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ABSTRACT

Ungulate impacts on woody vegetation have been a concern on Montana wildlife habitats for more than a half-century. Fenced areas restricting access of all ungulates (exclosures) were established between 1944 and 1988 on many habitats to evaluate ungulate impacts on shrubs. Our objective was to determine the effect of long-term browsing on big sagebrush (Artemisia tridentata*), bitterbrush (*Purshia tridentata*), curlleaf mountain mahogany (*Cercocarpus ledifolius*) and horizontal juniper (*Juniperus horizontalis*). We hypothesized that the long-term effect of ungulate browsing would not impact these common shrubs. Canopy cover and density of shrubs were measured in and out of exclosures (*n *=14) on environmentally paired sites. Big sagebrush canopy cover, density of mature big sagebrush, and production of winter forage (*n *=7) were greater with protection on four sites (*P *≤ 0.05). Differences were not restricted to one subspecies of big sagebrush. Bitterbrush canopy cover and density of mature shrubs (*n *=3) were greater with protection on two sites (*P *≤ 0.05). Curlleaf mountain mahogany canopy cover (n =2) was greater with protection on both sites (*P *≤ 0.05), while density of mature mahogany was greater at one site (*P *≤ 0.05). Horizontal juniper cover (*n *=2) was greater with protection at both sites (*P *≤ 0.01). We rejected our hypothesis at ten of the 14 sites evaluated. Long-term ungulate browsing has impacted shrubs at ten sites that are not geographically related. This has implications to plant communities and value of shrub habitats to wildlife.*

INTRODUCTION

Shrubs are a vital component of wildlife habitats by providing animals with necessary forage and cover. Shrubs due to their growth habits and nutritive properties provide valuable forage to browsing wildlife, and are an important food source during winter months (Bayless 1969; Cook 1972; Dorn 1970; Kasworm and others 1984; Kufeld 1973; Kufeld and others 1973; Lovass 1958; Martinka 1967; Ngugi and others 1992; Stevens 1970; Wilkins 1957; Urness 1989; Welch 1989). Shrubs often provide necessary thermal and security cover for wildlife according to growth habit and height (Carson and Peek 1987; Thomas and others 1979; Urness 1989). The sustainability of many wildlife species is dependent on the browse in their habitat. During the mid twentieth century, resource managers determined the need to study the impacts and extent of ungulate use of shrub communities. Most wild ungulate populations across the western United States had been restored during the first half of the century. It became apparent that wild and domestic ungulate browsing, as well as drought, was altering shrub communities, therefore reducing their ability to sustain wildlife populations (Mussehl and Howell 1971). This was particularly important on wildlife winter ranges. To evaluate the influence of ungulates on shrubs and other plants, ungulate proof exclosures were constructed on many winter ranges and other areas of concern across Montana. These exclosures provide experimental comparisons of plant communities in the absence or presence of ungulate browsing (Daubenmire 1940; Young 1958). Our objective was to determine the impact of long-term browsing by ungulates on shrub species growing under a variety of environmental conditions and management scenarios. We examined big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), curlleaf mountain mahogany (*Cercocarpus ledifolius*) and horizontal juniper (*Juniperus horizontalis*) at 14 exclosure sites across Montana. Our objective was achieved by comparing shrub species protected inside exclosures to the same species browsed outside exclosures.

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METHODS

Study Sites

Fourteen study sites were located throughout Montana on locations where shrub species of interest were present (table 1). Sites were chosen based on the presence of an exclosure functioning for a minimum of 10 years and the area providing important habitat to wild ungulates at least part of the year. The shrub species of interest at each site was the dominant shrub and had to be sufficiently dense and distributed both inside the exclosure and on the environmentally paired area outside the exclosure to warrant sampling. Confounding factors influencing only the browse community inside or only outside were taken into consideration when determining usability of a site.

