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Elk and Fire Impacts on Mountain Big Sagebrush Range in Yellowstone

Carl L. Wambolt[1] and Reyer J. Rens[2]

ABSTRACT

*Range recovery after fire has many implications for wildlife habitat. It was our objective to determine the effect of elk herbivory on recovery of mountain big sagebrush (*Artemisia tridentata vaseyana*) – bluebunch wheatgrass (*Agropyron spicatum*) – Idaho fescue* (Festuca idahoensis*) winter range a decade after a 1988 wildfire on the Black-tailed Deer Plateau of the Northern Yellowstone Winter Range. Our hypotheses were that shrubs and herbaceous plants will recover from fire equally with or without elk herbivory. Measurements were taken in and out of exclosures established in 1957 and 1962 on environmentally paired, protected and browsed-grazed sites (*n *= 12). Mountain big sagebrush cover (*n *= 5) averaged 20 percent with protection and 9.7 percent where browsed (*P *≤ 0.01). Mountain big sagebrush densities were not different (*P *≤ 0.01). The sprouting shrubs, rubber rabbitbrush* (Chrysothamnus nauseosus*), green rabbitbrush* (C. viscidiflorus*), and gray horsebrush (*Tetradymia canescens*), (*n *= 4) responded the same as mountain big sagebrush with cover of 5.8 percent and two percent where protected and browsed, respectively (*P *≤ 0.001), with no overall difference in density (*P *≤ 0.47). Few cover differences existed between individual pairs of protected and unprotected sites for herbaceous plants (*n *= 12). Similarly no cover differences were found over all sites for total herbaceous species, grasses, or forbs. We rejected our hypotheses for shrubs as elk herbivory did negatively impact shrub recovery after wildfire. Reductions of shrub cover and productivity in mountain big sagebrush-grass communities from wildfire and intense herbivory have implications for many organisms.*

Keywords: Artemisia tridentata*, elk, fire, sagebrush, Yellowstone*

INTRODUCTION

Ungulates rely on sagebrush (*Artemisia*) habitat types for winter forage on the Northern Yellowstone Winter Range (NYWR) (Wambolt 1996; Wambolt 1998; Wambolt and McNeal 1987; Wambolt and Sherwood 1999). Basin big sagebrush (*A. t. tridentata*) and Wyoming big sagebrush (*A. t. wyomingensis*), are important on the NYWR. However, it is mountain big sagebrush (*A. t. vaseyana*) that is most important there due to the larger area it occupies and its high preference by ungulates as forage (Wambolt 1996; Wambolt 1998).

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During winter basin big sagebrush is particularly important for ungulates as nutritious forage and for thermal and security cover (Wambolt 2004; Welch and McArthur 1979). Mechanisms that influence ungulate browsing patterns on sagebrush taxa on the NYWR have been investigated, including intensity of use (Bray and others 1991; Personius and others 1987; Singer and Renkin 1995; Striby and others 1987; Wambolt 1996; Wambolt and McNeal 1987; Wambolt and others 1994). Intense browsing has reduced big sagebrush populations on the NYRW (Wambolt 1996; Wambolt and others 1999; Wambolt and Sherwood 1999). Wildfire at least temporarily eliminates big sagebrush taxa as they respond negatively to fire (Wambolt and others 1999; Welch 2005). Loss of big sagebrush can impact numerous wildlife populations (Welch 2005).

During the early twentieth century, concern for the welfare of big sagebrush communities within Yellowstone National Park (YNP) received much attention (Cahalane 1943; Kittams 1950; Rush 1932; Wright and Thompson 1935). In response, the National Park Service (NPS) constructed 10 exclosures in 1957 and 1962, partially to study the relationships between ungulate foraging and big sagebrush. Two exclosures on the Black-tailed Deer Plateau containing only big sagebrush-grass habitat types completely burned during the large Yellowstone fires of 1988 creating an opportunity to investigate fire and elk herbivory influences on these communities.

