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Associations Between Bighorn Sheep and Elk in the Tom Miner Basin, Montana

Abstract

One of the hypotheses proposed for declines of bighorn sheep (Ovis canadensis) *is competition for forage between bighorns and elk* (Cervus elaphus). *We tested the rationale underlying this hypothesis in the Tom Miner Basin, Montana. Bighorn numbers in this area declined by 70 percent or more between the mid-1970s and mid-1990s. Elk numbers apparently increased substantially during the same period. Pellet counts and vegetation surveys in 1975 and 1994-1995 indicated an increase in elk use of areas near bighorn wintering sites but no negative changes in vegetation composition. During 1994-1995, elk pellets were found in >40 percent of plots in bighorn wintering areas that contained bighorn pellets. This evidently represented elk summer use of bighorn winter habitat because we did not observe elk using bighorn wintering areas during the winter. Multivariate habitat models indicated proximity to escape terrain was the primary factor determining use of specific sites on bighorn winter range, but tree analysis indicated a secondary negative association between elk and sheep pellet densities in 1995. Our measurements of summer utilization of forage in 1994 and 1995 did not indicate that use of sheep range by elk had detectable impacts on availability of forage for sheep during winter.*

Key words: bighorn sheep, *Cervus elaphus*, elk, interspecific interactions, *Ovis canadensis*

Introduction

Management of ungulates in the Yellowstone ecosystem has a long and controversial history (Tyers 1981, Houston 1982, Chase 1986, Kay 1990,Wagner *et al.* 1995, Yellowstone National Park 1997). Although ungulates in the Yellowstone ecosystem have been studied more intensively and for a longer time-span than ungulates in most, if not all, other areas of North America, no consensus on appropriate population levels or on factors regulating population levels has been reached (Boyce 1998, Kay 1998, Singer *et al.* 1998, Wambolt 1998). The attention ungulates in the Yellowstone ecosystem have received may be part of the problem. Records of counts, distribution, and impacts span more than 100 years (Tyers 1981, Yellowstone National Park 1997). This long data string includes reports and studies conducted by dozens of biologists and land managers using a wide array of techniques at varying levels of intensity. Faced with the choice of ignoring historic data sets or using them despite their limitations, most biologists elect to acknowledge historic data and struggle to find objective ways in which to use them. In this paper, we attempted to use historic data to provide insight on the relationship between elk and bighorn sheep in the Yellowstone ecosystem and to describe the problems we encountered when we compared new data with historic data.

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Rocky Mountain bighorn sheep were once abundant throughout the Rocky Mountains of North America (Couey 1950, Buechner 1960). By the late 1800s, most bighorn populations in the United States had declined due to competition with livestock, introduction of livestock diseases, hunting pressure, and development (Buechner 1960, Keating 1982). Sheep in Yellowstone National Park (YNP) received more protection than many herds, but numbers in the ecosystem outside the Park probably declined through the 1930s. By the 1960s, bighorn populations in the Yellowstone ecosystem outside YNP were increasing in response to regulation of hunting, changes in land use, and reduction of livestock stocking rates adjacent to the Park , but bighorns did not recolonize all areas occupied prior to European settlement and have never reached population levels implied by descriptions from early European settlers in the Yellowstone Valley (Buechner 1960, Keating 1982, Yellowstone National Park 1997).

Declines in bighorn sheep populations due to disease have occurred in the Yellowstone ecosystem (Buechner 1960, Meagher 1992), but disease seemingly does not explain declines, or failure to recover from declines, in units within this metapopulation that have occurred in the last two decades. Keating (1982) and Wagner (1995) speculated that high elk numbers could be directly or indirectly responsible for declines in other ungulate species in the system, including bighorn sheep, but were unable to unambiguously support their positions. Analyses of counts and age-structure data by Houston (1982) and Singer and Norland (1994) revealed no strong relationships between elk and sheep population trends in the Yellowstone ecosystem.

We discovered an unpublished U.S. Forest Service report (Grunigan 1976) in files of the Gardiner Ranger District of the Gallatin National Forest that contained precise information on pellet counts and vegetation composition, utilization, and condition on bighorn winter ranges in one area of the Yellowstone ecosystem , the Tom Miner Basin of Montana. To our knowledge, these data represent the earliest historic records that provide repeatable data on elk and sheep distribution as related to vegetation conditions in wintering areas shared by elk and bighorns in the Tom Miner Basin. Other available survey data indicated a decline in bighorn numbers concurrent with an increase in elk numbers in the Tom Miner Basin between the mid-1970s and mid-1990s (Legg *et al.* 1996, Yellowstone National Park 1997, Irby unpubl., Montana Fish, Wildlife, and Parks unpubl.). Although counts of elk and sheep during 1974-1996 were incomplete, limited mostly to winter and did not employ consistent techniques, we were able to piece together a probable scenario of population changes.

Counts of bighorn sheep in the Tom Miner Basin (Fig. 1) using fixed-wing aircraft during 1974-1987 averaged 75 (n = 11, SD = 27). The number of sheep apparently increased from the mid-1970s to the early 1980s and declined by ≥50 percent between the 1982-1983 and 1983-1984 winters. Counts from helicopter surveys during 1990-1996 averaged 23 (n = 5, SD = 9). Part of the decline may have been due to a shift in sheep distribution to lower-elevation winter ranges outside the Tom Miner Basin (Legg *et al.* 1996). We could not accurately separate losses due to demographic factors (reduced natality, mortality) from losses due to changes in distribution because of the way in which data from survey flights in the 1970s were summarized.

