TOPOGRAPHIC DISTRIBUTION OF SAGE GROUSE FORAGING IN WINTER

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Abstract: We studied sagebrush (*Artemisia* spp.) exposure above snow and topographic distribution of sage grouse (*Centrocercus urophasianus*) foraging sites in winter (Jan–Mar) in the Gunnison Basin, Colorado. Sage grouse feeding activity ($n = 157$ foraging sites) was not proportionally distributed among 5 topographic categories ($P < 0.001$). Most (46 and 75% of foraging sites in 1985 and 1986, respectively) feeding activity occurred in drainages and on slopes with south or west aspects. Use of slopes with north or east aspects was less than expected. Distribution of sage grouse feeding activity was influenced by topographic variation in snow depth and mountain big sagebrush (*A. tridentata vaseyana*) exposure above snow. During a severe winter in 1984, <10% of the sagebrush vegetation in the Gunnison Basin was exposed above snow and available to sage grouse. During milder winters in 1985 and 1986, exposure of sagebrush was 84 and 79%, respectively. We recommend that sagebrush be maintained in drainages and on slopes with south or west aspects.

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Sagebrush removal to increase grass forage may severely impact sage grouse habitat (Schneegas 1967, Wallestad 1975, Swenson et al. 1987). Wildlife biologists have described biotic characteristics of areas occupied by sage grouse to develop guidelines for maintenance of habitats (Braun et al. 1977, Autenrieth et al. 1982). Winter habitats are of particular interest because sage grouse are completely dependent on sagebrush for forage and cover during winter (Eng and Schladweiler 1972, Wallestad et al. 1975, Remington and Braun 1985).

Previous descriptions of sage grouse winter habitat have emphasized measurement of shrub structure (e.g., sagebrush ht and canopy cover) or density at use sites (Eng and Schladweiler 1972, Beck 1977, Connelly 1982, Schoenberg 1982). Quantitative descriptions of shrub structure are useful for assessment of winter habitats but the effects of snow cover on sagebrush exposure should also be considered. Because snow accumulation and sagebrush growth structure are affected by topographic features (Blaisdell et al. 1982), topographic criteria could be useful to assess availability and distribution of areas likely to be used by sage grouse in winter.

We evaluated topographic features at sage grouse winter foraging sites in the Gunnison Basin of southern Colorado in 1985 and 1986 and tested the hypothesis that sage grouse feeding sites were proportionally distributed among available topographic categories. Our objective was to evaluate whether topographic variation in snow depth and sagebrush structure influenced distribution of foraging. We also measured exposure of sagebrush throughout the Gunnison Basin during midwinter between 1984 and 1986 to assess the effects of winter conditions on habitat availability.

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STUDY AREA AND METHODS

The Gunnison Basin was a topographically diverse, 2,000-km^2 intermontane basin with elevations between 2,300 and 2,900 m. Broad (>2 km) alluvial flood plains abutted major streams and level outwash plains occurred at the mouths of tributary drainages. Uplands were moderately to steeply rolling with slopes ranging from 5 to 30°. Steep-sloped mesas with broad, flat tops occurred in several areas of the Gunnison Basin. Uplands were highly dissected by permanent and intermittent streams. Shallow, eroded gulches were common on upland slopes. Surrounding montane areas restricted movement of sage grouse from the Gunnison Basin.

Mountain big sagebrush was the dominant upland vegetation on approximately 1,600 km^2 of land in the Gunnison Basin (Hunter and Spears 1975, Hupp 1987). Black sagebrush (*A. nova*) was common on xeric ridge tops and south slopes. Antelope bitterbrush (*Purshia tridentata*) and mountain snowberry (*Symphoricarpos oreophilus*) were interspersed with sagebrush at some sites. Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) was a common understory shrub that often dominated sites where the sagebrush overstory had been removed.

We selected random points (n = 142 and 120 in 1985 and 1986, respectively) throughout sagebrush dominated areas in the Gunnison Basin. Circular plots (1-km diam) were established around each point and topographic features in each plot were categorized by slope and aspect (Table 1). We visited plots once each winter between 3 January and 15 March and searched them for feeding sites. Boundaries of circular plots and topographic categories within plots were easily discerned because of the rugged terrain of the region. Feeding sites were locations where we observed flocks or tracks in snow, and where evidence of sage grouse browsing on sagebrush leaves was apparent. Track observation was a valid criterion to locate feeding sites because snow cover was present throughout each winter. Boundaries of plots, topographic categories, and feeding sites were drawn on 7.5-minute topographic maps.