Our objective was to investigate recovery of mountain big sagebrush and associated species on the Black-tailed Deer Plateau of the NYWR a decade after the 1988 Yellowstone wildfires, a period during which the area was under relatively intense winter herbivory, largely by elk. We did this by comparing shrub and herbaceous cover and shrub densities between environmentally paired sites protected or unprotected from ungulate foraging within the area burned in 1988. We tested the hypotheses that these plant taxa recovered from the wildfire equally with or without elk herbivory.

STUDY SITES

The NYWR occupies 100,000 ha over an 80 km stretch along the lower elevations in northern YNP and extends northward into Montana along the Yellowstone, Gardner and Lamar drainages (Houston 1982). The Black-tailed Deer Plateau where the study was conducted is approximately midway between Mammoth and Tower Junction and near the center of the NYWR. The NPS

erected two 2 ha ungulate exclosures on this plateau, one in 1957 and the second in 1962, to evaluate the effects of ungulate grazing on mountain big sagebrush communities (Barmore 1980; Houston 1982; Singer and Harter 1996). The elevation is approximately 2,040 m, midway between the lower (1,600 m) and higher (2,600 m) elevations of the NYWR (Coughenour 1991; Houston 1982). Annual precipitation received at Mammoth (1,899 m) is approximately 400 mm, and at Tower Falls (1,912 m) 410 mm, the nearest weather stations (Farnes 1991). Half of the precipitation is received as snow, and most rainfall occurs in spring and early summer with the peak received in June (50mm) (Farnes 1991). The decade following the 1988 wildfires in YNP was characterized by winters of less than average severity (Farnes 1991). Pinedale glacial till is the parent material for Mollisols on the study area with a cryic temperature regime (Lane 1990). Texture is typically loam with course fragments ranging from gravel to boulders (Lane 1990). The mountain big sagebrush and bluebunch wheatgrass (*Agropyron spicatum*) habitat type dominates, especially on slopes with any south aspect. The mountain big sagebrush and Idaho fescue (*Festuca idahoensis*) habitat type is more likely found on north and east facing slopes. Green rabbitbrush (*Chrysothamnus viscidiflorus*), rubber rabbitbrush (*C. nauseosus*), and gray horsebrush (*Tetradymia canescens*) are less dominant than mountain big sagebrush, but common. These three shrubs have a sprouting habit.

METHODS

Sampling was conducted during the summers of 1998 and 1999, a decade after the wildfire. Twelve environmentally different sites based on slope and aspect were found in the two exclosures (Coughenour 1991). These 12 sites were paired with adjacent or nearby unprotected sites (table 1). Mountain big sagebrush, sprouting shrubs (green rabbitbrush, rubber rabbitbrush, and gray horsebrush), and herbaceous species dominated five, four, and three sites, respectively. However, all 12 sites were used in comparing cover of herbaceous species because they were important on all sites. Only established shrubs were sampled for density to avoid occasional abnormally high numbers of seedlings that always have a high mortality. Established shrubs were those with an average cover ≥ 15 cm from four intercepts (Wambolt and others 1994).

At each of the 12 sites, 10 stratified 30 m transects were located inside the exclosure as were 10 transects outside the exclosure on an environmentally paired site (Coughenour 1991; Wambolt and Sherwood 1999). The line interception method (Canfield 1941; Wambolt and others 2006) was used to obtain shrub cover. All shrub cover segments ≥ 3 cm were included. Open spaces and dead foliage ≥ 3 cm were excluded. A plumb bob was projected from the transect line to plants to determine precise intercepts. Along each 30 m line, belt transects of 2 x 30 m were created by measuring 1 m on both sides of the line transect. Densities of established shrubs were obtained within the 10 belt transects. A decimeter (20 x 50 cm) frame was placed at every third meter along each transect to estimate cover of herbaceous species (Daubenmire 1959). This resulted in 100 frames in each the protected and browsed-grazed portions of each environmental pairing.

Table 1—Slopes and aspects at the 12 locations where browsed and/or grazed sites and protected sites were paired by both characters. The paired sites are associated with two exclosures established in 1957 and 1962 on the Black-tailed Deer Plateau and burned during the Yellowstone fires of 1988. Sampling was conducted during the summers of 1998 and 1999.