Data for elk in the Tom Miner Basin were sparse during the 1974-1987 period (Fig. 1), but no fixed-wing surveys recorded more than 200

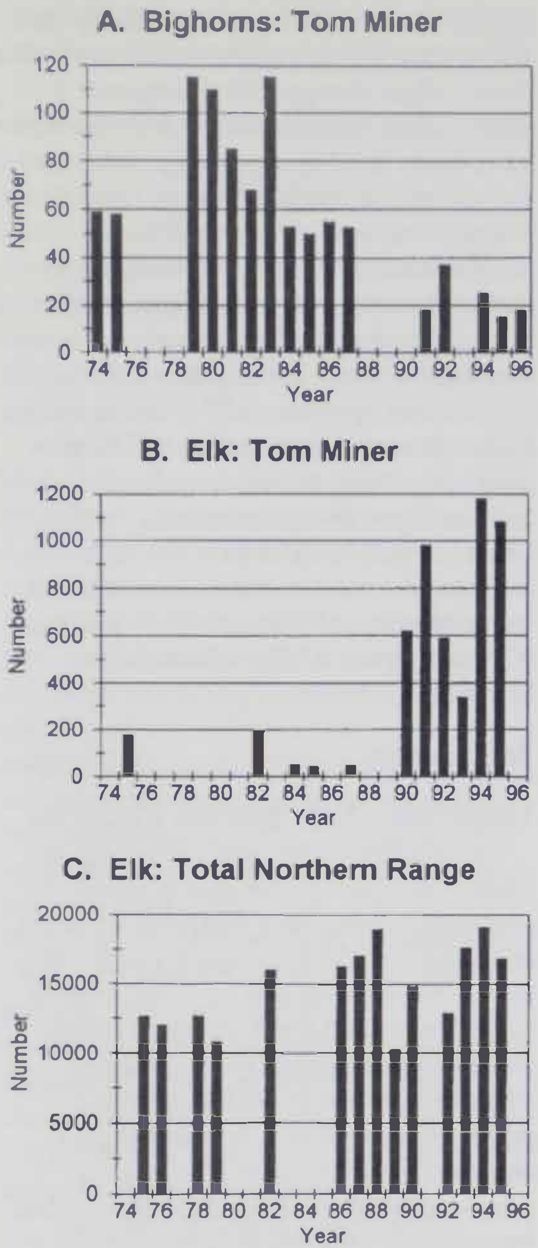


Figure 1. *Summary of bighorn sheep (A) and elk (B) counts in the Tom Miner Basin during 1974-1996 from Legg* et al. *(1996), Irby (unpubl.), and Montana Fish, Wildlife, and Parks (unpubl.). Surveys prior to 1990 were made with fixedwing aircraft. Surveys from 1990 to 1996 were made using helicopters. Counts from a mix of helicopter and fixedwing surveys reported in Yellowstone National Park (1997) for numbers of elk wintering in the Northern Range (including areas inside and outside Yellowstone National Park) are given in graph C. Labels on x-axes refer to January of each winter (1974 = winter 1973-1974).*

animals (mean = 102, n = 5, SD = 78). Helicopter counts, initiated by Montana Fish, Wildlife, and Parks in the 1989-1990 winter, averaged 798 elk (n = 6, SD = 330) during 1990-1996. Increased survey efficiency from use of helicopters during the 1990s probably accounted for some of the difference between recent surveys and the earlier counts. However, elk on the northern Range of Yellowstone National Park, which includes the Tom Miner Basin, increased in number and winter distribution between the 1970s and 1990s (Yellowstone National Park 1997, Lemke *et al.* 1998) suggesting that a real increase in elk numbers in the Tom Miner Basin occurred.

If the population scenario we outlined is valid, did increasing elk numbers cause the decline in sheep numbers? We assessed the potential for a cause and effect relationship by comparing forage condition, forage utilization patterns, and habitat use patterns for bighorns and elk in 1975 (Grunigen 1976) with those in 1994-1995 (Legg 1996). The specific study objectives were to:

1) Compare the relative intensity of ungulate use, vegetation coverage, and plant species composition in areas occupied by sheep in the Tom Miner Basin during 1975 with the same sites during 1994-1995; and
2) Assess the potential for forage abundance as a limiting factor for bighorn sheep on winter ranges in the Tom Miner Basin during 1994 and 1995.

Study Area

The Tom Miner Basin winter range (TMWR) is located in the upper Yellowstone River Valley and is one of five bighorn winter ranges adjacent to the northern boundary of Yellowstone National Park. It is 26 km northwest of Gardiner, Montana, in the Gallatin Mountains of southwestern Montana. Elevations in Tom Miner Basin range from 1500 m to >3000 m. The climate is cool continental with heavy snowfall. Snow cover restricts sheep to winter ranges from November to May in most years. Summers are short and mild (Chester 1976). The TMWR is composed of several small (<1-5 km^2) areas used by sheep scattered over 150 km^2. Wintering sites are typically on grass-covered southwest-facing slopes between 1800 m and 2500 m . These small wintering areas include whitebark pine (*Pinus albicaulis*)-subalpine fir (*Abies lasiocarpa*), bunchgrass, and subalpine vegetation types (Grunigen 1976). Most ridges are oriented from northwest to southeast. Summer ranges associated with the TMWR are ridge tops and alpine meadows ≥2000 m in elevation. Summer ranges are separated from wintering sites by <1 to 10 km (Keating 1982, Irby *et al.*1989, Legg 1996).

