations and occupied winter home ranges in Arizona. Of the 22 animals captured on summer range in Utah that lived long enough to complete a migration cycle, four used winter home range in Utah (18%). Based on these data, we believe that between 20-30% of the Paunsaugunt Plateau mule deer annually winter in Arizona.

The average straight line distance between seasonal ranges for Paunsaugunt Plateau mule deer that traveled south to winter ranges and north to summer ranges during 1995-96 was approximately 55.9 km. These animals began migrating to their winter ranges in early October. The 1995-96 fall migration periods lasted approximately six weeks, ending in mid November. The 1995-96 spring migration periods also lasted approximately six to seven weeks, beginning during the mid-March and ending in early May. On average, individual animals spent 20 and 14 days migrating during the spring and fall, respectively. There was no relationship between animal weight or age and distance traveled.

The Paunsaugunt Plateau mule deer that migrated south to Arizona, occupied winter ranges also used by the Kaibab Plateau mule deer herd. Most of these deer (80%) were present in Arizona by the first week of November. The Paunsaugunt Plateau herd arrived on and left the winter range four weeks earlier than Kaibab Plateau mule deer. By arriving earlier than the Kaibab Plateau herd, Paunsaugunt Plateau mule deer may contribute a significant portion of the population that is hunted in Unit 12B during Arizona's first general rifle season hunt. The first hunt in Unit 12B has traditionally started in late October. None of the mule deer monitored throughout this study were year long residents of the winter range. Lastly, none of the mule deer that were captured on the winter range located in Utah migrated south to summer ranges in Arizona.

Thirty-eight of the 59 mule deer captured on Utah and Arizona winter range used summer ranges in Utah. Twenty-three of these animals (60%) occupied summer home ranges on private land. Approximately 10% of the DMU considered to constitute available summer range in Utah is privately-owned. Fidelity to these summer home ranges was strong. Mule deer buck and doe home ranges were similar in size. Mule deer summer home ranges on private land were larger than home ranges on public land. Home ranges on public land were located on steeper slopes and at higher elevations than home ranges on private land. Public lands in this study experienced higher levels of disturbance and lower domestic livestock grazing intensities than the private land studied.

Mule deer summer ranges were representative of available vegetation types, regardless of land ownership or micro-habitat diversity. Mule deer densities were three times higher on private (89:100 ha) than public land (32:100 ha). Buck:doe ratios were higher on private (59:100) than public lands (31:100) . Fawn:doe ratios were lower on public (47:100) than private (52:100) land. There were no differences in estimated fawning dates and observed production rates for does monitored.

We were only able to determine the cause of death for 17 of the 31 (55%) study animals that died during this study. Mountain lions (*Puma concolor*) killed six animals (19%), four were killed in deer-vehicle collisions (13%), three were legally harvested (10%), two were poached (7%), and two were killed by other predators (7%). Although eight of the confirmed adult mortalities were attributed to predation (47%), we do not believe predation is a major factor limiting recruitment or population size for the Paunsaugunt Plateau mule deer. The high deer densities and buck:doe ratios observed on the summer ranges and heavy localized browse use suggest the herd may currently be at or exceeding summer habitat carrying capacities.

Deer-vehicle collision (DVC) data collected from roadside transects indicated that bucks and fawns are more likely to be killed crossing the highway during fall migration than does. Mule deer were not evenly distributed along the highway during seasonal migrations. More mule deer were observed between mile posts 39-42 than any other combination of mile posts. DVCs recorded by study personnel and the Utah Department of Transportation were not evenly distributed along the highway. More DVCs were recorded between mile posts 39-42 than any other mile posts. Migration corridors delineated by road transects were narrower than those identified through radio telemetry studies.

The results of the blood work analysis suggests that the mule deer populations during February on the winter are experiencing significant stress. Twenty-eight percent (n = 5) of the study animals captured on the winter range in 1996 had ticks. Two animals (11%) showed evidence of mange on their ears. All of the animals sampled negative for brucellosis and leptospirosis. However, 17 animals (94%) tested positive for bovine virus diarrhea (BVD), 15 (83%) for infectious bovine rhinotracheitis virus (IBR), and 15 (83%) for parainfluenza 3 virus (PI3). Eight animals (22%) tested positive for bluetongue virus and of these, two (25%) for epizootic hemorrhagic disease (EHD). The average white blood cell count of the sample exceeded normal population parameters. None of the animals that tested positive for diseases died during the duration of this study.

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Introduction

Management of the Paunsaugunt Plateau mule deer herd parallels that of the rest of Utah. From 1955 through 1965, the doe harvest exceeded the buck harvest. These "either sex" hunts were continued throughout the 1973-1974 season (Guymon and Coles 1985). A marked decrease in Utah mule deer populations in 1965, due to a bad winter, resulted in the UDWR withdrawing the special permits. The UDWR reestablished "buck only" hunts in 1975 in response to another bad winter (Phelps 1976).

The declines in mule deer numbers on the DMU were further exacerbated by logging operations which improved hunting access on public lands in the unit (Guymon and Coles 1985). Increased hunting pressure, coupled with a harsh winter in 1973, resulted in a crash in the Paunsaugunt Plateau mule deer population. In 1980, the UDWR closed the unit to deer hunting for 5 years as part of an experiment to restore the population.

By the end of 1985, both deer population and the buck/doe ratios on DMU had rebounded. The number of mature bucks had increased resulting in the highest preseason mature buck/doe ratios in Utah (UDWR 1992). The unit was reopened to limited-entry hunting in 1987. Today, the unit is considered to be one of the premier trophy mule deer units in North America (Migale 1995).

Currently, the Paunsaugunt Plateau mule deer herd provides significant economic opportunities for private landowners through Utah's Cooperative Wildlife Management Unit (CWMU) and Landowner Association (LA) programs. Under program guidelines, the landowners are allocated a number of permits for sale to private clients in return for public hunting access. The revenue generated from the sale of tags provides an additional incentive for landowners to include big game species and other wildlife as part of their farm or ranch management plan (Messmer and Dixon 1997, Messmer et al. 1998).

UDWR and AGF wildlife biologists, local landowners, and hunters have long believed that the Paunsaugunt Plateau mule deer herd migrated south to winter along the Utah/Arizona border. Although they were concerned about the impact that hunting would have on the trophy quality of the herd and hunter opportunity if the herd crossed state boundaries, no research had previously been conducted to determine if this situation existed. To address these longstanding questions, UDWR and AGF wildlife managers in cooperation with USU and local landowners initiated this study. To set a basis for this research, USU reviewed and summarized pertinent biological and ecological information on mule deer habitat use and migration patterns previously reported in the literature.

Literature Review

Migration

Migration between seasonal home ranges is an evolutionary adaptation to increase reproductive fitness and survival (Main 1994). In the fall, mule deer migrate to winter ranges in response to increased snowfall and reduced forage resources (Dasmann 1971, Mierau and Schmidt 1981, Mackie 1994). The extent of these movements are frequently dictated by the forage availability and climatic extremes (Wallmo 1980, Wallmo and Regelin 1981). As such, the quantity and quality of forage and habitat diversity found on seasonal ranges are important factors influencing individual animal fitness (Pederson and Harper 1978, Mackie 1994) and ultimately herd productivity (Jones et al. 1956, Julander et al. 1961, Pederson and Harper 1978).

Timing of fall migration varies and is dependent on factors such as length of photoperiod and increasing snow depths (Mierau and Schmidt 1981). Although increasing snow depths have been reported to initiate fall migration (Mierau and Schmidt 1981), some mule deer herds migrate well before the first snow (Garrott et al. 1987). Kucera (1992) reported that mule deer fall migration patterns in California differed annually. In this study, winter storms produced a pulsed migration, which was rapid, pronounced, and of short duration. In years without storms, the migration was gradual (Kucera 1992). Haywood et al. (1987) reported that the Kaibab Plateau mule deer herd migration period lasted 52 days, but individual deer spent < 20 days actually migrating. They observed no difference in migration timing or duration for bucks and does.

In seasonally resource-limited environments, mule deer tend to travel longer distances during migration (Gruell and Papez 1963, Garrott et al. 1987). Wallmo (1980) reported that mule deer may move > 80 km from summer to winter ranges. Haywood et al. (1987) reported that Kaibab Plateau mule deer migration distances ranged between 0.2 km and 64 km. Several other authors reported mule deer fall migration distances of < 30 km (Mierau and Schmidt 1981, Pac et al. 1988, Kufeld et al. 1989, Brown 1992, Kucera 1992).

Consequences of migration

Wildlife managers believed the Paunsaugunt Plateau mule deer herd occupies distinct, widely separated seasonal ranges and does not travel between them except during migration (Mackie 1994). Although migration is an adaptive strategy that can enhance the survival of a species occupying seasonally resource-limited environments, it is not without consequences. During migration, individual animals give up the security of their home ranges. This alone may contribute to increased hunting and predation mortality (Brown 1992, Horejsi 1988). Consequently, migratory herds may experience higher mortality rates than non-migrating populations (Wallmo 1980). In addition, traveling long distances requires additional energy. Less fit animals may succumb to environmental stress and die on route to seasonal ranges, especially if forage on seasonal ranges is sub-optimal (Julander at al. 1961, Julander 1962).

Migrating herds that must cross highways en route to seasonal ranges are at increased risk of DVCs (Reed 1981, Romin 1994, Kays and Tregoning 1995, Groot and

Hazebroek 1996, Lenhert 1996). If bucks in rut and fawns experiencing highways for the first time are more susceptible to DVCs, herd demographics could be altered (Russo 1960, Lenhert 1996). The latter may be especially true if migration corridors are bisected by several highways exhibiting seasonal high traffic volumes that coincide with these movements (Allen and McCullough 1976, Bashore et al. 1985). The raising of speed limits on many highways in the western states also increased the frequency and severity of DVCs (E. Cheng, Utah Dept. of Transportation, pers. commun.).

Some western mule deer herds cross state lines during seasonal migrations (Anon. 1962-1964, Wallmo 1980). Mule deer herds that migrate across state boundaries or between in-state hunt management unit boundaries may have increased potentials of being over-hunted because of diverse harvest management strategies (UDWR 1992, 1994). In many western states, mule deer archery hunts often begin in late August, followed by the rifle hunts in September-October, and muzzle loader hunts in November-December (Kuck 1995). These later hunts typically occur during the rut. Extended and multiple hunting seasons could adversely impact the demographics of mule deer herds that migrate across state borders or hunt management units (Connolly 1981). The effect of such multiple hunts on the herd composition could be additive rather than compensatory for mature bucks (Austin et al. 1992).

Recent evidence in elk (Noyes et al. 1996) and red deer (Clutton-Brock et al. 1982) suggests that the presence of an adequate number of old-age class males in a population may be essential to ensure synchrony in conception and parturition. If harvest management reduces the number of old-age males and alters breeding behavior during traditional reproductive periods, conception and parturition could be delayed. Delayed conception and parturition could result in long-term population consequences, to include reduced recruitment (Bubernik 1972, Bowyer 1991).

Environmental factors affecting mule deer home range use

The size and geographic location of individual mule deer seasonal home ranges is influenced by a number of factors. The juxtaposition of several vegetation or habitat types (macro-habitat diversity) may affect mule deer home range use more than specific terrain or vegetation features (Mackie 1994). Greater macro-habitat diversity on seasonal ranges may translate into smaller home ranges, higher densities, and increased mule deer survival thus, increased mule deer productivity (Hamlin and Mackie 1989).

In the Intermountain West, lands located at higher elevations generally receive more precipitation (Utah Climate Center 1996). More precipitation results in greater vegetation growth potentials contributing to increased macro-habitat diversity. If Hamlin and Mackie (1989) are correct, mule deer summer home ranges located at higher elevations would be expected to be smaller in size than lower elevation home ranges. In addition, high elevation summer ranges, exhibiting greater habitat diversity, also would be expected to support higher summer population densities (Hamlin and Mackie 1989, Mackie 1994).

Water availability also may affect home range use patterns in mule deer (Boroski and Mossman 1996). For example, lactating does are usually located closer to water than non-lactating females or males (Ross et al. 1981, Parker et al. 1993). Consequently, lactating does may have relatively smaller home ranges when compared to bucks (Ross et al. 1981, Main 1994).

