Mule deer habitat use in the Bennett Hills, Idaho

by Clint Jason Gray

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Fish and Wildlife Management
Montana State University

Abstract:
The factors governing mule deer (Odocoileus hemionus) habitat use patterns in south-central Idaho are poorly understood. Therefore, 16 radio-collared does were tracked from the ground in 1993, and 9 of the same does were also tracked in 1994 to gather data on habitat use and to document the effects of the primary land use in the area, cattle grazing, on mule deer. The field season of 1993 was cooler and wetter than the 1994 season. Average home range size during the hot and dry field season was significantly smaller than the average home range size during the cool, wet season ($P<0.01$). Deer showed a strong preference for the Mountain Brush cover type for all activities, Aspen and Riparian cover types for bedding, and Sage/Bitterbrush for feeding. Cooler northeastern and eastern aspects were preferred by deer and southwestern and flat aspects were avoided. Overall, deer appeared to prefer steeper than average areas, but within Mountain Brush they chose flatter sites. Areas near water were preferred and stock ponds may have made bedding areas that would have been too far from water otherwise available for use. Deer preferred microsites that did not have fresh sign of cattle. Habitat use appeared to overlap more between deer and cattle during the dry year and the latter part of the summer/fall period. A more detailed analysis of the effects of cattle on mule deer was not possible due to the high density of different landowners in the area. Hunting season did not affect bed concealment or flushing distance of deer but may have caused movements out of established home ranges and premature migration to the winter range. Deer chose shaded areas for bedding and preferred clumps of Salix sp. shrubs within the Mountain Brush cover type. Microhistological fecal analysis documented the transition from forbs to shrubs in late summer. A model built with multiple logistic regression identified overhead cover as the most important factor for determining sites likely to be used by deer. This study documented the importance of the Mountain Brush cover type to mule deer in sage steppe environments. It also identified the potential of hunting pressure to trigger premature migrations.

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Clint Jason Gray

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

12 July 1995
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Chairperson, Graduate Committee

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TABLE OF CONTENTS

TABLE OF CONTENTS - continued

TABLE OF CONTENTS - continued

LIST OF TABLES

LIST OF TABLES - continued

LIST OF FIGURES

Figure | Page

LIST OF FIGURES - continued

ABSTRACT

The factors governing mule deer (Odocoileus hemionus) habitat use patterns in south-central Idaho are poorly understood. Therefore, 16 radio-collared does were tracked from the ground in 1993, and 9 of the same does were also tracked in 1994 to gather data on habitat use and to document the effects of the primary land use in the area, cattle grazing, on mule deer. The field season of 1993 was cooler and wetter than the 1994 season. Average home range size during the hot and dry field season was significantly smaller than the average home range size during the cool, wet season ($P<0.01$). Deer showed a strong preference for the Mountain Brush cover type for all activities, Aspen and Riparian cover types for bedding, and Sage/Bitterbrush for feeding. Cooler northeastern and eastern aspects were preferred by deer and southwestern and flat aspects were avoided. Overall, deer appeared to prefer steeper than average areas, but within Mountain Brush they chose flatter sites. Areas near water were preferred and stock ponds may have made bedding areas that would have been too far from water otherwise available for use. Deer preferred microsites that did not have fresh sign of cattle. Habitat use appeared to overlap more between deer and cattle during the dry year and the latter part of the summer/fall period. A more detailed analysis of the effects of cattle on mule deer was not possible due to the high density of different landowners in the area. Hunting season did not affect bed concealment or flushing distance of deer but may have caused movements out of established home ranges and premature migration to the winter range. Deer chose shaded areas for bedding and preferred clumps of Salix sp. shrubs within the Mountain Brush cover type. Microhistological fecal analysis documented the transition from forbs to shrubs in late summer. A model built with multiple logistic regression identified overhead cover as the most important factor for determining sites likely to be used by deer. This study documented the importance of the Mountain Brush cover type to mule deer in sage steppe environments. It also identified the potential of hunting pressure to trigger premature migrations.

INTRODUCTION

Although mule deer (Odocoileus hemionus) are one of the most studied animals in North America, much remains to be learned in order to accomplish desired management goals. Much of the shortage of information can be attributed to the difficulty in measuring interactions between an animal and its environment. Add to this the broad spectrum of habitat use strategies utilized by mule deer to cope with conditions as varied as forested mountains with severe winters to hot, dry deserts in Mexico, and it becomes evident why many questions remain unanswered. This study was initiated as part of a long range program (Unsworth 1992) to answer questions about habitat factors which govern mule deer in the high elevation dry steppe of south-central Idaho and how these factors are related to livestock grazing, the primary land use of unirrigated lands in the steppe ecosystem.

Studies of mule deer habitat use (Mackie 1970, Uresk and Uresk 1982, Fielder and Mckay 1984, Austin and Urness 1985, Carson and Peek 1987, Kufeld et al. 1988) indicate that the habitat features critical to mule deer vary among sites. Factors influencing habitat use included water, topographical features, horizontal configuration, aspect, slope, elevation, roads, human activities (mainly hunting), cover types, forage, and livestock. Many of these factors are inter-related, making it difficult to identify individual effects.

Rautenstrauch and Krausman (1989) indicated that availability of water was the primary factor affecting mule deer habitat selection in southwest Arizona. Mackie

(1970) found decreased use of areas greater than 3/4 mile from water during summer and fall in central Montana. He also showed that deer preferred steeper, more rugged terrain than randomly available. Roads have been found to influence habitat use by mule deer (Rost and Bailey 1979). Brown and McDonald (1988) reported decreased diurnal activity and a shift to more secure habitats during hunting seasons in southeast Idaho. Austin and Urness (1985) discussed the importance of forage availability in an area with limited summer habitat. Succession may also play a large role in mule deer habitat selection (Bodurtha et al. 1989).

Ragotzkie and Bailey (1991) and Loft et al. (1991) found that livestock grazing had significant impacts on mule deer habitat use. In years of average and above average precipitation, mule deer and cattle diets have little overlap in many regions (Mackie 1970, Currie et al. 1977). This overlap probably increases during years of drought (Short 1977) or when overgrazing limits forage. In spite of this, mule deer have been shown to prefer ungrazed pastures even in years of adequate forage production (Loft et al. 1991, Ragotzkie and Bailey 1991).

Moderate grazing by cattle on mule deer summer range in the Sierra Nevadas was shown to decrease the availability of hiding cover for deer in meadow-riparian and aspen habitats (Loft et al. 1991), to reduce use of preferred habitats by deer (Loft et al. 1991), to increase home range size of deer (Loft 1988), and to increase the time deer spent feeding compared to areas with no grazing (Kie et al. 1991). These factors could adversely affect mule deer through increased exposure to predators and increased costs of foraging.

Although negative effects are abundant in the literature, cattle grazing may be an effective tool for enhancing forage availability for mule deer. Willms et al. (1979) found increased spring mule deer use of a pasture grazed the previous fall. On 2 adjacent ungrazed pastures in central Arizona, Wallace and Krausman (1987) reported higher deer densities in the pasture that was grazed the previous year. A rest-rotation grazing system is used on several elk winter ranges managed by the Montana Department of Fish, Wildlife and Parks to enhance forage (Frisina pers. comm. 1992). Livestock grazing may also promote diversity in habitat (Mackie 1978).

Despite the potential detrimental effects of cattle grazing on mule deer, cattle grazing will likely continue to be a dominant aspect of public land use in the West, and mule deer will likely continue to justify their presence on public land. Mule deer are Idaho's most important big game animal, providing over 1,000,000 days of recreation in 1991 (Unsworth 1992). In a bioeconomic analysis Loomis et al. (1991) found that the incremental benefits of deer hunting gained under a 2-years-off 1-year-on grazing system are greater than the lost net economic value of the forage to the rancher. Managers need to develop methods for management of both deer and cattle on the same lands.

The deer studied were part of a large migratory herd that moved from 20 km to 65 km between their summer range in the Bennett Hills and Sawtooth mountains and their winter range near King Hill, Idaho. The primary objective of this study was to describe summer/fall habitat use patterns of female mule deer in the Bennett Hills by quantifying variables discussed in the literature as possible factors influencing habitat use. Ancillary objectives included documenting the effects of livestock, hunting, and seasonal and annual variation in temperature and precipitation on female mule deer in the study area.

STUDY AREA

The study area was located in the Bennett Hills of south-central Idaho, in Big Game Management Unit 45 of Idaho Department of Fish and Game (IDFG) Region 4. It included portions of Elmore, Camas, and Gooding counties. The Bennett Hills are bounded on the north by Camas Prairie and on the south by the Snake River floodplain. Most of the study animals summered on the northern front of the Bennett Hills. Elevations in this geological formation range from 1,500 m in the south portion to 2,100 m on Bennett Mountain.

Located on the southern edge of the Idaho Batholith, much of the soil in the Bennett Hills is derived from granite. Snake River Basalt is also common. Most of the basalt has a mantle composed of loess and/or alluvium, but in some areas the mantle is absent. Andesite and rhyolite are also common components of some soils in the Bennetts (Case 1981, Noe 1991).

Mean annual precipitation at the Fairfield Ranger Station, near the study area, is 40.5 cm. Approximately 70% of the annual precipitation falls from November through April in the form of snow. Mean annual daily minimum temperature is 3° Celsius and maximum temperature is 14° C (National Climatic Data Center 1993).

The Bennett Hills are primarily rolling sagebrush rangeland with scattered stands of aspen and brush. Conifers were very rare on the study area. Riparian zones, consisting primarily of 3-4 m tall willow (Salix sp.), bordered the perennial streams, Camas Creek, Sheep Creek, King Hill Creek, and Dempsey Creek, on the study area. Meadows were common in level, low-lying areas.

The primary land use in the Bennett Hills is livestock grazing. Domestic sheep pass through the area in late spring and cattle are present all summer and fall. Ownership on the study area was predominantly private (71%), but there were also significant amounts of land managed by the Bureau of Land Management (9%), and Idaho Department of State Lands (17%). There was also a small portion of United States Department of Agriculture Forest Service land (3%).

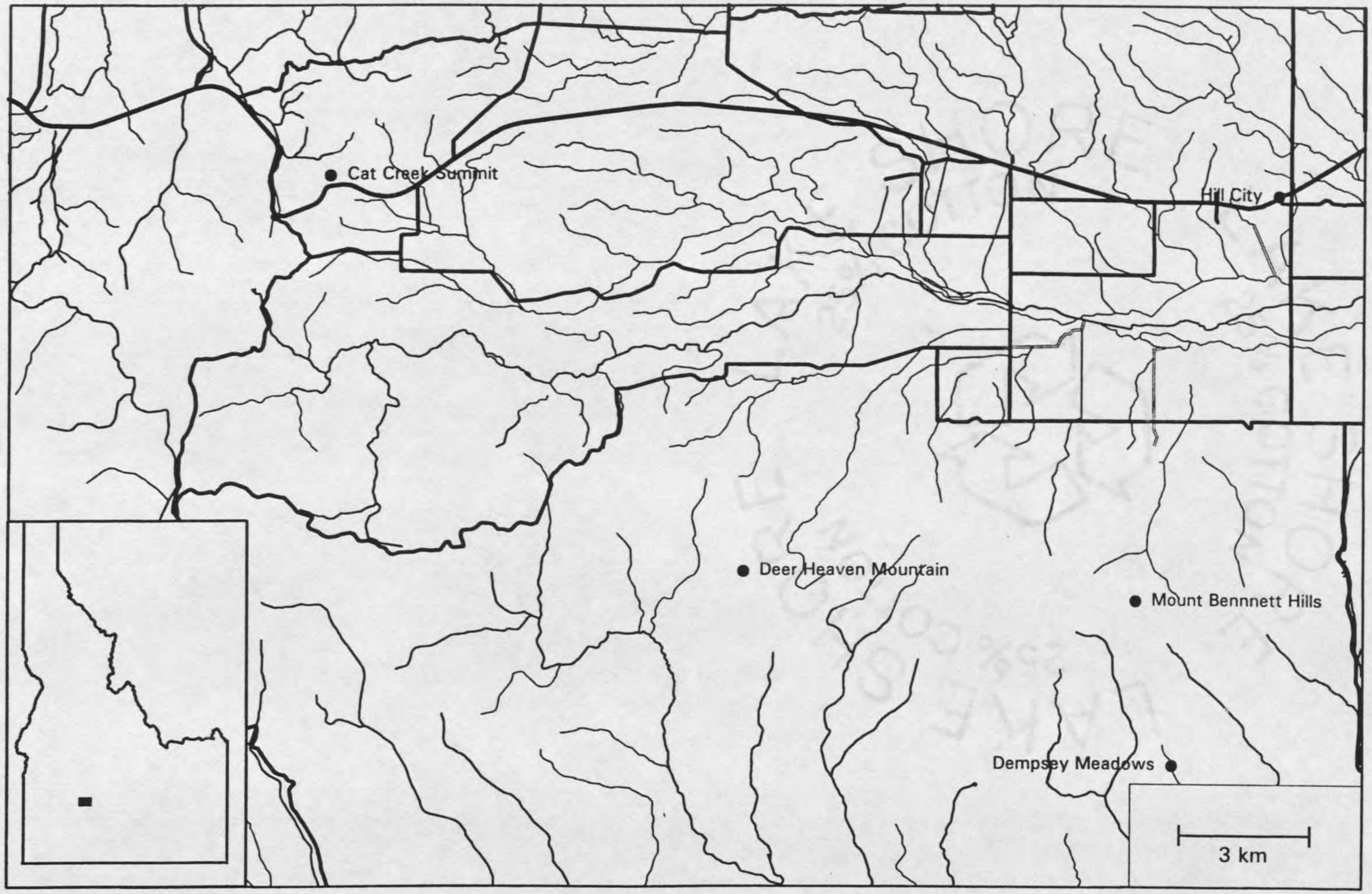

Figure 1. Map of the Bennett Hills Study Area. Heavy lines represent roads. Lighter lines depict drainages.

METHODS

Capturing and Radio-collaring Mule Deer

Forty-three mule deer were captured with a net gun from a helicopter and radio-collared during the winter of 1992. Each deer was fitted with a transmitter that had a time-delay, mortality-sensing device. Age was determined at capture from tooth replacement and wear (Robinette et al. 1957). Of the 22 radio-collared mule deer that survived the winter, only 5 (3 does, 2 bucks) remained in the Bennett study area. The remainder moved further north into the Sawtooth mountains. One of the bucks could not be tracked from the ground due to an uncooperative landowner. Thirteen additional does were captured and collared on July 11, 1993 to provide an adequate sample. Additional bucks could not be collared in the summer due to their antler growth. Since 1 buck is not an adequate sample from which to infer habitat use, only the 16 does were intensively tracked in 1993.