Land ownership in the Tom Miner Basin is a mix of private, state, and federal (YNP and Gallatin National Forest) lands. No public roads cross wintering sites in the TMWR, but public trails run through or near most sites. Seventy percent of the wintering areas used by sheep in the TMWR are publicly owned. Livestock grazing and hunting are the primary land uses on the winter and summer ranges. The USFS leases 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 private lands in the basin year round. Most of the hunting pressure in the Tom Miner Basin is directed towards elk and mule deer (*Odocoileus hemionus*). The number of permits for hunting sheep associated with the TMWR is unrestricted, but only rams with ≥3/4-curl horns can be legally harvested. Land ownership and sheep distribution limit hunter access to sheep. Over the past 20 years, restrictions on season length or quotas have been used to control harvest, and the general trend has been to increase restrictions (Irby *et al.* 1989).

In addition to elk and mule deer, the study area supported populations of white-tailed deer (*Odocoileus virginianus*), mountain goats (*Oreamnus americanus*), and moose (*Alces alces*). Only elk were abundant at the time of the study. Potential mammalian predators on sheep included grizzly bears (*Ursus arctos*), black bears (*U. americana*), coyotes (*Canis latrans*), and mountain lions (*Felis concolor*). Wolves (*C. lupus*) from YNP colonized the area in 1996.

METHODS

Ungulate Distribution Patterns

Comparisons Between 1994-1995 and 1975.—We used pellet group counts to compare density and distribution of elk and bighorn sheep at specific sites in 1994-1995 with results of pellet counts in 1975 reported by Grunigen (1976). Problems with pellet group counts include bias due to plot size (more pellet groups missed in a larger plot), observer error (missed groups and misidentification of species responsible for pellets), variability in defecation rates, and lack of consistency in number of pellet groups counted and time spent by ungulates at a specific site (Neff 1968, Collins and Urness 1981, Lancia *et al.* 1994). We used pellet counts despite their limitations because they allowed us to compare counts at sites identified and counted by Grunigen with those made 20 years later.

Grunigen (1976) selected transects based on maps of winter sheep distribution compiled from several years of observation by USFS and Montana Fish, Wildlife, and Parks personnel and information on cattle grazing allotments in USFS files at the Gardiner Ranger District. He tried to place transects in all areas where bighorn sheep winter range could be accessed by grazing cattle. He used techniques described in detail in USFS manuals (USDA Forest Service 1977), and he included topographic maps and aerial photographs with sites marked and accompanying descriptions that allowed us to place our plots within approximately 50 m of his plots.

In 1975, USFS personnel completed 38 pellet group transects during July-August. These transects were 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. Although we followed sampling techniques employed in 1975 to insure compatibility with 1994 and 1995 ungulate fecal counts, we made some modifications. In 1975, Grunigen counted only new pellet groups from bighorn sheep, elk, cattle, and other ungulates in each transect. In 1994 and 1995, we counted old and new pellet groups. Pellet group age was distinguished by the color, sheen, and texture of pellets as described by Grunigen (1976). To avoid confusion of old from new pellets, we did not measure transects on rainy days.

Each of Grunigen's transects consisted of 10 81-m^2 circles. Each transect in 1994 and 1995 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 four concentric circular belts with radii of 1.8, 3.7, 5.6, and 7.2 m, respectively. We totaled counts within the four circular belts for a whole plot count. To compare our data with Grunigen's 1975 data, we used only the new pellet group counts from the three inner increments (95 m^2). Pellet group counts for each ungulate species were converted to pellet groups/ha by dividing total pellet groups counted in the 10 plots by the total area sampled in the 10 plots in each transect. We assessed differences in pellet density using paired t-tests (Iman 1994) in the MSUSTAT package (Lund 1993). Deer and mountain goat observations at these sites during 1994-1995 were low, and opportunities for confusion of pellets from deer and mountain goats with those from sheep were negligible at most sites.

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 all seasons. Transects were selected to cover areas with different cattle grazing pressure, and all were in open, grass-dominated vegetation types that appeared adequate for sheep. Total new pellet groups from the 161-m^2 plots 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 through vegetation canopy), elevation, and aspect were measured for each transect. This analysis included transects used in comparisons with Grunigen'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 two to four, and eight to 10 plots were measured on each transect. When time permitted, units were measured three times in the summer and fall field season: prior to cattle grazing, immediately following cattle grazing, and before snowfall. Because all transects could not be measured three times in both years, we averaged available counts on units counted more than once to obtain a single estimate of pellet density/transect or plot/year.