Behavioral factors affecting mule deer use of seasonal home ranges

Nelson (1979) suggested that deer may select home ranges based on tradition, independent of habitat diversity. This learned behavior may be an artifact of a disturbance-avoidance response. Increased human disturbance, such as off-road vehicle use, hiking, logging, and other public-use activities can alter animal behavior patterns thus causing them to reduce home range size or seek refuge elsewhere (Chester 1980, Freddy et al. 1986, Vogel 1989, Cassirer et al. 1992). Hiking, in particular, has been shown to alter mule deer behavior more than other vehicular traffic (Freddy et al. 1986).

In many western states, public lands, which also constitute important seasonal mule deer ranges, frequently experience high public use. Thus, having higher levels of disturbance than private lands. In addition, hunting pressure on public lands is generally greater than on private lands (Jordan and Workman 1990). Consequently, mule deer summer home range use patterns and densities also may reflect historical settlement patterns and concomitant land uses.

Brown (1992) reported that mule deer exhibited a higher degree of fidelity to summer than winter ranges. Haywood et al. (1987) reported that home range site fidelity also was more pronounced in does than in bucks. Mule deer that demonstrate strong site fidelity may have increased survival because of better habitat conditions and familiarity with an area (Horejsi et al. 1988, Loft et al. 1991).

However, strong fidelity to a seasonal range also may have negative consequences for mule deer. During hunting seasons, rather than leave their home range, mule deer tend to conceal themselves more (Dasmann and Taber 1956, Kufeld et al. 1988). Thus, mule deer herds exhibiting a high degree of fidelity to seasonal home ranges, where hunters have unlimited access, may be at a greater risk of being over harvested (Haywood et al. 1987). Conversely, where hunter access is restricted, mule deer densities and herd composition also may be higher.

Relationship of landownership patterns on mule deer seasonal home range use

Although most of the West is publicly-owned, private lands based on topographical location alone, continue to constitute important seasonal habitats for mule deer and other wildlife (Larson and Bunnell 1989, Messmer and Dixon 1997). In northern Utah alone, over 60% of the critical mule deer winter range is privately-owned (Larson and Bunnell 1989). In the western states, public lands tend to be located at higher elevations, while the valleys and foothills are privately owned (Fife 1990). This reflects early settlement patterns. Although lower elevation lands typically receive less precipitation, irrigation has allowed for the cultivation of small grains and forage crops (Reed 1981) such as alfalfa (*Medicago sativa*). These agricultural crops provide alternative summer and winter forages for big game animals (Messmer and Schroeder 1996). Consequently, many private landowners, largely because of wildlife depredation of agricultural crops, feel it is they who are subsidizing public wildlife by providing critical habitat on private land (Conover 1994). In Utah alone, ranchers reported in excess of $5 million losses to their alfalfa crops largely because of damage caused by mule deer (Messmer and Schroeder 1996).

Previous studies also have reported that high levels of disturbance may cause mule deer to use smaller home ranges and establish sites in poor quality habitats (Loft et al. 1987, 1991). Consequently, land ownership patterns also may affect mule deer seasonal home range size and densities if concommitant land uses result in increased levels of disturbance (Reed 1981, Loft et al. 1987, Cassirer et al. 1992). Generally, most privately-owned lands have reduced levels of disturbance than public lands because access is limited to landowners and/or their employees (Jordan and Workman 1989, 1990). If disturbance levels affect habitat selection in mule deer, home ranges on private land would be expected to be larger than those found on public lands.

Relationship of domestic livestock grazing to mule deer home range use

Grazing by domestic livestock is the primary land use on western rangelands. In addition to grazing their rangelands, ranchers may lease summer grazing allotments on public land to supplement forage bases (Stoddard et al. 1975). Historically, western mule deer have benefitted from vegetation composition changes resulting from intensive livestock grazing (Severson 1990, Urness 1990, Holechek et al. 1995). Cattle or sheep grazing on mule deer summer and winter ranges can increase browsing for mule deer by reducing grass competition on preferred browse species (Julander 1962, Smith et al. 1979, Willms et al. 1981). Prescribed grazing could increase mule deer and other wildlife numbers by stimulating the growth of preferred forages and cover (Urness 1976, 1990; Clements and Young 1996). In general, light or moderately grazed habitats exhibit more plant species diversity than habitats that are ungrazed (Johnston 1961, Campbell 1973).

Other authors have reported that domestic livestock grazing of seasonal ranges is detrimental to mule deer and other wildlife species (Buechner 1950, Fleichner 1994, Clements and Young 1996). Continued heavy grazing may reduce food availability for ungulates (Holechek et al. 1995). High cattle numbers on seasonal ranges may also constrict mule deer home range sizes, and force them to utilize less preferred habitats on steeper slopes (Kie et al. 1991, Loft et al. 1991). In addition, if heavy grazing results in a reduction of suitable hiding cover, mule deer fawns also may be more susceptible to predation (Loft et al. 1987). Additionally, predation rates also may increase if heavy grazing regimes result in deer spending more time feeding and less time resting and watching for predators (Kie et al. 1991).

Supporters of maintaining grazing allotments argue that ending this practice could result in deterioration of existing forage and habitat conditions on private as well as public rangelands. Elimination of federal grazing allotments could result in a reduction of the available habitat base as private lands in response to local economic pressures are converted to other uses (Urness 1990). A reduced presence of private landowners and domestic livestock grazing on public lands also may result in reduced predator control efforts, especially on coyotes (*Canis latrans*).

Impact of predation on mule deer recruitment

Predation, especially by coyotes and cougars (*Felis concolor*), has been identified as a major factor regulating mule deer population densities (Robinette 1977, Connolly 1981). Mule deer fawns, in particular, are vulnerable to coyote predation (Hamlin et al. 1984, Martinka 1994). In areas where predation has been minimized by active predator control, low mule deer numbers have rebounded (Knowlton 1976, Austin 1977, Robinette 1977). Increased predation, in addition to impacting recruitment, also forces animals to develop unique anti-predator strategies. In the case of mule deer, this may include establishing home ranges and rearing young on steeper slopes (Riley and Dood 1984, Main 1994).

Study Objectives

The primary objectives of this study were: (1) to determine the extent, timing, and duration of the Paunsaugunt Plateau mule deer herd seasonal migrations, (2) to determine mule deer summer range habitat use patterns, fawn production, herd demographics, and densities relative to land ownership patterns, and (3) to determine corridors used by mule deer to cross U.S. Highway 89. In addition to these objectives, we evaluated the use of roadside transects and deer-vehicle collision data as an alternative methodology to radio telemetry studies for delineating mule deer migration corridors, determined mortality factors affecting the Paunsaugunt Plateau mule deer herd, and assessed general herd health of the mule deer occupying the winter range.

Completion of this project will fill in important information gaps with the knowledge necessary to provide a foundation for management of the herd on an inter-state and land ownership basis to preserve and enhance the existing socioeconomic and recreational benefits currently associated with this mule deer herd for the citizens of the region. This information also will enable the project cooperators to address public health and safety concerns relative to reducing deer-vehicle collisions on U.S. Highway 89.

Study Area

The Paunsaugunt Plateau lies within the boundaries of UDWR Paunsaugunt mule deer herd unit (37° 25.64' N, 112° 19.07' W). This unit consists of 285,263 ha within Garfield and Kale counties in South Central Utah (Fig. 1). Thirty-eight percent (107,287 ha) of the unit is considered mule deer summer range and 62% (176,683 ha) is winter range (UDWR 1994). Approximately 10% (10,728 ha) of the summer range is privately owned. Private lands are primarily managed for seasonal livestock grazing. The public land in the unit is managed by the B.M. (61%), U.S. Forest Service (13.7%), the state of Utah (6.4%), and the National Park Service (3.4%). Public lands are managed for multiple use and include livestock grazing, recreation, and hunting. This unit is composed of six major drainages. Elevations range from 1525 m on the winter range along the Utah/Arizona border to 2935 m at Black Butte on the Paunsaugunt Plateau summer range. The Buckskin Mountains originate east of Kanab, Utah and extend south across the Utah/Arizona state line to the Kaibab Plateau.

The mule deer migration corridor study was conducted along U.S. Highway 89, east of Kanab, Utah (37° 2.11' N, 112° 15.22' W). U.S. Highway 89 bisects the Paunsaugunt mule deer herd's seasonal ranges. The area north of the highway consists primarily of summer range. Migrating mule deer must cross the highway to reach the winter range located in the Buckskin Mountains which straddle the Utah/Arizona border. U.S. 89 connects southern Utah and Northern Arizona to major regional population centers. Current traffic volumes of 1800-2000 vehicles per day are projected to increase by 150% along this segment of U.S. Highway 89 by the year 2020 (B. Perry, Utah Dept. of Trans. pers. commun.). Further increases in this projected traffic volume are anticipated when the Grand Staircase Escalante National Monument and associated visitors center opens, east of Kanab. In addition, vehicle speed limits on the highway have been increased in 1996 from 88 to 104 kph.

Vegetation

The Paunsaugunt Plateau mule deer herd unit winter range within Utah is dominated by pinyon-juniper, sagebrush, and mixed vegetation cover types (Guymon and Coles 1985). Pinyon-Juniper vegetation type is characterized by pinyon pine (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*). The sagebrush vegetation type is characterized by big sagebrush (*Artemisia tridentata*) and sand sagebrush (*A. filifolia*). The mixed vegetation type consists primarily of the above species along with black sagebrush (*Artemisia nova*), serviceberry (*Amelanchier utahensis*), cliffrose (*Cowania stansburiana*), Gambel oak (*Quercus gambelii*), and snowberry (*Symphoricarpos* spp.). The Paunsaugunt mule deer herd winter range within Arizona is characterized bybig sagebrush and sand sagebrush interspersed with cliffrose, bitterbrush (*Purshia tridentata*), pinyon pine, and Utah juniper. There is less bitterbrush and more cliffrose than in the Utah portion (P. Arrohave, B.M., pers. commun.).

Paunsaugunt mule deer summer range in Utah consists of sagebrush, bitterbrush, snowberry, rabbitbrush (*Chrysothamnus spp.*), aspen (*Populus tremuloides*), fir (*Abies*

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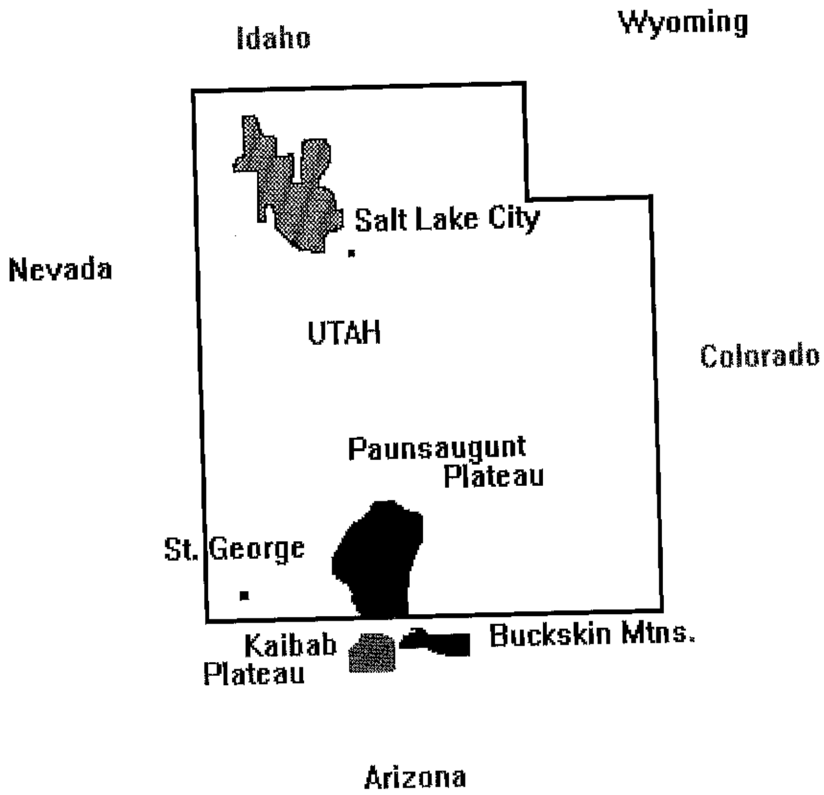

Figure 1. The Paunsaugunt Plateau in Southern Utah

spp.), pine (*Pinus* spp.), spruce (*Picea* spp.), wax currant (*Ribes cereum*), curlleaf mountain mahogany (*Cerocarpus ledifolius*), and Ponderosa pine (*P. ponderosa*). Irrigated alfalfa (*Medicago sativa*) is the primary forage grown on private land. Approximately 1000 ha of alfalfa are grown in the unit. The balance of privately owned land is non-irrigated seeded pasture or native range (Utah Agriculture Statistics 1994).