Thirty-four more deer were captured and radio-collared during the winter of 1993. Of the 31 radio-collared deer that survived the winter, only 3, (1 doe, 2 bucks), remained in the Bennett study area. These could not be tracked from the ground due to an uncooperative landowner so the 9 does remaining from the collaring efforts in 1993 were again tracked in 1994.

Deer Relocations

Radio-collared mule deer were relocated from a fixed wing aircraft (Maule M5-235) bi-monthly during the non-hunting season and weekly during September, October and November when weather conditions and pilot schedules allowed. The coordinates of each relocation were recorded by an onboard computer using a geographical positioning system. Information recorded included cloud cover, ambient temperature, relative wind speed, habitat, aspect, date and time. When a mortality signal was received, the radio-collared deer was located from the ground and cause of death determined. Aerial locations were used only for calculating home ranges.

Error of aerial locations can vary from less than 100 m to 1 km (Patric et al. 1988) so intensive ground tracking was employed to attain precise locations for use in micro level habitat analysis. A 2-element, H antenna and scanner/receiver were used to locate deer. All tracking was done during daylight hours. I attempted to obtain visual observations whenever possible. Locations were recorded as 1) visual, 2) auditory, or 3) triangulation. Auditory locations were common in dense brush when the deer would flush at close range but remained unseen due to screening vegetation. Triangulation locations were estimated from 3 bearings taken from as close as practical and with the greatest possible separation of angles to reduce the size of the error polygon (Heezen and Tester 1967, Springer 1979). These were not used for habitat analysis. Each relocation was plotted on topographic maps and recorded in latitude and longitude to 0.01 minute using a Garmin Global Positioning Device. Locations were later converted to Universal

Transverse Mercator (UTM) coordinates for home range analysis. Activity, group size, number of fawns, and number of deer seen within 1 km of the radio-collared animal were recorded. Activity was classified as feeding, bedding, traveling, escape, or unknown. At each location where a bed was found, concealment, percent of the bed shaded, what the bed was shaded by, and the distance I was from the deer when it flushed were recorded. Concealment was represented by an estimation of the percent of the deer not visible at 50 feet (17 m). A concealment rating scale from 1 to 10 was constructed by dividing the percent of the deer not visible by 10.

At each location where a radio-collared deer was seen or sign was found following an auditory location, the following site characteristics were recorded: elevation, aspect, slope, topography, horizontal configuration, and distance to the nearest water, stock, and primary and secondary roads. Elevation was taken from topographic maps (scale=1:24,000). Slope was measured with a clinometer. Topography was recorded as ridge top, upper slope, mid slope, lower slope, stream bed/bottom, or bench/flat. Horizontal configuration was classified as convex, straight, concave, or undulating. The nearest water was categorized as natural or artificial (i.e. stock ponds). I also noted if the pastures were stocked and if fresh sign of livestock were found within the plot. Maintained gravel roads were categorized as primary while tracks or unmaintained gravel roads were categorized as secondary. Distances to roads and water were measured from topographic maps (scale=1:24,000).

Cover type was also recorded at each location. Seven major cover types were identified by vegetation composition and structure. They were: Meadow, Low

Sage (<1 m), High Sage (>1 m), Sage/Bitterbrush, Mountain Brush, Riparian, and Aspen.

The Meadow type was found in low-lying areas which remained wet into late spring. It was composed of a grass/forb community and accounted for relatively little of the total area.

Big sagebrush (Artemisia tridentata) habitats dominated most of the area. Bitterbrush (Purshia tridentata), snowberry (Symphoricarpos sp.), currant (Ribes spp.), rabbitbrush (Chrysothamnus nauseosus and C. viscidiflorus), and serviceberry (Amelanchier alnifolia) were important shrub components of sagebrush habitats. Common forbs and grasses included balsamroot (Balsamorhiza spp.), buckwheat (Eriogonum spp.), lupine (Lupinus spp.), Idaho fescue (Festuca idahoensis), needlegrass (Stipa spp.), and oniongrass (Melica spp.).

Thick stands of bitter cherry (Prunus emarginata) and chokecherry (P. virginiana) were scattered throughout the area. Shrub components found in association with the cherries included Oregon grape (Berberis repens), ceanothus (Ceanothus sp.), willow (Salix spp.), stunted quaking aspen (Populus tremuloides), snowberry, and serviceberry. There was generally little grass or forb growth in the Mountain Brush habitats.

The Riparian type was found along streams and consisted primarily of very dense stands of willow shrubs. Mint (Mentha spp.) and sedge (Carex spp.) were commonly associated with these wet areas. In some areas cattle had reduced or eliminated the willow cover.

Homogeneous stands of aspen were scattered throughout the area. Stands heavily utilized by cattle tended to have very little understory, whereas those more remote from cattle had understories of variable density consisting of chokecherry, currant, serviceberry and snowberry. Forbs and grasses tended to be relatively sparse but horsemint (Agastache sp.) was commonly encountered.

At deer locations, all vegetation present within a 375 m^2 circular plot was noted. The percent cover for each species was estimated and assigned to a cover class (1=0-1%, 2=>1-5%, 3=>5-25%, 4=>25-50%, 5=>50-75%, 6=>75-95%, 7=>95%). In addition, the phenologic stages (West and Wein 1971) of shrubs, forbs, and grasses were recorded (Table 1). Utilization of each species was estimated and assigned to a utilization class (1=0-5%, 2=>5-20%, 3=>20-40%, 4=>40-60%, 5=>60-80%, 6=>80%). Every 2 to 3 days during the 1993 field season, fresh deer droppings were picked up, labeled, and put in paper bags. These were later analyzed microhistologically by the Composition Analysis Laboratory in Fort Collins, Colorado.

Table 1. Phenological stages and codes used for vegetation at Bennett Mountain.

Phenology Code	Shrubs	Grasses and Forbs
1	Flower	Vegetative growth
2	Fruit set	Flower buds
3	Fruit swelling	Flower
4	Fruit turning color	Fruit set
5	Fruit ripe	Fruit swelling
6	Fruit dry/dropping	Plant curing

Random Locations

Habitat availability was determined by going to 299 random points on the study area and measuring all habitat characteristics recorded at deer locations. This was accomplished by creating random locations in latitude and longitude to 0.01 minute using a random number table. These locations were then entered into a Garmin Global Positioning Device which was used to locate the random points with minimal human bias. To confirm that an adequate sample size of random plots was done, summary statistics were computed for 6 variables with subsets of the random points in increments of 25. The means or proportions of all variables tested stabilized by at least the 200th random point.

Home Range Analysis

Home range, "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943), was calculated and plotted for each radio-collared deer from June until the deer returned to winter range in 1993 and 1994. The minimum convex polygon (MCP) (Mohr 1947, Jennrich and Turner 1969) and the adaptive kernel methods (Worton 1989) were used to compute home ranges. The CALHOME microcomputer program (Kie et al. 1994) was used to run these analyses. Ground and aerial locations were used to calculate home ranges. Home ranges were not calculated for deer with <20 locations.

Statistical Analyses

Univariate Analyses

Student's t-tests (Freedman et al. 1978) were used to compare group means of all continuous variables such as slope, elevation, concealment, distance jumped, and distances to roads, water and stock. Groups that were compared included deer locations versus random locations, deer locations prior to 15 August versus deer locations after 15 August, deer locations prior to hunting season versus deer locations during hunting season, and 1993 deer locations versus 1994 deer locations. Since the deer tracked in 1994 were also tracked in 1993, a paired t-test was used to compare home range sizes between years. Overall comparisons included all radio-collared deer, whereas comparisons between years included only deer tracked both years.

For categorical variables such as cover type, aspect, topography and horizontal configuration, chi-square, goodness of fit tests (Zar 1984), were used to compare use versus availability and use in different time periods. Variables which showed significant variation from expected were subjected to the procedure suggested by Marcum and Loftsgaarden (1980) to determine preference, avoidance, or use in proportion to availability of individual categories by constructing Bonferroni simultaneous confidence intervals. This test is not as strong as the goodness of fit procedure because estimates of availability reduce the power of the test. MSUSTAT (Lund 1993), version 5.2, was used to run the t-tests, chi-square tests, and to produce summary statistics.

Multivariate Analysis

Multiple logistic regression, using best subset analysis (Hosmer and Lemeshow 1989), was used to create a model that identified a set of habitat variables that maximized the probability of predicting whether a given site was a deer location or a random location. The data set was also subjected to the step-up procedure. Only variables significant at the 0.15 level were included in the step-up model. The 7 independent variables used in the analysis were desirable food forb cover, desirable food shrub cover, lateral hiding cover, overhead hiding cover, slope, and distances to the nearest road and water (Table 2). These variables were chosen because they were significant in univariate analyses. The dependent variable had values of 0 for random points and 1 for deer locations. SAS, version 6.10, was used to run this analysis (SAS Institute 1989).

Table 2. Description of variables used in the multiple logistic regression.

Variable	Description
1. Forb Cover	Combined cover of forbs known to be utilized by mule deer, including: *Castilleja applegatei*, *Lupinus leucophyllus*, *Sphaeralcea grossulariifolia*, and *Potentilla* sp.
2. Shrub Cover	Combined cover of shrubs known to utilized by mule deer, including: *Prunus* spp., *Ceanothus* sp., *Rosa* sp., and *Purshia tridentata*.
3. Lateral Cover	Combined cover of plants providing lateral cover, including: *Ceanothus* sp., *Symphoricarpos* sp., *Ribes* spp., *Artemisia tridentata*, *Purshia tridentata*, and *Chrysothamnus nauseosus*.
4. Overhead Cover	Combined cover of plants providing overhead cover, including: *Populus tremuloides*, *Salix* spp., *Prunus* spp., and *Amelanchier alnifolia*.
5. Slope	Slope, measured in degrees.
6. Road Distance	Distance, in meters, to the nearest primary or secondary road.
7. Water Distance	Distance, in meters, to the nearest source of water.

RESULTS

In 1993, the 16 radio-collared does were relocated from the ground a total of 346 times throughout summer and fall. Visual observations were made on 77.7% of the relocations and 11.0% were established by hearing the animal in the brush. The remaining 11.3% of the ground locations were based upon triangulation and were used only for home range calculations. The 105 aerial locations logged during the same period were also used only in home range calculations.

Nine of the same deer were relocated 270 times from the ground throughout summer and fall of 1994. These locations were 58.9% visual, 20.7% auditory, and 20.4% triangulation. Thirty-one aerial locations were used in home range calculations.

Climatic Differences Between Years

The field season of 1993 was characterized by unusually cool, wet conditions, whereas the 1994 season was hot and dry (Figures 2 and 3). Phenology of plants as measured at deer locations progressed faster in 1994 (Figure 4, 5 and 6). The differences in years allowed me to compare deer habitat use in a dry year versus a wet year. For all measured variables that may have been affected by this, between years comparisons have been included. The 1993 data used in between years comparisons are only from the 9 deer also tracked in 1994.

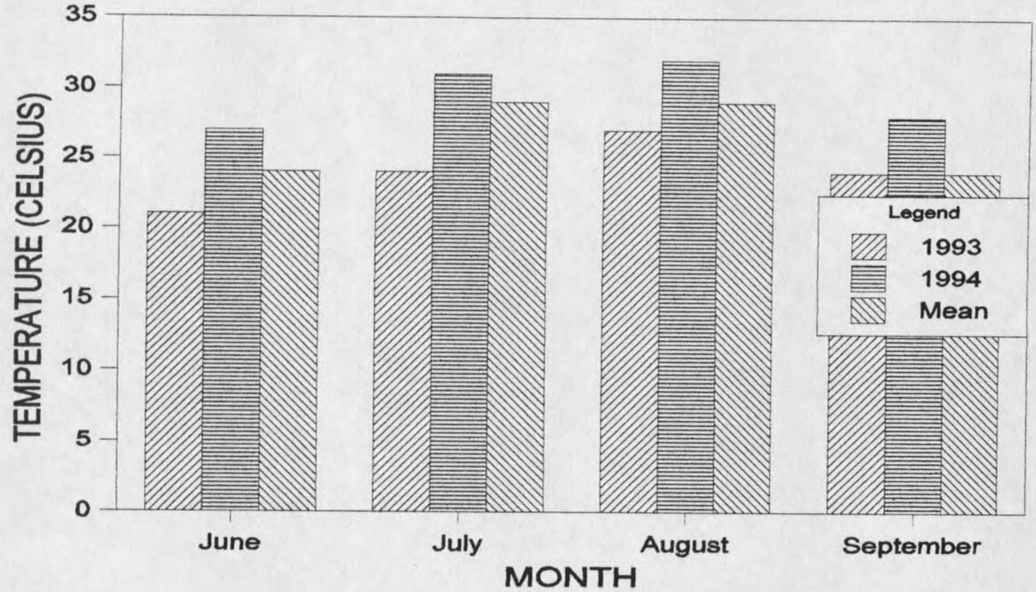

Figure 2. Average maximum temperature comparisons by month for 1993, 1994, and the 45-year mean, as measured at the Fairfield Ranger Station.

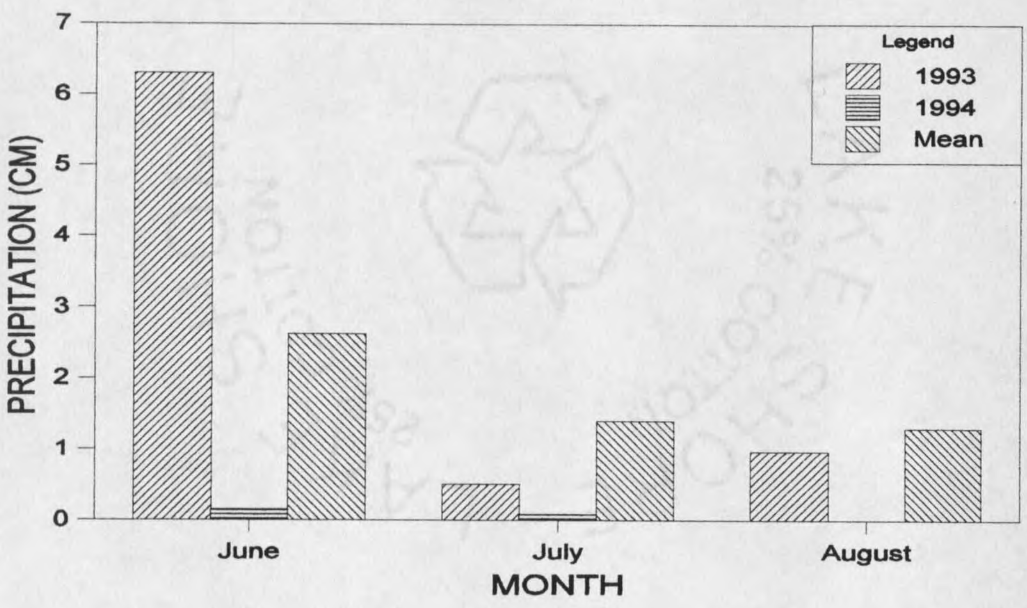

Figure 3. Average precipitation comparisons by month for 1993, 1994, and the 45-year mean, as measured at the Fairfield Ranger Station.

