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Big Sagebrush Response to One-Way and Two-Way Chaining in Southeastern Utah

John A. Fairchild
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Abstract—A decadent, mixed stand of Wyoming big sagebrush, *Artemisia tridentata wyomingensis*, and mountain big sagebrush, *Artemisia tridentata vaseyana*, located north of Cisco, Utah, was subjected to one-way and two-way chaining treatments in November 1987. The effect of the treatments on plant community characteristics and shrub vigor was documented over a 3-year period. Stand density was reduced 60 percent on sites chained two ways and 43 percent on sites chained over once. Shrubs on one-way chained sites produced more leader growth in 1989 and 1990 than those on untreated sites or sites chained two ways. Browse production on one-way chained sites surpassed that of untreated sites and two-way chained sites by 140 percent and 350 percent, respectively. Over the short term, a one-way chaining was shown to be an effective method for improving sagebrush vigor and production on a critical mule deer winter range.

Introduction

The importance of big sagebrush as winter forage for mule deer has received considerable attention as researchers have attempted to determine the species' role in mule deer nutrition. There is widespread agreement that it is frequently a dominant constituent of the winter diet of mule deer (Kufeld and others 1973; Leach 1956; Pederson and Welch 1982). Research shows it to be a highly digestible food during the winter (Urness and others 1977; Wallmo and others 1977; Welch and Pederson 1981), and its nutritional value is enhanced when taken with other forages (Nagy and others 1964; Smith 1959). Although its importance in the diet increases in late winter (Carpenter and others 1979; Wallmo and others 1977), it is not a starvation food, and has been shown to contribute substantially to the diet of mule deer in the fall and early winter when other forages are available.

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Historically, mule deer carrying capacity has increased on winter ranges that have experienced an increase in shrub density (Urness 1979). However, on many sagebrush ranges in Utah, shrub density has peaked, and plant communities have become dominated by old, decadent shrubs. Browse production has decreased dramatically in these areas, especially during recent drought periods (Davis and others 2000).

In the 1960s, Plummer and others (1968) suggested chaining as a viable method for thinning stands that had become extremely dense and decadent. This method was suggested with or without seeding on depleted game ranges to retain native grasses and forbs. Similarly, Cain (1971) reported on the effectiveness of the Ely chain in restoring depleted rangelands dominated by pinyon-juniper and big sagebrush. Mechanical treatment, as opposed to spraying or burning, allows for controlled or partial treatments where an adjustment in relative shrub density is desired (Urness 1979). Such treatments retain shrubs in the treated area and avoid the problems associated with establishing shrubs from seed on semiarid sites.

This study compared one-way and two-way chaining as tools for restoring decadent stands of big sagebrush on important big game winter ranges. Treatment and control sites were identified during the planning phase of a 134-ha chaining project. Two sites were used to evaluate each management alternative (no chaining, one-way chaining, and two-way chaining). The unmodified anchor chain that was used for the project measured 76 m in length and weighed 60 kg/m.

Location

The study site was located on an important mule deer winter range at the base of the Book Cliff Range, just east of Nash Wash in southeastern Utah. The elevation of the study area ranged from 1,945 to 1,980 m. The deer winter range was characterized by a narrow band of pinyon-juniper woodland, interspersed with sagebrush parks. The parks were dominated by Wyoming big sagebrush (*Artemisia tridentata wyomingensis*), but mountain big sagebrush (*Artemisia tridentata vaseyana*) was also present, a common situation on sagebrush winter ranges in the region (McArthur, personal communication).

Methods

Plant Community Assessment

A 30-m baseline was located at each of the six study sites following treatment. Three 30-m transects were run perpendicular to the baseline and centered on the 15-m mark. The transects were randomly located at 3-m intervals along the line. A 1-m^2 quadrat was positioned at 3-m intervals on alternating sides of the transect to yield 10 sampling quadrats per transect and 30 quadrats per site.

Cover was estimated for all plants, individual species, bare ground, litter, rock, and cryptogamic crust within each quadrat using a modified Daubenmire (1959) method described by Davis and others (2000). Shrub density was estimated along a 0.005-ha strip plot centered on the 30-m survey tape. Each shrub rooted within the strip was counted and placed in one of the following age classes: seedling, young, mature, decadent, or dead (USDI-BLM 1996). Mature shrubs were classified as decadent when 25 percent or more of the branches were dead. A one-way analysis of variance test was used to determine if mean plant cover and shrub density values differed among treatment and control sites. Sagebrush production was estimated at each site using a modified method for predicting annual production based on shrub crown measurements (Dean and others 1981). The modification involved estimating crown denseness as percent cover in two dimensions, rather than percent volume in three-dimensional space. Regression equations were developed for each site to predict annual biomass from crown measurements. Shrubs selected for analysis were aged according to the method described by Ferguson (1964). Stem diameter and annual ring count data for each shrub were subjected to regression analysis to allow prediction of ages from stem diameter measurements.