Methods

Objective 1. To determine the extent, timing, and duration of the Paunsaugunt Plateau mule deer herd seasonal migration

During 1995-96, 83 mule deer (73 does, 10 bucks), captured by helicopter using net-gunning techniques (Gese 1987, White and Bartmann 1994), were fitted with radio-transmitters (148-151 MHZ) equipped with a mortality pulse. Ground crews weighed, examined, and fitted captured mule deer with collars containing the transmitters. The captures were conducted in August 1994 (n = 12) and 1995 (n = 12) in Utah on the summer range and February 1995 (n = 25) and 1996 (n = 34) on the winter range located on the Utah/Arizona border.

Fall movements and locations of these animals were monitored beginning October 1994 through December 1997 by UDWR and AGF personnel using Cessna 185 aircraft. These aircraft were equipped with two externally mounted 3-element yagi antennas and a Model TR-2 receiver/scanner (Telonics, Inc., Mesa, Ariz.). Aircraft pilots or study personnel accompanying the flights used Navstar® or Loran-C® based navigation systems to determine Universal Transverse Mercator (UTM) ground coordinates for all animals. Mule deer locations and movement were monitored twice a month when the animals were on seasonal home ranges to check for mortalities. Once migration began, as determined by an abrupt change in seasonal locations of study animals, monitoring was increased to twice weekly. This bi-weekly monitoring was discontinued when ground movement ceased (Brown 1992). A total of 119 flights were conducted between October 1994 and December 1997.

Flight data was formatted with animal number, date, and UTM. The UTM coordinates were input into geographic information system (GIS) software and migration corridors mapped. UTM coordinates were overlaid on a digital elevation map (DEM) database to determine seasonal migration patterns. UTM's were used to determine the straight line distance traveled by each study animal. Northernmost and southernmost UTM's were plotted on GIS base maps. Time series analysis was used to detect changes in individual animals' home range elevation over time and thus determine initiation and cessation of migration movement and verify distances traveled (Bautista et al. 1992). Individual animal UTM location data was to calculate the distance that Paunsaugunt Plateau mule deer herd traveled during fall and spring migration periods.

Regression analysis was used to determine if any relationships existed between age, weight, and distance traveled during fall migration. A t-test was used to determine if differences existed in distance traveled between does and bucks ($P < 0.05$). To determine initiation and termination of individual deer migrations, we compared location and movement data to Julian calendar dates. To do this, we calculated annual geographic centers of activity (COAs) for each deer on summer and winter ranges. An animal was considered to initiate migration when a UTM was >1000 meters away from this COA. The date this movement occurred was assumed to be the start of an individual animal's migration.

After reviewing capture, movements and home range location data relative to state boundaries; the study animals were classified as being either part of the Paunsaugunt or the

Kaibab Plateau mule deer herds. Paunsaugunt Plateau mule deer consisted of those animals that used summer ranges in Utah and/or used winter ranges in either Utah or Arizona. None of these animals used summer ranges in Arizona. The Kaibab Plateau mule deer herd consisted of those animals which only were found in Arizona.

Objective 2. To determine Paunsaugunt mule deer summer range habitat use patterns, fawn production, herd demographics and densities relative to land ownership patterns

Fifty-nine mule deer (10 bucks and 49 does) that were randomly captured on BLM managed winter range (Thomas and Novak 1991, White and Bartmann 1994), were monitored to determine if summer home range use patterns for those animals that migrated north to Utah differed by land ownership. A random subsample of 23 of the adult mule deer (21 does and 2 bucks) that established summer home ranges in Utah were monitored on a daily basis to determine if macro-habitat use patterns differed based on landownership. Study animals were monitored from June through August for two consecutive summers.

Annually, we obtained >30 random locations per animal (Dickinson and Garner 1980, Riley and Dodd 1984). All animals were visually located UTM readings were recorded where the initial observations were made. If fawns were observed with does, its age was estimated. This estimate was used to determine when the fawn was born and if fawning dates and production rates differed by land ownership patterns.

To ensure adequate spatial and temporal representation, each study animal was located at different times each day using a Latin-square design (White and Garrott 1990, Krausman and Hayes 1993). UTM's were determined using a hand-held global positioning system unit which allowed for immediate and accurate locations (Foster 1993). UTM locations were differentially corrected. Mule deer location UTM's were input into the home range software, CalHome® (Kie et al. 1996), to determine home range size and configuration. Home range boundaries were generated using the adaptive kernel 95% contour interval method (Worton 1989). Data points were pooled and input into GIS software for spatial analysis to determine if any relationships existed between mule deer home range use, macro-habitat types, and land ownership patterns.

Fawn production, herd demographics and densities

To determine if differences existed in fawn production, herd composition, and mule deer densities by land ownership; pre-season herd composition surveys were conducted during late August of each year along two16.5 km permanent transects established on private and public land. The total area surveyed on public and private land was 257 and 253 ha, respectively. Three evening counts were conducted for two summers from one hour before sunset until approximately ½ hour after sunset. The individual counts were then summed and averaged to determine densities (Storm et al. 1992). Counts were conducted the last week in August allowing most of the fawns to be included (Shult and Armstrong 1984). The total area surveyed was determined by pacing out the distance observed at each 0.16 km interval and summing it for the entire transect. Chi-square tests of homogeneity ($P < 0.05$) were used to determine differences in mule deer densities and composition between sites (Daniel 1990).

Macro-habitat use

Macro-habitat availability for mule deer use and preferences were determined using GIS technology (Bloom et al. 1993), ARCINFO®, the software IMAGINE®, and a habitat availability/utilization standard statistical technique described by Neu et al. (1974). Vegetation cover maps of the area were constructed using B.L.M. vegetation type and GAP® analysis data (Homer et al. 1995). The study area used to determine habitat availability and subsequently preferences was defined by plotting the further extent of the area occupied by all study animals. The area contained within these boundaries was considered to be available for use as summer range by monitored mule deer. Vegetational macro-habitat types of mule deer home ranges were overlaid on the area within this boundary to determine habitat preferences. Homer et al. (1995) identified 39 vegetation types present on the study area. We collapsed the 39 vegetation types into 11 macro-habitats (Appendix A) for conducting chi-square analysis to ensure that a minimum of five mule deer and expected locations would be present in each vegetation type (Moore and McCabe 1993). Chi-square tests of independence were used to determine if differences existed in habitat use patterns and availability based on land ownership ($P < 0.05$).

Slope and elevation were recorded within each home range. Slopes were categorized into five levels; 0 = level, 1 = 1-10°, 2 = 11-20°, 3 = 21=30°, 4 = 31-40°, and 5 = >40°. Actual elevation (meters), for each deer location within a defined home range, was recorded as a numerical value and were averaged for analysis. Chi-square tests of homogeneity were used to determine differences in slope between home ranges ($P < 0.05$).

A paired t-test was used to determine if differences existed in home range elevations (Daniel 1990).

To determine home range site fidelity, individual animal COA were calculated (Brown 1992). The COA is the average UTM of seasonal locations for individual deer for each summer home range (Hayne 1949, Brown 1992). COAs for each animal were calculated using the adaptive kernel home range software (Worton 1989). Distances between COAs of seasonal ranges used in different years produces a measure of fidelity to the area (Brown 1992). Site fidelity was determined to be strong if distances between consecutive summer COAs were < 1 km (Brown 1992, Garrott et al. 1987).

Objective 3. To determine corridors used by mule deer to cross U.S. Highway 89 and evaluate the use of roadside transects, deer-vehicle collision data as an alternative methodology to radio telemetry studies for delineating mule deer migration corridors

Seasonal migrating mule deer concentrations along U.S. Highway 89 were monitored by systematic spotlight surveys conducted along a 32 km transect located between UDOT mile posts 55-35 (Reed 1969, Romin 1994). Transect location was determined after reviewing UDOT 1984-94 DVC records for U.S. Highway 89 from Kanab, Utah, east to the Arizona state line. The starting point for the transect was established at the mile post closest to Kanab, Utah, where the first UDOT DVC location was recorded. The transect endpoint was established at the mile post nearest to the last UDOT recorded DVC location, west of the Utah/Arizona state line.

To conduct the spotlight survey, one technician drove a study vehicle at speeds ≤15 kph along the shoulder of the highway while an observer/passenger searched the right-of-way, with a 400,000 candle-power spotlight, and recorded all mule deer present within 200 m of the highway. When animals were spotted, the vehicle was stopped to facilitate identification. In addition to mule deer numbers, we recorded animal location (mile post to the 0.16 km), time of observation, number of deer in each group, sex, and age (adult/fawn). Deer numbers were tabulated after completion of each transect and then summed for each day and overall the entire migration period (e.g., 2 fall and 2 spring) to conduct our analysis. In the spring, we assumed that deer were migrating from south to north and in the fall from north to south. Thus, in the spring, the transect was traveled in an east-to-west direction and the spotlight was pointed to the south. During the fall, the transect was traveled in a west-to-east direction and the spotlight pointed to the north. This procedure minimized safety concerns because it eliminated the need to direct the spotlight across the path of oncoming traffic and reduced the possibility of counting individual animals more than once (Cowardin and Blohm 1992).

Roadside surveys were conducted from sunset to two hours after sunset, and two hours before sunrise until sunrise, because most reported DVCs occur during these periods (Allen and McCullough 1976, UDOT unpublished data). We also conducted a survey between 2300 and 0100 to determine DVC risks if daily migration movements peaked during this time period. This information would be important if projected traffic volumes increased between 2300 and 0100 hours because of tourism or mineral extraction activities.

All DVC mortalities were recorded for the 1995-96 spring and fall migration periods and during the 1997 spring migration. We requested UDOT 1989-97 DVC records for the transect area. For purposes of analysis, we assumed that every DVC resulted in deer mortality (Allen and McCullough 1976).

We compared roadside transects and DVC data to radio telemetry migration data provided from aircraft to determine which techniques would be the most efficient in determining migration timing and corridors used by mule deer to cross a highway. The movements of radio-collared mule deer that crossed the highway during seasonal migrations were monitored by study personnel using Cessna 185 aircraft, equipped with two externally mounted Yagi antennas, Model TR-2 receiver/scanner (Telonics, Inc.,Mesa, Ariz.), and Navstar® or Loran-C® based navigation systems to determine Universal Transverse Mercator (UTM) ground coordinates for all animals. Once migration was initiated, as determined by abrupt changes in locations of study animals on seasonal ranges, monitoring frequency increased to twice weekly until the animals had settled in on seasonal ranges as indicated by <1 km change in ground locations between aerial flights (Brown 1992). During both years this constituted approximately a 5-week period.

We used chi-square to test if any differences existed in location of observed and UDOT DVC mortality data and roadside transect mule deer concentrations (Daniel 1990). Daily total numbers of mule deer observed along the transect were compared by time periods during migration and a chi-square test was used to determine if observations were evenly distributed ($P < 0.05$).

To delineate highway migration corridors using movement data generated from monitoring radio-collared deer, we plotted the last recorded animal location north and south of the highway and connected these locations by drawing a straight line. The point at which the line bisected the highway was used to delineate the corridor traveled by individual animals to cross the highway. We used a Wilcoxon matched-pairs signed-rank test ($P < 0.05$) to determine if migration corridors delineated by roadside surveys and DVC locations contained more deer per unit area than those delineated by using telemetry locations (Daniel 1990). To evaluate cost effectiveness, we compared estimated costs of conducting roadside surveys to radio telemetry monitoring.

