Movements and habitat use of bighorn sheep along the upper Yellowstone River Valley, Montana

by Kristin Louise Legg

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 upper Yellowstone River Valley has provided winter range for Rocky Mountain bighorn sheep for thousands of years. Some sheep populations declined during the 1980's, but others may have recolonized new ranges. The Montana Department of Fish, Wildlife, and Parks, the National Park Service and the US Forest Service all share in the responsibility for management of these sheep and their habitat. I conducted a study during 1994 and 1995 to gather more information on bighorn movements and habitat use in the Tom Miner Basin and Point of Rocks winter ranges. The Tom Miner Basin population has been decreasing over the past 20 years and little data were available on the Point of Rocks population. The objectives were to: (1) determine the seasonal range use patterns for sheep that utilize the Tom Miner Basin and Point of Rocks summer ranges; (2) compare the relative intensity of ungulate use, vegetation coverage, and plant species composition in areas occupied by sheep in 1975 with the same sites in 1994-1995; and (3) assess current cattle and elk distribution and use on bighorn winter ranges in the Tom Miner Basin. From March 1995 - September 1996, 10 radio-collared ewes were tracked from the Tom Miner and Point of Rocks winter ranges. The ewes in Tom Miner Basin used traditional migration patterns and summer ranges. The Point of Rocks ewes utilized summer range in Hyalite Basin and the Cinnabar winter range during the rut. I used pellet and grazing transects to assess summer and fall habitat utilization by elk and cattle on sheep winter range. From 1975 to 1995 elk use increased, sheep use decreased, and cattle use remained the same. Univariate chi-squared analysis and classification and regression tree analysis were used to determine bighorn habitat selection based on elevation, slope, aspect, closeness to escape terrain, grass cover, and the number of elk or cattle pellets. These analyses indicated that escape terrain was significant to bighorn habitat selection. Other habitat characteristics important to sheep habitat selection were elevation, slope, and the mean number of elk pellets. Cattle did not affect bighorn habitat selection since most cattle pellets occurred away from escape terrain. Elk may have some indirect influence on bighorns, but the influence was undetectable in this study. Vegetation condition and trend had not changed since 1975 and the vegetation quality did not vary due to the amount of ungulate use on the range. Vegetation utilization was high (30%) in areas with high cattle pellet densities, but utilization was low (<20%) in areas with high densities of bighorn and elk pellets. Vegetation condition and availability do not seem to be affecting bighorn habitat use in the Basin. I assessed other possible factors that may be limiting the Tom Miner Basin bighorn population. These factors were human disturbance (recreational and hunting), mountain goats, predation, weather, disease, inbreeding suppression, and intraspecific competition. Cursory analysis of data showed that human disturbance, mountain goats, disease, inbreeding suppression, and intraspecific competition were not important in limiting the bighorn population. Predation and weather were the two factors that I was unable to assess.

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Master of Science
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Fish and Wildlife Management

MONTANA STATE UNIVERSITY-BOZEMAN
Bozeman, Montana

December 1996

APPROVAL

of a thesis submitted by

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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.

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Date 11/27/96

AKNOWLEDGEMENTS

I appreciate the guidance and time contributed by the following people during my study: Dr Lynn R. Irby, Montana State University, who directed the study from start to finish; my graduate committee, Drs. Harold Picton, Jay Rotella, and Tom McMahon; Dr. Steve Cherry, Montana State University, for his statistical help; Dan Tyers, USFS, for finding the 1975 research project, his efforts to secure funding, donating volunteers and equipment, and always willing to listen; Dr. Peter Gogan, Biological Resources Division, for advice and contributions to funding; Tom Lemke, MDFWP, for advice and spending time in the field with me; Kevin Frey, MDFWP, who assisted in the preparation of radio-collars; Roger Stradley, Gallatin Flying Service, and Bill Chapman, Sagebrush Aero Flying Service, for their knowledge and talents; the Helicopter Wildlife Management Team, for capturing and collaring the ewes; Aarron Tewell, Hopi Hoekstra and the many other die-hard volunteers; and Tom Olliff, Yellowstone National Park, who helped get me started on this whole adventure. I would especially like to thank the landowners and ranch managers from the B-Bar Ranch (Tom Miner Basin), Point of Rocks (west side of the Yellowstone River), and Horse Creek Outfitters (Tom Miner Basin). Without access across their land, this project could not have been completed. This study was funded and supported by the Rob and Bessie Welder Wildlife Foundation, the Foundation for North American Sheep (95-25), the Biological Research Division, the Montana Department Fish Wildlife and Parks, the Gardiner Forest Service District, and the National Park Service. I thank all my friends, fellow graduate students, and family for their unending support. I greatly appreciate David Thoma's belief in me and companionship throughout this study.

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ABSTRACT

The upper Yellowstone River Valley has provided winter range for Rocky Mountain bighorn sheep for thousands of years. Some sheep populations declined during the 1980's, but others may have recolonized new ranges. The Montana Department of Fish, Wildlife, and Parks, the National Park Service and the US Forest Service all share in the responsibility for management of these sheep and their habitat. I conducted a study during 1994 and 1995 to gather more information on bighorn movements and habitat use in the Tom Miner Basin and Point of Rocks winter ranges. The Tom Miner Basin population has been decreasing over the past 20 years and little data were available on the Point of Rocks population. The objectives were to: (1) determine the seasonal range use patterns for sheep that utilize the Tom Miner Basin and Point of Rocks summer ranges; (2) compare the relative intensity of ungulate use, vegetation coverage, and plant species composition in areas occupied by sheep in 1975 with the same sites in 1994-1995; and (3) assess current cattle and elk distribution and use on bighorn winter ranges in the Tom Miner Basin. From March 1995 - September 1996, 10 radio-collared ewes were tracked from the Tom Miner and Point of Rocks winter ranges. The ewes in Tom Miner Basin used traditional migration patterns and summer ranges. The Point of Rocks ewes utilized summer range in Hyalite Basin and the Cinnabar winter range during the rut. I used pellet and grazing transects to assess summer and fall habitat utilization by elk and cattle on sheep winter range. From 1975 to 1995 elk use increased, sheep use decreased, and cattle use remained the same. Univariate chi-squared analysis and classification and regression tree analysis were used to determine bighorn habitat selection based on elevation, slope, aspect, closeness to escape terrain, grass cover, and the number of elk or cattle pellets. These analyses indicated that escape terrain was significant to bighorn habitat selection. Other habitat characteristics important to sheep habitat selection were elevation, slope, and the mean number of elk pellets. Cattle did not affect bighorn habitat selection since most cattle pellets occurred away from escape terrain. Elk may have some indirect influence on bighorns, but the influence was undetectable in this study. Vegetation condition and trend had not changed since 1975 and the vegetation quality did not vary due to the amount of ungulate use on the range. Vegetation utilization was high (30%) in areas with high cattle pellet densities, but utilization was low (<20%) in areas with high densities of bighorn and elk pellets. Vegetation condition and availability do not seem to be affecting bighorn habitat use in the Basin. I assessed other possible factors that may be limiting the Tom Miner Basin bighorn population. These factors were human disturbance (recreational and hunting), mountain goats, predation, weather, disease, inbreeding suppression, and intraspecific competition. Cursory analysis of data showed that human disturbance, mountain goats, disease, inbreeding suppression, and intraspecific competition were not important in limiting the bighorn population. Predation and weather were the two factors that I was unable to assess.