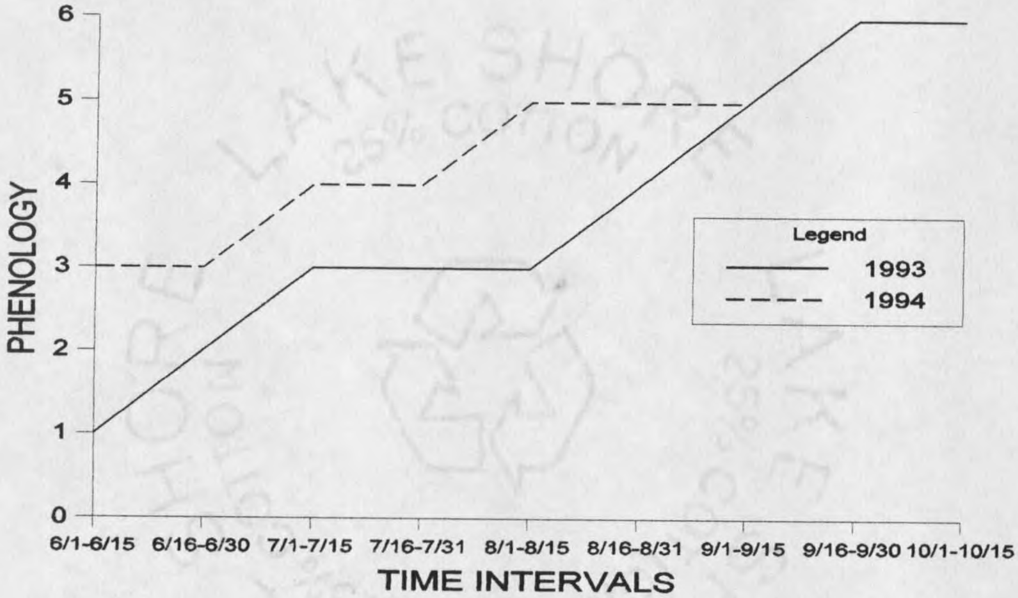

Figure 4. Median phenology of Prunus spp. shrubs as measured at deer locations in 1993 and 1994 in the Bennett Hills, Idaho (phenology codes are in Table 1).

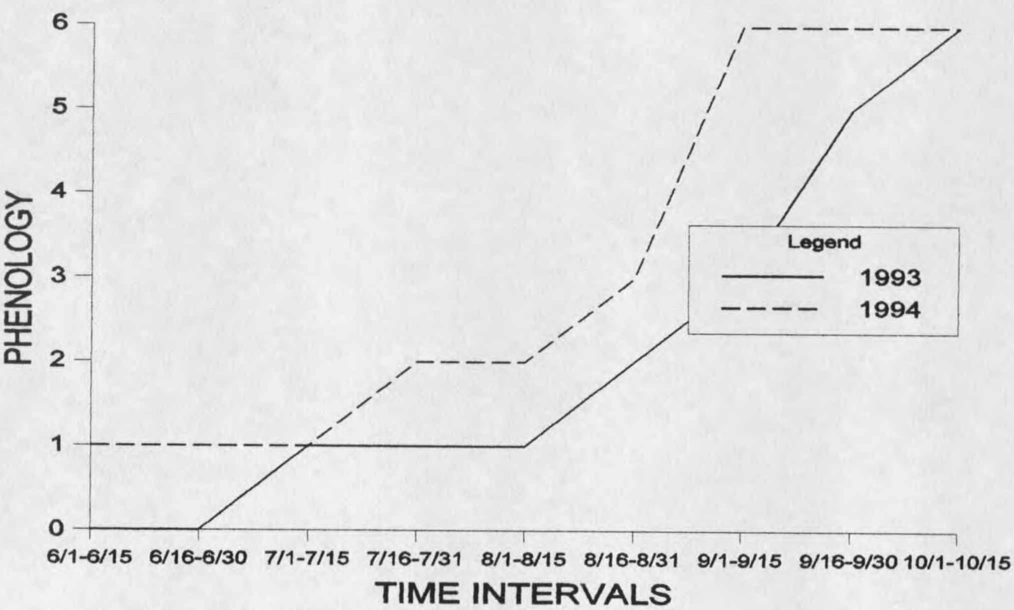

Figure 5. Median phenology of Chrysothamnus viscidiflorus as measured at deer locations in 1993 and 1994 in the Bennett Hills, Idaho (phenology codes are in Table 1).

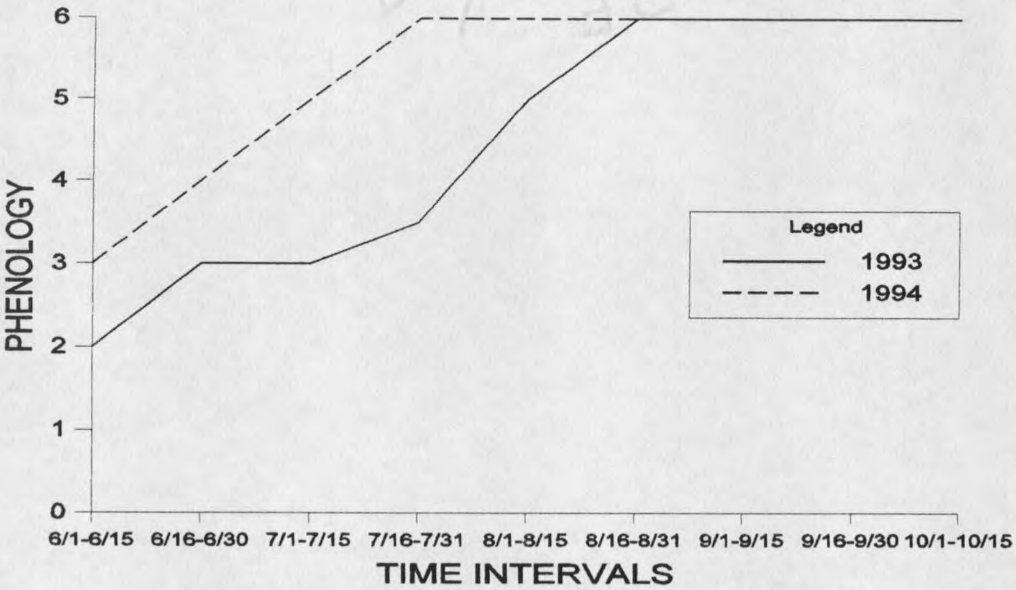

Figure 6. Median phenology of Agastache sp. forbs as measured at deer locations in 1993 and 1994 in the Bennett Hills, Idaho (phenology codes are in Table 1).

Home Range Analysis

Summer/fall home ranges were calculated for 9 deer tracked in 1993 and 1994 and for 6 additional deer tracked only in 1993 (Table 3). One deer was excluded from analysis because of an insufficient number of locations (n<20). A total of 439 locations were used in the calculation of 1993 home ranges, while 301 were used in 1994. Home ranges included locations from the time the deer arrived on the summer range in early June until they began moving back to the winter range in late October.

The minimum convex polygon method yielded smaller home range estimates than the 95% adaptive kernel in 87.5% of the data sets analyzed. Home ranges calculated with the MCP averaged 3.59 km^2 (SD=1.73 km^2) whereas those calculated with the 95% adaptive kernel averaged 4.22 km^2 (SD=1.97 km^2).

Table 3. Numbers of locations and home range sizes for all deer tracked in the Bennett Hills, 1993 and 1994.

	Ground Locations		Aerial Locations		Total Locations		MCP (km^2)		95% Adapt. Kernel (km^2)	
Deer	93	94	93	94	93	94	93	94	93	94
100	19	-	6	-	25	-	4.66	-	4.46	-
310	18	-	8	-	26	-	5.01	-	7.54	-
730	24	-	12	-	36	-	4.84	-	6.78	-
1391	19	-	6	-	25	-	4.94	-	5.92	-
1820	23	-	6	-	29	-	7.63	-	8.00	-
1940	19	-	9	-	28	-	3.79	-	4.74	-
360	24	29	8	3	32	32	3.85	1.72	4.03	2.01
430	25	30	8	4	33	34	5.12	2.54	5.57	3.09
510	23	34	8	5	31	39	4.39	2.26	5.21	3.72
611	23	29	7	3	30	32	4.44	0.81	3.65	0.90
771	22	32	2	4	24	36	3.72	5.75	4.41	5.32
1140	23	28	7	3	30	31	5.65	1.28	7.26	1.69
1560	25	29	6	3	31	32	2.73	2.28	3.22	3.08
1800	23	31	5	3	28	34	3.16	1.88	4.11	2.53
1950	24	28	7	3	31	31	2.92	0.75	3.19	0.92
Mean[a]	23.6	30.0	6.4	3.4	30.0	33.4	4.00	2.14	4.52	2.58

[a]1993 means are derived from only the 9 deer tracked in 1994 also.

Home ranges of the 9 deer tracked during both field seasons were significantly larger in 1993 ($P<0.01$). Estimates using the 95% adaptive kernel method averaged 4.52 km^2 (SD = 1.31 km^2) in 1993 and 2.58 km^2 (SD = 1.41 km^2) in 1994. The MCP home range estimates averaged 4.00 km^2 (SD = 0.99 km^2) in 1993 and 2.14 km^2 (SD = 1.50 km^2) in 1994. In all cases the number of locations used in 1994 calculations equalled or exceeded the number used in 1993. Number of locations per deer averaged 30.0 for 1993 calculations and 33.4 for 1994 calculations. The spatial relationship of individual deer's home ranges between years can be seen in Figures 7 and 8.

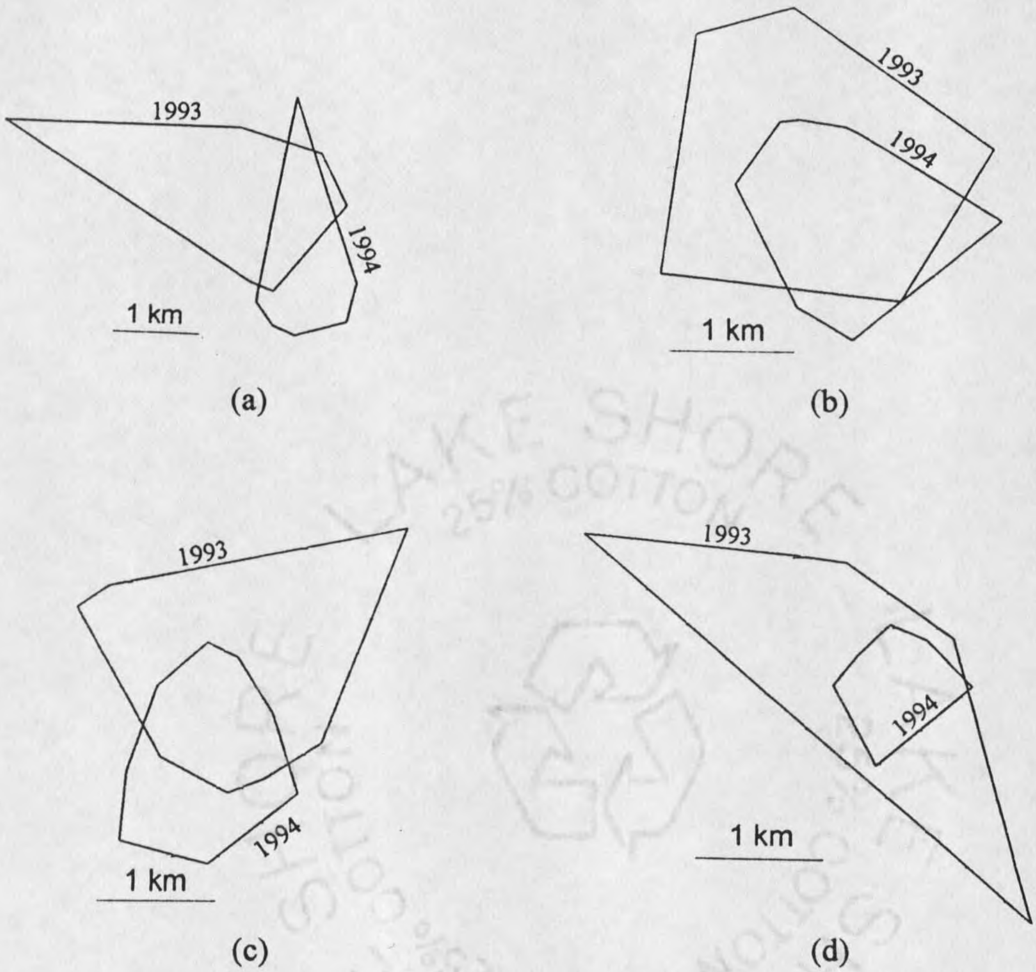

Figure 7. Home ranges of female deer in the Bennett Hills, Idaho in 1993 and 1994: a) deer 360, b) deer 430, c) deer 510, d) deer 611.