Objective 4. To determine mortality factors affecting the Paunsaugunt Plateau mule deer herd.

The radio transmitters placed on all study animals were equipped with a mortality sensor. This sensor emitted a rapid pulse if the animal remained sedentary for more than a six hour period. When mortality pulses were detected, the information was relayed to field personnel who then attempted to locate the animals as soon as possible and determine the cause of death. In addition, mortalities that were observed along U.S. Highway 89 east of Kanab, Utah; annually during March, April, November, and December were inspected to determine the cause of death.

Objective 5. To assess general herd health of the mule deer occupying the winter range.

We collected blood samples from 18 animals captured on the winter range in 1996. These blood samples were used to conduct hematological, serological, and bacterial isolation tests. All the blood work was conducted by the Wyoming State Veterinary Laboratory, Laramie, Wyoming. The animals sampled also were examined in the field to determine general body condition and the presence of parasites.

Results

Objective 1. To determine the extent, timing, and duration of the Paunsaugunt Plateau mule deer herd seasonal migration

Based on seasonal migration patterns, we determined that 62 of the mule deer monitored represented the Paunsaugunt Plateau mule deer herd. Of this total, 60 survived long enough to complete at least one migration period. Twenty-seven of these deer (45%) crossed the Utah/Arizona state line during seasonal migrations. This represents 32% of the animals studied that lived long enough (n = 79) for us to determine at least one seasonal migration pattern.

Of the deer that were captured on Utah summer ranges, only four of the 22 animals (18%) that survived lived long enough to complete one migration period, they occupied winter home ranges in Arizona. Conversely, 20 of the 39 deer actually captured in Arizona on the winter range (51%) established summer home ranges in Utah. Thus, we believe the actual percent of the population that annually winters in Arizona to be between 20-30%.

Paunsaugunt Plateau mule deer that migrated south to the winter range traveled on average 55 km between seasonal ranges (n = 49, SE = 15.8). There was no difference in the distance mule deer traveled between seasonal ranges by years ($\chi^2 = 0.055$, 94 df, P = 0.09). There was no difference between distance traveled by does ($\bar{x} = 55.4$ km, n = 43) and bucks ($\bar{x} = 56.7$ km, t = 0.86, P = 0.4). There also were no relationships between weight (r = -0.14, P = 0.33) or age (r = -0.20, P = 0.16) and distance traveled. During fall migration, the Paunsaugunt Plateau mule deer traveled between 0.0 and 22.0 km into Arizona ($\bar{x}$ = 7.1, n = 529, SE = 0.15).

In 1995-96, the Paunsaugunt Plateau mule deer began fall migration during the first week of October. The fall migration period ended in mid-November. Spring migration started in late March and ended mid May. Fall and spring migration periods lasted approximately six weeks. Individual animals spent approximately 14 and 20 days migrating during the spring and fall, respectively. Animal age (r = 0.20, P = 0.11) or weight (r = 0.16, P = 0.23) did not affect the date of initiation of fall migration. There also was no difference by sexes and fall migration initiation dates (t = 0.49, df = 8, P = 0.41).

In the fall, most of the Paunsaugunt Plateau mule deer herd that occupied winter home ranges in Arizona (88%) was present in the state by the first week of November. In the spring, most of this herd (87%) had reentered Utah by the last week of April. In essence, approximately one-third of the Paunsaugunt Plateau mule deer herd lives in Arizona for 24 weeks of the year.

Objective 2. To determine Paunsaugunt mule deer summer range habitat use patterns, fawn production, herd demographics and densities relative to land ownership patterns

Settling patterns, mule deer herd demographics, and densities

Of the 59 study animals captured on public winter ranges, 38 (64%) established home ranges in Utah. Sixty percent of these (n = 23) were located entirely on private land. Private lands comprised 10% of the available summer range in the DMU. There was no difference in capture weights ($\bar{x}$ = 75 kg, t = 0.55, 7 df, P > 0.25) and ages ($\bar{x}$ = 4.0, t = 0.39, 7 df, P > 0.25) between mule deer that summered on public and private land.

Mule deer densities were higher on private land (89 deer/100 ha) than on public land (32 deer/100 ha). Average buck:doe ratios were lower on public land (31:100) than on private (59:100) land (χ^2 = 50.5, 5 df, P < 0.0005). Fawn:doe ratios were lower on public (47:100) than on private land (52:100)). Although fawn:doe ratios were lower on public than on private land, we observed no differences in fawn production rates and fawning dates (Table 1). In 1996, fawning occurred an average 3 weeks earlier than 1995.

There was a higher ratio of mature (> 3 pts.) to immature bucks on private land verses public land (χ^2 =29.5, 1 df, P < 0.0005). Total buck density was higher on private land (24 bucks/100 ha) than on public land (7 bucks/100 ha).

Home range characteristics and macro-habitat use

Mule deer summer home ranges on public land exhibited greater macro-habitat diversity (t = 2.70, 5 df, P = 0.02) than home ranges on private land. Home range fidelity for all deer was considered to be absolute (e.g., average UTM for individual deer was ≤ 1km). Average home range size for all mule deer during this study was 176.4 ha (SE = 162.2 ha, n = 21). Home range size for bucks ($\bar{x}$ = 182.4 ha, SE=31.2 ha, n = 2) did not differ from does ($\bar{x}$ = 174.4 ha, SE = 170.8, n = 22; t = 0.11, 1 df, P > 0.25). Mule deer home ranges on private land ($\bar{x}$ = 228.2 ha, SE = 176.5 ha, n = 15) were larger than home ranges on public land ($\bar{x}$ = 75.1 ha, SE = 21.5 ha, n = 8; t =2.96, 5 df, P < 0.02). Mule deer home ranges on public lands were located on steeper slopes (χ^2 = 99.12, 8 df, P <

Table 1. Fawn production data for doe mule deer as monitored on Pausaugunt Plateau public (pu) and private (pr) land summer home ranges in Utah, 1995-96.

	1995			1996		
Deer Num.	Date.[a]	Age.[b]	Fawn [c]	Date.[a]	Age[b]	Fawn[c]
6pr	July 15	1 week	July 9	July 25	5 weeks (twins)	June 20
7pr	August 5	3 weeks	July 15	July 20	5 weeks	June 15
8pr	August 1	3 weeks	July 11	July 25	5 weeks	June 20
15pr	No Fawn	-----	-----	August 1	5 weeks	June 27
16pr	August 19	5 weeks	July 15	Mortality	-----	-----
21pr	July 19	2 weeks	July 5	July 6	4 weeks	June 8
23pr.	August 6	4 weeks	July 11	July 10	3 weeks	June 20
32pr	July 27	3 weeks	July 6	July 30	5 weeks (twins)	June 25
34pr	No Fawn	-----	-----	No Fawn	-----	-----
43pr	No Fawn	-----	-----	No Fawn	-----	-----
47pr	-----	-----	-----	August10	6 weeks	July 29
14pu	July 21	1 week	July 14	No Fawn	-----	-----
18pu	No Fawn	-----	-----	July 8	3 weeks (twins)	June 17
28pu	June 18	2 weeks	June 4	August10	7 weeks	June 22
36pu	N/A[d]	-----	-----	July 5	3 weeks	June 24
37pu	August 14	4 weeks	July 17	July 12	4 weeks	June 14
38 pu	August 1	3 weeks	July 10	July 5	3 weeks	June 14
42pu	No Fawn	-----	-----	July 5	4 weeks	June 7

[a] The date the does were first observed with a fawn
[b] The estimated age of the fawn
[c] The estimated fawning date
[d] Replacement for 16pr which died in 1996

0.0005) and at higher elevations (t = 7.21, 5 df, P < 0.0005) than home ranges on private land. Elevations on private lands involved in this study ranged from 2100 to 2700 m compared to 2100-2900 m on public land.

Macro-habitat use preference calculations were based on 711 individual locations. In general, mule deer used macro-habitat types in proportion to availability on private and public lands (Tables 2 and 3). Exceptions included wetlands or water areas (χ^2 = 32, df = 10, P = <0.0005), and ponderosa pine (χ^2 = 9.76, P = 0.002) habitat types on private land and juniper (χ^2 = 6.31, P = 0.12), aspen (χ^2 = 7.00, df = 10, P = 0.008), and spruce (χ^2 = 12.04, df = 10, P = 0.0005) habitat types on public land.

Table 2. Summer range vegetation preferences for the Paunsaugunt Plateau mule deer, 1995-96. (Private Land)

Vegetation Class	% Available	% Utilized	Obs. # deer locations	Exp. # deer locations	χ^2	*P*
Wetlands	0.4	2	10	2	32	<0.0005[a]
Mtn. Fir	2.0	3	13	8	3.12	0.0700
Pond. Pine	8.0	12	56	37	9.76	0.0020[a]
Juniper	8.0	10	45	38	1.29	0.2600
Other	5.0	6	27	24	0.38	0.5400
Aspen	2.0	2	7	7	0.00	1.0000
Grasslands	24.0	22	108	100	0.59	0.4400
Sagebrush	43.0	37	170	195	3.21	0.0700
Mtn. Shrub	8.0	7	30	37	1.32	0.2500
Spruce	0.2	0	0	0	N/A	N/A
Barrens	0.2	0	0	0	N/A	N/A

a Significant at the α = 0.05 level.

Table 3. Summer range vegetation preferences for the Paunsaugunt Plateau mule deer, 1995-96. (Public Land)

Vegetation Class	% Available	% Utilized	Obs. # deer locations	Exp. # deer locations	χ^2	*P*
Wetlands	0.5	0	0	1	1.00	0.3200
Mtn. Fir	18.0	13	34	44	2.27	0.1300
Pond. Pine	28.0	26	67	58	1.39	0.2400
Juniper	0.3	1	0.78	3	6.31	0.0120[a]
Other	0.0	0	0	0	N/A	N/A
Aspen	3.0	0	0	7	7.00	0.0080[a]
Grasslands	16.0	12	29	40	3.01	0.0800
Sagebrush	31.0	32	82	77	0.32	0.5700
Mtn. Shrub	11.0	9	22	28	0.90	0.3400
Spruce	10.0	3	7	24	12.04	0.0005[a]
Barrens	5.0	4	9	13	1.23	0.2600

[a] Significant at the $\alpha = 0.05$ level.

Objective 3. To determine corridors used by mule deer to cross U.S. Highway 89 and evaluate the use of roadside transects, deer-vehicle collision data as an alternative methodology to radio telemetry studies for delineating mule deer migration corridors

DVC Mortalities and Migration Concentrations

Migrating mule deer were not evenly distributed along the roadside transect ($\chi^2 =$ 14,704, 19 df, P < 0.0005). More deer were observed between mile points 39-42 than any other milepoints. No difference existed between observed DVC mortality ($\chi^2 = 0.861$, 19 df, $P > 0.25$), UDOT recorded DVC mortality ($\chi^2 = 0.600$, 19 df, $P > 0.25$), and observed mule deer concentrations (Fig.2). More mule deer were observed ($\chi^2 = 101.3$, 2 df, P < 0.0005) and more DVC's occurred ($\chi^2 = 21.6$, 2 df, P < 0.0005) during midnight than dusk or dawn survey periods (Figs. 3 and 4). Spring migration peak crossing of the U.S. Highway 89 occurred during the last week of March in each year ($\chi^2 = 970.3$, 16 df, P < 0.0005; Fig. 5). No peak migration periods were apparent were during annual fall migration ($\chi^2 = 23.4$, df 16, P > 0.10; Fig. 6).