Sampling

Comparisons were made by pairing the protected sites with environmentally similar unprotected sites. Considerations for pairing the sites environmentally were slope and aspect (Coughenour 1991). Pairing the sights by slope and aspect typically ensures similar soil types and microclimates. All measurements were taken at least 2 m from the exclosure fence to eliminate fence effects such as trailing. Sampling occurred from June through August in 2001 and 2002.

Canopy Cover
Shrub canopy cover was estimated using the line intercept method (Canfield 1941). Transect lines 30 m in length were established a minimum of 3 m apart. Transects were placed at regular intervals so that each transect represented an equal portion of the area compared (Coughenour 1991; Wambolt and Sherwood 1999). Exclosures were of varying size, so number of transects varied. Ten transects was the maximum required for an adequate sample on large sites (Wambolt and Sherwood 1999). As few as three transects may be adequate on smaller sites (Kay and Bartos 2000). Equal number of transects were established inside and outside each exclosure. Shrub canopy was measured in 3 cm increments along the line. A plumb bob was suspended from the line to accurately measure live shrub tissue intercepting the line. Shrub tissue intercepting less than 3 cm of the line was not included. Canopy cover of live shrub tissue for each species encountered was then calculated as a percent of the total line length. Lines were averaged together to obtain a mean canopy cover for shrubs inside or outside the exclosure.

Density
Density of shrubs was determined in 2 x 30 m belt transects. Line transects used for determining canopy cover provided the center of each belt. Belt transects were formed by measuring 1 m perpendicular to both sides of the line transect. The number of juvenile, mature, and dead shrubs rooted in the belt transect was recorded. Juvenile shrubs were those having an average crown cover < 15 cm from 4 axis measurements. Dead shrubs were those shrubs having no live tissue. Density for belt transects were then averaged together to obtain mean density for shrubs inside or outside the exclosure.

Sagebrush Winter Forage Production
Production of winter forage by big sagebrush taxa was estimated on seven sites using models developed by Wambolt and others (1994). Ten mature big sagebrush plants within each belt transect were measured for this parameter. Specific parameters measured on sagebrush plants varied by subspecies and form class (Wambolt and others 1994). Form classes depended upon historic low or high-use of big sagebrush. High use plants exhibit intense browsing by appearing “hedged”. After obtaining density of mature big sagebrush and individual big sagebrush production of winter forage, the production of winter forage for big sagebrush per belt transect was calculated. Production inside exclosures was then compared to production outside on a $kg/60m^2$ basis.

Statistical Procedures
Rice and Westoby (1978) point out the difficulties of interpreting exclosures. Quadrants may be replicated inside and outside exclosures, but not samples of the original vegetation subjected to an exclosure treatment. Location of an exclosure is typically arbitrary rather than random and management and grazing patterns vary between exclosures. Mackie (1973) cautioned against any generalizations concerning impacts of browsing due to variations in species, location, time, site or other environmental conditions affecting browse species productivity. For these reasons, sites were not combined, rather treated independently. We made no assumptions of pre-exclosure vegetation at the sites.

Canopy cover, density, and production of sagebrush winter forage inside the exclosure was compared to those parameters outside the exclosure at each site using a *t*-test. Equality of variances was tested using a Folded F test and variances were considered unequal when $P \leq 0.05$. A Student’s *t*-test was used when variances were equal to determine differences between parameter means. When mean variances were unequal, the Satterthwaite *t*-value was used to determine differences between parameter means. Parameter means were considered significant when $P \leq 0.05$. Differences at the $P \leq 0.1$ level were also reported.

RESULTS AND DISCUSSION

Evaluation of shrub species at 14 study sites throughout Montana determined that ungulate browsing has impacted the dominant shrub species at ten sites (tables 2 and 3). Shrub parameters were greater ($P \leq 0.05$) with protection inside the exclosure than browsed outside exclosures in order for browsing to be considered to be an impact. Differences were detected for all shrub species. Exclosures where differences were detected were not restricted to specific regions of Montana or years the exclosure provided protection. Differences in browse parameters were found between inside and outside of the most recently constructed exclosure (1990) as well as the oldest exclosure (1945).

