Browsing Effects on Wyoming Big Sagebrush Plants and Communities

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Abstract: The effect of likely yearlong browsing by several wild ungulate species on individual Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) plants and communities was studied. The investigation was conducted near Gardiner, MT, in the ungulate-rich boundary line area of the Northern Yellowstone Winter Range. Plant level responses were measured in this study and related to reported community responses. Individual sagebrush plants were significantly different ($P < 0.05$) in and out of an exclosure 35 years after it was constructed (1957) in regard to production, seedhead number, and leaf dry weight. Certain morphological characters of the same plants were not impacted by browsing. These results relate well to previously detailed plant community responses on this important ungulate range. The Wyoming big sagebrush has been greatly reduced in the study area by browsing.

Introduction

Big sagebrush (*Artemisia tridentata*) taxa are particularly important for ungulates as forage and often security and/or thermal cover in portions of the Northern Yellowstone Winter Range (NYWR) that are relatively free of snow. Under these conditions, the plants remain accessible for foraging throughout winter (Wambolt 1998). Twentieth-century naturalists (Cahalane 1943; Kittams 1950; Rush 1932; Wright and Thompson 1935) have commented on the conspicuous use of sagebrush for forage and cover by ungulates on the NYWR and expressed concern over what they considered excessive use of sagebrush in the winter diets of ungulates in Yellowstone National Park (YNP).

The effects of Yellowstone's large populations of ungulates on sagebrush taxa on the NYWR have been debated for more than 70 years (Rush 1932; Wright and Thompson 1935). The National Park Service (NPS) was concerned enough about sagebrush and other browse on the NYWR that they constructed ten 2-ha exclosures on the NYWR in 1957 and 1962 to investigate the relationships between ungulate foraging and plant communities.

We used a NPS exclosure erected in 1957 to test the hypothesis that Wyoming big sagebrush plants protected from browsing for 35 years would exhibit growth characteristics similar to browsed plants. These results were then related to plant community responses on the NYWR.

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Study Area and Methods

The natural winter range provided by the Gardiner Basin is created by the orographic effects on precipitation of mountain peaks up to 3,353 m in elevation. Ideal winter range on extensive south- or west-facing aspects in the Gardiner Basin have been influenced by glacial scouring, morainal deposition, and outwash sediments. In the portion of the NYWR where this study was conducted, the sagebrush habitat is the Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*)-bluebunch wheatgrass (*Agropyron spicatum*) type.

Individual plant characteristics (table 1) were sampled from 20 plants randomly selected and then paired by size in and out of the 1957 exclosure. Seedheads were counted. Ten leaders were clipped per plant. Leaves were counted and dried at 65 °C, and dry weight was determined for each leader and its leaves. The Kolmogorov-Smimov test compared differences in distributions, and the Wilcoxon test compared distribution medians.

Sampling of community characteristics were made in and out of the above described exclosure (1957 construction) and a second similar exclosure constructed in 1962 approximately 300 yards from the first exclosure. This sampling included measurements of individual sagebrush plants for seedhead number and length, average cover, major and minor axes, crown depth, and overall height. These measurements estimated sagebrush productivity from models previously developed from Wyoming big sagebrush plants in

Table 1—Average differences between browsed and unbrowsed Wyoming big sagebrush plants.

Characteristic	Browsed[a]	Unbrowsed[a]
Production (g/plant)	10.0a	44.7b
Seedheads per plant	0.08a	60.3b
Leader length (mm)	22.9a	22.3a
Leader dry weight (g)	.02a	.02a
Leaves per leader	43.0a	44.0a
Leaf area (mm^2)	354.0a	354.0a
Leaf dry weight (g)	0.06a	0.08b

[a]Values followed by different letters are significant ($P \leq 0.05$).

the Gardiner Basin (Wambolt and others 1994). Additional production information is reported in Wambolt and Sherwood (1999). Shrub density and line intercept (canopy cover) were determined for both young and old plants. Because the 2-ha exclosures contained considerable environmental variation, the sagebrush habitat within each exclosure was stratified (Hurlbert 1984) by separating topographic, soil, and microclimatic variation into eight paired sites. With random sampling using paired sites (in and out of the exclosures), it is unlikely that comparable distributions of topo-edaphic positions would have been obtained regardless of sample size (Coughenour 1991). Sampling areas were paired in and out of each exclosure within four slope-aspect combinations (table 2). These areas were compared with students' t-tests.