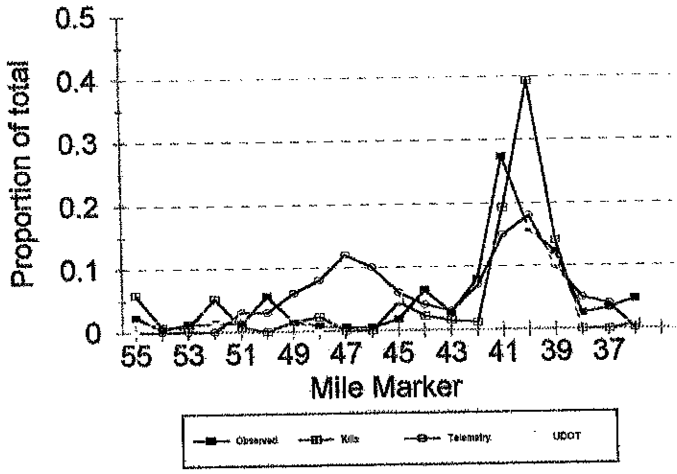

Fig. 2. Proportion of observed (2 year) and UDOT (6 year) recorded DVC mortality, mule deer concentration locations, and telemetry data by mile post, 1995-97.

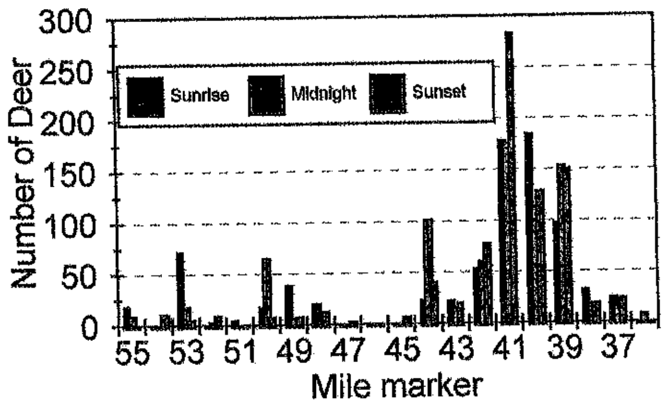

Fig. 3. Total number of migratory mule deer counted during spring migration from a vehicle along a standardized 32km survey at dusk, midnight, and dawn along U.S. Highway 89, east of Kanab, UT, 1994-96.

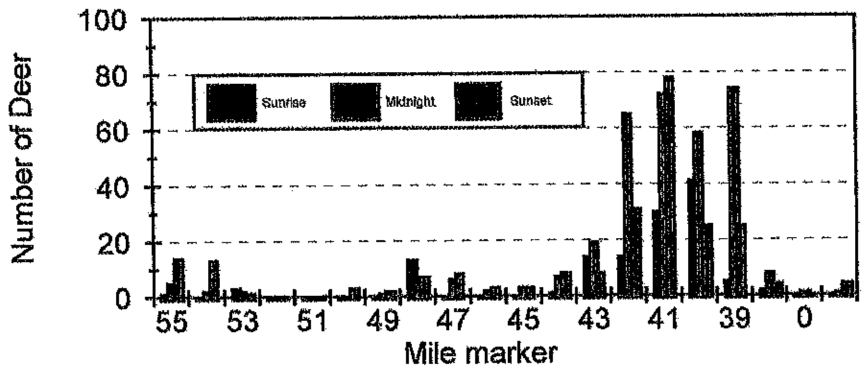

Fig. 4. Total number of migratory mule deer counted during fall migration from a vehicle along a standardized 32km survey at dusk, midnight, and dawn along U.S. Highway 89, east of Kanab, UT, 1994-96.

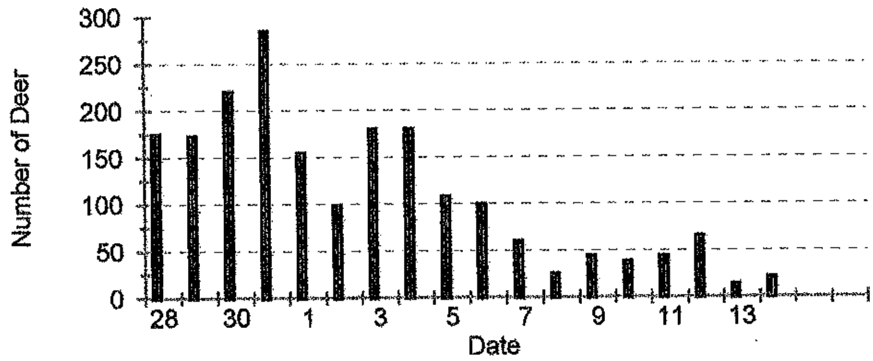

Fig. 5. Deer counted during spring migration (March 28-April 14) along standardized surveys at dusk, midnight, and dawn, along U.S. Highway 89, east of Kanab, UT, 1995-96.

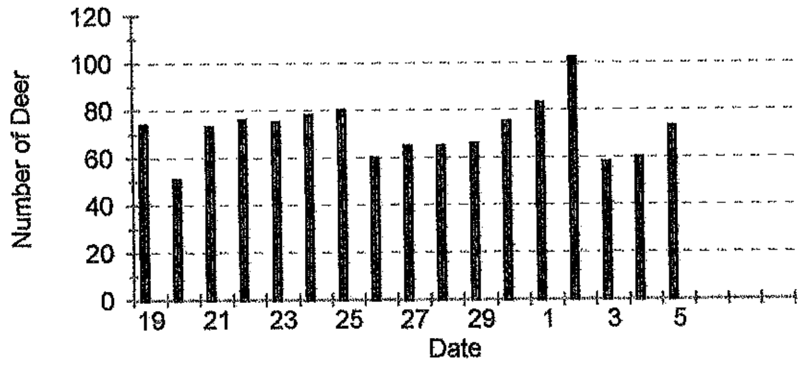

Fig. 6. Deer counted during fall migration (October 19.-November 5) along standardized surveys at dusk, midnight, and dawn, along U.S. Highway 89, east of Kanab, UT, 1995-96.

Highway migration corridors delineated by plotting bi-weekly radio-telemetry locations were wider than corridors delineated by observed mule deer concentrations ($P = 0.0002$), observed DVCs ($P = 0.0001$), and UDOT recorded DVCs ($P = 0.0004$). Fifty percent of observed mule deer crossing occurred between mile posts 39-42. To obtain a similar crossing percentage using only collared deer movements, the corridor width increased from mile post 37-51; more than twice the width of corridors delineated by recorded DVCs, observed DVC mortality, and deer concentration data. More bucks and fawns were killed due to automobiles in fall ($\chi^2 = 365.6$, 2 df, $P < 0.0005$) than were expected, based on fall pre-season herd composition counts (Table 4).

Table 4. Percentage of DVCs involving mule deer bucks, does, and fawns as compared to fall herd demographics along U.S. Highway 89, east of Kanab, Utah, 1994-96.[a]

Does		Bucks		Fawns	
DVCs	Counts	DVCs	Counts	DVCs	Counts
25.5	39.2	42.7	26.4	31.7	34.3

[a] Percentages based on DVC data collected between October 15 - November 7, 1994-1996; Census data percentages based on pre-season herd composition counts.

In 1995, we estimated it cost $1,000 to capture and equip a study animal with a radio-collar. The total cost to capture and fit the 83 mule deer used in this study exceeded $83,000. In addition, the cost of monitoring flights was approximately $175/hour or $1,050/flight (10hr). Multiplying this amount by 20 for the number of migration flights conducted annually (10 in the spring and 10 in the fall) results in total annual cost of $21,000 or $63,000 for the duration of the study. Conversely, the data collected by ground transects cost an estimated $3,000 per year ($37/animal) or $9,000 for the duration of this study. This is a difference of $54,000.

Objective 4. To determine mortality factors affecting the Paunsaugunt Plateau mule deer herd.

Thirty-one of the deer monitored died during this study. The cause of death for 14 animals (45%) could not be determined. Mountain lions (*Puma concolor*) killed 6 animals (19%), 4 were killed in deer-vehicle collisions (13%), 3 were legally harvested (10%), 2 were poached (7%), and 2 were killed by other predators (7%).

Objective 5. To assess general herd health of mule deer occupying the winter range.

The blood work analysis suggests that the mule deer populations during February on the winter are experiencing significant stress. Twenty-eight percent (n = 5) of the study animals captured on the winter range in 1996 had ticks. Two animals (11%) showed evidence of mange on their ears (Table 5). All of the animals sampled negative for brucellosis and leptospirosis. However, 17 (94%) tested positive for BVD, 15 (83%) for IBR, 15 (83%) for PL3. Eight animals (44%) tested positive for bluetongue virus and of these, 2 (25%) for EHD (Table 6). The average white blood cell count of the sample (4.5 thousand cells per microliter) exceeded published population parameters (3.9), with four animals exceeding 5.0 (Table 7).

Table 5 - General body condition of mule deer captured in Arizona on the winter range, February 1996.

Arizona Mule Deer Serology and Bacterial Isolation
February 12/13, 1996

Ear Tag	Brucellosis	BTID	EHDID	BT CElisa	BVD	IBR	BRSV	PI 3	Lepto	Chlamydia Isol.	Moraxella Isol.
51	neg*	pos	neg	pos	pos	pos	neg	pos	neg	not done	not done
52	neg	weak pos	neg	neg	pos	neg	neg	pos	neg	not done	not done
53	neg	pos	pos	pos	pos	pos	neg	pos	neg	not done	not done
54	neg	neg	neg	neg	pos	pos	neg	pos	neg	not done	not done
55	neg	neg	neg	neg	neg	pos	neg	neg	neg	not done	not done
56	neg	neg	neg	neg	pos	pos	neg	neg	neg	not done	not done
88	neg	weak pos	neg	neg	pos	neg	neg	pos	neg	not done	not done
89	neg	neg	neg	neg	pos	pos	neg	pos	neg	not done	not done
90	neg	pos	neg	neg	pos	pos	neg	pos	neg	not done	not done
91	neg	neg	neg	neg	pos	pos	neg	pos	neg	negative	negative
92	neg	neg	neg	neg	pos	pos	neg	pos	neg	negative	negative
94	neg	weak pos	neg	neg	pos	pos	neg	pos	neg	not done	not done
95	neg	neg	neg	neg	pos	pos	neg	pos	neg	not done	not done
96	neg	weak pos	neg	neg	pos	neg	neg	neg	neg	not done	not done
97	neg	neg	neg	neg	pos	pos	neg	pos	neg	negative	negative
98	neg	neg	neg	neg	pos	pos	neg	pos	neg	negative	negative
99	neg	pos	pos	pos	pos	pos	neg	pos	neg	negative	negative
100	neg	neg	neg	neg	pos	pos	neg	pos	neg	negative	negative

* = brucellosis standard plate agglutination at 1:25 dilution
** = unknown substances in serum interfered with the cells used in the test. Titer is equal to or less than that given.

BTID = bluetongue virus immunodiffusion test
EHDID = EHD virus immunodiffusion test
BT CElisa = bluetongue virus competitive Elisa test
BVD = bovine virus diarrhea

IBR = infectious bovine rhinotracheitis virus
PI 3 = parainfluenza 3 virus
Lepto = leptospirosis

Table 6 - Serological and bacterial results for mule deer captured in Arizona on the winter range, February 1996.