Site number[a]	Slope[d] (%)	Aspect (°from north)
1	Moderate	132
2	Steep	160
3[b]	Gentle	165
4[b]	Flat	
5	Moderate	122
6[c]	Gentle	82
7[b]	Gentle	180
8[c]	Moderate	144
9[c]	Moderate	138
10[c]	Moderate	154
11[c]	Steep	116
12[b]	Gentle	71

[a]All sites were used in herbaceous species comparisons.
[b]Sites used in sprouting shrub comparisons.
[c]Sites used in mountain big sagebrush comparisons.
[d]Slope classes are: Flat ≤ 3 percent, Gentle = 4–15 percent, Moderate = 16–29 percent, Steep = 30–44 percent.

Two sample t procedures were used to compare cover (shrub and herbaceous) and density (shrub) means between protected and browsed-grazed sites after insuring the data were normally distributed (Coughenour 1991; Wambolt and Sherwood 1999). To make simultaneous inferences at the $P = 0.05$ level, the tests were adjusted using the Bonferroni procedure (Neter and others 1996).

RESULTS

The comparison between protected and browsed areas over all five mountain big sagebrush dominated sites found mountain big sagebrush cover lower ($P \leq 0.001$) on browsed areas at 9.7 percent compared to 20 percent where protected (table 2). The three sprouting shrubs collectively

comprised considerably less cover than mountain big sagebrush (table 2). However, relationships were similar. Sprouting shrubs had less cover ($P \leq 0.001$) at two percent on browsed areas than on unbrowsed areas at 5.8 percent on the four sites on which they were the dominant shrubs (table 2).

Table 2—Percent cover (n = 10) of all mountain big sagebrush and sprouting shrubs (Green rabbitbrush, rubber rabbitbrush, and gray horsebrush) with standard deviations in parentheses at environmentally paired protected or browsed sites on the Black-tailed Deer Plateau of Yellowstone National Park and sampled the summers of 1998 and 1999.

Site	Protected (%)	Browsed (%)	Probability > t[a]
Mountain big sagebrush			
6	16.3 (5.2)	7.9 (5.2)	0.002
8	20.3 (5.5)	6.3 (4.4)	0.001
9	24.8 (6.4)	10.9 (3.8)	0.001
10	18.1 (8.2)	11.4 (5.5)	0.045
11	20.5 (5.0)	11.9 (3.1)	0.001
Sprouting shrubs			
3	4.3 (2.3)	0.7 (0.4)	0.001
4	4.4 (2.6)	2.9 (1.5)	0.120
7	6.7 (3.4)	0.9 (0.6)	0.001
12	7.6 (3.4)	3.7 (1.6)	0.006

[a]The comparative P value for similar inferences is 0.01.

Over the five mountain big sagebrush sites density was not reduced ($P \leq 0.12$) by browsing. Established mountain big sagebrush densities ranged from 45.9 to 147.8 and 32.5 to 129.4 per 60 m^2 where protected and browsed, respectively (table 3). Individual comparisons of four of the five sites dominated by mountain big sagebrush showed no differences ($P \leq 0.05$) in density, although site 11 had more plants ($P \leq 0.018$) where protected (87.6 per 60 m^2) than where browsed (71.4 per 60 m^2). The density of sprouting shrubs was not different ($P \leq 0.47$) across the four sites they dominated at an average of 73.9 and 82.2 per 60 m^2 where protected and browsed, respectively (table 3).

Over all 12 sites total herbaceous cover was not different ($P \leq 0.37$) at 51.3 percent and 52.4 percent where protected and grazed, respectively (table 4). Grasses comprised the majority of the herbaceous cover with averages of 36.7 percent and 38.6 percent where protected and grazed, respectively ($P \leq 0.085$). Forb cover was not different ($P \leq 0.27$) either with averages of 14.6 percent and 13.9 percent where protected and grazed, respectively.