We attempted to use line transects (Burnham et al. 1980) to measure search effort and the likelihood of detecting feeding sites in each topographic category. However, due to rugged terrain, maintenance of straight lines often was not feasible. Topographic categories were highly interspersed and foraging sites in 1 category were often discovered when an observer was in a different topographic unit. Therefore, it was not possible to independently measure search effort in each topographic category. Instead, 1 or 2 observers sampled topographic distribution of foraging sites by systematically walking through a plot and traversing the interior of each topographic category present. Estimates of foraging distribution are biased if sampling effort was not proportionally distributed among topographic categories. However, we believe that topographic categories were encountered in proportion to their availability and that our estimated distributions of foraging activity are valid. Thorough searches of the plots and high interspersion of topographic categories facilitated proportional sampling. JWH participated in >95% of surveys to assure consistency in sampling.

Table 1. Categories of slope and aspect used to classify topography in randomly selected sage grouse survey plots, Gunnison Basin, Colorado, 1985–86.

Topographic category	Site description
Low flat	Areas of <5° slope, broad (>100 m) flood or outwash plains adjacent to areas of higher topography, terraces on slopes.
High flat	Areas of <5° slope, broad (>100 m) mesa or ridge tops topographically higher than surrounding terrain.
Drainage	Narrow (<100 m) flood plains of permanent and intermittent streams, shallow eroded gulches on slopes.
Southwest slope	Slopes >5° with south or west aspects.[a]
Northeast slope	Slopes >5° with north or east aspects.[b]

[a] Aspects with compass bearings of 136–315°.
[b] Aspects with compass bearings of 316–135°.

Feeding sites were discrete and topographic features at feeding sites could be classified (Table 1). On the few occasions when large feeding sites overlapped 2 topographic categories, the observation was assigned to the category in which most foraging appeared to take place. We used a Chi-square analysis to test the null hypothesis that distribution of feeding sites was proportional to areal availability of topographic categories. Areal availability of topographic categories was based on survey plots where feeding activity was observed, and was estimated from topographic maps. Areas of topographic categories in circular plots where foraging was not observed were not considered when calculating availability. To improve independence of observations, a feeding site was not included in analysis of topographic distribution if it was close (<200 m) to a previously discovered feeding site in the same circular plot. Confidence limits (95%) were calculated for the observed proportions of foraging in each topographic category. Confidence intervals were compared to expected proportions to evaluate whether observed use of a topographic category differed from expected use (Byers et al. 1984, Alldredge and Ratti 1986).

We measured topographic variation in snow depth and shrub structure. Snow depth was assessed during ground searches for feeding sites. Measures of snow depth were obtained at 5 points spaced at 50-m intervals along transects in each topographic category present in a circular plot. Transects were initiated at a point near the center of the sampled category. Sagebrush structure and density were measured at 100 random sites following snow melt. Twenty random sites were sampled in each of 5 topographic categories (Table 1). We selected random sites within a sample of the same 1-km diameter plots used to evaluate topographic distribution of sage grouse foraging. A 15-m transect was oriented in a north–south direction at each random site. We recorded height and transect intercept length of live (>20% of stems with green foliage) sagebrush shrubs beneath the tape. Live sagebrush plants within 0.5 m of the 15-m transect were counted to obtain an estimate of density. We measured shrub dimensions and density along a second, 15-m transect that crossed the center of the first line at a perpendicular angle. Summary statistics calculated for each random vegetation site included total length of live big sagebrush canopy that was intercepted by transects (canopy cover); mean height of live big sagebrush plants beneath the transects; standard deviation of big sagebrush plant height as a proportion of mean height (CV ht); and number of live sagebrush plants/m^2. These variables were selected for analysis because they have previously been used in assessment of sage grouse winter habitat (Eng and Schladweiler 1972, Connelly 1982, Schoenberg 1982). We used analysis of variance to test null hypotheses of no differences in means of structural variables among terrain categories.