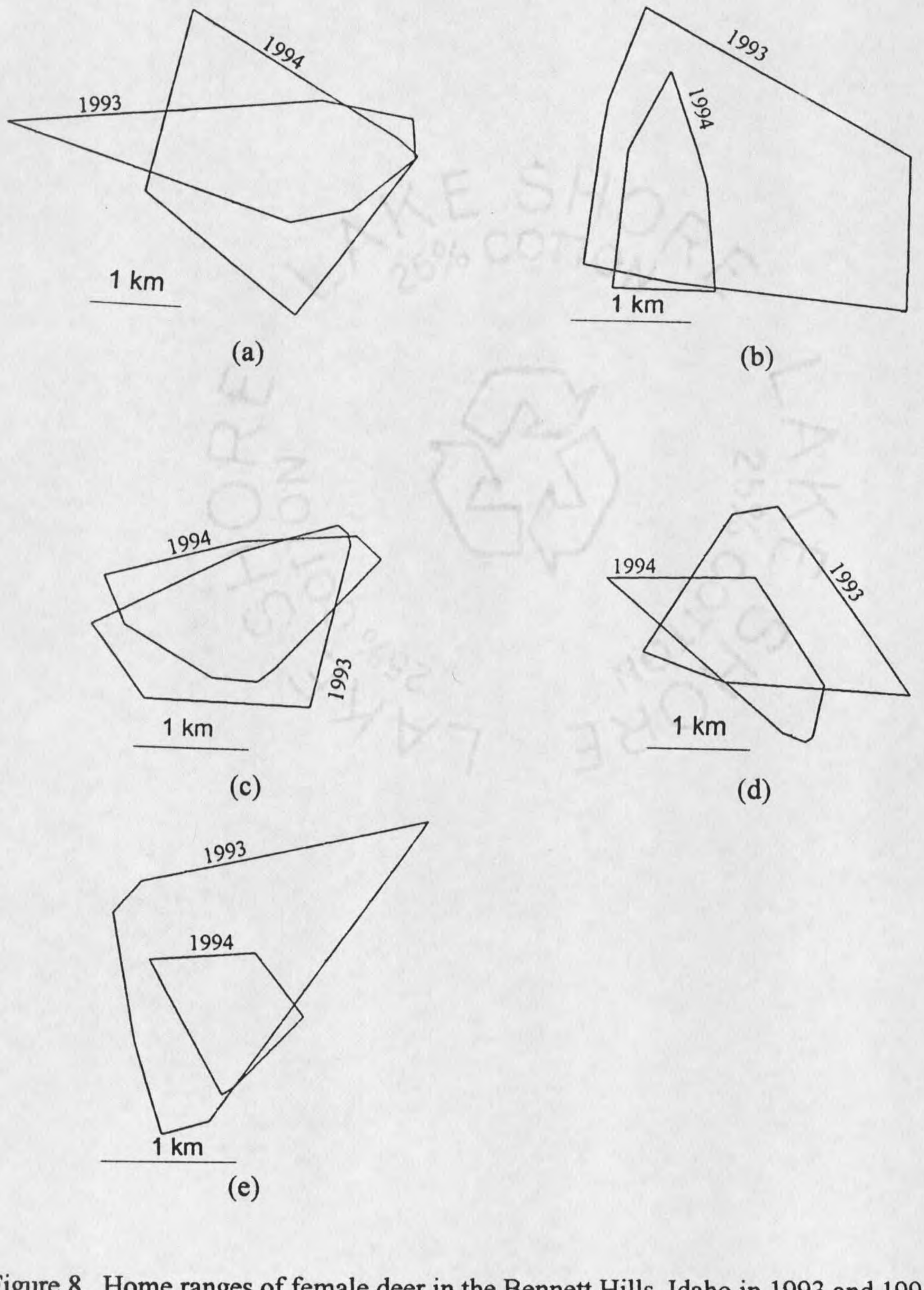

Figure 8. Home ranges of female deer in the Bennett Hills, Idaho in 1993 and 1994: a) deer 771, b) deer 1140, c) deer 1560, d) deer 1800, e) deer 1950.

Cover Type Use

Overall Cover Type Use

Cover type was recorded at 535 deer locations during the summer/fall field seasons of 1993 and 1994 (Figure 9). With all activities and both years combined, deer did not use cover types in proportion to availability (X^2=1879, d.f.=6, $P<0.01$). The Marcum-Loftsgaarden analysis indicated that deer selected for Mountain Brush and Aspen, selected against Grass, Low Sage, and High Sage, and used Sage/Bitterbrush and Riparian cover types in proportion to availability ($P<0.05$).

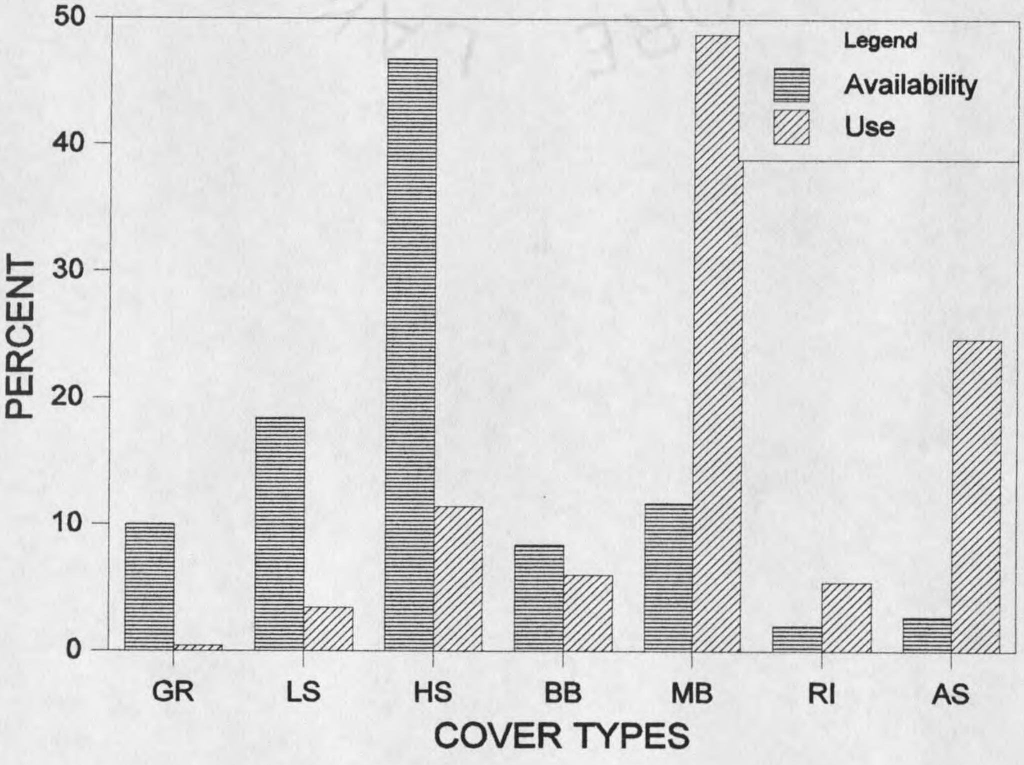

Figure 9. Overall deer use and availability of cover types (GR=Grass, LS=Low Sage, HS=High Sage, BB=Bitterbrush, MB=Mountain Brush, RI=Riparian, AS=Aspen) in the Bennett Hills, Idaho.

Activity and Cover Use

Cover type was recorded at 396 deer bedding sites, 82 deer feeding sites, and 57 unknown activity sites (Figure 10). The locations classified as unknown were mainly instances where the deer was not seen or heard until it was fleeing and subsequent inspection of sign in the area did not indicate the type of activity.

Deer did not use cover types for bedding in proportion to availability (X^2=1708, d.f.=6, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer selected for Mountain Brush, Riparian, and Aspen and selected against Grass, Low Sage, High Sage, and Sage/Bitterbrush cover types for bedding (P<0.05).

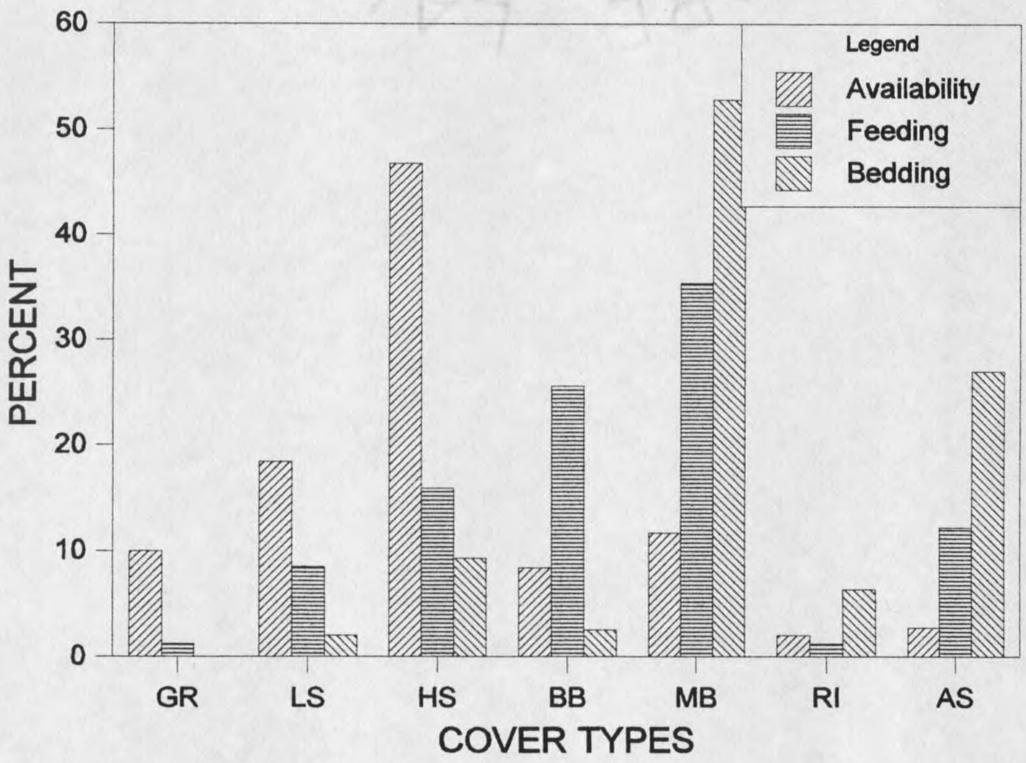

Figure 10. Availability, feeding use, and bedding use of cover types (GR=Grass, LS=Low Sage, HS=High Sage, BB=Bitterbrush, MB=Mountain Brush, RI=Riparian, AS=Aspen) by mule deer in the Bennett Hills, Idaho.

Deer also did not use cover types for feeding in proportion to availability (X^2=123.2, d.f.=6, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer selected for Sage/Bitterbrush and Mountain Brush, selected against Grass and High Sage, and used Low Sage, Riparian, and Aspen cover types in proportion to availability for feeding (P<0.05).

Habitat use differed significantly between feeding and bedding sites (X^2=86.07, d.f.=6, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer used Sage/Bitterbrush more for feeding, Mountain Brush, Riparian and Aspen more for bedding, and the other cover types equally (P<0.05).

Variability Between Years

For deer followed in both years, cover type was recorded at 193 locations in 1993 and 224 locations in 1994 (Figure 11). Cover type selection differed significantly between years (X^2=14.30, d.f.=6, P<0.03). The Marcum-Loftsgaarden analysis indicated that deer used High Sage more in 1993 than in 1994 and used all other cover types equally in both years (P<0.05).

Aspect Use

Overall Aspect Use

Aspect was recorded at 522 deer locations during the summer/fall field seasons of 1993 and 1994 (Figure 12). With all activities and both years combined, deer did not use aspects in proportion to availability (X^2=416.2, d.f.=8, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer selected for northeastern and eastern, selected

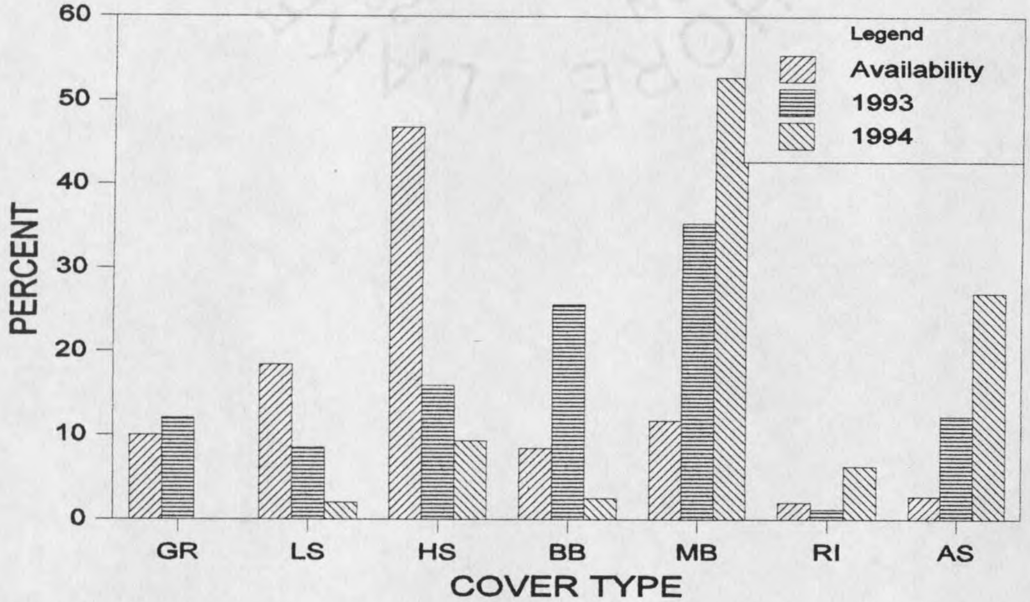

Figure 11. Availability, use in 1993, and use in 1994 of cover types (GR=Grass, LS=Low Sage, HS=High Sage, BB=Bitterbrush, MB=Mountain Brush, RI=Riparian, AS=Aspen) by mule deer in the Bennett Hills, Idaho.