INTRODUCTION

Rocky Mountain bighorn sheep were once abundant throughout the Rocky Mountains of North America (Couey 1950, Buechner 1960). In the late 1800's, bighorn populations declined due to competition with livestock, introduction of livestock diseases, hunting pressures, and development (Buechner 1960, Keating 1982). Bighorn populations increased once hunting regulations, management areas, and relocation practices were established to protect the sheep, although bighorns did not recolonize all areas occupied prior to European settlement (Buechner 1960, Geist 1971, FWS 1993).

Bighorn sheep populations in the upper Yellowstone River Valley, Montana, were not exempt from these declines. Hunting regulations and changes in land use allowed populations to increase, and sheep colonized historic range through the 1970s (Buechner 1960, Keating 1982). Although some of the populations gained were lost in the 1980s from a Chlamydia outbreak (Meagher 1982, Meagher et al. 1992) and possibly other factors (Legg et al., in press), some herds in the area evidently colonized new ranges or shifted seasonal ranges during the same period (L. Irby, Montana State University, pers. comm.).

The Montana Department of Fish, Wildlife, and Parks(MDFWP), National Park Service (NPS), Biological Resources Division (BRD), United States Forest Service (USFS), and the Northern Yellowstone Cooperative Wildlife Working Group (NYCWWG) share responsibility for the conservation and management of bighorn sheep and their habitats in the upper Yellowstone River Valley. These agencies expressed an interest in gathering more information on bighorn sheep from 2 of 4 winter ranges, Tom Miner Basin and Point of Rocks. The Tom Miner Basin bighorn population has slowly decreased over the past 20 years from unknown causes and few data were available on the Point of Rocks population. The agencies were particularly interested in obtaining data on summer distribution, migration corridors, and factors that regulate population growth for these two subpopulations.

Therefore, I monitored by following habitat use and movements of ewes associated with the Tom Miner Basin and Point of Rocks winter ranges. Also, collected on bighorn sheep from the 1970's to the mid 1980's (Grunnigen 1976, Keating 1982, Irby et al. 1986, Gehman 1985, Irby et al. 1989) were used to assess trends in ungulate populations and vegetation that occurred over the past 2 decades.

The specific study objectives were to:

1. Determine the seasonal range use patterns for sheep that utilize the Tom Miner Basin and Point of Rocks winter ranges with emphasis on changes in distribution that have occurred in the last decade in the Tom Miner Basin and describe the movements of the Point of Rocks herd.

2. Compare the relative intensity of ungulate use, vegetation coverage, and plant species composition in areas occupied by sheep in 1975 with the same sites in 1994-1995.

3. Assess current cattle and elk distribution and use on bighorn winter ranges in the Tom Miner Basin.

During the study, I was able to test the following null hypotheses:

H_1: Bighorn distribution has not changed in the Tom Miner Basin in the past decade.

H_2: Bighorns at Point of Rocks migrate to the Tom Miner Basin summer ranges.

H_3: Ungulate use has not changed in the Tom Miner Basin since 1975.

H_4: Vegetation and soil condition and trend on sites used by bighorns in the Tom Miner Basin have not changed since 1975.

STUDY AREA

The upper Yellowstone River Valley in Montana includes 4 major bighorn winter ranges adjacent to the northern boundary of YNP; the Everts winter range (EWR), the Cinnabar winter range (CWR), the Tom Miner Basin winter range (TMWR), and the Point of Rocks winter range (PRWR) (Fig. 1). This study focused on the TMWR and the PRWR. The TMWR is located 26 km northwest of Gardiner, Montana in the Gallatin Mountains of southwestern Montana. The TMWR borders the northwest corner of Yellowstone National Park (YNP) and the PRWR is 8 km northeast of the Tom Miner Basin along the Yellowstone River.

Elevations range from 1500 m to over 3000 m in the Tom Miner Basin. The TMWR is composed of several small (1 - 5 km^2) bighorn wintering areas scattered over 150 km^2. Wintering sites are typically on grass-covered southwest-facing slopes between 1800 m and 2500 m and within 100 m of escape terrain. These small wintering areas include whitebark pine (<u>Pinus albicus</u>)-subalpine fir (<u>Abies spp.</u>), bunchgrass, and subalpine vegetation types (Grunnigen 1976). Dominant land form features in the Tom Miner Basin include Sheep Mountain, Fortress Mountain, Bighorn Peak, Ramshorn Peak, and Tom Miner Creek (Fig. 2). Most ridges are oriented from northwest to southeast. The PRWR and other winter ranges along the Yellowstone River are at lower elevations (1500 - 2000 m), drier, and in grass or sage-steppe communities. Summer ranges for all herds are ridge tops and alpine meadows greater than 2000 m in elevation.