We estimated the proportion of sagebrush in the Gunnison Basin that was exposed above snow during midwinter (24 Jan–24 Feb) each year from 1984 through 1986. Approximately 416 km of low (<200 m) altitude transects were flown via fixed-wing aircraft during 1–2 days each year. Transects were oriented on north–south axes throughout the Gunnison Basin and were separated by 3.2-km intervals. JWH observed sagebrush through a 25-cm^2 viewing square marked at shoulder height on the passenger window of the cabin. At 15-second intervals, the presence or absence of exposed sagebrush in the viewing square was recorded. Sagebrush was considered unavailable if no exposed crowns were visible in the viewing square. A second observer was responsible for keeping the pilot informed of the aircraft's position relative to transect lines. Transects were marked on 7.5-minute topographic maps to facilitate correct orientation of the aircraft. Sagebrush exposure was calculated as the percentage of observation points at which sagebrush crowns were visible above snow cover.

RESULTS

We observed 74 winter feeding sites in 51 circular plots in 1985 and 83 feeding sites in 52 plots in 1986. Track and flock sightings provided similar estimates of topographic distribution of foraging (Hupp 1987). Therefore, track and flock sightings were pooled for analysis. Feeding activity was not proportionally distributed among topographic categories in 1985 or 1986 (χ^2 = 92.9, 4 df, $P < 0.001$, and χ^2 = 163.5, 4 df, $P < 0.001$, respectively). Sage grouse often foraged in drainages (23 and 33% of feeding sites in 1985 and 1986, respectively), even though that category comprised only 4 and 5% of the survey plots (Fig. 1). A high proportion (23 and 42%) of sage grouse feeding sites also occurred on southwest slopes each year, although use was