Analysis.—We used χ^2 analysis (Neu *et al.* 1974) to measure habitat availability vs. bighorn habitat use for individual independent variables and as an aid in interpreting the regression and classification trees used in the multivariate analysis. Years were analyzed separately to evaluate stability of relationships we observed. Habitat characteristics identified as independent variables in univariate and multivariate tests included elevation (categorized in 305-m intervals), aspect (two 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(0; 1-14 pellet groups/ plot; >14 pellet groups/plot), and cattle feces density (0; 1-19 fecal piles/plot; >19 fecal piles/plot) .

Classification and regression trees were used in multivariate analysis of the distribution of bighorns with the same habitat characteristics used in χ^2 analysis to determine if combinations of habitat features were important in defining habitat use. 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 that we 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 χ^2 and tree tests was set at $P < 0.05$.

Vegetation Trend, Condition, and Utilization

Vegetation and Soil Trends Between 1975 and 1994-1995.—Five vegetation condition and trend transects read in 1975 were repeated in 1994 to assess changes in vegetation in the TMWR the past 20 years. Six additional transects in sites used by or suitable for use by sheep were read in 1995. All transects were in the *Festuca idahoensis*/ *Agropyron spicatum* or *Artemisia tridentata*/ *Festuca idahoensis* habitat types (Mueggler and Stewart 1980). Grunigen (1976) used pace-line transects and an evaluation system for vegetation and soil developed by the USFS . We repeated the techniques as closely as possible based on guidelines in a USFS manual (USDA Forest Service 1977). During both periods, transects were 50 paces in length and placed in open grassland or sage (*Artemisia tridentata*) grassland parallel to ridge lines. 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. Vegetation condition was given one of five categorical ratings (Very Poor to Excellent) based on abundance of "desirable", "intermediate", and "undesirable" plant species noted in the handbook for specific range types. Vegetation trend was categorized as declining, stable, or improving based on visual assessment of vigor in desirable plant species, presence of exotics, ground coverage by vegetation and litter, and estimated utilization of standing biomass. Soil condition was categorized (Very Poor to Excellent) based on the number of 2-cm diameter plots with bare soil and/or evidence of erosion. Soil trend was based on litter accumulation, extent of visible erosion, soil compaction, and extent of bare soil.

Vegetation Utilization in 1994-1995.—Grazing transects were completed with each pellet transect to assess range utilization. Transects followed the USFS method of measuring range utilization (USDA Forest Service 1977). Each grazing transect consisted of four 100-pace lines with 50 sampling points at two-pace intervals. A sampling point was considered grazed if 5 percent or more of the vegetation in a 133-cm^2 diameter loop was grazed. We obtained percent utilization for each line by calculating the frequency of grazing (number of sampling points grazed divided by 50) and comparing this with a graph used to convert percent grazed to percent utilized for mountain grasslands (USDA Forest Service1977). We then averaged percent utilization of the four lines to estimate percent utilization of each grazing transect. The USFS manual classified transects with >30 percent utilization as high-use and potentially overgrazed.

Results

Ungulate Use of Bighorn Winter Range

1975 Versus 1994-1995.—Detailed information on pellet group density comparisons has been reported in Legg (1996), but a summary of the changes we observed between 1975 and 1994-1995 appears in Table 1. Mean sheep pellet group density for 1994-1995 was 82 percent lower than in 1975, mean elk pellet group density in 1994-1995 was 176 percent higher than in 1975, and mean cattle fecal pile density in 1994-1995 was 75 percent lower than in 1975 (paired t-tests, $P < 0.01$). Pellet group densities were not significantly different between 1994 and 1995 for sheep and elk (paired t-tests, $t = 0.57$ and 1.33 for sheep and elk, respectively, $P > 0.19$). The rotational grazing system in use on national forest land allowed more cattle on sites near sheep winter range in 1994 than in 1995, so fecal density in 1994 was higher than in 1995 (paired $t = 1.92$, $P = 0.06$). Pellet groups from deer and moose were rare (< 1 pellet group/ha) in all years at all sites. Mountain goats were observed within 1 km of only one transect in 1994 or 1995.

Table 1. *Mean pellet group/ha (SD in parentheses) and frequency of occurrence of fecal material for bighorn sheep, elk, and cattle for 38 transects in Tom Miner Basin during 1975, 1994, and 1995.*

Category	1975	1994	1995
Mean pellet groups/ha (SD)			
Bighorns	31.4 (56.5)	4.8 (11.2)	6.5 (19.6)
Elk	19.8 (24.1)	47.7 (46.2)	61.8 (67.1)
Cattle	32.4 (42.6)	13.7 (38.2)	2.2 (6.6)
Frequency of occurrence (%)			
Bighorns	47	51	44
Elk	82	100	97
Cattle	66	28	13
Bighorns + elk	24	51	41
Bighorns + cattle	32	15	3
Bighorns + elk + cattle	24	15	3

In 1975 Grunigen found new (<1-yr old) sheep pellets on 47 percent of the transects, new elk pellets on 82 percent, and new cattle feces on 66 percent (Table 1). Both sheep and elk pellets were found on 24 percent of his transects. In our study new sheep pellets were located on 44 (1995) to 51 (1994) percent of the transects, elk pellets on almost all transects in both years, and cattle pellets on <30 percent of the transects in both years. Sheep and elk pellets occurred on 51 percent (1994) and 41 percent (1995) of the transects.