Shrub Vigor Assessment

At 2-m intervals along each baseline, the nearest mature sagebrush plant was selected for the shrub vigor analyses. Subspecies determinations were made for each shrub according to the method described by Stevens and McArthur (1974). Baseline shrubs were sampled in fall to obtain estimates of annual leader growth, number of seed stalks per shrub, and seed stalk frequency, weight, and length. A one-way analysis of variance test was used to determine if mean shrub vigor measurements differed among treatment and control sites.

One of each of the replicated treatment and control sites was selected to evaluate browse utilization by mule deer. The first 10 shrubs selected for the shrub vigor assessment along the baseline of each of the three sites were included in the utilization study following the method described by Smith and Urness (1962). The "use-index" (leader length times percent use) described by Smith and Urness (1962) was used to evaluate treatment effects on browse use by mule deer.

Results

Precipitation

A rain gauge was located within 1.6 km of the study area and monitored monthly by the USDI-BLM. A summary of moisture received from November to May and from June to October is given for the years 1987 to 1990 in table 1. Winter precipitation, which greatly influences annual vegetative growth, decreased steadily from 203 cm (1987 to 1988) to 91 cm (1989 to 1990). The severity of the drought in the Nash Wash area was verified by observations of pinyon pine (*Pinus edulis*) trees at lower elevations that died in 1989 and 1990. The dead trees were scattered across the landscape, and many exceeded 100 years in age (Davis, personal communication).

Plant Community Responses

Shrub Density and Production—Pretreatment shrub density averaged 18,500 plants/ha on the six sites. Density estimates in the final year (1990) showed one-way chained sites supporting 10,500 plants/ha and two-way chained sites supporting 7,500 plants/ha, for reductions of 43 percent and 60 percent, respectively. Sagebrush seedling establishment was negligible on treated and control sites (<1 percent). Annual production (kg/ha) of shrubs in the one-way chained treatment was consistently greater than in the two-way chained treatment or the control from 1988 to 1990 (table 2). Over the 3 years, browse production on one-way chained sites surpassed that on untreated sites and two-way chained sites by 140 percent and 350 percent, respectively.

Table 1—A summary of moisture received (mm) from November to May and June to October, 1987 to 1990, at a BLM precipitation gauge 1.6 km from the Nash Wash study site.

	1987 to 1988	1988 to 1989	1989 to 1990
	mm		
June to October	236	91	99
November to May	203	155	91
Total	439	246	190

Table 2—Browse production on chained one-way, two-way, and control treatments[a].

	Year			
Treatment	1988	1989	1990	Average
	kg ha^{-1}			
One-way	430	570	480	490[a1]
Two-way	130	130	160	140[b]
Control	370	380	300	350[c]

[a]Values not sharing the same letter superscript are significantly different at the 0.05 level.

Age Structure—Seedling establishment did not contribute significantly to shrub density of the treatment or control sites at Nash Wash. In the 3 years following the chaining, seedlings averaged about 1 percent of the stand density on treated sites and were almost nonexistent on untreated sites.

The untreated sites supported a shrub population that had a higher proportion of older shrubs than was found on either treatment. The regression equation generated to predict age (y) based on stem diameter (x) was $y = 0.83x + 12.26$, with a coefficient of simple determination of 0.52. Even though only 52 percent of the variation in age was accounted for by measuring stem diameters, some trends were apparent. Shrub age on control sites ranged from 32 to 97 years and averaged 54 years. Shrubs averaged 43 years of age (range: 19 to 62 years) on the one-way chained sites and 39 years (range: 19 to 62 years) on the two-way chained sites. Older shrubs with wide stem diameters lacked flexibility, offered resistance to the force of the chain, and were more effectively uprooted than were the younger plants.

Although age-class determinations (seedling, young, mature, and decadent) can vary among observers, their value in characterizing shrub populations has been recognized by many researchers and land management agencies. There was no significant difference in the contribution made by each age-class on one-way and two-way chained sites. However, a higher proportion of decadent shrubs was consistently found in the untreated sites (table 3). The widest margin of difference was noted in 1990 following the dry winter of 1989 to 1990. The proportion of older shrubs classified as mature rose to a high in 1989 on all sites.

Plant Cover—Cover class estimates for sagebrush did not reveal cover differences between treatments, but did show a difference between treatments and controls. The 3-year average for sagebrush cover on treated sites and control sites was 6 percent and 14 percent, respectively. Total herbaceous plant cover was highly variable and limited on all sites. The 3-year average for herbaceous plant cover on one-way chained, two-way chained, and control sites was 7 percent, 14 percent, and 5 percent, respectively. Cheatgrass made up about 50 percent of the herbaceous plant cover on all sites (table 4). The extremely low cover values for all sites in 1990 reflected the severity of the drought.