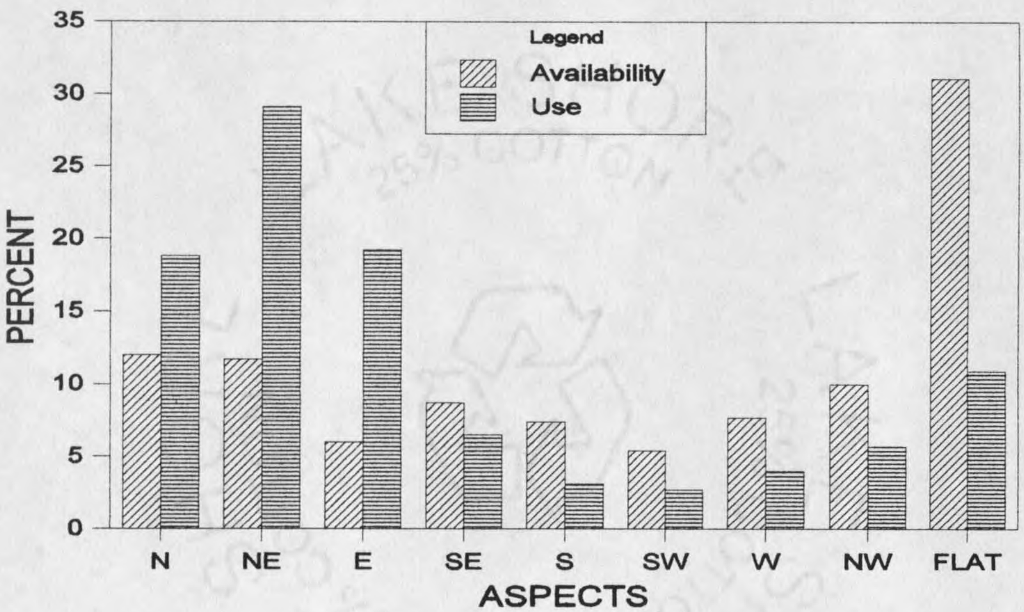

Figure 12. Availability and overall use of aspects by mule deer in the Bennett Hills, Idaho.

against southwestern and flat aspects, and used all other aspects in proportion to availability ($P<0.05$).

Variability Between Years

Aspect was recorded at 193 deer locations in 1993 and 210 deer locations in 1994 (Figure 13). Aspect selection differed significantly between years ($X^2=16.26$, d.f.=8, $P<0.01$). The Marcum-Loftsgaarden analysis indicated that deer used southeastern aspects more in 1993, northern aspects more in 1994, and all other aspects equally in both years ($P<0.05$).

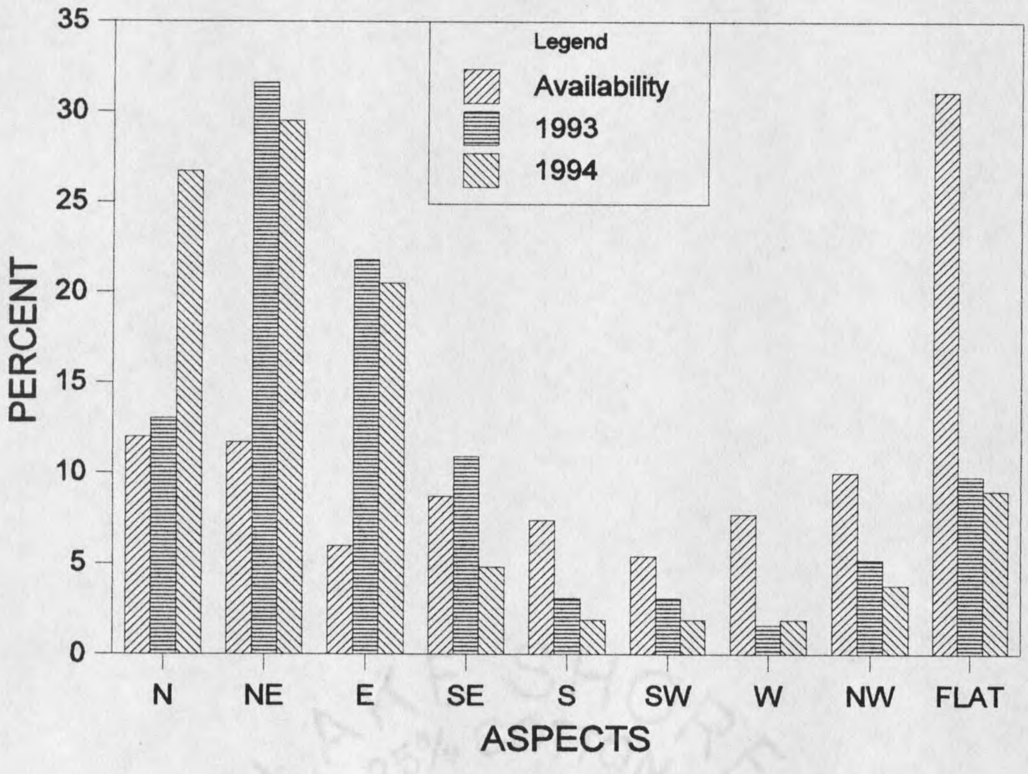

Figure 13. Availability and use in 1993 and 1994 of aspects by mule deer in the Bennett Hills, Idaho.

Relation to Mountain Brush

An analysis of aspect use within Mountain Brush was included because it was the most used cover type on the study area and cover types were at least partially dictated by aspect. Aspect was recorded at 249 deer locations in the Mountain Brush cover type (Figure 14). Aspect selection within Mountain Brush differed significantly from aspect availability within Mountain Brush (X^2=41.69, d.f.=8, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer selected for northeastern aspects, selected against southern aspects and used all other aspects within Mountain Brush in proportion to availability (P<0.05).

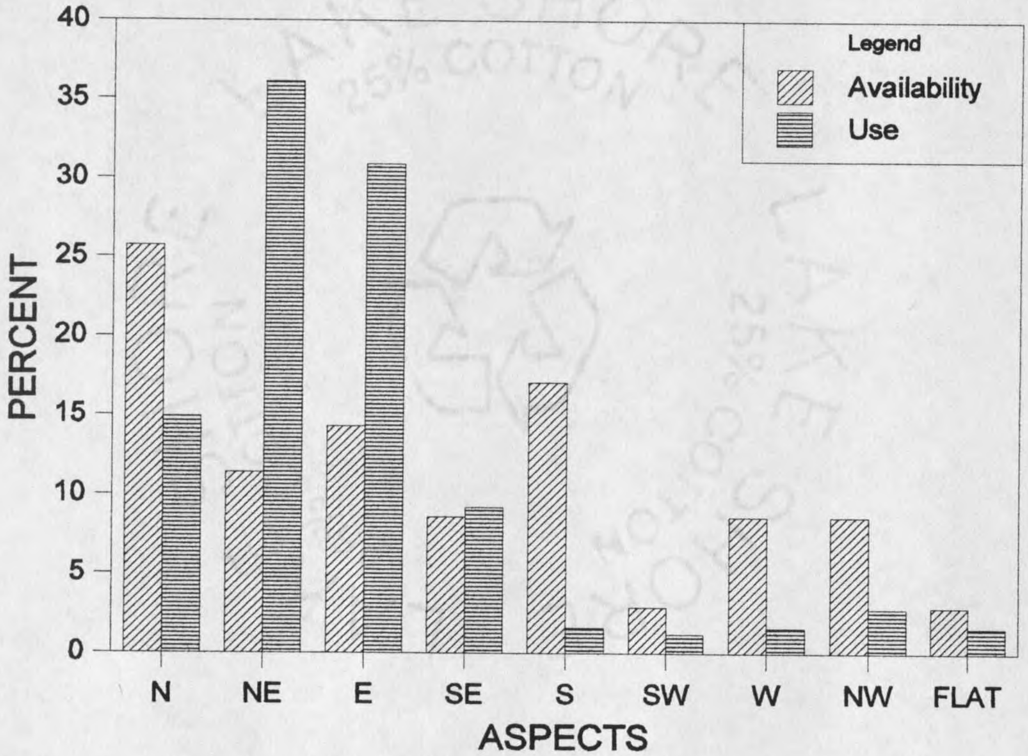

Figure 14. Availability and use of aspects within the Mountain Brush cover type by mule deer in the Bennett Hills, Idaho.

Topography Use

Overall Topography Use

Topography was recorded at 521 deer locations during the summer/fall field seasons of 1993 and 1994 (Figure 15). With all activities and both years combined, deer did not use topography in proportion to availability (X^2=271.8, d.f.=5, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer selected for mid-slope, selected against lower slopes and benches or flats, and used ridge tops, upper slopes and stream beds in proportion to availability (P<0.05).

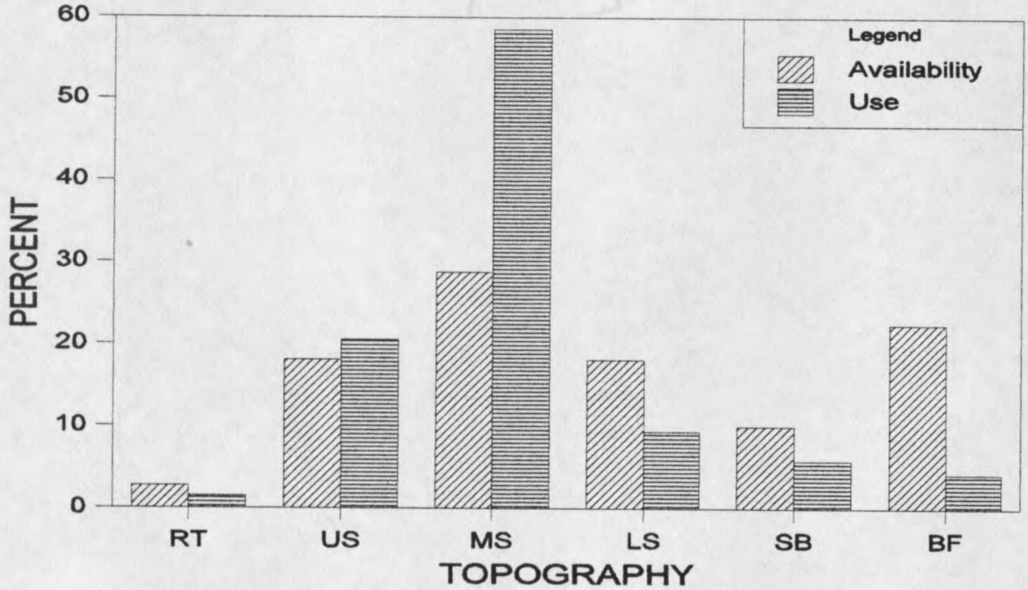

Figure 15. Availability and use of topography (RT=ridge top, US=upper slope, MS=mid-slope, LS=lower slope, SB=stream bed, BF=bench or flat) by mule deer in the Bennett Hills, Idaho.

Variability Between Years

Topography was recorded at 193 deer locations in 1993 and 209 locations in 1994 (Figure 16). Topography use differed significantly between years (X^2=106.8, d.f.=5, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer used upper slopes more in 1993, mid-slopes more in 1994, and all other areas equally in both years (P<0.05).

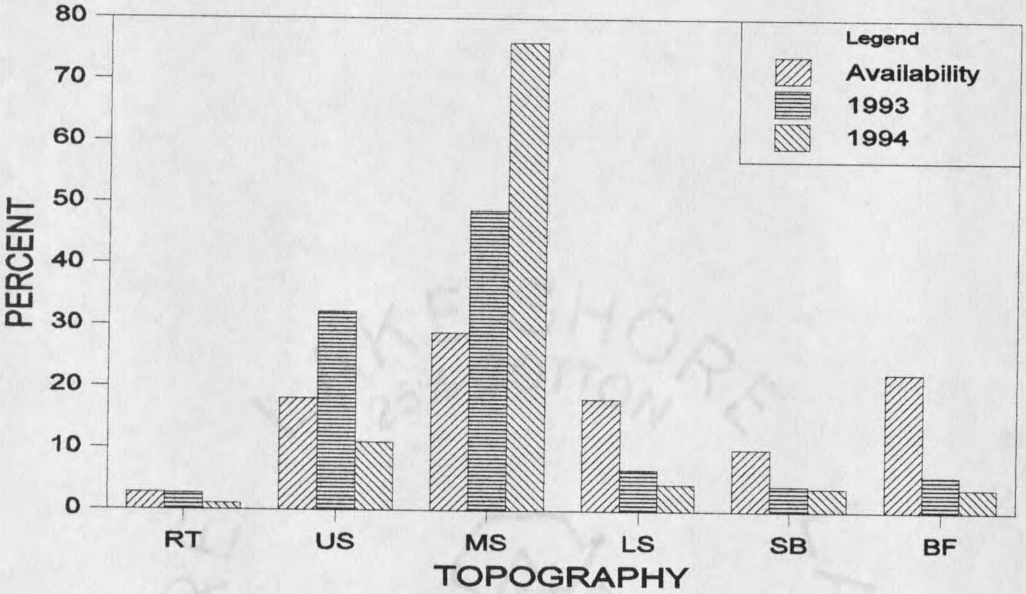

Figure 16. Availability and use in 1993 and 1994 of topography (RT=ridge top, US=upper slope, MS=mid-slope, LS=lower slope, SB=stream bed, BF=bench or flat) by mule deer in the Bennett Hills, Idaho.

Horizontal Configuration Use

Overall Horizontal Configuration

Horizontal configuration was recorded at 517 deer locations in the summer/fall field seasons of 1993 and 1994 (Figure 17). With all activities and both years combined, deer did not use horizontal configurations in proportion to availability (X^2=121.4, d.f.=3, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer selected for straight, selected against convex and undulating, and used concave horizontal configurations in proportion to availability (P<0.05).

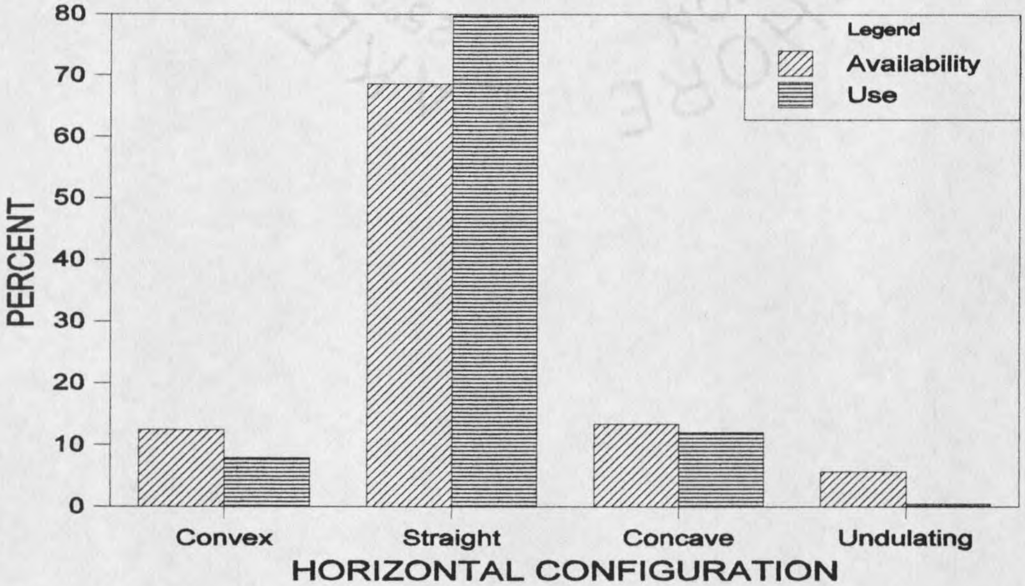

Figure 17. Availability and overall use of horizontal configurations by mule deer in the Bennett Hills, Idaho.