Habitat Use Patterns in 1994-1995.—One hundred and forty-seven pellet transects measured in 1994 and 1995 were available for univariate and multivariate habitat use analysis. Two transects were excluded from all univariate and multivariate analysis. One transect occurred in a location with high mountain goat use. It was excluded from analyses because pellets from bighorns were difficult to distinguish from goat pellets. Another transect was excluded because numbers of new bighorn pellets were unreasonably high (several times higher than any other site). This indicated that we were unable to accurately distinguish new from old pellets at this site.

Of the 145 usable transects, 24 (17%) were repeated 3 times in the 1994 and 1995 field seasons. The 65 transects measured in 1994 included 206 plots used in χ^2 analysis. The 80 transects measured in 1995 yielded 369 plots for χ^2 analysis. One hundred and forty-five plots on 54 transects were measured in both years.

Even after we narrowed the habitat range included by restricting transects to open, grass-covered sites on slopes, the univariate chi-square analyses indicated selection by sheep for all features we included (elevation, aspect, slope, escape terrain, grass cover, elk pellet groups, and cattle pellet groups). Within our restricted habitat matrix, sheep selected moderate to high elevations, the drier slopes, a mix of slope steepness, areas close to escape terrain, sites with relatively low grass cover, and sites with low densities of elk and cattle feces (Table 2).

Classification and regression trees

Table 2. *Chi-square (χ^2) analysis of bighorn habitat use versus habitat availability for pellet group transects in 1994 (65 transects), 1995 (80 transects), and 1994 and 1995 combined (54 transects measured in both years) for habitat features of elevation, aspect, slope, escape terrain, grass cover, elk pellet groups, and cattle feces counts. Contribution of levels within categories to χ^2 values[1] was determined following Neu* et al. *(1974).*

Habitat feature	1994 χ^2 (*P*)	1995 χ^2 (*P*)	1994/1995 χ^2 (*P*)
Elevation (m)	110.05 (<0.01)	48.15 (<0.01)	88.46 (<0.01)
1829 - 2133	-	-	-
2134 - 2438	o	+	+
2439 - 2743	-	o	-
≥2744	+	o	o
Aspect	13.17 (<0.01)	6.23 (0.01)	14.55 (<0.01)
N, NE, E, SE	-	-	-
S, SW, W, NW	+	+	+
Percent slope (%)	47.28 (<0.01)	157.28 (<0.01)	79.11 (0<0.01)
<10	-	-	-
10-20	o	+	-
20-30	o	-	+
>30	o	+	o
Distance to escape	280.70 (<0.01)	429.30 (<0.01)	401.28 (<0.01)
≤ 100 m	+	+	+
> 100 m	-	-	-
Grass Cover	25.78 (<0.01)	48.93 (<0.01)	57.01 (<0.01)
low (ground visible)	+	+	+
high	-	-	-
Elk pellet groups	41.30 (<0.01)	270.06 (<0.01)	68.55 (<0.01)
low[2]	+	+	+
high	-	-	-
Cattle feces	43.18 (<0.01)	120.26 (<0.01)	130.88 (<0.01)
0	+	+	+
≤ 19 per plot	-	-	-
> 19 per plot	-	-	-

[1] (-) bighorn sheep use < expected; (+) bighorn sheep use > expected; (o) bighorn sheep use no different from expected ($P < 0.05$).

[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.

identify relationships between independent and dependent variables in a hierarchal fashion with the most consistent factors forcing the earliest dichotomies. Hierarchal divisions based on presence or absence of bighorn pellet groups, classification trees (Fig. 2), indicated that the most consistent habitat selection criterion for sheep was proximity to escape cover. In 1994 this was the only division that met entry requirements. In 1995 sheep evidently selected sites near escape terrain that were not used heavily by elk.

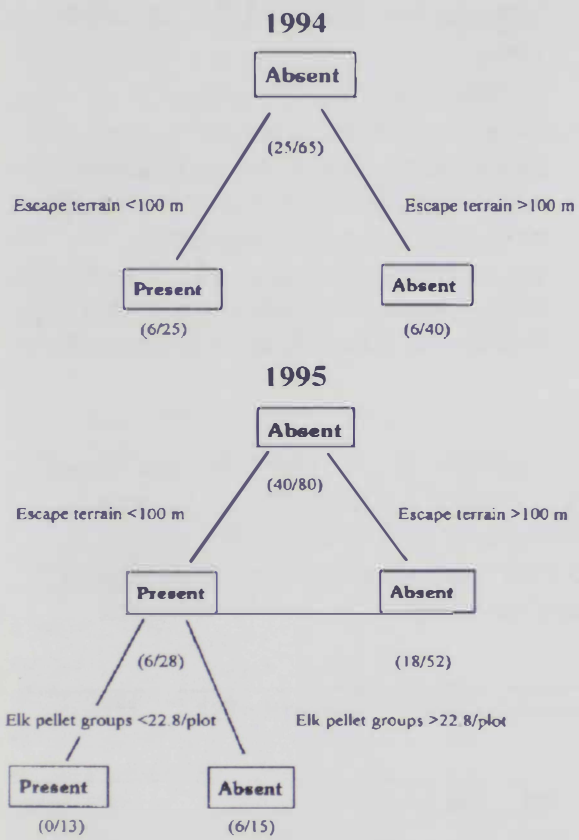


Figure 2. *Classification trees for 1994 and 1995 based on presence or absence of bighorn pellet groups in 161-m² plots. The ratios below node boxes represent misclassification fractions with the denominator as the total number of transects for the node and the numerator as the number of transects selected incorrectly for the node. The habitat characteristic that determined node branching is printed adjacent to the node branch.*

Hierarchal divisions based on continuous variables, regression trees (Fig. 3), also indicated sheep selected proximity to escape terrain as a primary site factor in both years. In 1994 a second selection division entered suggesting sheep next considered slope steepness. In 1995, the second branching indicated they avoided areas with high elk use.