Differences in shrubs between excluded and protected areas developed from years of exclusion (tables 1 and 2). Intensity of ungulate browsing outside exclosures has likely been variable at some locations due to ungulate populations fluctuating through the years. A period of decreased browsing pressure may allow these communities to partially recover before the next period of intense browsing. Shrub communities outside exclosures have evolved in such a manner, while browsing inside exclosures is not a consideration in development of plants and their communities. The value in comparing protected to unprotected vegetation is to understand the site and plant community potential. In extreme cases, browse communities inside exclosures resulted in identification of a community that had been lost outside. Further browsing impacts may result in loss of shrubs in the plant community.

Table 1—Study site locations and descriptions.

Site	Environment Description	Years of Protection[a]	Latitude	Longitude	Elevation in Meters	Slope in Degrees	Aspect
1-Porcupine Creek	Mtn. Foothills	56	45.225805	-111.235500	2113	4	W-SW
2-Hyde Creek	Mtn. Foothills	39	45.016722	-111.716722	1972	8	E
3-Tepee Creek	Mtn. Foothills	46	45.070305	-111.164833	2143	16	S
4-Johnson Creek	Mtn. Foothills	35	45.835555	-113.022916	1880	10	S
5-Crooked Creek	Mtn. Foothills	40	45.093583	-108.414527	1930	8	E
6-Pine Ridge	Prairie Breaks	32	47.783777	-106.861805	740	5	SE
7-Cottonwood	Prairie Breaks	35	48.476638	-107.784027	704	3	SE
8-Poverty Flat	Montane Forest	43	48.919444	-115.206888	838	2	E
9-Young Creek	Montane Forest	43	48.991333	-115.193138	812	2	W
10-Dry Cottonwood	Mtn. Foothills	40	46.213555	-112.65675	1728	17	S
11-Scudder Creek	Mtn. Foothills	48	45.304805	-113.091888	2041	13	SE
12-Sykes Coulee	Mtn. Foothills	38	45.016611	-108.295138	1501	2	SE
13-Deer Hill	Mtn. Foothills	13	48.102111	-112.679305	1477	10	NW
14-Picket Pin	Mtn. Foothills	40	45.436361	-109.936027	1870	24	SW

[a]Numbers of years site inside exclosure has been protected from browsing.

Big Sagebrush

Big sagebrush taxa were evaluated at seven sites. Protection from all ungulates from 32 to 56 years allowed big sagebrush to attain greater ($p \leq 0.01$) canopy cover at four sites (table 2; sites 1,3,5,7). Less significant ($p \leq 0.1$) differences in canopy were detected at a fifth site (site 4). Differences in canopy cover of big sagebrush between unprotected and protected areas were not restricted to one subspecies.

Rens (2001) reported canopy cover of mountain big sagebrush at five sites on the Northern Yellowstone Winter Range (NYWR) was greater ($P \leq 0.0001$) inside (20.0 percent) than outside (9.7 percent) exclosures. Wambolt and Sherwood (1999) also on the NYWR reported average canopy cover of big sagebrush at 19 sites was 19.7 percent inside big game exclosures and 6.5 percent outside. They reported areas protected from browsing had three times greater ($P \leq 0.0027$) canopy cover of big sagebrush than unprotected areas. We found sites with canopy cover differences inside and outside exclosures averaged 15.5 percent and 6.9 percent, respectively and all big sagebrush sites averaged 12.3 percent inside and 7.1 percent outside.