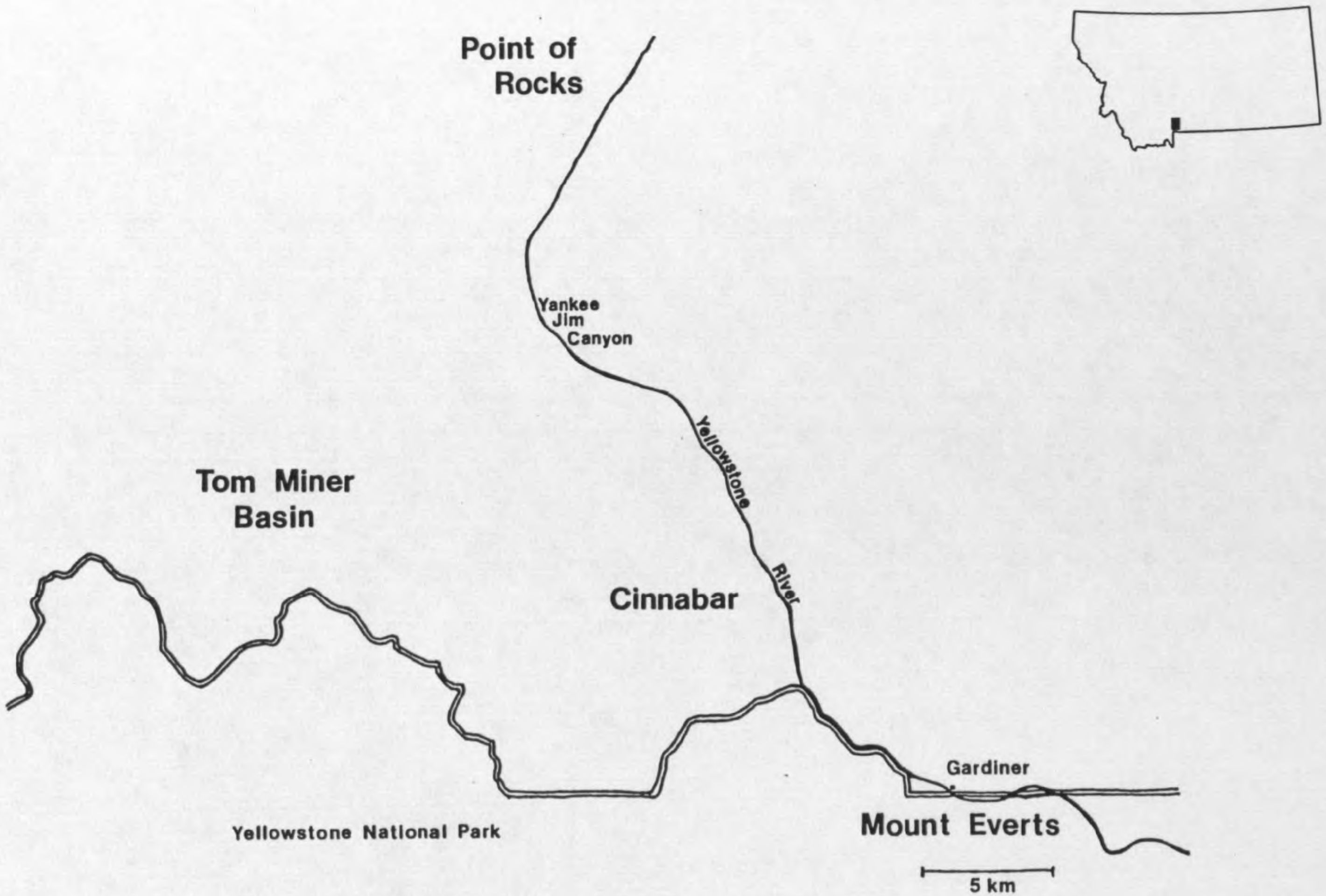

Figure 1. The locations of the Tom Miner Basin, Point of Rocks, Cinnabar and Mount Everts winter ranges in the upper Yellowstone River Valley.

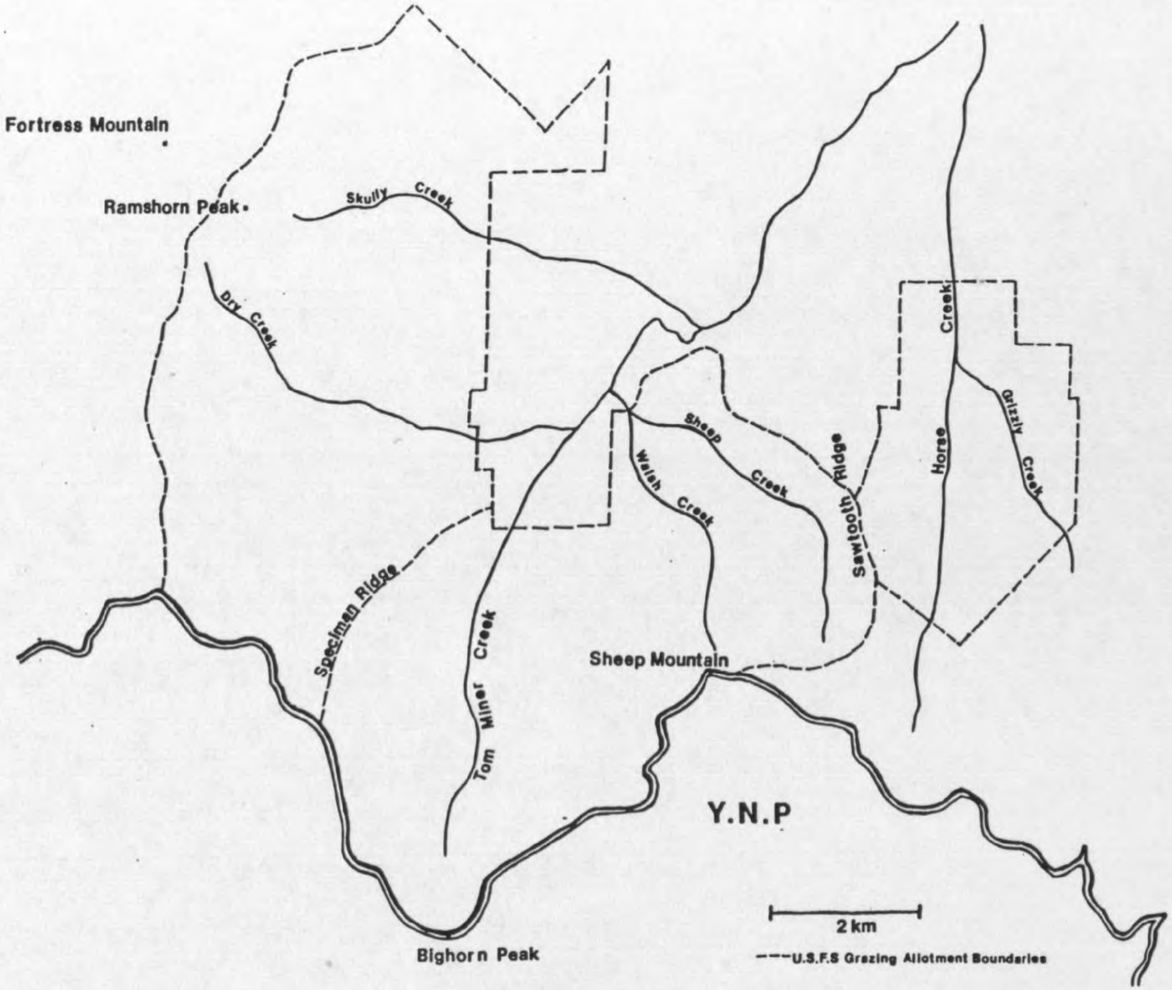

Figure 2. Detailed map of Tom Miner Basin with features mentioned in the text.

The climate of the Gallatin Mountains is cool continental with heavy snowfall beginning in November and snow cover remaining until late May. Summers are short and mild (Chester 1976). Monthly temperature means, minimum and maximum temperatures, and monthly precipitation for January 1994 through April 1996 are listed in Appendix, Table 7. The 2 years of the study had average temperatures and percipitation (NOAA 1995).

Land ownership in the study area is a mix of private, state, and federal (YNP and Gallatin National Forest [GNF]) lands. County roads cross or are adjacent to both winter ranges, but the PRWR is more easily accessible by vehicle in winter than the TMWR. Seventy percent of the wintering areas used by sheep in the TMWR are publicly owned. All of the PRWR is privately owned.

Livestock grazing and hunting are the primary landuses on both winter ranges. The USFS leases Gardiner National Forest land for cattle grazing from late June through October. Grazing leases are mostly in mountain meadows from 1800 - 2500 m and overlap some bighorn winter ranges. The USFS rotates the duration and timing of use for each allotment to vary the distribution of cattle use in Tom Miner Basin each year. Cattle and horses are grazed on the PRWR year round. Hunting pressure directed toward sheep is higher on the TMWR than the PRWR. Recreational use not directly associated with sheep (elk and deer hunting, hiking, horse packing, wildlife viewing) is higher on the TMWR than the PRWR in summer and fall but both areas experience low to moderate use in winter and spring.

Other large mammals in the study area include elk (Cervus canadensis), whitetailed deer (Odocoileus virginianus), mule deer (O. hemionus), mountain goats (Oreamnus americanus), moose (Alces alces), grizzly bears (Ursus arctos), black bears (Ursus americana), coyotes (Canis latrans), timber wolves (C. lupus), and mountain lions (Felis concolor).

METHODS

Seasonal Range Use Patterns

In March 1995, 7 ewes from the PRWR and 3 ewes from the TMWR were fitted with color-coded radio-collars. Sheep were captured by helicopter net-gun (Barrett et al. 1982, Andryk et al. 1983). The ewes were ear-tagged with numbered metal tags, and aged. Blood and throat cultures were taken from each ewe and sent to the MDFWP for analysis.

The ewes were located from the ground or air (Piper Supercub) at weekly intervals during fall and spring migrations and biweekly intervals while sheep were on summer and winter ranges. I made weekly and biweekly flights from May - December 1995 and 4 times from May - September in 1996. Ground observations were made from April - December 1995. The sex, age class, and group size of marked and unmarked bighorns were documented during flights and ground observations. To assess changes in distribution, observations of bighorns during the 1994/95 field study were compared with historic sheep locations over the past decade (Constan 1975, Keating 1982, Gehman 1985, Irby et al. 1986 and 1989).