Variability Between Years

Horizontal configuration was recorded at 193 deer locations in 1993 and 209 locations in 1994 (Figure 18). Horizontal configuration use differed significantly between years (X^2=121.4, d.f.=3, P<0.01). The Marcum-Loftsgaarden analysis indicated that deer used convex more in 1993, straight and undulating more in 1994, and concave horizontal configurations equally in both years (P<0.05).

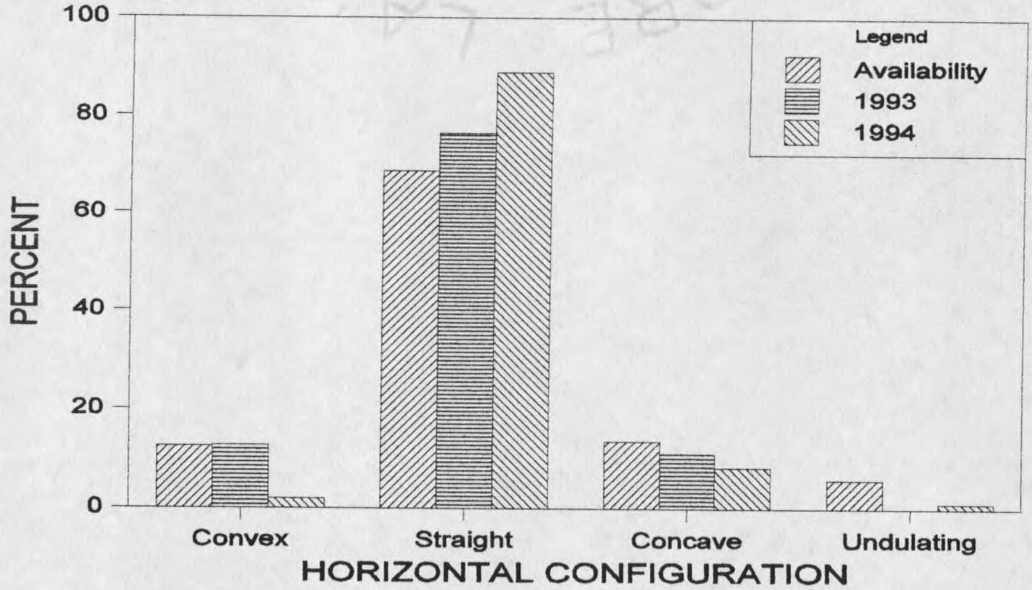

Figure 18. Availability and use in 1993 and 1994 of horizontal configurations by mule deer in the Bennett Hills, Idaho.

Elevation and Slope Use

Elevation, as measured at 521 deer locations, averaged 2,039 m (SD=41 m). This was significantly different than the average of 2,023 m (SD=45 m) measured at random locations ($P<0.01$).

Slope, as measured at 521 deer locations, averaged 12.3° (SD=5.7°). This was significantly steeper than the average of 8.9° (SD=7.3°) measured at random locations. Slope at bedding sites averaged 12.2° (SD=5.5°) and did not differ significantly from the average of 12.6° (SD=5.8°) measured at feeding sites ($P=0.55$). Slope at deer locations within Mountain Brush averaged 14.0° (SD=4.3°) which was significantly steeper than deer locations at all other cover types combined which averaged 10.9° (SD=6.3°)

(P<0.01). However, it was significantly less than the average of 16.1° (SD=7.5°) measured at random locations within Mountain Brush (P=0.01).

Distance to Roads

Overall Distance to Roads

Distance to a primary road, as measured at 494 deer locations, averaged 1,297 m (SD=841 m). This was significantly less than the average distance of 1,544 m (SD=999 m) measured at random locations (P<0.01). Distance to a secondary road averaged 731 m (SD=517 m) at 516 deer locations which did not significantly differ from the average of 721 m (SD=576 m) measured at random locations (P=0.79).

Before and During Hunting Season

Distance to a primary road was measured at 463 deer locations prior to the opening of hunting seasons and 31 locations during hunting seasons. Distance to a primary road averaged 1,278 m (SD=826 m) prior to hunting season and 1,581 m (SD=1,013 m) during hunting season. This difference approached significance (P=.0514). Distance to a secondary road averaged 727 m (SD=518 m) prior to hunting season and 790 m (SD=500 m) during hunting season. This was not a significant difference (P=0.85).

Table 4. Distances, in meters, to primary and secondary roads from random and deer locations, overall, before and during hunting seasons in the Bennett Hills, Idaho.

	Random	Overall	Pre-Hunting	During Hunting
Primary Rd.	1544	1297	1278	1581
Secondary Rd.	721	731	727	790

Distance to Water

Overall Distance to Water

Distance to water, as measured at 518 deer locations, averaged 364 m (SD=321 m). This was significantly less than the average distance of 426 m (SD=311 m) measured at random locations ($P<0.01$). The nearest water source was artificial at 39.7% of deer locations and 27.1% of random locations. Type of water was not distributed proportionately between deer and random locations ($X^2=13.28$, d.f.=1, $P<0.01$).

Variability Between Years

The inter-year distances to water did not differ significantly ($P=0.56$). Mean distance to water in 1993, based on 191 locations, was 399 m (SD=424 m) and in 1994, based on 208 locations, was 380 m (SD=202 m). Type of water nearest deer locations also did not differ between years ($X^2=2.355$, d.f.=1, $P=0.12$).

Variability Between Seasons

Distance to water, as measured at 242 deer locations prior to 15 August, averaged 324 m (SD=224 m). This was significantly less than the average of 398 m (SD=384 m) measured at 276 locations after 15 August ($P<0.01$).

Distance to Livestock

Overall Distance to Livestock

Distance to livestock, as measured at 483 deer locations, averaged 500 m (SD=330 m). This did not differ significantly from the average of 446 m (SD=550 m) measured at random locations ($P=0.11$). Fresh sign of livestock was noted at 26.8% of deer locations which significantly differed from the 43.9% of plots with fresh sign at random locations ($X^2=23.89$, d.f.=1, $P<0.01$).

Variability Between Years

Distance to livestock was measured at 303 deer locations in 1993 and 180 locations in 1994. The 1993 average, 570 m (SD=342 m), was significantly larger than the average of 382 m (SD=272 m) measured in 1994 ($P<0.01$). Fresh sign of livestock was noted at 24.2% of deer locations in 1993 and 30.3% in 1994. This difference was not significant ($X^2=2.272$, d.f.=1, $P=0.13$).

Variability Between Seasons

Distance to livestock, as measured at 212 deer locations prior to 15 August, averaged 561 m (SD=405 m). This was significantly larger than the average of 452 m

(SD=247 m) measured at deer locations after 15 August ($P<0.01$). Fresh sign of livestock was noted at 20.5% of deer locations prior to 15 August and 32.1% after 15 August. This difference was significant (X^2=8.428, d.f.=1, $P<0.01$).

Table 5. Distances, in meters, from random locations and deer locations overall, pre and post 15 August, and between years, to the nearest water and livestock in the Bennett Hills, Idaho.

	Random	Overall	Pre 8/15	Post 8/15	1993	1994
Water	426	364	324	398	399	380
Livestock	446	500	561	452	570	382

Concealment and Distance When Flushed

The concealment rating of deer averaged 9.2 (SD=1.2) prior to hunting season and 8.9 (SD=1.7) during hunting season. This was not a significant difference (P=0.30). My distance from deer when they flushed also did not differ significantly before and during hunting season (P=0.75). Prior to hunting season the deer flushing distance averaged 50 m (SD=31 m), and the distance during the season averaged 48 m (SD=30 m).

Deer Bed Shading

At 325 deer bedding locations, the percent of the bed that was shaded was estimated. Shading averaged 81% (SD=19%). The primary source of the shade was also recorded. The 5 most common sources of shade are listed in Table 6. Although all sources listed in the table are living plants, other less common sources included boulders, dead horizontal tree trunks, and topographic irregularities.

Table 6. Sources of mule deer bed shade, the percent of all beds each shaded, and sample sizes in the Bennett Hills, Idaho.

Shade Source	% of Beds	n
Prunus spp.	40	135
Populus tremuloides	23	78
Salix spp.	20	69
Artemesia tridentata	6	21
Amelanchier alnifolia	4	16

Food Habits

Microhistological fecal analysis was conducted on samples collected in August through October of 1993 (Table 7). Most of the plants identified in this procedure were also identified in the field at deer locations (Table 8). When calculating median utilization classes, I omitted category 1 (0-5% utilization) because all medians would have equalled 1 otherwise.

Table 7. Mean percent relative density and standard deviation of discerned fragments from mule deer fecal samples collected in the Bennett Hills, Idaho.

	August		September		October	
Plants	Mean	SD	Mean	SD	Mean	SD
All Grasses	0	0	0	0	0	0
Seeds	6	7.36	1.26	1.74	6.07	5.26
Legume Pod	2.46	4.04	4.07	4.36	9.39	5.6
Lupinus spp.	64.89	10.84	61.01	12.59	5.26	2.38
Potentilla spp.	2.89	0.33	1.89	1.73	2.36	2.17
Solonum spp.	0.65	1.46	0	0	0	0
Artemesia tridentata	0	0	0	0	0.7	1.57
Berberis repens	0	0	2.51	2.56	1.43	1.96
Ceanothus sp.	2.9	2.96	11.05	2.68	22.59	7.07
Purshia tridentata	18.56	4.52	18.21	8.7	52.2	9.25
Symphoricarpos sp.	1.65	1.53	0	0	0	0

Table 8. Frequency of utilization greater than 5% and median utilization class (1=0-5%, 2=>5-20%, 3=>20-40%, 4=>40-60%, 5=>60-80%, 6=>80%) of selected shrubs and forbs noted at 383 deer locations that did not have fresh sign of livestock.

Shrubs	%	M[a]	Forbs	%	M[a]
Acer sp.	75.0	3	Balsamorhiza sp.	14.8	2
Amelanchier alnifolia	4.6	2	Castilleja applegatei	90.9	3
Ceanothus sp.	74.7	2	Crepis spp.	27.7	2
Chrysothamnus nauseosus	10.0	2	Eriogonum spp.	12.7	2
Populus tremuloides[b]	21.0	2	Geranium spp.	8.5	2
Prunus spp.	73.0	2	Helianthella sp.	9.0	2
Purshia tridentata	36.7	2	Lupinus leucophyllus	100.0	3
Ribes spp.	11.2	2	Penstomen spp.	28.3	2
Rosa sp.	36.7	2	Sphaeralcea grossulariifolia	80.0	4
Salix spp.	58.8	2			
Symphoricarpos sp.	11.0	2			

[a]Medians were calculated by omitting category 1 (0-5% utilization).
[b]Only includes plants < 5m in height.

Multivariate Habitat Analysis

Subset analysis of the multiple logistic regression produced all possible models with combinations of the 7 independent variables. The models were ranked from "best" to "worst" based on the Cp value (predictive squared error). The best results for predicting a deer location were derived from a 3 variable model including overhead cover, shrub cover, and lateral cover (Hosmer Lemeshow statistic =4.159, d.f.=5, P=0.53):

$$\Pr(\text{deer}) = \frac{e^{-1.522 + (0.056 * \text{Overhead Cover}) + (0.001 * \text{Shrub Cover}) - (0.013 * \text{Lateral Cover})}}{1 + e^{-1.522 + (0.056 * \text{Overhead Cover}) + (0.001 * \text{Shrub Cover}) - (0.013 * \text{Lateral Cover})}}$$

Overhead Cover and Shrub Cover were positively related to the probability of a point being a deer location and lateral cover was negatively related. The overall prediction success of this model was 39.9%. The best single variable model used only overhead cover (Hosmer Lemeshow statistic =31.96, d.f.=5, P<0.01) and had a prediction success of 37.4%. Stepwise analysis of the same data set yielded the same 3 variable model as the best subset analysis.

Table 9. Independent variables and their summary statistics (Average % cover and standard deviation) chosen for inclusion in the model by both subset and stepwise analysis of the logistic regression for predicting deer (n=489) and random (n=284) locations in the Bennett Hills, Idaho.

	Deer		Random					
Variable	Av	SD	Av	SD	Cp[a]	R^2	F	P
Overhead Cover	50	34	9	21	31.96	0.37	461.41	<0.001
Lateral Cover	29	25	40	25	6.67	0.40	27.17	<0.001
Shrub Cover	32	34	7	17	4.16	0.40	4.51	0.034

[a]Cp=predictive squared error.

DISCUSSION

Home Range

The overall average MCP estimate of summer/fall home range size for female deer in the Bennett Hills of 3.6 km^2 was similar to that of nonmigratory mule deer in southwestern Texas (3.8 km^2; Dickinson and Garner 1979) and eastern Montana (6.3 km^2; Wood et al. 1989), but considerably smaller than the summer/fall means reported in southcentral Washington (26.9 km^2; Eberhardt et al. 1984), westcentral Arizona (32.3 km^2; Hayes and Krausman 1993), and southwestern Arizona (121 km^2; Rautenstrauch and Krausman 1989). If home range size is inversely related to habitat quality as suggested by Bailey (1984), then the Bennett Hills should be excellent habitat for female mule deer.

Average 95% kernel home range size during the hot and dry field season of 1994 was only 57.1% of the average size during the cooler field season of 1993 (53.5% as estimated by the MCP) for deer tracked in both years. This may have been the result of deer concentrating use in more mesic microsites instead of dispersing use over a larger area. Another factor may have been decreased diurnal activity during the hotter year. Hayes and Krausman (1993) reported a decrease in diurnal activity by female mule deer during hot and dry periods that was partially compensated for by increased nocturnal activity; however, 88% of the area used nocturnally fell within areas used during the daytime. I think it was probably a combination of these 2 factors with the former being the primary explanation. If deer decreased diurnal activity, their bedding areas should still have been dispersed over similar sized areas in both years.