DISCUSSION

Shrub Canopy Cover

Our results indicate browsing suppressed recovery of shrubs after fire. Browsing lessened mountain big sagebrush dominance when it resulted in a decline of cover from 20 percent to 9.7 percent ($P \leq 0.001$) on our sites. On unburned portions of the NYWR, Wambolt and Sherwood (1999) reported similar results from communities established much longer with no known fire effects since YNP was created in 1872. Their protected sites had not been browsed for either 32 or 37 years. They found average big sagebrush cover on protected portions was three times greater ($P \leq 0.0027$) than where browsed over 19 sites. Their cover averaged 19.7 percent inside and 6.5percent outside at 11 mountain big sagebrush and eight Wyoming big sagebrush sites. Blaisdell (1953) reported little re-establishment of mountain big sagebrush 12 years after burning in Idaho. In a similar manner, just north of YNP on seven NYWR sites burned 10 to 14 years previously, mountain big sagebrush cover averaged 1.2 percent compared to 33 unburned sites that averaged 14.2 percent despite very heavy browsing (Wambolt and others 1999).

Table 3—Density of established mountain big sagebrush plants and sprouting shrubs (Green rabbitbrush, rubber rabbitbrush, and gray horsebrush) per 60 m^2 (n = 10) with standard deviations in parentheses at environmentally paired protected or browsed sites on the Black-tailed Deer Plateau of Yellowstone National Park and sampled during the summers of 1998 and 1999.

Site	Protected (shrubs per 60 m^2)	Browsed (shrubs per 60 m^2)	Probability > t[a]
Mountain big sagebrush			
6	45.9 (19.1)	32.5 (11.1)	0.071
8	74.4 (16.3)	42.7 (44.8)	0.059
9	147.8 (49.0)	129.4 (58.4)	0.458
10	99.1 (27.5)	103.9 (33.7)	0.731
11	87.6 (15.4)	71.4 (12.2)	0.018
Sprouting shrubs			
3	67.0 (12.9)	43.3 (17.8)	0.003
4	89.3 (37.1)	88.1 (24.3)	0.933
7	63.3 (17.8)	30.1 (14.2)	0.001
12	76.2 (21.4)	167.5 (73.2)	0.003

[a]The comparative P value for similar inferences is 0.01.

Ordinarily the sprouting shrubs we sampled should be expected to flourish after fire with light to moderate browsing (Wambolt and others 1999; Wambolt and Sherwood 1999), until successionally replaced by the habitat type dominant, mountain big sagebrush (Blaisdell 1953; Wambolt and Payne 1986; Young and Evans 1974). However, we found 2 to 3 times as much sprouting shrub cover on unbrowsed sites as compared to browsed sites a decade after fire. Wambolt and Sherwood (1999) reported two percent canopy cover of sprouting shrubs in protected areas and 1.1 percent where browsed ($P \leq 0.0027$) on 19 unburned areas across the NYWR. Mehus (1995) working on the NYWR, but north of YNP also found cover of *Chrysothamnus* taxa greater ($P \leq 0.001$) where burned (8.5 percent) 19 years earlier than on unburned areas

(0.9 percent). These earlier studies support our findings that intense herbivory has reduced sprouting shrubs, despite their relative resiliency to browsing.

Table 4—Cover (n = 100) of all herbaceous vegetation and perennial grasses with standard deviations in parentheses at protected or grazed sites on the Black-tailed Deer Plateau of Yellowstone National Park that were environmentally paired and sampled the summers of 1998 and 1999.

Site	Protected (%)	Grazed (%)	Probability > t[a]
Herbaceous vegetation			
1	56.8 (7.8)	58.9 (9.6)	0.516
2	37.3 (8.3)	45.5 (6.4)	0.022
3	49.3 (5.1)	51.2 (3.7)	0.358
4	58.6 (5.6)	54.0 (3.3)	0.040
5	64.5 (8.7)	55.3 (3.4)	0.022
6	62.5 (7.2)	56.2 (4.3)	0.029
7	52.3 (3.2)	42.5 (3.4)	0.001
8	52.6 (6.8)	59.8 (4.7)	0.017
9	39.2 (6.4)	42.9 (6.7)	0.221
10	41.6 (10.3)	50.9 (6.0)	0.024
11	48.6 (6.3)	56.9 (6.1)	0.008
12	55.2 (3.0)	55.9 (3.9)	0.636
Perennial grasses			
1	50.9 (6.3)	44.1 (4.3)	0.028
2	23.1 (7.2)	31.3 (5.9)	0.012
3	38.1 (5.3)	35.3 (4.8)	0.226
4	42.0 (6.7)	39.4 (2.9)	0.288
5	32.9 (5.0)	42.3 (4.2)	0.001
6	49.4 (6.1)	41.9 (4.9)	0.007
7	37.7 (2.8)	30.8 (4.0)	0.001
8	38.2 (5.5)	46.7 (6.0)	0.005
9	27.2 (5.6)	32.3 (5.8)	0.062
10	28.9 (8.6)	36.4 (3.5)	0.027
11	32.3 (3.2)	42.5 (3.1)	0.001
12	39.8 (2.8)	40.9 (2.4)	0.334