Arizona Mule Deer Hematology
February 12/13, 1996

Ear Tag	HCT %	HGB g/dl	MCHC g/dl	WBC*	Granulo*	% Gran	Lym/Mono*	% L/M	Platelets*	% Retic	% Lympho	% Mono	% Neutro	% Eosin
51	45.0	15.9	35.3	4.8	2.5	52	2.3	48	180	0.3	NR	NR	NR	NR
52	54.4	16.9	31.1	8.0	5.0	62	3.0	38	149	0.2	52	3	37	8
88	52.2	18.3	35.1	3.2	1.8	56	1.4	44	319	NR	NR	NR	NR	NR
89	44.2	15.8	35.7	4.3	2.4	56	1.9	44	191	NR	NR	NR	NR	NR
90	49.0	17.5	35.7	5.8	3.1	53	2.7	47	251	NR	70	3	21	6
91	48.9	17.1	35.0	3.9	2.5	64	1.4	36	344	NR	56	0	32	12
92	54.9	19.4	35.3	5.2	2.3	44	2.9	56	194	NR	NR	NR	NR	NR
94	50.0	18.0	36.0	3.4	1.4	41	2.0	59	133	NR	NR	NR	NR	NR
95	49.1	18.0	36.7	2.9	1.5	52	1.4	48	128	NR	63	0	20	17
96	44.8	15.7	35.0	4.1	1.9	46	2.2	54	245	NR	71	2	22	5
97	47.5	16.9	35.6	5.7	2.6	46	3.1	54	234	0.8	NR	NR	NR	NR
98	44.7	15.8	35.3	4.1	2.2	54	1.9	46	202	NR	42	1	34	23
99	45.1	16.0	35.5	4.1	1.8	44	2.3	56	222	NR	NR	NR	NR	NR
100	48.1	17.5	36.4	3.6	1.8	50	1.8	50	163	NR	59	1.5	28	12
Average	48.4	17.1	35.3	4.5	2.3	51.4	2.2	49	211	0.4	11.2	1.4	7.5	7.0
Std. Dev.	3.6	1.1	1.3	1.3	0.9	6.8	0.6	6.8	64.2	0.3	42.3-44.5	5.8-6.6	39.4-41.8	7.6-8.9
Normal-a	44.8	17.0	NA	2.9-3.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Normal-b	48.0	18.2	37.7	3.9	NA	NA	NA	NA	NA	NA				

* = thousand cells per microliter
All cell counts enclosed within the box are the result of manual counts using a hematocytometer.
All cell counts and values not enclosed in the box are from an automated blood analyzer.
Normal-a = Normal values from Fowler, Murray E. 1986, Zoo and Wild Animal Medicine
Normal-b = Normal values from DelGiudice et al. 1990, Journal of Wildlife Disease

HCT = hematocrit
HGB = hemoglobin
MCHC = mean corpuscular hemoglobin concentration
WBC = white blood cells

Gran or Granulo = granulocytes
L, Lym, or Lympho = lymphocytes
M or Mono = monocytes
Retic = reticulocytes
Neutro = neutrophils
Eosin = eosinophils

Table 7 - Hematological results for mule deer captured in Arizona on the winter range, February 1996.

Arizona Mule Deer History
February 12/13, 1996

Ear Tag	Sex	Age	Latitude	Longitude	Thelazia	Ticks/anus	Ticks/ears	Comments
51	F	1.5	36:48:24	112:22:25	no	?	no	
52	F	3.5	36:43:78	112:24:94	no	yes	no	
53	F	?	?	?	no	?	?	
54	F	1.5	?	?	no	?	?	
55	F	2.5	?	?	no	?	?	
56	F	adult	?	?	no	?	?	
88	F	4.5	36:51:81	112:13:55	no	?	?	high respiratory rate
89	F	1.5	36:51:51	112:14:50	no	yes	no	
90	F	1.5	36:54:91	112:13:85	no	yes	no	
91	F	4.5	36:56:67	112:13:81	no	yes	no	high respiratory rate, hair scraped off back of both ears
92	F	3.5	36:53:23	112:15:01	no	?	?	
94	F	3.5	?	?	no	?	no	apparent mange in both ears
95	F	1.5	36:51:80	112:16:61	no	?	no	apparent slight mange in both ears
96	F	0.5	36:47:24	112:16:56	no	?	?	not breathing for short period after released from sling
97	F	4.5	36:44:96	112:23:15	no	?	?	
98	F	5.5	36:49:15	112:20:52	no	?	?	
99	F	4.5	36:49:58	112:19:02	no	yes	no	
100	F	6.5	36:50:62	112:18:58	no	no	no	faint corneal opacity in right eye

Discussion

Objective 1. To determine the extent, timing, and duration of the Paunsaugunt Plateau mule deer herd seasonal migration.

Most of the Paunsaugunt Plateau mule deer migrated south to lower elevation winter ranges around the Buckskin Mountains that bisect the Utah/Arizona state line. These deer returned in the spring to occupy home ranges they had used the previous year. We found no difference in migration distances and timing relative to sex, age, or weight of the animals.

Snowfall and photoperiod have been previously reported to influence the timing of mule deer migrations (Garrott et al. 1987, Kucera 1992). In this study, snowfall had no effect on migration timing. In both 1995 and 1996, the deer initiated fall migration movement at the similar times. In 1997 however, the herd began migration three weeks later than the previous two years. But upon doing so, the herd moved rapidly, arriving on the winter range about the same time they had previously. This suggests that some other factor, possibly forage conditions on the summer range, may have had a greater influence on initiation of migration movements than photoperiod. In 1997, later season rainfall improved forage and water conditions throughout the summer range.

A review of the temporal and spatial movement data indicates that the Paunsaugunt Plateau mule deer herd arrives on its Arizona winter range at least four weeks prior to the Kaibab Plateau mule deer herd. Most Paunsaugunt Plateau mule deer arrive on the winter range at about the time that Arizona's first general season rifle hunt begins in Unit 12B. Most of these hunters frequent the area around the Buckskin Mountains (B. Lemons, AGF, pers. commun). This is where the Paunsaugunt Plateau mule deer are concentrated. If the Paunsaugunt Plateau herd are the only mule deer present in this area at the time of the hunt, they also would represent the majority of the harvest. Most of the Arizona mule deer harvest in Unit 12B is taken during the first general rifle season. This information suggests the need for increased coordination between wildlife managers in Utah and Arizona if the trophy quality of the hunts and hunter opportunity associated with the Paunsaugunt Plateau mule deer herd are to be preserved.

Objective 2. To determine Paunsaugunt mule deer summer range habitat use patterns, fawn production, herd demographics and densities relative to land ownership patterns.

In this study, 60% of monitored mule deer, randomly captured on winter range, occupied home ranges on private land, which constituted 10% of the summer range available in the DMU for use by the Paunsaugunt mule deer herd. The UDWR estimates that up to 50% of Utah's mule deer population inhabits privately owned land at some time during annual life cycles. However, private land constitutes < 34% of Utah's land base (Public Land Statistics 1991).

Although similar macro-habitat types were present on private and public land, the proportions of each were different. Mule deer home ranges on public land contained greater macro-habitat diversity than those on private land. Regardless, mule deer used macro-habitat types, whether on public or private land, in proportion to availability. Some macro-habitats (e.g. wetland) were used more than expected. This probably was more a reflection of low mathematical proportions rather than a biological measure of importance (Porter and Church 1987, Wolff 1995).

Greater macro-habitat diversity within home ranges often translates into higher mule deer densities (Hamlin and Mackie 1989). This may be because mule deer that live in diverse habitats may tend to establish smaller home ranges since essential habitat requirements are found in greater abundance (Wood 1987, Mackie 1994). Consequently, smaller home ranges in an area may mean more habitat is available for additional animals. In this study, mule deer home ranges on public lands were smaller than home ranges on private lands. We believe the increased habitat diversity contained in mule deer home ranges on public lands was an artifact of the increased precipitation occurring at higher elevation. Average annual precipitation for public land ($\bar{x} = 70$ cm) was approximately twice the average annual precipitation ($\bar{x} = 36$ cm) recorded on private land (Utah Climate Center 1996). Mule deer summer home ranges on private lands exhibited less overall habitat diversity and included macro-habitats more characteristic of xeric environments. Mammals in xeric environments usually have larger home ranges than conspecifics inhabiting more mesic areas (McNab 1963, Hayes and Krausman 1993).

In this study, mule deer home ranges on the public land were smaller than home ranges located on the more arid private lands. If Wood (1987) and Mackie (1994) are correct, mule deer using private land would have been expected to travel greater distances to meet their daily needs, cover, and forage. This travel alone would contribute to increasing home range size. In particular, distance to water has also been cited as a factor affecting home range size (Ordway and Krausman 1986, Hayes and Krausman 1993). We believe distance to water did not affect home range size of the animals studied. Mule deer studied on both private and public land had to travel < 1km to obtain free water. This is well within the daily range of movements cited by other authors (Ross et al. 1981, Bowyer 1985, Hamlin and Mackie 1989).

Furthermore, Hamlin and Mackie (1989) and Mackie (1994) suggested that areas exhibiting smaller individual mule deer home ranges would support higher mule deer densities. We found the opposite to be true. Mule deer densities and herd composition ratios also were higher on private land. In effect, private lands which exhibited proportionately less macro-habitat diversity, supported three times more mule deer than public lands.

Home ranges on public land were located at higher elevations and on steeper slopes than home ranges on private land. Kie et al. (1991) reported similar observations and attributed this behavior to livestock grazing. In this study, public land was grazed in summer months (June-September). Our observations support Kie at al. (1991) who suggested that cattle usually prefer riparian, low-slope habitats; thus forcing mule deer upward onto steeper sloped habitats.

Steeper-sloped habitats may also have been selected as an anti-predator strategy. Ungulates will often choose high slope habitats to give birth and raise young as predators often prefer habitats that exhibit less relief (Main 1991, Bergerud et al. 1984, Riley and Dood 1984).

During this study, there was no an active predator control on public land (R. Rodrigez, Dixie National. Forest, pers. commun). However, on the private land, mammalian predators, in particular coyotes, were controlled (R. Heaton, Alton, pers. commun). Several authors have reported that in areas of high coyote numbers, mule deer fawn survival, hence recruitment, is low (Brown 1961, McMichael 1970).

However, we believe the differences observed in mule deer habitat use patterns and densities between public and private lands may be more be related to historical settlement patterns and concomitant land uses. Historically, pioneers settled land that was located on foothills and valley floors because of water availability and the presence of arable lands (Fife 1980). Most public land in the west includes habitats that, by their nature, are to rugged and difficult to develop (Noonan and Zagata 1980).

The public lands in this study were managed by the U.S. Forest Service and used heavily by recreationists. Over 1.3 million people annually visited the public land in the study area (Dixie National Forest 1996). In contrast, access to private land is limited. Consequently, higher disturbance on public landmay have contributed to observed differences in mule deer densities, home range size between both sites, herd productivity, and mortality (Urness 1976, Nelson 1979). Human disturbance such as increased hunting pressure, recreation, and logging have been shown to drive wildlife from traditional areas into more secluded regions (Dunaway 1971, Rybar 1973, Cowan 1974, Booth 1978, Chester 1980, Horejsi et al. 1988, Cassirer et al. 1992). In the study area, each hunter utilizing private land had an average of 500 ha available to them over an extended 45 day hunting period while public hunters had only 80 ha available to them to hunt over an 11 day general season (Jordan and Workman 1990, Messmer and Dixon 1997). Public land also contained numerous logging roads that could serve as additional travel routes for humans, thereby increasing accessability to remote habitat (Light 1973, Povilitis 1997). Subsequently, mule deer attempting to minimize human contact may have responded by occupying smaller home ranges located on steeper slopes (Kie et al. 1991, Loft et al 1991).

Observed long term differences in mule deer densities may have also been the result of the impacts of heavier grazing pressures on private than public lands. Private lands were grazed at 0.27 animal unit months AUM's/ha, while public lands were grazed at 0.19 AUM's /ha. Urness (1990) argued that a reduction in grazing pressure on grasses increases grass growth and competition on browse species and forb species. Increased grazing pressure reduces grass competition on browse, thus creating mule deer habitat (Urness 1976, 1990, Clements and Young 1996). On our study area, the public land was dominated by grasses, while the private land was dominated by a shrub/forb complex. Consequently, high mule deer densities on the private land observed in our study may be an artifact of long-term heavy grazing practices in addition to differences in disturbance levels.

However, be believe that hunter harvest may be the most important factor influencing mule deer population composition and densities on both public and private lands in the study area. On average, 368 mule deer are harvested on public lands while approximately 68 are taken off the private land (UDWR 1996). Almost five times the number of deer are harvested on public than on private land although private lands in the study area contained nearly three times more deer per unit area than public lands and up to 60% of the Paunsaugunt Plateau mule deer population may inhabit private land. Thus, higher harvest of bucks and does on public land may be directly contributing to observed differences in mule deer densities and composition given low recruitment rates observed.

Objective 3. To determine corridors used by mule deer to cross U.S. Highway 89 and evaluate the use of roadside transects, deer-vehicle collision data as an alternative methodology to radio telemetry studies for delineating mule deer migration corridors.