Cover Type Use

The Mountain Brush cover type was the most frequently used type on the study area for overall use (48.8%), feeding use (35.4%), and bedding use (52.8%), despite being the third most common cover type at 11.7% of surface area availability. This preference was probably due to a variety of factors, including the suitability of Mountain Brush for food, security and thermal cover. The Mountain Brush cover type was composed primarily of dense Prunus spp. stands in which evidence of deer browsing was usually conspicuous. Other important food shrubs such as Oregon grape, ceanothus, and willow were common in these stands. Although forb growth was generally sparse within the Mountain Brush cover type, the ecotonal fringe area between the Mountain Brush and adjacent sage cover types were often characterized by a relatively high density of forbs.

Deer appeared to feel secure in the Mountain Brush cover type. The flushing distance for bedded deer averaged 45.5 m (SD=26.8 m) in Mountain Brush compared with 67.2 m (SD=40.7 m) in sage habitats. When locating bedded deer in Mountain Brush, I often passed by deer at <20 m without being aware of their presence. Deer often jumped from beds only when I passed by them a second time. Deer bedded in more open cover types rarely behaved in this manner.

Some deer made repeated use of specific beds in Mountain Brush stands despite being displaced by me every 3 to 5 days. Repeated use of the same beds over the years created oval depressions worn into the ground. Often a series of traditional beds would be found around an especially thick clump of brush where deer presumably moved from bed to bed throughout the day to remain shaded. When locations were made at these sites, the deer were almost always in the traditional bed providing maximum shade. Clumps of willow surrounded by Prunus spp. seemed to be especially attractive to deer seeking a bedding site.

Overall, the Mountain Brush cover type provided a cool, secure place for daytime activities. In the hotter, dryer summer of 1994, decreased use of the High Sage cover type compared with the cooler summer of 1993 was noted. Because all locations used for analyses in this study were obtained during daylight hours, I may have underestimated use of habitats used at night and overestimated use of habitats used primarily diurnally, such as Mountain Brush. How much bias using only diurnal locations introduced would be difficult to determine. Hayes and Krausman (1993) reported that general patterns of diel habitat use were accurately represented by daylight observations. Kufeld et al. (1988) observed different habitat selection patterns during different periods of the day, apparently due to different activity patterns between night and day, e.g. increased feeding at night.

The Aspen cover type appeared to be the second most preferred type. Aspen cover types accounted for 27.0% of deer bedding sites. Mountain Brush and Aspen combined accounted for 79.8% of bedding locations despite making up only 14.4% of availabile vegetation. The Aspen cover type was probably preferred for the same reasons discussed for Mountain Brush but to a lesser degree since ground level hiding cover was generally sparser and availability of preferred food shrubs was lower.

Deer used the Aspen cover type in proportion to availability for feeding. Most aspen stands in the Bennett Hills had a park-like structure with dense stands of grass comprising the bulk of the understory. The scarcity of forbs and shrubs probably limited deer feeding activity. As with Mountain Brush, the areas immediately adjacent to aspen stands were often characterized by increased shrub and forb production.

Overall, the Sage/Bitterbrush and Riparian cover types were used in proportion to availability. However, deer did select Sage/Bitterbrush for feeding and Riparian for bedding. I suspect that actual use of Sage/Bitterbrush for feeding was higher than daytime sampling indicated. Deer sign was abundant in this type and frequency and intensity of utilization on bitterbrush was high. Microhistological fecal analysis indicated high relative density of bitterbrush, especially later in the summer and fall (52.20% (SD=9.25%) average in October). For these reasons, I suspect that deer utilized the Sage/Bitterbrush cover type heavily at night.

The use of the Riparian cover type for bedding was highest during the hottest days of August. Although no measurements of temperature were taken, I suspect that the temperature under the tree canopy in the Riparian cover type was the coolest available in the study area. Extremely dense willow brush shaded damp, lush grass kept cool by evaporative cooling. However, increased use of this habitat was not noted during the hotter summer of 1994, so the importance of this habitat during periods of high temperature is not clear. Availability of preferred deer foods in this habitat was generally low.

The Grass, Low Sage, and High Sage cover types were not preferred by mule deer under any conditions. The Grass and Low Sage habitats had very little to offer to deer in terms of food or cover. Few preferred deer forbs grew in the Grass cover type, and the few that did dried out early in the summer due to lack of shade. Most Low Sage was associated with rock and bare soil flats where all vegetation was sparse, and this vegetation dried very early in the summer.

High Sage was by far the most abundant cover type on the area, comprising 46.8% of available vegetation. Deer use of this type was never high, but deer did use it more during the cooler summer of 1993. Production of forbs and shrubs utilized by deer was moderately high, and lateral cover for bedding concealment was also good. Sign found in this cover type indicated that deer used it for feeding at night. The low frequency of daytime use is probably attributable to the presence of Mountain Brush and Aspen cover types in the Bennett Hills. In the absence of these highly preferred cover types, I predict the use of High Sage would greatly increase and/or deer density would be much lower.

Aspect, Topography, and Horizontal Configuration

Overall, mule deer selected for northeastern and eastern aspects and selected against southwestern and flat aspects. During the hot, dry season of 1994, deer shifted some use away from southeastern aspects to northern aspects. Deer were probably using north to east aspects because they were cooler. Availability of north, northeast and east aspects combined was 29.7% and deer use of these aspects was 67.1% overall. The selection of aspect was confounded by the uneven distribution of the Mountain Brush cover type over aspects. Most Mountain Brush cover types (51.4%) were on north to east aspects. However, if deer were selecting areas of use based only on the presence or absence of Mountain Brush then the proportion of aspects used by deer should equal the proportion of aspects occupied by Mountain Brush. However, this was not the case. Within Mountain Brush, deer selected north to east slopes disproportionately (81.9%). They used northeastern aspects significantly more than their frequency of occurrence within Mountain Brush. Although not statistically significant, it appeared that deer may have been avoiding southern aspects within Mountain Brush (availability=17.1%, use=1.6%).

Deer used the mid-slope of hillsides more than any other topographic position. They selected against lower slopes and benches or flats. Ridge tops, upper slopes and stream beds were used in proportion to availability. The majority of Mountain Brush found on the study area was located at mid-slope, which probably explains this selection. Lower slopes were generally dominated by High Sage and benches or flats were primarily covered by Grass and Low Sage habitats, all non-preferred cover types. Deer used upper slopes proportionately more during the cool 1993 field season and mid-slopes more during the hot 1994 field season. One possible explanation for this is that mid-slopes were generally nearer water than upper slopes. A more likely explanation was that mesic mid-slopes remained cooler and supported better forage than the drier upper slopes during the dry year.

Deer selected against convex horizontal configurations because convex sites tended to be dry and unproductive. Explaining the avoidance of undulating sites and the use in proportion to availability of concave sites is more difficult. Logically, deer should have preferred these horizontal configurations due to their more mesic nature. I may have missed nocturnal use of these sites since all locations were diurnal, and/or they may have been avoided for bedding because they did not provide a clear view of approaching danger. Convex sites were used proportionately more in the wet year, and straight and undulating sites were used proportionately more in the dry year. The increased use of concave sites I expected during the dry year was not observed. This may have been an artifact of my sampling schedule or due to the reluctance of deer to bed in sites offering poor visibility.

Elevation and Slope

Although a significant difference between the average elevation of deer and random locations was detected, the absolute difference (16 m) does not have any practical implications. The reason for the observed difference was the higher proportion of random locations on the Camas Creek flats. The deer tended to spend their days on the slope away from the flats. This tendency was also reflected in the relatively low use of bench or flat areas (4.2% of deer locations) compared to their availability (22.4% of random locations).

Deer selected significantly steeper slopes on average than those at random locations. This, too, was at least partially due to the higher proportion of random locations situated on the flats surrounding Camas Creek. Deer seldom used the flats due to a paucity of preferred cover types. Mountain Brush was associated with steeper slopes than most other cover types. Deer apparently selected for Mountain Brush, and steeper slopes were incidentally associated with that cover type, because slope was steeper at deer locations within Mountain Brush than in other cover types. Within Mountain Brush, deer appeared to prefer more level sites than random sampling indicated were available.

Roads, Water and Livestock

No significant relationship was detected between deer and secondary roads. Neither overall average deer distance compared with random distance nor deer distance prior to hunting season compared with deer distance during hunting season varied significantly. Secondary roads were distributed relatively evenly over the study area and hunter access to these was extremely limited due to private land ownership. Distance to primary roads was significantly less for deer locations than for random locations. This was probably an artifact of the location of deer I sampled to the road system in the study area rather than an actual preference for proximity to primary roads. The primary road that was nearest to most points on the study area ran east and west along the northern border of the study area. Most home ranges of radio-collared deer were near the northern edge of a remote area extending approximately 24 km south of this road.

The arrangement of primary roads in the study area was also at least a partial explanation for the greater distance from deer to primary roads measured during hunting season as compared to before hunting season. At about the beginning of hunting season

(October 5) both years, the deer began a gradual movement to the south, towards the winter range and away from the primary road on the north edge of the study area. This movement could be interpreted in 2 ways: 1) deer were moving away from the primary road in response to hunting pressure, or 2) deer were simply beginning their seasonal migration to winter range. I tend to support the latter interpretation because several radio-collared deer initiated southern movements 1 to 9 days prior to the opening of hunting season. The hunting season may have served as a trigger or impetus to the migration.

Deer locations tended to be closer to water than would be expected, based upon random locations. Water was not a particularly scarce resource in the Bennett Hills. Camas Creek, a perennial stream, was located near the northern edge of the study area and most deer had a portion of the creek in their home ranges. Sheep Creek fed Camas from the south and ran yearlong in 1993 but dried up in mid-August of 1994. Stock ponds were distributed throughout the area, and many of them became dry in August of both years.

A disproportionate number of deer locations were nearer stock ponds than natural sources of water. This was probably due to the tendency of the flat and gently sloping areas of the Camas Creek floodplain to support mainly grass and sage communities, creating a corridor 200-800 m wide of unfavorable deer habitat. Stock ponds were more commonly located near Mountain Brush and Aspen cover types. Actual utilization of artificial water sources versus natural water sources cannot be inferred from these data, but it would be logical to assume that use of stock ponds may increase the fitness of deer by reducing exposure and travel in low security cover types. The reduction in availability of water was reflected in the significantly greater average distance after 15 August as compared to before 15 August. This would imply that as water decreased in availability, deer did not alter areas of use to maintain a similar proximity to water. I would not expect this to hold true in areas with extremely scarce water sources.

Overall, average distance to livestock did not vary significantly between deer locations and random locations; however, deer did appear to prefer sites that did not have fresh sign of livestock. There was evidence to suggest that habitat use by deer and cattle overlapped more during dry years and dry seasons than during wetter conditions as suggested by Short (1977). Both the inter-year and the pre and post 15 August comparisons showed a significantly shorter average distance to livestock during the dry year or season. Fresh sign of livestock also significantly increased in frequency at deer locations after 15 August.

The effects of cattle grazing on mule deer in the Bennett Hills could not be quantitatively addressed due to the chaotic distribution of land ownership, cattle, and deer on the study area. The 9 deer studied both years used areas owned by 13 different private landowners in addition to BLM and Forest Service lands. The home range of each deer included portions of land owned by ≥4 different landowners, with each landowner using different stocking rates and turnout dates. This scenario resulted in no opportunity to compare deer habitat use in stocked versus non-stocked pastures, or deer habitat use under varying stocking rates.

Concealment and Flushing Distance

Hunting seasons did not seem to affect either the concealment rating of bedded deer or the distance I was from bedded deer when they flushed. Evidently deer utilized the same combination of hiding and escape strategies throughout the year. However, movements out of the home range area increased during hunting season. Whether this was in response to hunting season or merely coincidental to the fall migration was difficult to determine. I detected no evidence of the radio-collared deer becoming habituated to my approach.

Deer Bed Shading

Sargent et al. (1994) discussed the possible importance of behavioral thermoregulation by mule deer. They reported that deer on their study area in south-central Washington sought out shaded bedding sites that still permitted radiative heat loss. Mule deer in the Bennett Hills behaved similarly. Sources of shade reported for this study generally reflect the dominant plant species associated with various cover types; i.e. the most common source of shade, *Prunus* spp., reflects the most frequently used cover type for bedding, Mountain Brush, and the second most common source of shade, *Populus tremuloides*, reflects the second most used cover type for bedding, which was Aspen.

Willows did not follow this pattern. They provided primary shade at 20% of the deer beds while the Riparian cover type in which they dominated accounted for only

6.3% of deer bedding locations. The explanation lies in the tendency of deer to seek out isolated patches of willows within otherwise homogeneous stands of Prunus spp. in Mountain Brush habitat. The denser, taller foliage of the willow may have provided superior shade and security.

Food Habits

Although the collection period of scats for microhistological fecal analysis was relatively short, the results clearly document the transition period from forbs to shrubs. Lupinus spp. comprised the bulk of the relative density in August (64.89%) and September (61.01%). By October, bitterbrush accounted for 52.20% of the relative density. This collection was made during the cool, wet field season, so I would expect the shift to shrubs to occur earlier in a normal, drier year.

Estimation of plant utilization at deer locations identified several species that were not included in the fecal analysis. Utilization of plants was only calculated at deer locations where no fresh sign of livestock was present to reduce the possibility of confusing utilization by livestock with that of deer. Mackie (1970) identified most of the same foods in central Montana for mule deer that I did in southcentral Idaho.

Multivariate Analysis

The results of the model-building process were informative although not particularly useful. A relatively low predictive success (39.9%) was obtained with the input of 3 labor-intensive variables: overhead cover and lateral cover (measures of structure) and shrub cover (a measure of forage availability). Such site-specific variables could not be acquired from most Geographic Information Systems (GIS) so they would have to be measured in the field. The most important variable in the model, overhead cover, was generally highest in the Riparian, Mountain Brush, and Aspen cover types. These cover types comprised only 16.4% of the study area, yet 78.9% of all deer locations were in one of these types. These cover types could easily be identified by a GIS or by one of several methods of remote imaging. Equipped with only knowledge of deer use of cover types and a GIS, a manager could predict deer locations at least as accurately as the model.

CONCLUSIONS

Mule deer does in the Bennett Hills were able to satisfy their basic needs in a relatively small area indicating that the habitat quality in sites selected by the radio-collared does was quite high. The presence of the Mountain Brush cover type was a major contributor to the high quality of the range, and its quality and quantity may be the key indicator of habitat quality in the high elevation steppe of southcentral Idaho. This cover type should be monitored and maintained at least at current levels. I identified only 2 major threats to this cover type under current land uses: 1) overstocking of cattle could degrade stands, and 2) the tradition of burning large tracts of sage in the fall could reduce acreage and canopy coverage of stands.