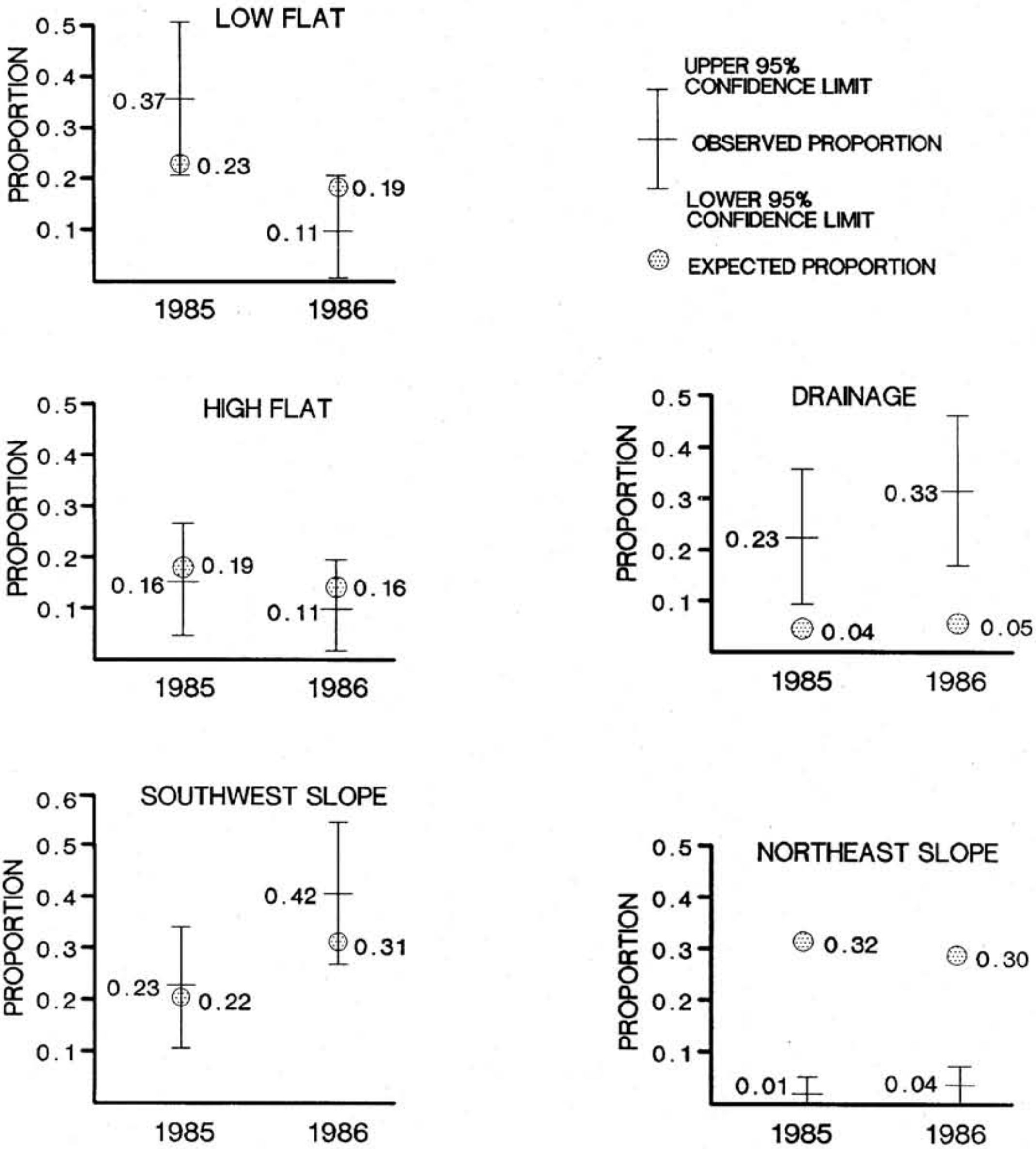

Fig. 1. Observed and expected proportions of sage grouse winter feeding sites within topographic categories in the Gunnison Basin, Colorado, 1985–86. Confidence limits (95%) for observed use were calculated following Byers et al. (1984). Failure of an expected proportion to fall within a confidence limit indicates that feeding activity in a topographic category was different ($P < 0.05$) than expected. Proportions are based on observation of 74 and 83 feeding sites in 1985 and 1986, respectively.

proportional to availability (Fig. 1). Use of low flat sites was greater (37% of feeding sites) in 1985 than in 1986 (11% of feeding sites [Fig. 1]). Feeding activity (16 and 11% of feeding sites) on high flat sites was proportional to availability (Fig. 1). We observed little (1 and 4%) feeding activity on northeast slopes even though that topographic category comprised 32 and 30% of the survey plots (Fig. 1).

Topographic variation in snow depth and sagebrush structure was apparent. In both years, snow depth increased between January and February and decreased in March (Fig. 2). Snow was deepest in drainages, low flat sites, and northeast slopes. Snow was shallowest on southwest slopes and depths were intermediate on high flat sites. Null hypotheses of no topographic differences in mean height, canopy cover, and

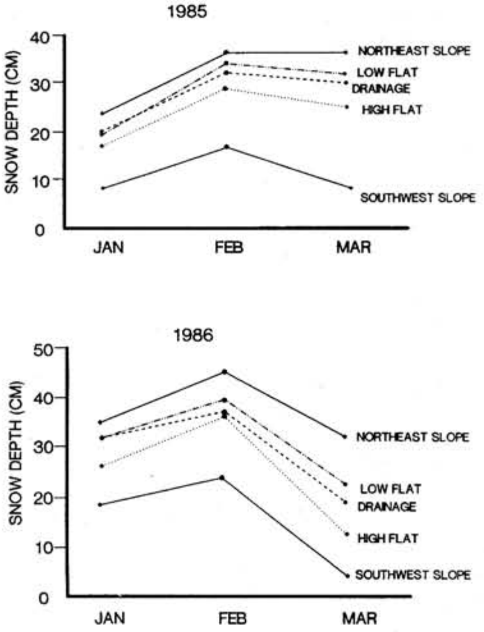

Fig. 2. Mean monthly winter (1 Jan–15 Mar) snow depths within topographic categories (n = 424 and 436 transects in 1985 and 1986, respectively) in the Gunnison Basin, Colorado. Standard errors of means ranged from ±0.6 to ±3.1.

sagebrush density were rejected ($P < 0.006$) (Table 2). Big sagebrush plants in drainages were taller than plants in other topographic categories. Big sagebrush plants on low flat sites and northeast slopes were shorter than plants in drainages, but taller than sagebrush on high flat sites and southwest slopes. Big sagebrush canopy cover in drainages was greater than in all terrains other than low flat sites. Canopy cover on northeast slopes was sparse relative to drainages. Big sagebrush canopy cover on southwest slopes and flat high sites was sparse relative to canopy cover in other terrains. Sagebrush density on flat high sites was high relative to density in drainages and southwest slopes.