Population Status

During 1994 and 1995, bighorn counts from observations during the study, the MDFWP survey, and the Annual Cooperative Bighorn Sheep Count were used to estimate the minimum bighorn sheep population sizes for the upper Yellowstone River Valley winter ranges. The MDFWP survey is a helicopter survey completed annually in the spring since 1991 (Lemke, unpubl. in MDFWP, ann. rep., Helena). The Annual Cooperative Count is a winter ground count conducted since 1979 by the NPS, USFS, and MDFWP (Caslick 1993). Counts in 1994 and 1995 were compared with past surveys (MDFWP; Meagher, unpubl; GNF files; Keating 1982; Irby, unpubl.) in the past decade to obtain trends in sheep populations from winter ranges in the upper Yellowstone River Valley.

Ungulate Use Patterns in the Tom Miner Basin

Use Patterns: 1975 versus 1994-1995

I used pellet group counts in 1994 and 1995 since this method was used in 1975 and comparisons could be made between years. Pellet group counts are an economical method to assess wild ungulate habitat use (Irby 1981). Problems with this method include biases with the size of plots used (the larger the plot the more pellets missed) and observer error (missed groups, differences between observers determining ungulate species and age of pellets) (Neff 1968).

Fecal pellet counts were made in 1994 and 1995 for comparison with counts completed in 1975 by USFS personnel (Grunnigen 1976) to determine if ungulate use had changed on the TMWR over the past 20 years. In 1975, USFS personnel completed 39 fecal pellet group transects from July through August. These transects were randomly placed in areas of potentially high sheep use and ran perpendicular to the contours of open slopes on the southwest side of the Tom Miner Basin (Grunnigen 1976). Transect locations were marked on aerial photos. I relocated these sites and set up comparable transects in 1994 and 1995. Although I followed sampling techniques employed in 1975 to insure compatibility with 1994 and 1995 ungulate fecal counts, I made some modifications. In 1975, Grunnigen counted only new pellet groups from bighorn sheep, elk, cattle, and other ungulates in each transect. In 1994 and 1995, I counted old and new pellet groups. Pellet group age was distinguished by the color, sheen, and texture of pellets (Grunnigen 1976). To avoid confusion of old from new pellets, I did not measure transects on rainy days. Grunnigen's transects consisted of 10 81-m^2 circles. The 1994 and 1995 transects included 10 161-m^2 circles. The potential for missing pellet groups in large plots (Neff 1968) was minimized by breaking the plots into smaller increments within each circle. Each plot was divided into 4 concentric circular belts with radii of 1.83 m, 3.66 m, 5.49 m, and 7.16 m respectively. Counts within the 4 circular belts were totaled for a whole plot count. To compare with Grunnigen's 1975 data, only the new pellet group counts from the 3 inner increments (95 m^2) were used. Pellet group counts for each ungulate species were converted to pellet groups per hectare (PGH) by dividing total pellet groups counted in the 10 plots by the total hectares (0.08) covered in the transect.

I assessed the differences in pellet density for the Tom Miner Basin using paired t-tests (Iman 1994) in the MSUSTAT package (Lund 1993). Comparisons included bighorn, elk, and cattle for 1975 versus 1994, 1975 versus 1994, and 1994 versus 1995. Significance levels for a two-tailed test statistic were set at $p < 0.05$ (Type I error level).

Use Patterns in 1994 - 1995

In 1994 and 1995, additional pellet group transects were completed throughout the Tom Miner Basin as an index to ungulate use and distribution on bighorn winter range during the summer and fall. The transects were selected to cover areas with different cattle grazing pressure and areas that appeared adequate for sheep. Total new pellet groups from the 161-m^2 circles were used for analysis. Slope angle (% slope), distance to escape terrain (< 100 m or > 100 m), grass cover density (ground visible or ground not visible), elevation, and aspect were measured for each transect. This analysis included transects used in comparisons with Grunnigen's (1976) data. Transects were completed every 73 m in elevation from the bottom to top of a sample unit to determine if ungulate use differed with elevation. The number of transects per unit varied from 2 to 4. Some units were measured 3 times in the summer and fall field season, the first prior to cattle grazing, the second following cattle grazing, and the third before snow fall and the number repeated was limited due to time constraints. The results from the 3 transects were averaged to obtain the mean pellet groups per location for the summer and fall seasons.

Chi-square analysis (Neu et al. 1974) was used to measure habitat availability versus bighorn habitat use for individual independent variables and as an aid in interpreting the regression and classification trees used in the multivariate analysis. Habitat characteristics identified as independent variables in univariate and multivariate tests included elevation (categorized in 305-m intervals), aspect (2 categories - cool, wet slopes [NE, N, E,] and dry warm slopes [S, SE, SW, W, NW]), slope (categorized in 10% intervals), distance to escape terrain (< 100 m, > 100 m), grass cover density (ground visible or ground not visible), elk pellet density and cattle pellet density.

Multivariate analysis was used to identify if bighorns were selecting for a particular habitat characteristic over other habitat characteristics. Classification and regression trees were used in multivariate analysis of the distribution of bighorns with the above habitat characteristics. Classification and regression trees are similar to the approach used to create dichotomous botany keys and have been used extensively in the medical field (Ripley 1996) and in raptor studies (Grubb and King 1991). Tree analysis can be considered a nonparametric alternative to linear or linear logistic and additive or additive logistic models for identifying structure in complex multivariate data (Clark and Pregibon 1992, Steinberg and Colla 1995). Classification trees are used with categorical data, and regression trees are used with continuous data (Steinberg and Colla 1995). The computer program S was used to analyze the ungulate use data I collected on the TMWR. Methods for this analysis are described in Statistical Models in S (Clark and Pregibon 1992). The level of significance for all statistical test was set at $p < 0.05$.

Vegetation Trend, Condition, and Use on the TMWR

Vegetation Trends between 1975 and 1994-1995

Four vegetation condition and trend transects completed in 1975 were repeated in 1994 and 1995 to assess changes in vegetation in the Tom Miner Basin over the past 20 years. Grunnigen (1976) used pace-line transects (USFS 1977). He placed the transects in areas that "appeared typical of the unit as a whole." The transects were 50 paces in length and paralleled the ridge line. The dominant ground cover type in a 2-cm diameter circle was recorded at each pace. Ground cover types included bare soil, erosion pavement, rock, litter, moss, and individual plant species that were placed in 3 desirability classes (desirable, intermediate, or least desirable) (Grunnigen 1976). Each transect was rated for soil and vegetation condition, and trend was estimated using methods described by the USFS (1977). These same methods were used in the 1994 and 1995 field seasons. I added additional transects in 1994 and 1995 to cover areas not included in Grunnigen's survey.

Vegetation Use in 1994-1995

Grazing transects were completed with each pellet transect to assess range utilization. Transects followed the USFS method of measuring range utilization (USFS 1977). Each grazing transect consisted of 4 100-pace lines with 50 sampling points at 2-pace intervals. A sampling point was considered grazed if 5% or more of the vegetation in a 133-cm^2 diameter loop was grazed. Percent utilization for each line was obtained by calculating the frequency of grazing (number of sampling points grazed / 50) and comparing this with a graph of percent grazed to percent utilized for mountain grasslands from a USFS range management manual (1977) (Appendix, Fig. 12). The percent utilization of the 4 lines was averaged to obtain the estimated percent utilization of each grazing transect. The USFS manual classified transects with > 30% utilization as high use and potentially overgrazed.