Ungulate browsing also had an affect on density of big sagebrush plants. Four sites that had greater ($P \leq 0.01$) canopy cover of big sagebrush inside the exclosure also had greater ($P \leq 0.01$) density of mature big sagebrush inside the exclosure (table 2; sites 1,3,5,7). At site 4, density of mature big sagebrush inside the exclosure was greater ($P \leq 0.01$) than density outside, but canopy cover differences were less significant ($P \leq 0.1$). Our results agree with Wambolt and Sherwood (1999), as they reported a high association between big sagebrush cover and density ($r = 0.92$; $P \leq 0.000$). Density of mature Wyoming big sagebrush at site 6 was slightly higher ($P \leq 0.1$) outside the exclosure, which is attributed to competition with sweet clover inside the exclosure.

Table 2—Shrub canopy cover and density of mature shrubs at 14 environmentally paired sites either browsed or protected.

		Percent Live Canopy Cover			Density of Mature[a] Shrubs/$60m^2$			Density of Young Shrubs/$60m^2$		
Site	**Shrub Species**	**Protected**	**⇔[b]**	**Browsed**	**Protected**	**⇔[b]**	**Browsed**	**Protected**	**⇔[b]**	**Browsed**
1	Mt. Big Sagebrush	18.3	***	8.8	60.6	**	22.7	11.3		7.8
2	Mt. Big Sagebrush	9.5		8.7	24.4		25.7	4.3	**	13.3
3	Mt. Big Sagebrush	17.0	***	10.3	46.5	***	34.7	6.6		6.7
4	Mt. Big Sagebrush	11.1	*	8.4	50.4	***	36.7	6.5	***	17.3
5	WY Big Sagebrush	4.1	**	2.1	55.0	***	24.9	4.7		4.5
6	WY Big Sagebrush	3.9		5.3	15.6	*	33.2	2.1	**	5.5
7	WY Big Sagebrush	22.4	***	6.2	106.1	***	51.7	16.3		11.8
8	Bitterbrush	2.4	***	0.0	5.9	***	0.7	0.2		0.3
9	Bitterbrush	4.0		7.8	9.0	**	20.6	1.0		1.7
10	Bitterbrush	4.1	**	0.6	7.2	*	2.7	0.5		1.3
11	Curlleaf Mt Mahogany	34.9	***	11.0	31.3	**	14.1	2.0		0.1
12	Curlleaf Mt Mahogany	14.4	**	9.6	18.6		17.0	0.0		1.2
13	Horizontal Juniper	27.3	***	0.3						
14	Horizontal Juniper	47.1	***	6.0						

[a]Shrubs having a minimum canopy of 15 cm
[b]Paramater comparison using *t*-test; *$p \leq 0.1$; ** $p \leq 0.05$; *** $p \leq 0.01$

Density of young big sagebrush was not greater ($P > 0.05$) with protection at any site (table 2). Snow may be protecting these young shrubs for several years, allowing them to grow to mature size before they are browsed (Mehus 1995; Wambolt and Sherwood 1999). Density of young big sagebrush was greater ($P \leq 0.05$) outside the exclosure at all sites where no differences in canopy cover were detected (table 2; sites 2,4,6). Protection afforded by snow and less browsing at these sites may allow more young shrubs to grow than at sites where ungulates are impacting sagebrush canopy cover.

Density of dead big sagebrush was unreliable as a comparison between protection and browsing. Some differences ($P \leq 0.01$) were detected at three sites (11, 16, 32) where big sagebrush canopy cover was also greater ($P \leq 0.01$) inside. Because cover and density are highly associated (Wambolt and Sherwood 1999), it may be logical that density of dead would also be higher. Additionally, dead shrubs may remain more recognizable and deteriorate slower in the absence of trampling by ungulates, thus estimation of their density may be higher inside exclosures.

Table 3—Production of big sagebrush winter forage at 7 environmentally paired sites either browsed or protected.