The short-term effects of a dry year on mule deer habitat use appeared to be minimal. Deer shifted to cooler cover types and aspects. Overlap with cattle habitat use may also have increased. An extended drought lasting several years or more would probably magnify these effects.

Although the effects of livestock on mule deer could not be quantified in this study, I believe the impact is minimal at current stocking rates. Cattle were only on the study area for approximately the same period of time as deer, June through October. They were moved off the area during winter due to high snow depths. During the summer/fall period, deer and cattle dietary overlap is minimal and forage production is high.

I could detect little or no response of female mule deer to hunting seasons in the Bennett Hills other than increased movement out of established summer/fall home ranges. Hunting pressure is fairly high in this area with 800 to 2000 doe permits issued for Unit 45 in 1993 and 1994. Hunting season, rather than snow depth or temperature, may have triggered the fall migration to winter range. If this is true, early movement due to hunting has the potential to prematurely deplete limited forage on winter range. Based on normal weather patterns, deer could easily remain on the summer range for an additional 3 to 6 weeks in the fall. A trial delay of the hunting season in Unit 45, with continued aerial monitoring of radio-collared deer, may reveal if deer would utilize the extra time on summer/fall range.

Management Implications

1. Mountain Brush and Aspen cover types should be maintained at current levels.
2. Burning of sagebrush tracts which contain significant amounts of bitterbrush should be discouraged.
3. Riparian condition should be monitored and steps taken if degradation is detected.
4. Consider the possible effect of hunting season on the timing of the deer migration.

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APPENDIX

FREQUENCY, MEDIAN AND MEAN COVER CLASS OF VEGETATION IN COVER TYPES

Table 10. Frequency (percent of plots with plant species)/median/mean cover classes (1=0-1%, 2=>1-5%, 3=>5-25%, 4=>25-50%, 5=>50-75%, 6=>75-95%, 7=>95%) of vegetation recorded at deer locations, by cover type, on the Bennett Hills study area, 1993 and 1994.

Species	Grass	Low Sage	High Sage	Sage/Bitter.	MtnBrush	Riparian	Aspen
N =	2	18	60	31	246	28	127
Trees							
Populus tremuloides (<5m)	....	....	5/2/2.3	6/1/1.5	48/2/2.4	7/3/3.0	71/2/2.6
Populus tremuloides (>5m)	....	....	3/2/2.5	....	17/2/2.4	11/4/4.3	95/4/4.4
Salix spp.	....	....	....	....	22/4/3.9	96/5/5.3	11/3/3.0
Shrubs							
Acer sp.	....	....	....	....	1/2/2.7	....	2/3/3.0
Amelanchier alnifolia	....	28/1/1.6	55/2/1.8	48/2/1.8	41/2/2.4	4/1/1.0	43/2/2.3
Artemisia arbuscula	....	....	....	3/3/3.0	....	....	....
Artemisia cana	....	....	2/1/1.0	....	....	....	....
Artemisia longiloba	....	11/3/3.0	....	3/3/3.0	....	....	....
Artemisia ludoviciana	....	6/1/1.0	....	....	....	....	....
Artemisia tridentata	50/2/2.0	100/4/3.9	98/5/4.8	100/4/4.3	25/2/2.0	4/4/4.0	24/2/2.0
Berberis repens	50/1/1.0	28/1/1.8	18/1/1.5	3/2/2.0	76/2/2.3	....	28/2/1.9
Ceanothus sp.	50/1/1.0	6/2/2.0	8/3/2.8	....	43/3/3.0	....	2/1/1.5
Chrysothamnus nauseosus	50/1/1.0	28/2/2.2	22/2/2.4	42/3/2.5	6/2/1.6	4/3/3.0	....
Chrysothamnus viscidiflorus	100/3/3.0	83/2/2.4	88/2/2.4	71/2/2.3	10/2/1.7	....	19/2/1.8
Prunus spp.	50/2/2.0	28/2/2.2	20/2/1.7	42/1/1.6	98/5/4.5	....	48/3/2.9
Purshia tridentata	....	44/2/1.8	22/2/1.8	100/3/3.1	3/2/1.9	4/3/3.0	1/2/2.0
Ribes spp.	50/1/1.0	44/2/2.3	40/2/2.0	23/2/1.9	22/2/2.1	21/1/1.2	51/2/2.3
Rosa sp.	....	11/1/1.5	5/1/1.3	13/1/2.0	14/1/1.3	50/2/1.8	17/2/1.6
Symphoricarpos sp.	50/2/2.0	44/2/2.6	70/2/2.3	48/2/2.1	91/3/2.6	25/2/2.4	95/3/2.8
Tetradymia canescens	50/2/2.0	6/2/2.0	17/2/1.8	32/2/1.6	1/1/1.0	....	1/1/1.0
Forbs							
Achillea millefolium	50/2/2.0	33/1/1.3	43/2/1.6	45/2/1.8	8/1/1.3	18/3/2.8	30/2/1.7
Agastache sp.	....	6/2/2.0	10/1/1.5	13/1/1.5	54/2/1.7	....	65/2/2.0

Table 10. Continued.

Species	Grass	Low Sage	High Sage	Sage/Bitter.	MtnBrush	Riparian	Aspen
Allium spp.	....	6/2/2.0	....	10/2/1.7	....	....	....
Astragalus filipes	....	33/3/2.8	7/3/2.8	....	1/2/2.0	....	....
Balsamorhiza sagittata	100/2/2.0	67/3/2.7	35/2/1.8	45/2/2.1	3/1/1.4	4/2/2.0	8/1/1.3
Calochortus sp.	....	6/2/2.0	8/1/1.2	....	1/1/1.0	....	4/1/1.0
Castilleja applegatei	....	6/1/1	2/1/1.0	6/1/1.5	2/1/1.3	....	4/2/1.6
Castilleja sp. (other)	....	28/2/2.0	7/2/1.8	10/2/2.0	....	....	....
Cirsium spp.	50/1/1.0	6/1/1.0	22/1/1.1	13/1/1.3	12/1/1.0	25/1/1.0	10/1/1.0
Crepis spp.	....	6/1/1.0	17/1/1.4	6/1/1.5	....	....	6/1/1.6
Cryptantha sp.	....	28/2/2.4	7/2/2.0	13/2/2.5	2/2/2.5	....	2/2/2.5
Eqisetum sp.	....	....	....	....	....	....	....
Eriogonum spp.	....	61/3/2.5	75/2/2.4	39/2/2.4	2/2/1.8	4/3/3.0	6/2/1.6
Geranium sp.	....	6/1/1.0	17/1/1.0	10/1/1.0	2/1/1.0	....	20/1/1.5
Helianthella sp.	....	....	2/2/2.0	3/2/2.0	4/2/2.0	....	1/2/2.0
Lithosperma sp.	50/1/1.0	17/1/1.3	32/1/1.2	26/1/1.1	12/1/1.2	....	9/1/1.2
Lupinus leucophyllus	50/3/3.0	....	5/2/1.7	....	....	....	....
Lupinus spp. (other)	....	56/2/2.4	70/2/2.5	42/2/1.9	2/1/1.8	....	13/2/2.0
Mentha sp.	....	....	....	....	....	50/2/2.1	2/2/2.0
Penstomen spp.	....	22/1/1.5	10/1/1.0	10/1/1.0	11/1/1.4	7/1/1.0	30/1/1.4
Potentilla spp.	....	....	2/1/1.0	....	2/1/1.0	11/2/1.7	5/1/1.5
Solidago spp.	50/1/1.0	....	3/1/1.5	....	9/2/1.8	....	9/2/2.4
Sphaeralcea grossulariifolia	....	....	3/1/1.0	....	4/1/1.1	....	3/1/1.0
Tregopodon spp.	....	....	3/1/1.0	....	....	....	3/1/1.0
Urtica sp.	....	....	2/2/2.0	....	1/1/1.0	18/2/1.6	2/2/2.0
Wyethia sp.	....	....	2/1/1.0	....	1/3/2.7	....	....

Table 11. Frequency (percent of plots with species)/median/mean of cover classes (1=0-1%, 2=>1-5%, 3=>5-25%, 4=>25-50%, 5=>50-75%, 6=>75-95%, 7=>95%) of vegetation, by cover type, as recorded at random locations in the Bennett Hills, Idaho, 1993 and 1994.

Species	Grass	Low Sage	High Sage	Sage/Bitter.	MtnBrush	Riparian	Aspen
N =	30	55	140	25	35	6	8
Trees							
Populus tremuloides (<5m)	....	....	3/3/2.5	4/3/3.0	37/3/2.8	17/2/2.0	75/3/3.2
Populus tremuloides (>5m)	....	....	1/2/2.5	4/3/3.0	9/1/1.7	33/3/3.0	88/4/4.0
Salix spp.	3/2/2.0	....	1/2/2.5	....	17/3/3.3	100/4/4.2	25/3/3.5
Shrubs							
Acer sp.	....	2/3/3.0	....	....	....	17/1/1.0	13/1/1.0
Amelanchier alnifolia	7/1/1.5	22/1/1.5	36/1/1.5	52/2/1.9	77/2/2.1	33/2/2.5	50/2/2.5
Artemisia arbuscula	....	2/2/2.0	....	....	....	....	13/2/2.0
Artemisia cana	....	2/1/1.0	....	....	....	....	....
Artemisia longiloba	7/1/1.0	35/3/2.7	....	12/3/3.0	....	17/1/1.0	13/1/1.0
Artemisia ludoviciana	3/3/3.0	....	....	....	3/3/3.0	....	....
Artemisia tridentata	50/2/2.1	76/4/3.5	100/4/4.4	100/4/4.0	66/3/3.3	50/3/3.0	63/3/3.0
Berberis repens	3/3/3.0	2/2/2.0	9/2/1.8	4/2/2.0	66/2/2.2	....	25/2/2.5
Ceanothus sp.	....	....	4/2/2.2	8/1/1.5	49/3/2.6	....	25/2/2.5
Chrysothamnus nauseosus	7/2/2.5	16/2/1.6	16/2/2.1	36/2/1.9	23/2/1.8	....	25/1/1.5
Chrysothamnus viscidiflorus	33/2/1.8	49/2/2.1	71/2/1.8	60/1/1.5	54/2/1.9	33/1/1.5	38/2/1.7
Prunus spp.	3/3/3.0	5/1/1.3	16/2/1.8	16/1/1.8	91/3/3.6	17/2/2.0	63/3/2.8
Purshia tridentata	10/2/1.7	18/2/1.7	29/2/1.6	100/3/2.9	49/2/2.0	....	13/1/1.0
Ribes spp.	7/1/1.0	2/1/1.0	24/2/1.8	8/2/2.0	29/2/1.8	50/2/2.3	38/2/2.0
Rosa sp.	3/1/1.0	2/1/1.0	16/1/1.1	8/1/1.0	37/2/1.7	83/2/2.0	38/2/1.7
Symphoricarpos sp.	7/3/3.0	13/1/1.4	50/2/1.8	36/2/2.6	97/2/2.2	50/3/2.7	100/3/2.8
Tetradymia canescens	7/1/1.5	2/2/2.0	9/1/1.3	12/1/1.3	20/2/1.9	....	....
Forbs							
Achillea millefolium	37/1/1.8	27/2/1.9	41/1/1.3	12/2/1.7	40/1/1.2	67/2/2.0	38/1/1.3
Agastache sp.	....	2/2/2.0	6/1/1.5	....	31/2/1.8	33/2/2.0	63/2/2.2

Table 11. Continued.

Species	Grass	Low Sage	High Sage	Sage/Bitter.	MtnBrush	Riparian	Aspen
Allium spp.	3/2/2.0	2/1/1.0	....	28/2/1.7	....	....	....
Astragalus filipes	3/4/4.0	4/1/2.0	14/2/2.1	8/1/1.0	....	....	....
Balsamorhiza sagittata	13/2/2.0	22/2/2.3	39/2/1.8	48/2/1.8	40/2/1.6	33/2/2.0	25/2/2.0
Calochortus sp.	10/1/1.7	11/1/1.3	4/1/1.2	....	....	....	....
Castilleja applegatei	....	....	2/1/1.3	....	9/1/1.3	....	....
Castilleja sp. (other)	7/1/1.0	27/2/1.7	11/1/1.3	4/1/1.0	3/1/1.0	....	13/2/2.0
Cirsium spp.	17/1/1.2	20/1/1.0	14/1/1.0	12/1/1.0	40/1/1.0	....	13/1/1.0
Crepis spp.	3/1/1.0	11/1/1.5	10/1/1.0	4/1/1.0	3/1/1.0	17/1/1.0	....
Cryptantha sp.	7/2/2.5	9/2/2.2	....	....	....	17/2/2.0	....
Eqisetum sp.	....	2/1/1.0	....	....	....	....	....
Eriogonum spp.	37/2/2.0	65/2/2.1	67/1/1.5	60/2/1.6	43/1/1.2	17/1/1.0	25/1/1.5
Geranium sp.	7/1/1.0	4/2/2.5	26/1/1.1	4/1/1.0	23/1/1.1	33/1/1.0	25/1/1.0
Helianthella sp.	....	....	5/1/1.6	12/2/1.7	26/2/1.8	....	....
Lithosperma sp.	3/1/1.0	11/1/1.2	30/1/1.2	16/1/1.3	43/2/1.7	33/1/1.0	13/1/1.0
Lupinus leucophyllus	3/2/2.0	....	6/1/1.4	8/1/1.0	3/1/1.0	....	....
Lupinus spp. (other)	40/2/2.1	55/2/2.3	62/2/1.9	40/2/1.7	23/1/1.0	33/1/1.5	25/1/1.0
Mentha sp.	....	....	....	....	....	33/2/2.0	....
Penstomen spp.	3/1/1.0	9/1/1.2	16/1/1.1	8/1/1.5	11/1/1.5	....	38/2/2.3
Potentilla spp.	3/1/1.0	....	6/1/1.3	....	20/1/1.3	33/1/1.5	....
Solidago spp.	....	....	2/1/1.6	....	9/2/1.7	17/3/3.0	25/3/3.0
Sphaeralcea grossulariifolia	....	....	1/1/1.0	....	17/1/1.0	17/1/1.0	13/1/1.0
Tregopodon spp.	....	5/1/1.0	2/1/1.0	....	3/1/1.0	....	....
Urtica sp.	....	....	....	....	....	....	....
Wyethia sp.	13/3/2.8	2/3/3.0	1/1/1.0	8/1/1.0	....	....	....