Other Factors Influencing Bighorn Habitat Use on the TMWR

Mountain goats, human use (recreational and hunting), predators, weather, disease, inbreeding, and intraspecific competition have all been identified as potential limiting factors for other sheep populations (Oldemeyer et al. 1971, McCollough et al. 1980, Skiba and Schmidt 1982, Heimer et al 1986, Harrison and Hebert 1988, Haas 1989, Varley 1994). Data on vegetation condition and ungulate fecal distribution directly or indirectly addressed interspecific and intraspecific competition. I evaluated the impact of other factors in the Tom Miner Basin bighorn population based on a variety of available information. All human, elk, cattle, and mountain goats observed in the study area in 1994 and 1995 were recorded to see how bighorn sightings were associated with sightings of other species. Pellet group transects were completed on 2 bighorn summer ranges to determine if any range overlap was evident between elk and sheep use on the summer ranges.

Information on hunting was obtained from MDFWP files. The influence of predation was assessed from studies by Murphy (in prep.) and observations during fieldwork in 1994-1996. Disease prevalence was assessed from blood samples collected during this study, past studies, and disease samples collected in YNP. Weather information was gathered from weather data collected by the MDFWP (Farnes, unpubl.) and the weather station in Gardiner, Montana (NOAA 1995). The potential for inbreeding suppression was indirectly assessed from data collected during this study and past studies (Keating 1982, L. Irby, Montana State University, unpubl.).

RESULTS

Seasonal Range Use Patterns

A total of 281 locations was recorded for 10 radio-collared ewes. Approximately one third of the locations came from the 3 TMWR ewes. Five of the 7 collared ewes captured at Point of Rocks provided > 50% of the locations. One collar on a Point of Rocks ewe failed in August 1995, and another was removed in January 1996 because of interference with radio frequencies used by the Montana State Highway Department. The ewe with the malfunctioning radio was observed 4 times after the failure. Groups of sheep not associated with the marked animals were observed 41 times. Group size for marked and unmarked groups ranged from 1 to 30.

Movements of the radio-collared sheep were recorded from April 1995 through September 1996. In May of both years, the ewes from Point of Rocks moved 16 km north to summer range in the Hyalite Basin south of Bozeman, Montana. The Tom Miner Basin ewes wintered on the south side of the basin and migrated 6 km northwest to Fortress Mountain in the spring (Fig. 3).

In autumn 1995, both groups of ewes returned to the same winter ranges where they were captured. Five ewes from the PRWR went to the CWR, approximately 16 km to the southeast of the PRWR, from mid October to December then moved to the PRWR. The other 2 ewes remained south of Hyalite Basin during this time and returned to the PRWR in December. Flights in early autumn 1996 showed all ewes were following the

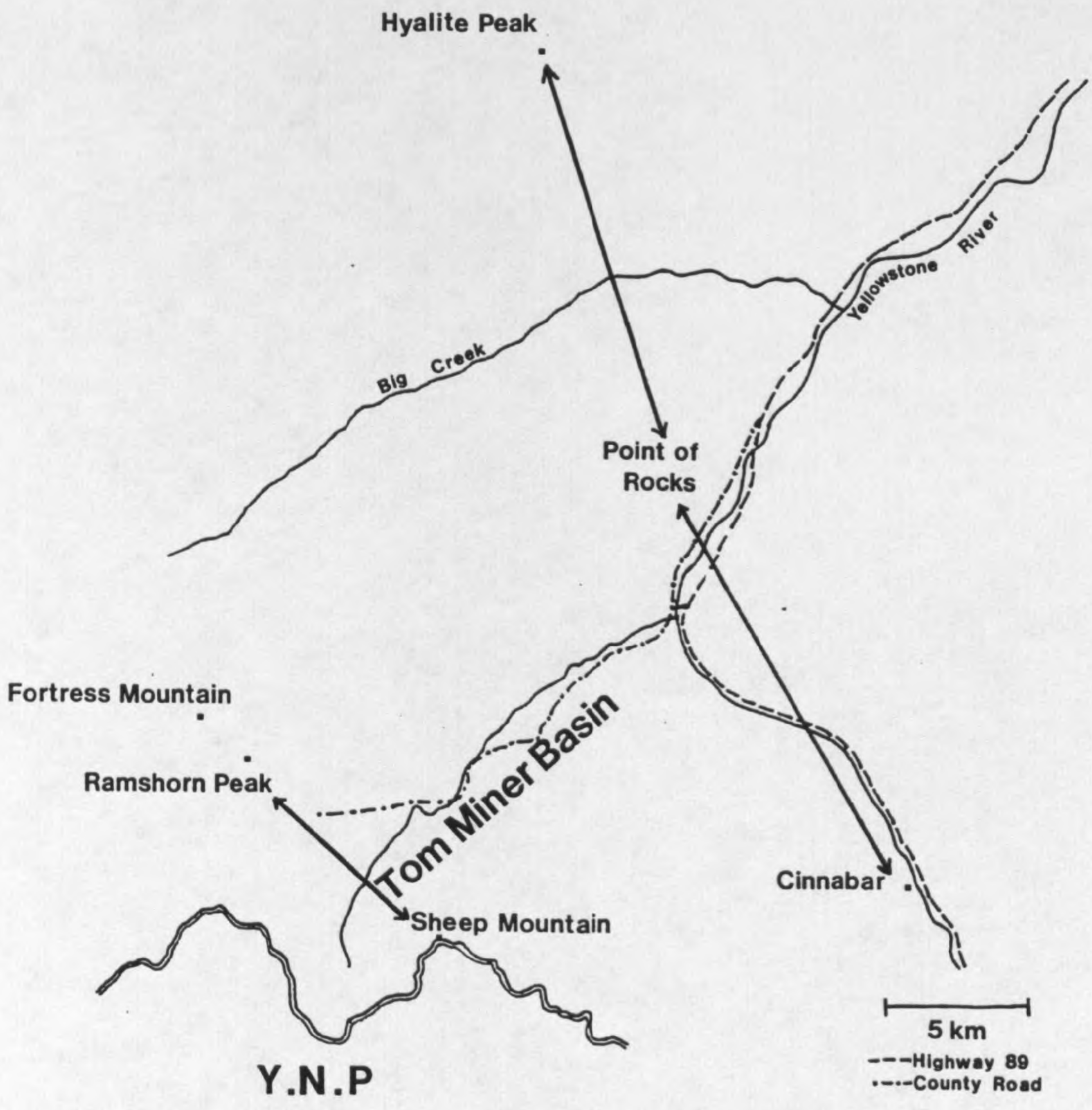

Figure 3. Movements of the 10 radio-collared ewes from Tom Miner Basin and Point of Rocks in 1995 - 1996.

same movement patterns I observed in autumn 1995.

Population Estimates and Trends

The minimum population estimate for bighorns using the Tom Miner Basin summer ranges, Bighorn Peak, and Fortress Mountain, based on unrepeated group sightings in 1994-1995, was 43 sheep. I observed 32 bighorns in the Hyalite Basin during the 1995 summer. The number of individuals, sex classification, and ram:100ewe and lamb:100ewe ratios from each range are presented in Table 1. During the study, 17 sheep were counted on the TMWR and approximately 30 sheep were associated with the PRWR.