Discussion

Because of heavy browsing, plants outside the exclosure had no terminal leader growth. However, the plants inside the exclosure were dominated by terminal growth, and axial long shoots were rare. Thus, for further investigation, it was necessary to compare the terminal leaders of protected plants inside the exclosure to axial long shoots on browsed plants.

Unbrowsed plants had consistently higher production than browsed plants (table 1). The average production per plant was 10 g with browsing and 45 g with protection. No measurements of dead crown were taken, but plants under protection appeared vigorous, whereas plants outside the exclosure had large amounts of dead crown.

The greatest difference between browsed and unbrowsed plants was in seedhead production. Seedheads overaged 0.08 per browsed plant and 60.3 per unbrowsed plant. Related studies confirm that stress, such as herbivory, may delay or prevent flowering for several years (Bazzaz 1987; Maschinski and Whitham 1989; McConnell and Smith 1977). The lower overall production of browsed sagebrush plants indicates that foliage loss results in reduced reproductive potential. Bilborough and Richards (1991) found that buds for flowering stems on mountain big sagebrush were located on short shoots at the distal end of the terminal leader. Because almost all terminal leaders were removed on browsed plants, flowering stems would have to be initiated from elsewhere. The loss in seedhead production from browsing on the NYWR has undoubtedly resulted in declines in reproduction for sagebrush because the taxon lacks any asexual means of reproduction.

A companion study found that the addition of average seedhead weight improved the capability of models to predict production of winter forage from the three NYWR big sagebrush subspecies (Wambolt and others 1994). However, these improved models could only be used for two of the taxa when they exhibited light use (browse form class). Heavily used plants produced few inflorescences; therefore, the addition of average seedhead weight to the model was most useful for predicting forage production from low-use plants (Wambolt and others 1994). The segregation of browse form classes and inclusion of average seedhead weight in the models acknowledge the impact browsing has had on the annual production and reproduction of NYWR sagebrush and relate well to our findings of individual plant characteristics.

Thirty-five percent of mountain big sagebrush (*A. t. vaseyana*) plants were killed by heavy browsing between 1982 and 1992 (Wambolt 1996). Many surviving plants developed a heavy-use browse form class with a high percentage of dead crown. The dead crown in the three big

Table 2—Percent canopy cover of Wyoming big sagebrush and number of big sagebrush plants (with a minimum canopy of 15 cm) per 60 m^2 at eight environmentally paired sites, either browsed or protected. The paired sites are associated with the exclosures established either in 1957 or 1962 (Wambolt and Sherwood 1999).

Site	Slope[a]	Aspect	Protected	Browsed	Probability > t
			- - - - - Canopy cover (percent)- - - - -		
Gardiner-57A	Flat	Flat	3.9	0.0	0.0001
Gardiner-57B	Steep	E	3.6	.1	.0004
Gardiner-57C	Gentle	SW	4.5	1.1	.0001
Gardiner-57D	Gentle	NWW	1.4	.4	.0073
Gardiner-62A	Moderate	NEE	21.8	.4	.0001
Gardiner-62B	Flat	Flat	17.6	4.3	.0000
Gardiner-62C	Very steep	NEE	2.4	.2	.0012
Gardiner-62D	Very steep	SE	6.8	.0	.0001
			- - - - - - Density (per 60 m^2) - - - - - -		
Gardiner-57A	Flat	Flat	9.0	.5	.0002
Gardiner-57B	Steep	E	8.1	.5	.0002
Gardiner-57C	Gentle	SW	15.1	5.0	.0005
Gardiner-57D	Gentle	NWW	7.7	1.0	.0001
Gardiner-62A	Moderate	NEE	36.0	1.2	.0001
Gardiner-62B	Flat	Flat	39.2	.2	.0001
Gardiner-62C	Very steep	NEE	2.2	.0	.0090
Gardiner-62D	Very steep	SE	6.9	.7	.0001

[a]Slope classes are: flat ≤ 3 percent, gentle = 4 to 15 percent, moderate = 16 to 29 percent, steep = 30 to 44 percent, very steep ≥ 45 percent.

sagebrush subspecies increased in proportion to the overall amount of browsing received by each taxon. The percentage of dead crown in live plants for mountain big sagebrush, Wyoming big sagebrush, and basin big sagebrush (*A. t.* ssp. *tridentata*) was 58.7, 45.4, and 30.1, respectively (Wambolt 1996).