[a]The comparative P value for similar inferences is 0.0042.

Shrub Density

Mountain big sagebrush establishment and thereby density was not affected ($P \leq 0.12$) by elk browsing in the significant manner that growth and subsequently cover was in the decade after the 1988 fire (table 3). This may be partially explained by the fact that sites nine and 10 are located in depressions that accumulate snow, thereby protecting small establishing plants from browsing. Wambolt and Sherwood (1999) determined browsing on 19 unburned NYWR sites was intense enough to reduce sagebrush density. They found 30.5 plants where browsed and 15.3 plants (per 60 m^2) ($P \leq 0.0027$) where protected 32 or 37 years with no known fire events since establishment of YNP. Our results likely differ due to the interaction of browsing and fire over a shorter period of one decade with winters of less than average severity (Farnes 1991). On intensively browsed, burned and unburned portions of the NYWR north of YNP, Wambolt and others (1999) found an average of 52 plants on 33 unburned sites and 14 plants on seven burned sites, per 60 m^2, 10 to 14 years after fire. Wambolt and Hoffman (2001) reported that 47 percent of the mountain big sagebrush plants that established between 1978 and 1992 did so during 1988 due to a series of ideal conditions. We believe that if these ideal conditions for shrub establishment had not coincided with the fire, that both the mountain big sagebrush density and cover we found would be considerably lower.

Our findings (table 3) regarding densities of sprouting shrubs are quite variable among sites. This is likely due to the southerly exposures of sites three and seven accumulating less snow and therefore, providing more browsing opportunities for elk than on sites four and 12. Our results for sprouting shrubs on our burned study area again differ from unburned portions of the NYWR (Wambolt and Sherwood 1999). While our sprouting shrub densities were not always less where browsed, Wambolt and Sherwood (1999) found consistently higher densities ($P \leq 0.0027$) where protected (16.6 per 60 m^2) than on browsed portions (13.1 per 60 m^2) of 19 sites. The higher densities (table 3) we found following burning are very common without intense browsing (Blaisdell 1953; Wambolt and others 1999; Wambolt and Payne 1986; Young and Evans 1974). Mehus (1995) on the NYWR north of YNP found nine times as many rabbitbrush plants on the portion of a site burned 19 years earlier compared to the unburned portion.

Evidently mountain big sagebrush in and out of the exclosures had an equal opportunity to reestablish. Big sagebrush reestablishment after fire is highly dependent on survival of mature plants to serve as a seed source (Johnson and Payne 1968). However, the 1988 fire burned intensely enough to eliminate all mature mountain big sagebrush plants on our study area. The even-aged distribution of mountain big sagebrush plants across the area indicates reestablishment occurred from soil born seed surviving the fire and germinating that growing season (Wambolt and others 1999). These seedlings became established through a series of ideal weather conditions and a 40 percent reduction in elk numbers (Wambolt and others 1999).