Table 1. Bighorn total summer range counts from the Tom Miner Basin and Point of Rocks in 1995 includes classification and lamb:100ewe and ram:100ewe ratios.

RANGE	Ewes	Rams	Lambs	Year.	Total	Lamb:Ewe	Ram:Ewe
Tom Miner Basin							
Ramshorn/Fortress							
1994	12		11		23	92	
1995	15	5	6		26	40	33
1996	13	1	5	2	21	38	8
Bighorn							
1994	11		7		18	64	
1995	9	1	5		15	56	11
Tom Miner Basin Combined							
1994	23		18		41	78	
1995	24	6	11	2	43	45	25
Point of Rocks ewes at Hyalite Basin							
1995	18	10	4		32	22	56
1996	14	9	6		29	39	64
All Ranges Combined							
1994	23		18		41	78	
1995	42	16	15	2	75	36	38
1996	27	10	11		48	41	37

Ungulate Use on Bighorn Winter Range: 1975, 1994, and 1995

Use Patterns: 1975 versus 1994-1995

Thirty-eight fecal pellet transects measured in 1975 were remeasured at approximately the same time of year (June-August) in 1994 and 1995. Paired t-tests used to compare the pellet groups per hectare (PGH) for each ungulate species (1975 versus 1994, 1975 versus 1995, and 1994 versus 1995) showed significant differences ($p < 0.05$) in all but 3 comparisons (Table 2). Bighorn sheep pellet density decreased by 85% from 1975 to 1994 ($t = 3.35$, $df = 37$, $p = 0.002$, power = 0.80) and by 79% from 1975 to 1995 ($t = 3.10$, $df = 37$, $p = .004$, power = 0.72). Elk pellet density in 1975 was 42% of that recorded in 1994 ($t = 3.93$, $df = 37$, $p = 0.000$, power = 0.90) and 32% of that recorded in 1995 counts ($t = 4.45$, $df = 37$, $p = 0.000$, power = 0.95). Cattle fecal density decreased by 58% from 1975 to 1994 ($t = 3.00$, $df = 37$, $p = 0.005$, power = 0.52) and by 93% from 1975 to 1995 ($t = 4.41$, $df = 37$, $p = .000$, power = 0.99). No significant differences were found between the years 1994 and 1995 for elk ($t = 1.33$, $df = 37$, $p = .193$, power =0.18), bighorns ($t = 0.57$, $df = 37$, $p = 0.573$, power =0.07), or cattle ($t = 1.92$, $df = 37$, $p = .063$, power = 0.43). Pellet groups from deer and moose were rare in 1975, 1994, and 1995.

Use Patterns: 1994 - 1995

One hundred and forty-seven fecal pellet transects measured in 1994 and 1995 were used in univariate and multivariate habitat use analysis. Of the 147 transects, 24 (16%) were repeated 3 times in the 1994 and 1995 field seasons. The mean for the 3

Table 2. Paired t-test of bighorn, elk, and cattle pellet densities for 1975 versus 1994, 1975 versus 1995 and 1994 versus 1995.

Species Year	Mean	N	SD	Min	Max	Years Compared in t-test	t	p-value	Confidence Interval	
Bighorn										
1975	31.40	38	56.48	0	206	1994 - 1975	3.35	.002	-42.74	-10.51
1994	4.79	38	11.17	0	58	1994 - 1995	0.57	.573	- 7.67	4.31
1995	6.48	38	19.64	0	116	1995 - 1975	3.10	.004	-41.00	- 8.64
Elk										
1975	19.85	38	24.10	0	81	1994 - 1975	3.93	.000	13.39	42.05
1994	47.67	38	46.25	0	162	1994 - 1995	1.33	.193	-35.68	7.45
1995	61.80	38	67.14	0	331	1995 - 1975	4.45	.000	22.96	60.91
Cattle										
1975	32.44	38	42.55	0	170	1994 - 1975	3.00	.005	- 31.85	- 6.15
1994	13.66	38	38.24	0	166	1994 - 1995	1.92	.063	- 0.63	23.48
1995	2.24	38	6.59	0	28	1995 - 1975	4.41	.000	-44.44	-16.25

visits was used in the analysis. Analyses were run on 1994, 1995, and combined 1994-1995 data. Fifty-five transects were completed in the same locations in 1994 and 1995. The averages for 1994 and 1995 transects measured in both years were used in the combined 1994 and 1995 data analysis. Two outliers were excluded from all univariate and multivariate analysis. One transect occurred in a location with high mountain goat use and pellets from the bighorns were difficult to distinguish from goat pellets. The second transect was excluded because of an unexplainable high number of bighorn pellets; confusion with old from new pellets or between species may have occurred.

The univariate chi-square analyses indicated habitat selection by sheep habitat for all features measured (elevation, aspect, slope, escape terrain, grass cover, elk pellet groups, and cattle pellet groups). In 1994, 1995, and combined 1994-1995, escape terrain had the highest chi-square value and aspect had the lowest value. All other habitat characteristics varied in the level of chi-square value (rank) for the three years. Elevation had the second highest chi-square value in 1994 and percent slope had the third highest. In 1995, elk pellet groups and degree slope had the second and third highest chi-square values; respectively. In the combined 1994 - 1995 data cattle pellet groups were second, elevation third, and percent slope had the fourth highest chi-squared value (Table 3). Results from the univariate chi-squared analysis test with confidence intervals for 1994, 1995, and combined 1994 - 1995 are in Appendix, Table 8a, b, c.

The chi-square analyses ranked habitat characteristics in the same patterns as the classification and regression trees. Classification and regression trees identified similar relationships between independent and dependent variables as the chi-square analysis in

Table 3. Chi-squared (X^2) analysis of bighorn habitat use versus habitat availability for pellet group transects in 1994, 1995, and 1994 and 1995 combined for habitat features of elevation, aspect, slope, escape terrain, grass cover, elk pellet groups, and cow pellet groups. Includes X^2 value and rank. The X^2 habitat values were ranked in order of highest to lowest for a specific year.

Habitat Feature(degrees freedom)	Year					
	1994	X^2(rank) p-value	1995	X^2(rank) p-value	1994/1995	X^2(rank) p-value
Elevation(3)		110.05 (2)		48.15 (6)		88.46 (3)
6000	-[1]	<0.0001	-	<0.0000	-	<0.0000
7000	o		+		+	
8000	-		o		-	
9000	+		o		o	
Aspect(1)		13.17 (7)		6.23 (7)		14.55 (7)
N, NE, E, SE	-	0.0003	-	0.0126	-	0.0003
S, SW, W, NW	+		+		+	
% Slope(3)		47.28 (3)		157.28 (3)		79.11 (4)
10	-	<0.0000	-	<0.0000	-	<0.0000
20	o		+		-	
30	o		-		+	
40	o		+		o	
Escape(1)		280.70 (1)		429.30 (1)		401.28 (1)Dÿÿÿ
# 100-m	+	<0.0000	+	<0.0000	+	<0.0000
> 100-m	-		-		-	
Grass Cover(1)		25.78 (6)		48.93 (5)		57.01 (6)
low(ground vis.)	+	<0.0000	+	<0.0000	+	<0.0000
high(ground not vis.)	-		-		-	
Elk Pellet Groups(2)		41.30 (5)		270.06 (2)		68.55 (5)
0		<0.0000	+	<0.0000		<0.0000
low[2]	+		+		+	
high	-		-		-	
Cow Pellet Groups(2)		43.18 (4)		120.26 (4)		130.88 (2)
0	+	<0.0000	+	<0.0000	+	<0.0000
# 19	-		-		-	
> 19	-		-		-	

[1](-) bighorn sheep use < expected; (+) bighorn sheep use > expected; (o) bighorn sheep use expected habitat availability ($p < 0.05$).