Availability of exposed sagebrush in the Gunnison Basin was affected by winter snow accumulations. In 1984, exposed sagebrush was visible at only 7% of 627 observation points along aerial transects. Snowfall between November 1983 and March 1984 was approximately 186 cm (Natl. Oceanic Atmos. Adm. 1983–86). The 1985 and 1986 winters were milder with November–March snowfalls of 97 and 90 cm, respectively (Natl. Oceanic Atmos. Adm. 1983–86). Exposed sagebrush was visible at 84 and 79% of observation points in 1985 and 1986, respectively.

DISCUSSION

Topographic variation in shrub structure reflected differences in site conditions. Big sagebrush plants were tall and vigorous in drainages. Soils on low flat sites and northeast slopes were well-drained and sagebrush height and canopy cover were intermediate relative to other terrain categories. Xeric conditions on high flat sites and southwest slopes resulted in stands of short sagebrush plants with open canopies. High sagebrush density on high flat sites was due to the tendency of black sagebrush to occur in stands of small, closely spaced plants.

Topographic distribution of sage grouse feeding sites was affected by sagebrush height relative to snow depth (Fig. 3). Sage grouse foraged at sites where sagebrush exposure above snow was maximized. Between 46 and 75% of foraging occurred in drainages and on southwest slopes. Use of drainages was likely greater than expected because sagebrush was more available than in other topographic categories (Fig. 3). Drainages were sheltered from wind and sage grouse may have reduced thermoregulatory costs by foraging beneath closed canopies. Grouse frequently exploited southwest slopes because snow was less deep than in other categories (Fig. 3). While foraging on southwest slopes, sage grouse used sites where sagebrush height and

Table 2. Big sagebrush structural characteristics at random sites in the Gunnison Basin, Colorado, 1985–86.

	Topographic category										
	Low flat		High flat		Drainage		Southwest slope		Northeast slope		
Variable	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	P[a]
Canopy (cm)[b]	855	47	367	54	959	83	478	66	636	82	<0.001
Mean ht (cm)	43.3	2.9	31.6	2.1	52.8	1.9	28.8	2.5	41.5	3.5	<0.001
CV for ht (%)	29.6	1.5	27.6	2.8	31.2	1.6	29.9	2.2	27.8	2.1	0.71
Plants/m²	1.3	0.1	2.0	0.2	1.3	0.1	1.4	0.2	1.4	0.1	0.006

[a] Probability that mean values of structural variable were similar among terrains.
[b] Mean total length of big sagebrush canopy intercept.

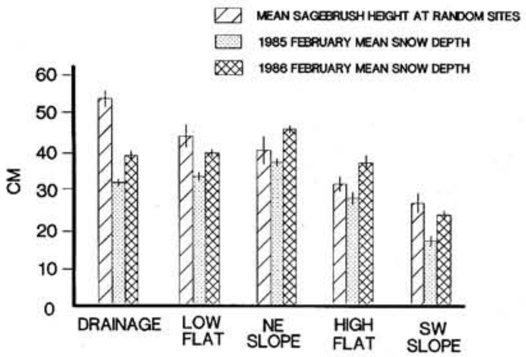

Fig. 3. Mean sagebrush height (±1 SE of the $\bar{x}$) at random locations relative to snow depth within topographic categories in the Gunnison Basin, Colorado, 1985–86.

canopy cover were greater than at random locations (Hupp 1987).

Foraging on low flat sites was affected by snow accumulations and was greater in 1985 than in 1986. Mean January snow depth on low flat sites was shallower in 1985 ($\bar{x}$ = 17.5 cm) than in 1986 ($\bar{x}$ = 32.9 cm). Many (48%) 1985 observations in the low flat category occurred in January prior to heavier midwinter snow accumulations. Because sagebrush was less available, use of low flat sites was reduced when snow depths exceeded approximately 30 cm in February 1985 and throughout the 1986 winter. When snow depth exceeded approximately 30 cm, sage grouse were less likely to forage on low flat sites and more likely to exploit sagebrush in drainages and on southwest slopes.

Thirteen percent of the feeding sites were observed on high flat sites while only 2% of feeding sites occurred on northeast slopes. Mean height of big sagebrush plants in these topographic categories was shorter and canopies were more open than in drainages. Snow depths were greater than on southwest slopes and sagebrush exposure was reduced (Fig. 3). Northeast slopes and high flat sites may be used during mild winters with <30 cm of snow. However, during winters when snow depths are >30 cm on northeast slopes and >20 cm on high flat sites, little foraging is likely to occur in these topographic categories.