Herbaceous Plants

We found little impact from winter grazing on the herbaceous species. Cover for the dominant herbaceous species, *Agropyron spicatum* and *Festuca idahoensis*, was not different where grazed or protected. The same was true for forbs over all 12 study sites. Others have reported little difference in grass or forb production on the NYWR from either fire or grazing compared to protected areas

(Coughenour 1991; Singer and Harter 1996). Similarly without considering the interaction with fire that our study included, little change in herbaceous parameters due to herbivory has been found on the NYWR (Coughenour 1991; Houston 1982). Understory cover was not lower on sites with higher shrub cover. This has been found in widespread previous research which indicated the absence of increased herbaceous production from sagebrush reduction (Anderson and Holte 1981; Blaisdell 1953; Daubenmire 1975; Kuntz 1982; Peek and others 1979; Wambolt and others 2001). Because our measurements were made 10 years post-fire, grazing impacts may have been smaller than if measured within a couple of years after the fire (Singer and Harter 1996). However, nine years after another YNP fire Houston (1982) did find nearly twice as much production from perennial grasses on an unburned portion of range compared to a burned portion with 138 g per m^2 and 79 g per m^2, respectively.

CONCLUSIONS

Herbaceous plants are known to generally sustain non-growing season grazing without negative effects (Cook and Stoddart 1963). In addition, herbaceous plants are often relatively unavailable for intense winter grazing due to snow cover. There were no important effects from elk winter grazing on herbaceous species following the 1988 wildfire on our study area. Thus, we accept our hypothesis for herbaceous plants, that elk herbivory did not influence their recovery from fire.

However, the impact of ungulate winter browsing on unburned established stands of mountain big sagebrush on the NYWR is documented to include declines (Mehus 1995; Wambolt 1998; Wambolt and Sherwood 1999). Investigations in the greater Yellowstone area of fire impacts on this important NYWR taxon indicate that typically there is minimal recovery of mountain big sagebrush stands for several decades following fire (Wambolt 1998; Wambolt and McNeal 1987; Wambolt and others 1999; Wambolt and others 2001). Fortunately for sagebrush dependant wildlife, 1988, the year of the large Yellowstone fires provided ideal conditions for nearly half of all mountain big sagebrush established on the NYWR between 1978 and 1992 to begin growth (Wambolt and Hoffman 2001). Relatively rapid establishment was promoted by favorable germination and establishment conditions the year following the fire. Without these favorable conditions, undoubtedly mountain big sagebrush cover and density would have been much lower only a decade after the fire when we conducted our investigation. Thus, it is not surprising we found mountain big sagebrush plants did establish equally on sites either protected or available to elk browsing a decade after fire.

In considering the ecological implications of NYWR browsing on sagebrush communities elsewhere it is important to realize that our study sites had not been subjected to as much past herbivory as were other NYWR sites previously documented that typically have more open winters for foraging (Mehus 1995; Wambolt 1998; Wambolt and others 1999; Wambolt and Sherwood 1999). This was partially due to our study site location which was determined by the earlier placement of the exclosures and subsequently the 1988 fire. Also important was the less than average winter severity during the decade after the wildfires on the NYWR (Farnes 1991).

Most importantly we learned that regardless of past browsing levels and fast recovery from the fire regardless of browsing, that browsing affects the growth of establishing mountain big sagebrush plants. The cover of the mountain big sagebrush plants was significantly reduced from browsing, thereby reducing the amount of forage they produce for wintering ungulates like elk as well as other habitat values (Wambolt and others 1994). We thereby reject our hypothesis regarding mountain big sagebrush and conclude that elk herbivory negatively impacted the taxon's recovery after this wildfire.

Green rabbitbrush, rubber rabbitbrush, and gray horsebrush, all shrubs commonly associated with mountain big sagebrush were impacted similarly. Their decline from fire and browsing is typically unexpected, partially because all of these shrubs have a habit of sprouting when disturbed that generally results in increased growth, not a decline (Wambolt and Sherwood 1999). A decade after the fire the sprouting shrubs show the same herbivory diminished recovery pattern as mountain big sagebrush indicating an unusually heavy browsing effect. Therefore, we also reject our hypothesis regarding the sprouting shrubs collectively.

Although this study considered plant recovery after wildfire with intense elk herbivory, our plant response findings parallel previous findings on the NYWR that did not include fire effects. We conclude the impact of elk foraging was the same during the decade after the 1988 fire as found previously and greatly reduced the shrubs of mountain big sagebrush communities. The decline of all the shrub taxa on mountain big sagebrush-grass range has the potential to negatively affect numerous wildlife species that rely on the shrubs as forage or security-thermal cover (Welch 2005).

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