[2]Low and high break points of elk pellet groups were # 10.4 and >10.4 for 1994, < 23 and $ 23 for 1995, and < 14 and $ 14 for 1994 and 1995 combined.

1994, 1995, and combined 1994 - 1995 data. Cattle pellet groups were not included in all of the trees because cattle selected areas away from escape terrain.

Classification trees were based on the presence or absence of bighorn pellet groups. For all chosen classification trees (1994, 1995, and combined 1994 - 1995) transects with the highest bighorn pellet frequencies occurred within 100 m of escape terrain. The 1995 classification tree was the only one with a second branching after escape terrain. This branch split on the number of elk pellet groups. Bighorns apparently selected areas with less than a mean of 22.8 elk pellet groups (Fig. 4).

Regression trees were constructed using the continuous variable of mean bighorn pellet groups. The 3 regression trees (1994, 1995, 1994 and 1995 combined) first branched on escape terrain with the highest densities of bighorn pellet groups within 100 m to escape terrain. In 1994 a second branch divided bighorn pellet groups by slope steepness with a mean of 10.02 pellet groups associated with slopes > 12% near escape terrain (Fig. 5). In 1995, the second splitting variable was the number of elk pellet groups found near escape terrain. Areas with fewer than 22.2 elk pellet groups had a mean of 23.3 bighorn pellet groups versus a mean of 3.6 bighorn pellet groups when mean elk pellet groups were > 22.2 (Fig. 5). The combined 1994 and 1995 regression tree branched 2 additional times after splitting on escape terrain. Elevation was the second splitting variable and slope was the third splitting variable. A mean of 24.45 bighorn pellet groups was found at elevations < 2475 m near escape terrain. If the elevation was > 2475 m, a mean of 10 bighorn pellet groups occurred in areas > 12.5% slope and a mean of 1.28 bighorn pellet groups occurred on slopes < 12.5% (Fig. 6).

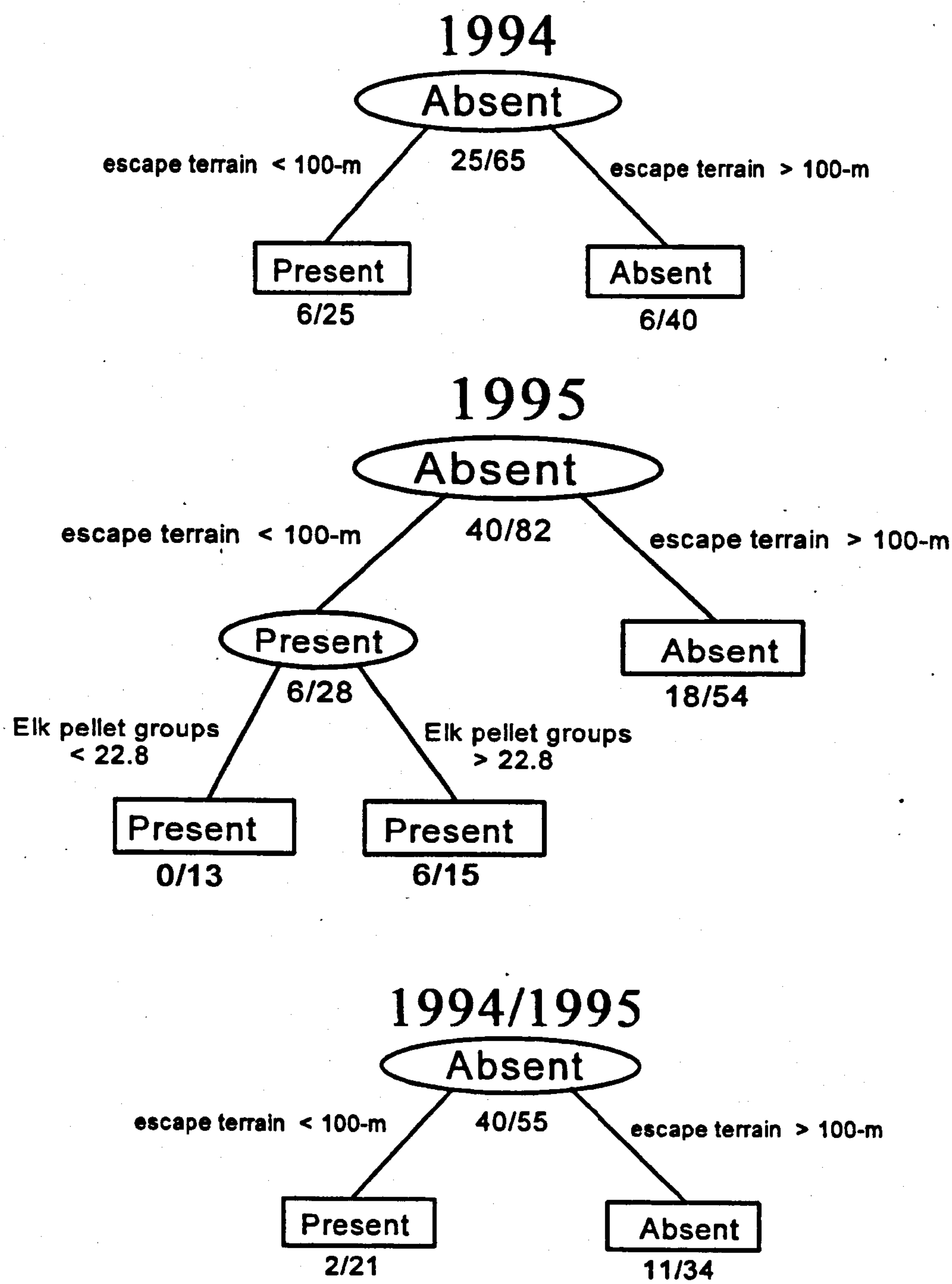

Figure 4. Classification Trees for 1994, 1995, and 1994/1995 bighorn pellet groups. Selection was based on the presence or absence of bighorn pellet groups. The ratio is the misclassification rate. The denominator represents the total number of transects for the node and the numerator is number of transects selected incorrectly for the node. The habitat characteristic that determines when the tree branches is next to the branch.