Vegetation /Soil Trend and Condition

Grunigen (1976) classified vegetation condition at four of five sites in the Tom Miner Basin as fair in 1975. He assessed vegetation trend as improving at four of five sites. In 1994

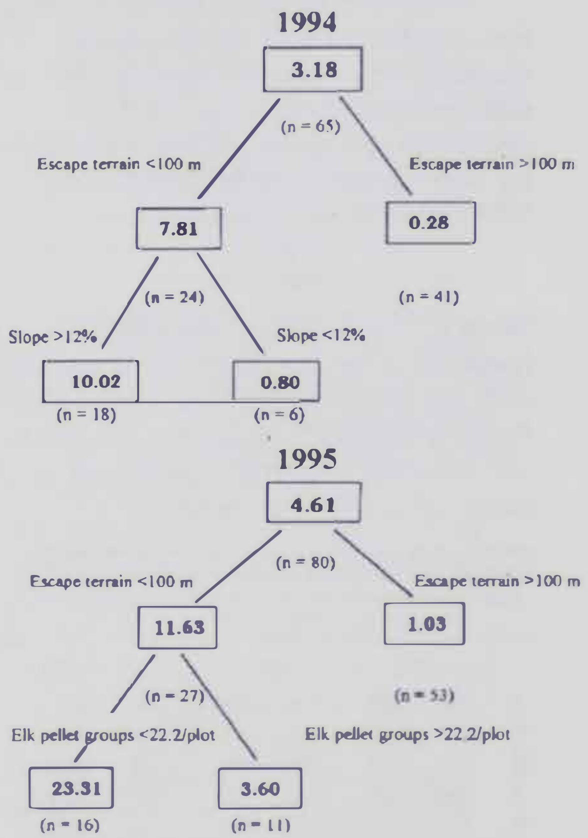


Figure 3. *Regression tree analysis for 1994 and 1995. Boxes defining classification nodes include mean bighorn pellet groups per 161-m² plot at the node. Number of plots for each branch (n) and the characteristics determining branching are given in the figure.*

at the same sites, we rated vegetation as good (Table 3) at four of five sites, and rated trend as improving on all sites. Vegetation condition at additional sites that we measured in 1995, and used by sheep, elk, or both species, were classified as fair-to-excellent. Graminoids that were most common in 1975 (*Festuca idahoensis, Agropyron spicatum*, perennial *Bromus* spp., *Poa* spp., and *Carex* spp.) also were most common in 1994 and 1995.

In 1975 soil condition was rated at fair to excellent, and soil trend was classified as improving in four of five sites (Table 3). In 1994 and 1995 soil condition at 10 of 11 transects was rated as good or excellent, and the predicted trend was upward at nine of 11 sites.

When we examined the relationship between intensity of use by elk and sheep during winter and spring prior to measurement, as indicated by fecal density, to condition and trend ratings for sites measured in 1975, 1994, and 1995 (Table 3), we found a mixed pattern. The four sites with high elk use (>10 pellet groups/ha), all from the 1994-1995 period, had good to excellent vegetation and soil condition and improving vegetation and soil trends. We identified five sites with high use by sheep, four from 1975 and one from 1995. Vegetation condition was ranked as fair on four sites and good on one. Vegetation trend, however, was classified as upward on four of five sites. Soil condition was classified as excellent on three sites, good on one, and fair on one. Soil conditions were rated as improving on all five sites.

Vegetation Utilization in 1994-1995

The 147 grazing transects completed in 1994 and 1995 were located at the same sites as pellet-group transects. Only 14 transects (9% of all transects) indicated >30 percent utilization of the range in 1994 and 1995. All other transects had little-to-no visible utilization. The transects with

Table 3. *Vegetation and soil condition and trend measures in 1975 and 1994 from transects completed in the Tom Miner Basin. Condition was rated on a 5-category scale (very poor, poor, fair, good, excellent) and trend was classified as up, stable, or down based on USDA Forest Service (1977) guidelines. Transects 1-5 were measured in 1975 and 1994. Transects 6-11 were only measured in 1995. Relative elk and sheep use[1] at the sites based on fecal counts are indicated in the table.*

Transect	Ungulate use[1]				Vegetation condition		Vegetation trend		Soil condition		Soil trend	
	Elk	Sheep	Elk	Sheep								
	1975		1994		1975	1994	1975	1994	1975	1994	1975	1994
1	low	high	low	mod	fair	fair	down	up	fair	fair	down	up
2	low	high	mod	mod	good	good	up	up	excellent	excellent	up	up
3	low	high	mod	low	fair	good	up	up	excellent	excellent	up	up
4	low	high	high	low	fair	good	up	up	good	good	up	up
5	mod	low	high	low	fair	good	up	up	excellent	excellent	down	up
			1995			1995		1995		1995		1995
6			mod	low		fair		up		good		down
7			high	low		excellent		up		excellent		up
8			high	low		excellent		up		excellent		up
9			mod	mod		good		up		good		down
10			low	low		good		up		good		up
11			low	high		fair		up		excellent		up

[1] Low = < 5 pellet groups/ha; mod = 5-10 pellet groups/ha; high = >10 pellet groups/ha.