		Kilograms of Winter Forage/$60m^2$		
Site	**Shrub Species**	**Protected**	**⇔[a]**	**Browsed**
1	Mt. Big Sagebrush	3.7	**	1.3
2	Mt. Big Sagebrush	1.8		1.8
3	Mt. Big Sagebrush	3.6	***	1.8
4	Mt. Big Sagebrush	2.5		2.6
5	WY Big Sagebrush	0.6	***	0.2
6	WY Big Sagebrush	0.3		0.4
7	WY Big Sagebrush	1.9	***	0.6

[a]Paramater comparison using *t*-test; ** $p \leq 0.05$, *** $p \leq 0.01$

Estimates for winter forage production by big sagebrush were greater ($P \leq 0.05$) with protection at four of seven sites (table 3; sites 1,3,5,7). These sites also had greater percent canopy cover and density of mature big sagebrush inside the exclosure. Sites where differences were detected produced 60 percent more big sagebrush forage for winter per 60 m^2 inside than outside exclosures. Wambolt and Sherwood (1999) on the NYWR reported similar results. They reported protected mountain big sagebrush produced 88 percent more forage for winter than unprotected sagebrush. Rens (2001) reported more than twice that (176 percent) when protected and unprotected mountain big sagebrush were compared.

Bitterbrush

Ungulate browsing has negatively impacted bitterbrush on two of the three sites evaluated (table 2; sites 8 and 10). At site 8, bitterbrush canopy cover and density of mature shrubs were greater ($P \leq 0.05$) inside the exclosure. Canopy cover was greater with protection at site 10, while differences in density were less significant ($P \leq 0.1$). At site 9, density was greater ($P \leq 0.05$) outside the exclosure, while there was no difference in canopy cover. Bitterbrush differences at site 9 may reflect apparent greater canopy cover and density of conifer trees inside the exclosure than outside.

Our results agree with other work done on bitterbrush including previous evaluation of sites 9 and 10 (Mackie 1973). Mackie (1973) also found greater density of bitterbrush outside at site 9 and greater inside at site 10. Unprotected areas had greater production of bitterbrush twigs than inside the exclosures at all 7 sites Mackie (1973) sampled. Mackie (1973) concluded differences in bitterbrush parameters were determined primarily by individual site characteristics and secondly by ungulate browsing. Kay (1995) found bitterbrush growing in the Greater Yellowstone Ecosystem, had less ($P \leq 0.05$) canopy cover, height, size, and volume outside a big game exclosure. He attributed this difference to repeated use by wild ungulates. The mixes results of our evaluation of bitterbrush also suggest other site factors in addition to browsing may explain some differences between protected and browsed sites.

Curlleaf Mountain Mahogany

Canopy cover of curlleaf mountain mahogany was greater ($P \leq 0.05$) inside the exclosure at both sites (11 and 12) where it was sampled. Differences in densities were not consistent between sites (table 2). Density of young mahogany was not different ($P \leq 0.05$) inside and outside exclosures at either site (table 2). Browsing has not limited recruitment of new mahogany plants. Density of mature and dead mahogany was greater ($P \leq 0.05$) inside the exclosure at site 11, but no differences were detected at site 12. Browsing appears to limit the size of individual shrubs at site 12, while canopy cover and number of mature shrubs were altered by ungulate browsing at site 11. Mackie (1973) studied site 11 and reported similar densities and canopy coverage but he emphasized that production of young twigs was greater outside the exclosure.

Horizontal Juniper

The two sites where horizontal juniper was evaluated had an exclosure protecting shrubs from all ungulate browsing and an exclosure only excluding livestock. Exclusion of all ungulates at site 13 for 13 years and at site 14 for 40 years has allowed horizontal juniper to attain very high canopy cover (27.3 percent and 47.1 percent; table 2). Areas with exclusion of livestock only yielded canopy cover of 3.2 percent and 18.2 percent (figure 1). Areas accessible to all ungulates had canopy coverage of 0.3 percent and 6.0 percent (table 2). Differences between canopy cover of each phase of both exclosures were significant ($P \leq 0.05$; figure 1). These data suggest that the combined presence of wild ungulates and domestic ungulates has had the most detrimental effect on horizontal juniper, but wild ungulates alone have negatively impacted horizontal juniper.