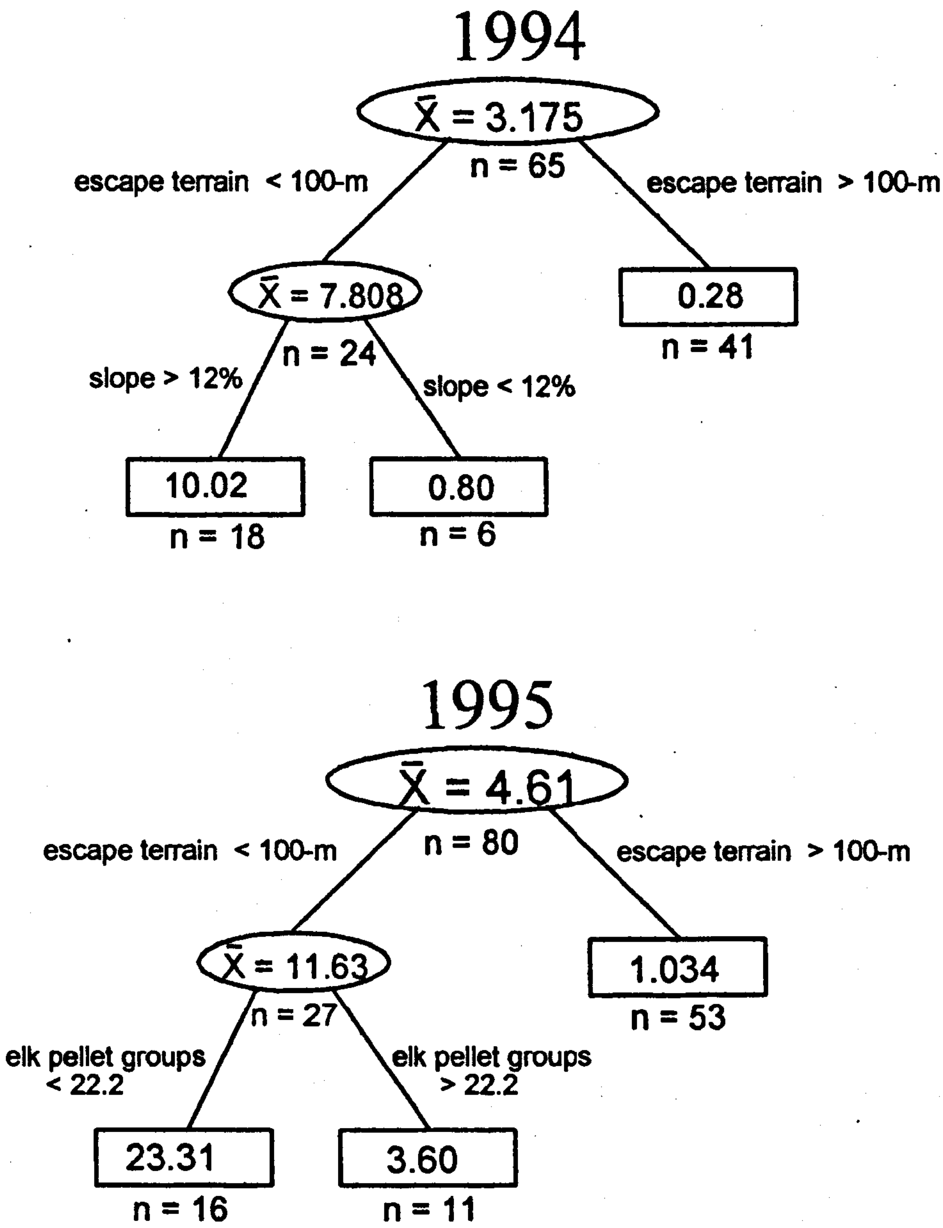

Figure 5. Regression trees for 1994 and 1995 bighorn pellet groups on the TMWR. n = number of transects for each node. Terminal nodes contain the mean bighorn pellet groups for n when the tree branches on the selected habitat characteristic.

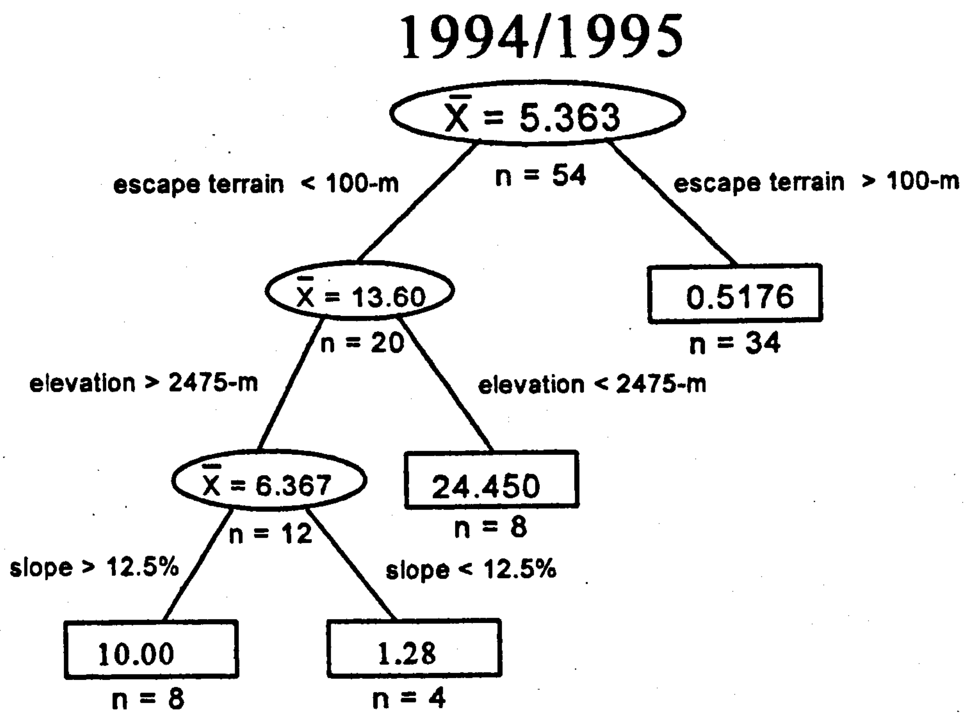

Figure 6. Regression tree for 1994/1995 bighorn pellet groups on the TMWR. See Figure 5 for explanation of symbols and numbers.

Vegetation Trend and Condition

Vegetation Trends between 1975 and 1994-1995

Trend and condition for vegetation and soil at sites in the Tom Miner Basin measured by Grunnigen (1976) indicated vegetation was in good condition in 1975 and had not changed by 1994-95 (Table 4). Vegetation condition at additional sites used heavily by sheep, elk, or both species that I measured in 1994 and 1995 were classified as "fair" to "excellent" (Table 4). When sites heavily used by ungulates were compared to sites lightly used by ungulates, no differences in the frequency of "fair", "good", or "excellent" vegetation classifications were found.

Table 4. Vegetation and soil condition and trend measures in 1975 and 1994 from transects completed in the Tom Miner Basin. Condition was rated on a scale of very poor to excellent (very poor, poor, fair, good, excellent) and trend was either up or down based on USFS description for range analysis. All percent grazing utilization at these sights was less than 20%. Transects 1-5 were transects repeated in 1975 and 1994 and transects 6-11 were additional transects completed in 1995 in areas with various ungulate use.

Transect	Relative Ungulate Use[a]		Vegetation Cond		Soil Condition		Vegetation Trend		Soil Trend	
	1975	1994	1975	1994	1975	1994	1975	1994	1975	1994
1	le, hs	le, ms	fair	fair	fair	fair	down	up	down	up
2	le, hs	me, ms	good	good	excellent	excellent	up	up	up	up
3	le, hs	me, ls	fair	good	excellent	excellent	up	up	up	up
4	le, hs	he, ls	fair	good	good	good	up	up	up	up
5	me, ls	he, ls	fair	good	excellent	excellent	up	up	down	up
		1995		1995		1995		1995		1995
6		me, ls		fair		good		up		down
7		he, ls		excellent		excellent		up		up
8		he, ls		excellent		excellent		up		up
9		me, ms		good		good		up		down
10		le, ls		good		good		up		up
11		le, hs		fair		excellent		up		up

[a] Relative ungulate use is based on pellet groups at each transect for elk and bighorns: le = low elk, ls = low sheep, me = moderate elk, ms = moderate sheep, he = high elk, hs = high sheep.