A significant difference was found between the development of protected and browsed big sagebrush communities (table 2). Wambolt and Sherwood (1999), who studied mountain big sagebrush in addition to Wyoming big sagebrush, stated:

> Since the period of exclosure construction in 1957 and 1962, there has been a significant difference in the development of protected and browsed big sagebrush communities. Average big sagebrush canopy cover on protected sites was 202 percent greater ($P \leq 0.0027$) than on browsed sites over the nineteen-paired sites. The average big sagebrush cover for all 19 sites was 19.7 percent inside and 6.5 percent outside the exclosures. This relationship was universal on sites with Wyoming big sagebrush or mountain big sagebrush, flat to very steep topographies, and all aspects and precipitation levels.

However, the differences between in and out of the exclosures at the Wyoming big sagebrush sites discussed in this paper were much greater than at the mountain big sagebrush locations. The Wyoming big sagebrush sites under protection averaged almost 10 times more sagebrush cover than where browsing had continued following exclosure construction. Ungulate browsing also affected numbers of big sagebrush plants. Across the NYWR, big sagebrush plants were twice as numerous with protection as with browsing.

The production differential for Wyoming big sagebrush was great, but because browsed plants were so reduced in size, their growth parameters were not suitable for production models (Wambolt and others 1994). The response of the sprouting shrubs, green rabbitbush (*Chrysothamnus visidiflorus*), rubber rabbitbrush (*C. nauseosus)*, and gray horsebrush (*Tetradymia canescens*), as measured by canopy cover and density, was similar to that of big sagebrush across the NYWR.

Singer and Renkin (1995) and Wambolt and Sherwood (1999) found a large impact from browsing on the Wyoming big sagebrush in the Gardiner Basin (fig. 1). Wambolt and Sherwood (1999) considered the difference in impact between Wyoming big sagebrush and mountain big sagebrush with this statement: "Pronghorn and mule deer often forage heavily on big sagebrush taxa (Welch and McArthur 1979). Mule deer diets averaged 52 percent big sagebrush over a 10 year period (Wambolt 1996), only a couple of kilometers away from the eight Wyoming big sagebrush paired sites. A high degree of utilization is reflected in the great impact on Wyoming big sagebrush populations at these eight sites where elk may also be present with pronghorn and mule deer (Singer and Renkin 1995)."

Wambolt (1996) concluded that any of the four NYWR sagebrush taxa would be heavily browsed if severe winter conditions precluded ungulates from exercising their preferences. However, mountain big sagebrush was clearly the preferred taxon by mule deer and elk. The fact that Singer and Renkin (1995) and Wambolt and Sherwood (1999) found Wyoming big sagebrush to be more impacted than mountain big sagebrush was largely a function of snow depth limiting pronghorn and mule deer foraging over the larger distribution of mountain big sagebrush. The intensive competition from a large elk population also restricted the winter range of the smaller ungulates to the Wyoming big sagebrush habitat type.

Conclusions

The historical evidence and recent studies (Patten 1993; Wambolt 1998; Wambolt and Sherwood 1999) indicate a significant decline of NYWR sagebrush. This potentially impacts ungulates that rely on sagebrush habitat for meeting their nutritional needs and other requirements. Sagebrush taxa are highly nutritious and preferred forage for ungulates (Welch and McArthur 1979). They have been bred and selected to improve the forage values of rangelands (Welch and Wagstaff 1992). Sagebrush is particularly high in protein. Welch and McArthur (1979) found the midwinter crude protein content of 21 big sagebrush accessions averaged 12.4 percent (range = 10 to 16 percent).

Ungulates such as pronghorn are impacted as the loss of their highest winter protein source (sagebrush) continues (Welch and McArthur 1979). This loss will manifest itself in a decreasing ability to meet their nutritional needs and requirements for reproduction. The implications for other organisms are clear. In concert with the decline of the native vegetation (sagebrush and dependent species), it is reasonable to expect that numerous animals (Welch 1997) will be impacted.

The following points summarize our findings:

1. Wyoming big sagebrush shrubs that were protected from ungulate browsing produced significantly more forage than browsed shrubs.
2. Seedhead production was severely reduced by browsing. Heavily browsed stands may have difficulty regenerating.
3. Leaders on browsed shrubs have the same number of leaves as those on unbrowsed shrubs, but the mass of leaves is reduced.
4. Shrub composition of the Wyoming big sagebrush habitat type has been significantly changed by browsing on the NYWR.
5. Big sagebrush may be overused and severely damaged on big game winter ranges.

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