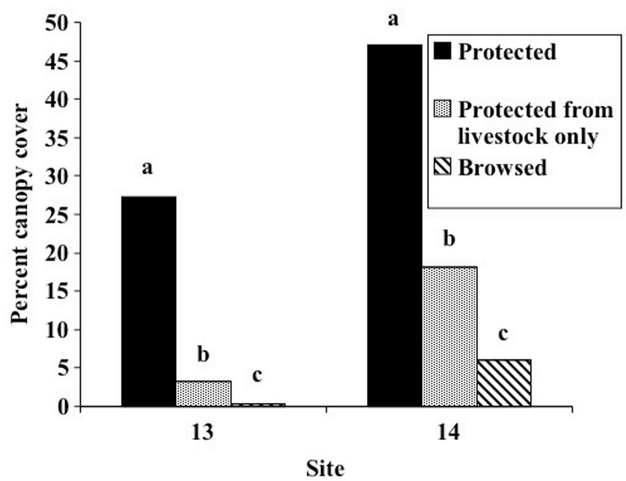

Figure 1—Percent canopy cover of horizontal juniper at 2 sites; environmentally paired either protected, protected from livestock or browsed. Sets of bars with different letter are significantly different ($p \leq 0.05$).

Kasworm and others (1984) studying ungulate diets near site 13, reported horizontal juniper as being very important forage to wintering elk (*Cervus elaphus nelsoni*), bighorn sheep (*Ovis canadensis*), and mule deer (*Odocoileus hemionus*). Presence of horizontal juniper in fecal samples of cattle (0.9 percent) suggests they consume only a small amount of it (Kasworm and others 1984). Cattle are much larger animals and consume greater quantities of forage than elk, bighorn sheep, and mule deer, so the actual amount of horizontal juniper consumed by cattle may be similar to that of wild ungulates. We also observed greater cover of grasses inside the livestock exclosures, which may conceal horizontal juniper directly or hold more snow during winter, thus preventing some use by wild ungulates. Livestock consume grass outside the exclosures, which may expose horizontal juniper and allow wild ungulates to browse juniper more readily. This theory contradicts Keigley and Olson (2001) where they observed horizontal juniper was more abundant inside a big game exclosure and outside, compared to inside the livestock exclosure. They suggest that a combination of reduced light availability during the growing season due to tall grass, and browsing by wild ungulates in winter is restricting growth of horizontal juniper inside the livestock exclosure. Although our theory and Keigley and Olson's (2001) contradict each other, they agree with the findings of Kasworm and others (1984) that wild ungulates are heavily using horizontal juniper.

CONCLUSIONS

Concerns about browsing impacts have typically been centered on areas of special interest such as the Northern Yellowstone Winter Range (Kay 1995; Rens 2001; Ripple and Larsen 2000; Wambolt and Hoffman 2001; Wambolt and Sherwood 1999). Our study did not consider specific areas or taxa; rather, multiple shrub species across various environments with functional exclosures. Thus, this study shows the impacts of ungulates across many environmental and management scenarios.

Ten of the 14 study sites sampled provided evidence that long term browsing by ungulates is limiting the growth of dominant shrub. Logically, we would expect individual plants of landscape dominants to receive lighter levels of use, while plants of uncommon species might be more intensely used due to their rarity. We found this was not the case; rather browsing has impacted landscape dominants such as big sagebrush, bitterbrush, curlleaf mountain mahogany and horizontal juniper.

Wild and domestic ungulate populations on some of these areas should be re-evaluated. Impact on browse species has altered the vegetation of some ungulate ranges, which in turn may prove to be a long-term detriment to ungulate populations. Other wildlife species depending on these shrub communities have likely also been impacted. Consideration for shrub communities should be emphasized when managing ungulate populations.

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