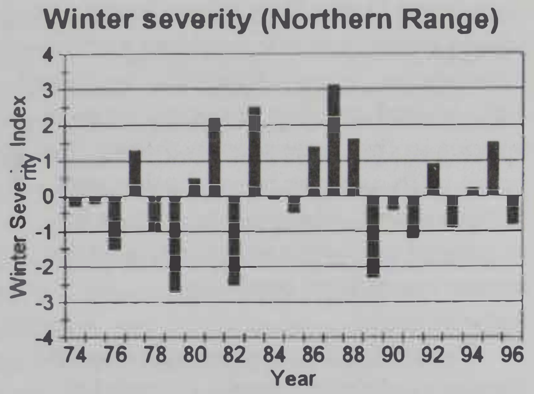
>30 percent utilization all occurred >100 m from escape terrain and in areas with high densities of cattle feces. Areas with high densities of elk or bighorn feces had low utilization (91% of 147 transects had < 25% utilization).

Discussion

We encountered many problems in our attempt to integrate Grunigen's (1976) data with new data. They ranged from a mathematical error that we made when calculating radii, which resulted in a slight difference in area covered in the inner three belts of our pellet sampling areas vs. plots counted by Grunigen. We also encountered philosophical problems associated with using techniques known to have major limitations (Neff 1968), i.e., maintaining consistency in comparisons. We were fortunate to have study sites physically marked on aerial photographs that allowed us to relocate Grunigan's plots with a high degree of accuracy, but we doubt that our plots were as accurately sited as would be possible today with geographic positioning technology. We also were fortunate to have a detailed description of the techniques Grunigen used for counting pellets and published descriptions of techniques he used to measure vegetation and soil status. Unfortunately, the vegetation techniques described in the USFS monitoring manual were designed to obtain general trend information in a manner that required as little time as possible. This did not allow us to detect small differences between conditions in 1975 and 1994-1995.

The differences we observed in regression and classification trees for 1994 and 1995 indicated that winter conditions could influence pellet distribution. If this were the case, differences in pellet distribution between 1975 and 1994-1995 could reflect differences in animal distribution rather than changes in population size. Although we do not know how winter variability in the Tom Miner Basin affects overlap in elk and sheep distribution, Legg (1996) observed very little spatial overlap between the two species in the same season during two years with average precipitation and temperatures. Plausible scenarios for increased or decreased overlap under severe conditions could be hypothesized.

Variability in snow conditions and forage availability across the winter range during each winter further complicated interpretation of winter impacts on ungulate distribution. Farnes (1999) developed a spatially explicit winter severity index scaled to a range of +4 to -4 from 1949-1999 means for winter snow water equivalents (index of snow depth), cumulative temperatures below defined critical temperatures for individual ungulate species (index of cold stress), and forage production on winter ranges (index of food availability). Houston (1981:65) indicated that winter 1974-1975, the winter preceding Grunigen's pellet counts, was severe enough to cause over 500 elk deaths on the northern winter range. The Farnes *et al.* (1999) model indicated that winter was severe (-1.7) in the high elevation areas of the northern winter range but much milder (-0.2) in the lower elevation winter range outside YNP. We have no basis upon which to judge the reliability of the Farnes (1999) model, but plots of the two sites closest to Tom Miner Basin for which Farnes (1999) calculated winter severity, the high elevation upper Gallatin elk winter range and the low elevation portions of the northern winter range (Fig. 4), indicated wide differences between severity at the two sites in the same winters. We do not know how this variability would influence sheep or elk distribution in the Tom Miner Basin, but nine radio-collared sheep followed for two or more consecutive years in three studies in the Tom Miner area (Keating 1982, Legg



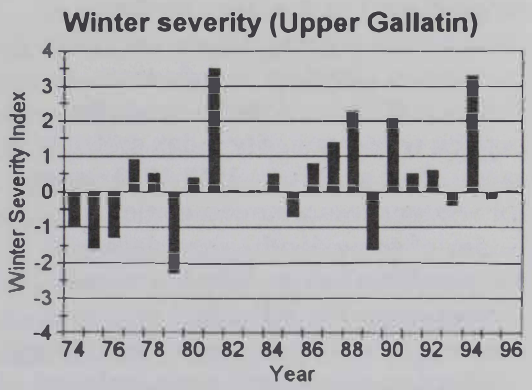


Figure 4. *Winter severity calculated by Farnes (1999) for elk on the Northern Winter Range outside Yellowstone National Park and on the Upper Gallatin Winter Range, 1974-1996. The winter severity index is based on winter precipitation, estimated forage production in year preceding the winter, and number of days with temperatures below critical values for elk. The index is scaled to a range of -4 (most severe winter = very low temperatures, low forage availability, and high precipitation) to +4 (mildest winter = warm temperatures, high forage availability, and low precipitation) with average temperature, forage availability, and precipitation = 0. Labels on the x-axis refer to January of each winter (1974 = winter 1973-1974).*

1996, and Irby, unpubl.) did not exhibit marked changes in winter range between years.