In contrast to our findings in the Gunnison Basin, Eng and Schladweiler (1972) and Beck (1977) observed that sage grouse in Montana and northern Colorado, respectively, rarely used sagebrush on slopes during winter. Both studies reported greater use of flat (≤5°) areas. Beck (1977) suggested that sage grouse rarely foraged on slopes to minimize exposure to avian predation. Snow depths in those studies were shallow (3–25 cm) relative to winter conditions in the Gunnison Basin during 1985 and 1986. In northern Colorado, Schoenberg (1982) observed 32–46% of sage grouse winter use sites in drainages during winters in which snow accumulations were comparable to those we observed in the Gunnison Basin. During milder winters on the same northern Colorado study area, Remington and Braun (1985) observed that sage grouse primarily foraged on well-drained ridges, benches, and in draws where Wyoming big sagebrush (*A. t. wyomingensis*) was available. They suggested that Wyoming big sagebrush was nutritionally superior to other sagebrush taxa on their study area, and that sage grouse selection of feeding sites was influenced by taxonomic composition and nutritional quality of big sagebrush.

Topographic distribution of feeding activity probably varies among sage grouse populations due to geographic differences in winter conditions and taxonomic composition of big sagebrush communities. In the Gunnison Basin, the big sagebrush community was comprised of a single subspecies and there was no spatial variation in chemical composition of foliage (Hupp 1987). Distribution of sage grouse feeding activity was affected by sagebrush exposure above snow rather than by topographic differences in nutritional quality of forage. In contrast, 2 subspecies of big sagebrush were present in northern Colorado and chemical composition of foliage differed between taxa (Remington and Braun 1985). Selection of feeding sites by sage grouse in that region was influenced by the distribution of the nutritionally superior subspecies except during severe winters when preferred feeding areas were covered by snow (Schoenberg 1982, Remington and Braun 1985). Due to geographic variation in habitats, recommendations for management of winter foraging areas of sage grouse should be based on locally gathered data or derived from areas with similar winter conditions and sagebrush communities.

MANAGEMENT IMPLICATIONS

It is difficult to assess availability of sage grouse winter habitat on the basis of shrub structure measures if data on snow depth are not available. Because snow depth and sagebrush growth forms varied among topographic categories, topographic criteria were useful to assess distribution and availability of sage grouse winter foraging habitat in the Gunnison Basin. Topographic criteria may be more useful for habitat assessment than shrub structure measures because intensive vegetation sampling is not required.

Maintenance of sagebrush in drainages is a particularly important aspect of winter habitat management for sage grouse in the Gunnison Basin. During the severe winter in 1984, only 7% of the 1,600 km^2 of sagebrush vegetation in the Gunnison Basin was not snow-covered and was available to sage grouse. Reduced habitat availability in 1984 affected the physiological condition of sage grouse (Hupp and Braun 1989). Sagebrush that was exposed in 1984 primarily occurred in drainages. Drainages are a small proportion (3–4%) of the total land area in the Gunnison Basin, yet these sites are frequently the focus of sagebrush treatments due to vigorous sagebrush growth. Removal of sagebrush in drainages has a disproportionately severe effect on availability of sage grouse winter feeding habitat. Reduction of drainage habitat could result in a population decline similar to that observed by Swenson et al. (1987) following limited removal of vigorous sagebrush on a Montana wintering area. Maintenance of sagebrush in drainages assures that vigorous sagebrush is available to sage grouse during severe winters when sagebrush may not be exposed in other topographic categories. Maintenance of sagebrush on southwest slopes should also be emphasized due to the frequent observation of foraging activity on that terrain. We recommend that guidelines suggested by Braun et al. (1977) and Autenrieth et al. (1982) be considered during management of sagebrush on northeast slopes, low flat, and high flat topographies. These findings have implications for other regions occupied by sage grouse in which the terrain is heterogeneous, winter snows typically exceed 30 cm on low flat areas, and where the big sagebrush community is comprised of mountain big sagebrush. Different patterns of topographic distribution may occur in areas with shallower snow accumulations or where the sagebrush community is comprised of other taxa.

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