Mule deer migration corridors delineated by aircraft-obtained telemetry location and movement data were wider than those delineated by mortality and mule deer concentration data. Factors reducing accuracy of telemetry studies for defining migration corridors include equipment limitations and logistical constraints (Mech 1983, Garrott and White 1990). Given the number of mule deer being monitored and limited resources, we were only able to conduct two monitoring flights per week during migration periods. In addition, flights were not conducted on weekends or during inclement weather. In our study, time elapsed between consecutive telemetry locations varied from three days to one week. To determine corridors using telemetry data, we connected the ground location data points to produce a straight line. Since deer may parallel highways for several kilometers before crossing (Romin 1994), it may be incorrect to assume that the location where the straight line of movement intersects the highway is the location where deer crossed.

Lastly, aircraft-obtained telemetry location data may differ by 400 m from actual ground locations (Garrott et al. 1987, Leptich et al. 1994, Carrel et al. 1997). To utilize telemetry aircraft location data to delineate migration corridors, consecutive daily locations (to include ground-to-air correction factors) must be recorded, or the animals must be equipped with personal GPS transmitters (Fancy et al. 1988, Garrott and White 1990, Leptich et al. 1994). However, due to the current high cost of the these technologies their practical application is limited.

When a DVC is reported, information recorded by law enforcement officials is entered into UDOT's vehicle accident data banks. Unfortunately, many DVCs are not reported because (1)there is no damage to the vehicle, as in the case of large trucks; (2) damage is minimal or less than deductible; and (3) alcohol or other illegal substances may be involved (S. Norfeldt, Utah Highway Patrol, pers. commun.). Thus, to acquire the most accurate information, on-site data collection may still be needed, especially if mitigation plans are to be developed to reduce DVCs.

Dasmann and Taber (1956) reported that mule deer are more active from midnight to dawn on seasonal ranges. They suggested this behavior minimized contact with humans. Montgomery (1963) and Eberhardt et al. (1984), reported that mule deer were more active on seasonal ranges at dusk and dawn. Contrary to other studies, mule deer in this study were migrating and consequently, more active during midnight survey periods. Thus, in our study the probability of a mule deer involved in a DVC increased during midnight hours.

Fortunately, on most highways between 02300-0100, traffic volumes are generally lower than other time periods (S. Ramsey, Utah Dept. of Trans. pers. commun.).

However, if traffic volumes increase during these time periods because of changes in human activity patterns, migrating mule deer may be subjected to increased DVC risks.

In Utah, when the Grand Staircase Escalante National Monument and associated visitors center officially opens, increased traffic volumes may result. To exacerbate the situation, vehicle speed limits on the highway have been increased from 88 to 104 kph in an effort to accommodate increasing tourism traffic (D. Barnhurst, Utah Dept. Of Trans. pers. commun.). An increase in traffic volume and speed limits will undoubtedly result in higher incidences of DVCs. In addition, mineral and oil development may occur in the area which would also increase traffic volumes and may cause DVCs to increase.

Our results confirm the relationship between observed deer concentrations, observed DVC mortality, and UDOT reported DVC locations. Consequently, these methods could provide managers with cost-effective, accurate alternatives to telemetry studies for delineating migration corridors in areas where mule deer must negotiate one or more highways during seasonal migrations.

Objective 4. To determine mortality factors affecting the Paunsaugunt Plateau mule deer herd.

We were not able to determine the cause of death of 14 of the monitored mule deer that died in this study because of the condition of the deteriorated condition of the carcass. In most cases, field personnel were not aware that an animal had died until after a flight was conducted. Because flights were only conducted at two week intervals while animals were on the summer and winter ranges, several weeks passed until mortalities could be relocated.

Information collected from animals where the cause of death could be identified suggests that predation, hunting, and DVCs are a prime cause of mortality in the herd. At present, given herd demographic and fawn data collected on the summer, we have no evidence to suggest that predation is a limiting factor for this herd. However of paramount concern is the number of mortalities attributed to poaching and DVCs. We believe both of these sources of mortality are manageable through increased cooperation between Utah and Arizona.

Objective 5. To assess general herd health of the mule deer occupying the winter range.

Mule deer, particularly those experiencing suboptimal forage conditions, which are typically winter ranges, are susceptible to a variety of diseases and parasites. The results of the blood work suggest that the mule deer populations during February on the winter range are experiencing significant stress as evidenced by the number of animals exhibiting viral infections. These infections, however did not appear to contribute to increasing herd mortality rates.

Eight animals tested positive for hemorrhagic disease. Hemorrhagic disease is a general term for EHD and bluetongue virus. Both diseases are closely related and spread by a small biting midge fly. Hemorrhagic disease outbreaks tend to occur in the late fall as animals concentrate around watering sites. Often the outbreaks will go unnoticed because carcasses quickly decompose or are scavenged. Infected animals may recover from the disease. None of the animals that tested positive for these diseases died during this study.

Humans do not get hemorrhagic disease, so handling and consumption of meat from deer that have recovered from the disease pose no health hazard (Hibler 1981).

BVD has been demonstrated to cause still births and neonatal deaths in infected domestic livestock. Research conducted in Canada, to determine the susceptibility of elk to BVD, indicated that the virus did not cause clinical signs in exposed yearling elk (Deregt and Tessaro 1998). However, the elk did maintain and excrete the virus for up to one week after inoculation and infected other elk placed into contact with them 48 hours after inoculation. This suggests that BVD could be spread through a herd of elk and transmitted to livestock. Although, evidence of the role of mule deer in virus shedding and the susceptibility of mule deer to clinical disease from BVD is lacking, this work with elk suggests that the virus would affect mule deer populations in a like fashion. None of the mule deer affected with BVD died during this study.

Clinical signs for IBR include high fever, anorexia, and ocular discharges. In livestock, the fever can result in decreased milk production and abortions in yearlings. In most cases, infected animals will recover if no secondary infections occur. There is no evidence of clinical disease in elk or other cervids.

PI3 virus results in a fever and nasal discharges. In most cases, animals recover if no secondary infection occurs. None of the animals affected with either virus died during this study. PI3 can be transmitted from infected animals to humans. Transmission may be by aerosol or direct contact with nasal or oral mucus fluids. However, since the virus does not exist long in the environment with a live host, transmission of the virus to humans through the consumption of meat from infected or recovered animals appears unlikely (Hsiung and Chang 1994).

Research and Management Implications

Objective 1. To determine the extent, timing, and duration of the Paunsaugunt Plateau mule deer herd seasonal migration

The long-term consequences of continued hunting, without addressing the problem associated with the inter-state herd migration of deer herds, may eventually lead to an erosion of herd integrity and related hunter opportunity. Although additional research would be needed to accurately quantity what percentage of the animals harvest by Arizona hunters in Unit 12B consist of Paunsaugunt Plateau mule deer, our interpretation of the available data suggests that the potential exists. In response to these findings, Utah and Arizona have begun to meet annually regarding implementation of harvest management strategies. Arizona has reduced the number of early general rifle season tags available in Unit 12B. The unit is now managed under an alternative framework designed to ensure the presence of an older age class of bucks in the harvest (Arizona Game and Fish 1998).

Objective 2. To determine Paunsaugunt Plateau mule deer summer range habitat use patterns and population densities in relationship to land ownership patterns and land uses

The research completed under this objective highlighted the role of private lands in southern Utah in conserving mule deer populations. Our findings suggest that managers may need to reevaluate management paradigms regarding the use of domestic livestock, predation control, and access restrictions to manage mule deer seasonal habitats.

Ranching practices have changed in recent years on the Paunsaugunt Plateau summer range. Cattle have replaced sheep and rotational grazing has resulted in improved range conditions (Urness 1976, Austin 1990, White 1996). Sheep diets tend to overlap much more with mule deer than cattle diets (Smith and Julander 1953). Consequently, competition for resources is greater between sheep and mule deer than cattle (Smith and Julander 1953, Terrel and Spillett 1975).

In addition, there has also been increased water development on private lands. This has affected the distribution of livestock and wildlife. The private land in this study, contained water development sites approximately every 0.5 km. Consequently, livestock were not as concentrated in one specific area which may have decreased competition between cattle and mule deer.

This study demonstrates that private land on the Paunsaugunt Plateau provided a significant amount of mule deer summer range habitat for the mule deer herd in the area. Consequently, if private landowners are expected to maintain this important habitat base, consideration should be given to providing the necessary incentives (Noonan and Zagata 1982). These incentives should include technical and financial assistance.

In Utah, the Cooperative Management Wildlife Unit and Paunsaugunt Landowner Association programs have been designed to promote co-existence between wildlife and private landowners. Under program guidelines, landowners are allocated a number of big game permits that can be sold to private clients. Revenue generated through the selling of trespass permits provides additional incentive for landowners to incorporate big game species and other wildlife as part of their farm or ranch management plan (Messmer and Dixon 1997, Messmer et al. 1998).

We believe that to sustain mule deer populations over the long term, harvest and access management strategies may have to be adjusted to maintain a balance between habitat, wildlife populations, and human recreational uses. This should include conducting research to answer questions regarding what levels and types of human disturbances can affect mule deer habitat use and reproduction.

The future of mule deer management in the West is tied to habitat conservation on both public and private land. Thus, multi-use management of land resources is becoming more important on private and public lands (Bernardo et al. 1994). By reducing levels of human disturbance through improved hunting and access management and manipulating grazing intensities on public and private lands to achieve desired habitat conditions, biologists may be able to better manage for mule deer as well as other species of wildlife

Objective 3. To determine corridors used by mule deer to cross U.S. Highway 89 and evaluate the use of roadside transects, deer-vehicle collision data as an alternative methodology to radio telemetry studies for delineating mule deer migration corridors

Mule deer migration corridors are often delineated by analyzing movements of radio-collared animals (Haywood et al. 1987). However, radio-telemetry studies are expensive and due to the nature of analysis techniques, may not accurately depict actual migration corridors. Our study suggests that conducting telemetry studies for the sole purpose of defining migrational corridors and/or to develop mitigation plans to reduce DVCs may not be as efficient as ground surveys.

However, censusing mule deer along roadside transects can be time consuming and logistical constraints often dictate when and how many counts can be conducted. Thus, if managers want to census migratory mule deer along highways, they should consider collecting this data during midnight hours. Collecting data during midnight also would reduce conflicts with traffic (lower traffic volumes), and allow for more data to be collected (larger sample size). To further define migration corridors, managers should consider using DVC data to augment mule deer censuses.

Other studies have described situations in which mule deer have crossed numerous highways when moving between seasonal ranges (Brown 1992, Romin and Bissonette 1996). However, this study only determined migration corridors across a single 2-lane highway. If a herd crosses two or more highways during movements between seasonal ranges, migration corridors could more effectively be determined using the survey methods identified. Although this study also identified some limitations of DVC data, even an incomplete DVC database may provide immediate insights into migration, timing, and migration corridors when time or resources available for data collection is a limited. Lastly, based on our experience with traffic when conducting our roadside transects, we believe that using temporary warning signs, located at critical highway crossing points for migrating herds that cross highways during migration, may reduce DVCs. The signs could make motorists more aware of potential risks. If motorists respond to the warning signs by reducing the speed of their vehicles, this could reduce the number of DVCs.

A pilot project conducted subsequent to this research to test the effectiveness of using temporary signs to warn motorists of increased DVCs risks during mule deer migrations showed promise. Preliminary results suggest that motorist reduced their speeds within the migration corridors that were identified by temporary signing. During the 1998 spring and fall migration periods, a 70% reduction in DVCs was recorded (Messmer and Hendricks 1999).

Objective 4. To determine mortality factors affecting the Paunsaugunt Plateau mule deer herd.

Although the mortality data collected during this study represents only those animals for which the cause could be identified, we believe that of the three primary causes of death identified, DVCs and poaching are the most manageable. Work is currently underway to reduce the number of DVCs that occur during seasonal migrations. The UDWR has implemented an aggressive enforcement program to reduce poaching in the area.