Despite the problems we described, pellet counts on bighorn wintering sites in the Tom Miner Basin were consistent with a decrease in sheep and an increase in elk between 1975 and 1994. Pellet counts were sensitive enough to detect a documented decrease in cattle AUMs on bighorn winter ranges between 1975 and 1994 (Legg *et al.* 1996), and they did reflect changes in cattle distribution between 1994 and 1995.

If pellet counts were valid indicators of distribution for sheep and elk, we had two snapshots in time to use in assessing the validity of a "cause" (increase in elk numbers) for a biological "effect" (decline in sheep numbers). Grunigan's vegetation and soil measurements in 1975 and our replication of these measurements in 1994-1995 enabled us to go one step farther than correlation analysis in examining this hypothesis. Pellet counts and the limited population surveys available were consistent with a negative relationship between sheep and elk numbers but not proof of this relationship (Romesburg 1981, Ratti and Garton 1994).

If elk were responsible for the decline in sheep, they could do so by actively or passively excluding sheep from suitable grazing areas or by utilizing limited forage before sheep could use it. We believe active exclusion of sheep by elk was unlikely. In 20 years of observing bighorn sheep in the Yellowstone ecosystem, Irby has never observed active aggression by elk towards sheep. Sheep were seldom seen in the same area as elk, but when groups of the two species were together, neither species appeared to be influencing movement of the other species.

Passive exclusion (elk occupying a site thereby denying it to sheep) is more feasible but would be difficult to distinguish from different habitat preferences of the two species and require significant spatial overlap during the same seasons. Tree analysis identified low elk pellet numbers and frequency as a secondary factor in predicting high sheep pellet numbers and frequency in 1995 transects, but elk were not abundant in sheep habitat in the same seasons as sheep. During the 1994 and 1995 summer seasons, Legg spent 1,054 hours on bighorn summer (16%) and winter ranges (84%) in the Tom Miner Basin (Legg 1996). During summer ground work, she recorded 820 elk observations on or near bighorn winter ranges. She sighted only 50 elk on summer ranges used by bighorns, but no elk were seen within 1.6 km of sheep. Elk were not observed on any bighorn wintering sites during November through May in either year of the study.

Grazing by other ungulate species on bighorn winter ranges during the growing season could effectively deny sheep forage during winter. However, this would require either heavy long-term grazing pressure, which should be reflected in species composition changes and site condition declines, or in heavy utilization of current growth. If competition for forage from other ungulates were a factor in the decline or failure to recover from the decline, elk were the most likely species involved. Fecal transects indicated that elk did use many areas on or near bighorn winter ranges in 1975 and that elk use had increased by 1994-1995. Cattle use of bighorn winter range was much higher in 1975 than in 1994 or 1995, but most cattle use in both periods was on relatively gentle slopes (Legg 1996) >100 m from escape terrain. Deer use of sheep winter range was low in both periods. Mountain goats were not observed in the study area until after the bighorn population decline.

Measurements that we expected to identify long-term plant community changes were not consistent with overuse by ungulates. Floral composition at sites measured in 1975 and 1994-1995 remained relatively stable, and palatable climax species dominated grassland communities in both periods. Vegetation and soil condition in 1994-1995 were similar to or rated higher than condition in 1975.

Measurements that we expected to identify short-term utilization, which could have influenced sheep forage available for the 1994-1995 and 1995-1996 winters, indicated low frequency of utilization in the Tom Miner Basin in both the 1994 and 1995 summers. Sites classified as heavily utilized (USDA Forest Service 1977) were grazed by cattle and were not in preferred sheep winter habitat. Forage utilization on preferred sheep winter habitat was undetectable or low in both summers.

Our measurements and analyses indicated that any negative impacts of elk on sheep numbers in the Tom Miner Basin were subtle, if they occurred. There were several ways in which elk use of forage could impact sheep numbers that would have been missed in our design. Summer and early autumn vegetation and pellet measurements did not identify elk use of bighorn wintering areas in late autumn after our measurements were taken. We were unable to measure forage utilization following severe winter conditions when elk use of sites critical to sheep survival could have conceivably depleted essential winter forage for sheep without creating long-term impacts on soils or vegetation. We also may have made vegetation and soil comparisons over too short a period to detect changes due to increased elk numbers. Measurable changes in vegetation composition and soil trend, due to over-use on bighorn winter ranges, may require more than one or two decades.

Elk also may have impacted sheep indirectly. High elk numbers could support a high predator density. Occasional sheep kills by these predators could be sufficient to heavily influence population trends in a small sheep population while having minimal effects on a large elk population. This hypothesis is consistent with our data and with probable trends in predator numbers over the past two decades (Legg *et al.* 1996). We, however, are considerably more cautious in proposing this hypothesis after our analysis of data related to herbivore distribution and site condition.

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