We believe that predation on adult animals, although identified as the primary cause of mortality, is not a major limiting factor affecting the Paunsaugunt Plateau mule deer herd. However, predation on fawns by coyotes has been suggested (Knowlton 1978) as a major factor affecting recruitment. The minor differences observed in fawn:doe ratios and predator management philosophies, between the public and private land studied, suggests that predation may not be impacting fawn survival on public lands.

Objective 5. To assess general herd health of the mule deer occupying the winter range.

Health data suggests that the mule herd occupying the winter range is undergoing high levels of stress during late winter. Although none of the animals that tested positive for viral infections died during this study, the presence of both blue tongue and BVD are cause for concern. Past research indicates that both of these diseases can be transmitted to domestic livestock. The presence of both these viruses in domestic cattle herd can result in significant economic losses.

The fact that both the Paunsaugunt and Kaibab Plateau mule deer herds share ranges grazed by domestic livestock creates a management dilemma. Additional research is needed to determine what role mule deer play in BVD and other virus shedding. In addition, research to determine the susceptibility of mule deer to clinical diseases from BVD, PI3, and IBR needs to be conducted.

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APPENDIX

Utah vegetation codes are by grouped by cover-type. Cover-type categories are listed by *principle* species which define the cover type in addition to prevalent *primary associated* species which can occur as part of the cover-type in localized areas. This is an overview of the most common species associated with each cover-type and is not intended as a complete species list. General descriptions of each cover-type are in bold type.

1. **MOUNTAIN FIR-Mountain Fir, Mountain Fir/Mountain Shrub. Conifer forest principally dominated by combinations of white fir *Abies concolor* and doug fir *Pseudotsuga menziesii* or woodland with Mountain fir dominate/associate or co-dominate with mountain shrub.**

   Primary associated tree species include ponderosa pine *Pinus ponderosa,* pinyon *Pinus edulis,* or *Pinus monophylla,* spruce *Picea engelmanni* and *Picea pungens* and subalpine fir *Abies lasiocarpa,* limber pine *Pinus flexilis,* and aspen *Populus tremuloides.*

   Principle shrub species include oak *Quercus gambelii,* maple *Acer grandidentatum,* snowberry *Symphoricarpos* spp., grape *Berbaris* spp., serviceberry *Amelanchier* spp., manzanita *Arctostaphylos* spp., and ninebark *Physocarpus* spp.

   Primary associated shrub species include common juniper *Juniperus communis* and sagebrush *Artemesia* spp.

2. **JUNIPER-Juniper, Pinyon, Pinyon/Juniper. Conifer forest principally dominated byjuniper *Juniperus scopulorum, Juniperus monosperma* and *Juniperus osteosperma.***

   Primary associated tree species include pinyon *Pinus edulis* or *Pinus monophylla* and mountain mahogany *Cercocarpus ledifolius,* ponderosa pine *Pinus ponderosa,* white fir *Abies concolor* and doug fir *Pseudotsuga menziesii.*

   Primary associated shrub species include sagebrush *Artemisia* spp., blackbrush *Coleogyne ramosissima,* and oak *Quercus gambelii.*

3. **ASPEN-Alpine, Aspen, Aspen/Conifer, Lodgepole, Lodgepole/Aspen, Maple. Deciduous forest principally dominated by quaking aspen *Populus tremuloides,* or aspen co-dominant with conifer, or lodgepole *Pinus flexilis.***

   Principle associated conifer species include spruce; *Picea engelmannii* and *Picea pungens,* fir; *Abies lasiocarpa, Abies concolor* and *Pseudotsuga menziesii,* and pine; *Pinus contorta* and *Pinus ponderosa,* and limber pine *Pinus flexilis.*

   Primary associated shrub species include snowberry *Symphoricarpos* spp., and serviceberry *Amelanchier* spp.

4. **PONDEROSA PINE-Ponderosa Pine, Ponderosa Pine/Mountain Shrub. Conifer forest principally dominated by ponderosa pine *Pinus ponderosa* or woodland with ponderosa pine *Pinus ponderosa* dominant/associate or co-dominant with mountain shrubs.**

Principle mountain shrub species include manzanita *Arctostaphylos* spp., bitterbrush *Purshia tridentata*, oak *Quercus gambelii*, snowberry *Symphoricarpus* spp., and curlleaf mountain mahogany *Cerocarpus ledifolius*.

Primary associated tree species include pinyon *Pinus edulis*, juniper *Juniperus* spp., white fir *Abies concolor*, and doug fir *Pseudotsuga menziesii*.

Primary associated shrub species include sagebrush *Artemesia* spp., and rabbitbrush *Chrysothamnus viscidiflorus*.

5. **SAGEBRUSH-Sagebrush, Sagebrush/Perennial Grass, Blackbrush, Creosote-Bursage, Salt Desert Scrub, and Greasewood. Shrubland principally dominated or co-dominated by big sagebrush *Artemisia tridentata*, black sagebrush *Artemisia nova*, low sagebrush *Artemisia arbuscula*, silver sagebrush *Artemisia cana* and perennial grasses.**

Principle grass species include bluebunch wheatgrass *Agropyron spicatum*, sandburg bluegrass *Poa secunda*, crested wheatgrass *Agropyron cristatum*, needlegrass *Stipa comata*, sand dropseed *Sporobolus cryptandrus*, blue gramma *Bouteloua gracilis*, thurbersneedlegrass *Stipa thurberiana*, western wheatgrass *Agropyron smithii*, indian ricegrass *Oryzopsis hymenoides*, galleta *Hilaria jamesii*, and cheatgrass *Bromus tectorum*.

Primary associated shrub species include rabbitbrush *Chrysothamnus* spp., bitterbrush *Purshia tridentata*, oak *Quercus* spp., shadscale *Atriplex confertifolia*, greasewood *Sarcobatus vermiculatus*, creosote *Larrea* spp., spiny hopsage *Grayia spinosa*, mormon tea *Ephedra* spp., snakeweed *Xanthocephalum* spp., turpentine bush *Thamnosa montana*, dalea *Dalea fremonti*, honey mesquite *Prosopis glandulosa*, brittlebush *Encelia farinosa*, gray molly *Kochia vestita*, mat-atriplex *Atriplex corrugata* castle valley clover *Atriplex cuneata*, winterfat *Ceratoides lanata*, budsage *Artemesia spinescens*, fourwing saltbush *Atriplex canescens*, halogeten *Halogeten glomeratus*, desert trumpet *Eriogonum inflatum*, and horsebrush *Tetradymia canescens*.

Primary associated tree species include juniper *Juniperus* spp.,

Other associated species include joshua tree *Yucca brevifolia*, datil yucca *Yucca baccata* and prickly pear *Opuntia engelmannii*.

6. **MOUNTAIN SHRUB-Mountain Shrub, Oak, Mountain Mahogany. Deciduous shrubland principally dominated by alder leaf mountain mahogany *Cercocarpus montanus*, cliffrose *Cowania mexicana*, bitterbrush *Purshia tridentata*, serviceberry *Amelanchier utahensis* and *Amelanchier alnifolia*,**

buckbrush *Ceanothus* spp., chokecherry *Prunus virginiana,* snowberry *Symphoricarpus spp.,* pointleaf manzanita *Arctostaphylos pungens,* and bearberry *Arctostaphylos uva-ursi.*
Primary associated shrub species include sagebrush *Artemisia* spp., oak *Quercus* spp., and maple *Acer* spp.
Primary tree species include aspen *Populus tremuloides,* juniper *Juniperus* spp., pinyon *Pinus* spp., ponderosa pine *Pinus ponderosa,* and mountain mahogany *Cercocarpus ledifolious.*

7. **WETLANDS-Water, Wetland, Wet Meadow, Mountain Riparian, Lowland Riparian. Areas of open water or water saturated meadows that contain principally grasses, forbs, sedges, and rushes.**
Principle species include sedges *Carex* spp., rushes *Juncus* spp., reedgrass *Calamagrostis* spp., timothy P*hleum* spp., hairgrass *Deschampsia cespitosa,* willowherb *Epilobium* spp., cirquefoil *Potentilla* spp., saxifrage *Saxifraga* spp., cattail *Typha latifolia,* and bullrush *Scirpus* spp.
Primary woody species include willow *Salix* spp., narrowleaf cottonwood *Populus angustifolia,* thinleaf alder *Alnus tenuifolia,* water birch *Betula occidentalis,* black hawthorn *Crataegus douglasii,* rocky mountain maple *Acer glabrum,* red-osier dogwood *Cornus stolonifera,* wild rose *Rosa woodsii,* fremont cottonwood *Populus fremontii,* salt cedar *Tamarix pentandra,* netleaf hackberry *Celtis reticulata,* velvet ash *Fraxinus elutina,* desertwillow *Chiloptis linearis,* and squawbush *Rhus trilobata.*

8. **SPRUCE-Spruce/Fir, Spruce/Fir/Mountain Shrub. Conifer forest principally dominated by combinations of spruce *Picea engelmannii* and *Picea pungens* and sub-alpine fir *Abies lasiocarpa* or woodland with Spruce-Fir dominate/associate or co-dominate with mountain shrub.**
Principle shrub species include currants *ribes* spp., snowberry *Symphoricarpus* spp., ninebark *Physocarpus* spp., chokecherry *Prunus virginiana,* maple *Acer glabrum,* mountain lover *Paxistima myrsinites,* blueberry *Vaccinium* spp., elderberry *Sambucus* spp., grape *Berberis repens,* and serviceberry *Amelanchier* spp.
Primary associated tree species include doug fir *Pseudotsuga menziesii,* lodgepole *Pinus flexilis,* white fir *Abies concolor,* bristlecone pine *Pinus aristata,* and aspen *Populus tremuloides.*
Primary associated shrub species include common juniper *Juniperus communis,* and sagebrush *Artemisia* spp.

9. **BARRENS-Barren, Pickleweed Barrens. Barren rock, sand, saltflats, playas, lava or a mosaic of sparsely vegetated playa flats.**
Principle shrub species include pickleweed *Allenrolfea occidentalis.*

<u>Other</u> <u>associated</u> <u>species</u> include samphire *Salicornia* spp., saltbrush *Atriplex* spp., greasewood *Sarcobatus* spp., saltgrass *Distichlis* spp., and seepweed *Suaeda* spp.

10. GRASSLAND-Desert Grassland, Dry Meadow, Grassland. Perennial and annual grasslands including mostly forbs and grasses and some shrubs.

<u>Principle</u> <u>grassland</u> <u>species</u> include galleta *Hilaria jamesii,* indian ricegrass *Oryzopsis hymenoides,* three-awn *Aristida glauca,* sand dropseed *Sporobolus airoides,* bluebunch wheatgrass *Argopyron cristatum,* basin wildrye *Elymus cinereus,* needlegrass *Stipa comata,* blue gamma *Bouteloua gracilis,* thurbers needlegrass *Stipa thurberiana,* western wheatgrass *Argopyron smithii,* squirreltail *Sitanion hystrix,* cheatgrass *Bromus tectorum,* timothy *Phleum* spp., poa's *Poa* spp., spike trisetum *Spicatum* spp., and sedges *Carix* spp.

<u>Principle</u> <u>forb</u> <u>species</u> include yarrow *Achillea millefolium,* dandelion *Taxaxacum officinale,* richardson's geranium *Penstemon* spp., muleears *Wythia ampplexicaulis,* golden aster *Chrysopis villosa,* arrowleaf balsamroot *Balsamorhiza sagittata,* hawkbit *Agoseris pumila,* larkspur *Delphinium* spp., scarlet gilia *Pulchella* spp., rabbitbrush *Chrysothamnus viscidiflorus,* cirquefoil *Potentilla* spp., snowberry *Symphoricarpus* spp., elderberry *Sambucus cerulea,* and desert trumpet *Eriogonum inflatum.*

<u>Principle</u> <u>shrub</u> <u>species</u> include sagebrush *Artemisia* spp., shadscale *Atriplex confertifolia,* greasewood *Sarcobatus vermiculatis,* and creosote *Larrea tridentata.*

<u>Principle</u> <u>tree</u> <u>species</u> include juniper *Juniperus* spp.

11. OTHER-Agriculture, Urban. Row crops, irrigated pasture, hay fields, dry farm crops, and commercial land with a high density of residential areas.