Shrub Vigor Responses

Leader Growth—The most striking impact of the thinning treatments was an increase in the length of vegetative leaders on remnant shrubs. Average leader length for sagebrush in treated areas was almost double that of control sites in 1988 (table 5). No significant difference in leader growth between the two treatments was observed the first year after chaining, but sagebrush vegetative growth on one-way chained sites surpassed that of two-way chained sites in 1989 and 1990. Essentially no growth was observed on control sites in 1990 due to the drought. In addition, leader growth in 1990 on shrubs from treated sites was well below the average observed on control sites during the previous two growing seasons.

Seed Production—The reproductive growth response to thinning was more gradual than the vegetative growth response. During the first growing season, seed stalk production was similar on treated and untreated sites. No significant differences were detected in the average number of seed stalks per shrub or the average length of seed stalks among treatments and controls (table 6). In 1989, the number of seed stalks per shrub increased slightly (although not significantly), and seed stalk length on treated sites

Table 4—Total herbaceous cover and percent contribution from cheatgrass (in parentheses) on chained one-way, two-way, and control treatments[a].

Year	One-way	Two-way	Control
	percent		
1988	11[a] (45)	18[b] (61)	10[a] (90)
1989	9[a] (67)	18[b] (50)	4[a] (25)
1990	2[a] (50)	5[a] (20)	2[a] (50)

[a]Values not sharing the same letter superscript are significantly different at the 0.05 level.

Table 5—Average sagebrush leader length in chained one-way, two-way, and control treatments[a].

Treatment	Year 1988	1989	1990
	cm		
One-way	7.5[a]	9.4[a]	1.4[a]
Two-way	7.1[a]	7.3[b]	1.2[b]
Control	4.0[b]	3.9[c]	1.0[c]

[a]Values not sharing the same letter superscripts in each column are significantly different at the 0.05 level.

Table 3—Proportion of decadent shrubs in the stand on chained one-way, two-way, and control treatments[a].

Shrub condition	Year 1988 1-way	1988 2-way	1988 Control	1989 1-way	1989 2-way	1989 Control	1990 1-way	1990 2-way	1990 Control
	percent								
Decadent	86	90	99*	59	58	64	76	74	98*
Not decadent	14	10	1*	41	42	46	24	26	2*

[a] Proportions followed by asterisks are significantly different (<0.05 level) than those of the other treatments based on categorical analysis using the chi-square statistic.

Table 6—Seed stalk length and number per shrub in chained one-way, two-way, and control treatments[a].

	Year					
	1988		1989		1990	
Treatment	Length	Number	Length	Number	Length	Number
	cm		*cm*		*cm*	
One-way	16.9[a]	0.5[a]	17.0[a]	3.3[a]	5.1[a]	14.7[a]
Two-way	17.2[a]	0.4[a]	15.1[a]	1.3[a]	4.9[a]	10.2[a]
Control	10.1[a]	1.0[a]	9.4[b]	1.3[a]	2.4[a]	0.3[b]

[a]Values not sharing the same letter superscripts in each column are significantly different at the 0.05 level.

exceeded that on control sites by 170 percent. In addition to almost a doubling in length, seed stalk weight per cm was 6 times greater on shrubs from treated versus control sites, averaging 0.097 gm/cm and 0.016 gm/cm, respectively. In 1990, shrubs from treated sites produced far more seed stalks than shrubs from control sites; however, stalk length did not vary significantly (table 5).

Browse Use by Mule Deer—Treatment effects on browse utilization by wintering mule deer are summarized in table 7. No significant differences were detected in browse use between the two treatments, but there were differences between treatments and controls. Deer utilized more forage from shrubs in treated areas than untreated areas even though utilization percentages were comparable. Average utilization for each treatment and control ranged from 67 to 77 percent during winter 1988 to 1989 and from 51 to 67 percent in 1989 to 1990. Significantly higher use-index values (leader length times percent use) were associated with shrubs from treated versus untreated areas during both winters.

Discussion

Utah Division of Wildlife Resources (UDWR) and BLM biologists have recognized the depleted condition of the deer winter range in the Nash Wash area since the mid-1960s. The close proximity of this critical winter range to the adjacent salt desert shrub type at lower elevations, traditionally used by sheep during the winter, has led to excessive use of sagebrush and preferred herbaceous species. Coles and Pederson (1967) were concerned that the combined winter use by deer and sheep on sagebrush in the Nash Wash area was excessive, and that if allowed to continue, would result in a widespread sagebrush die-off. In an effort to avoid such a loss, the Grand Resource Area (USDI BLM) modified the grazing plan for the Nash Wash area and limited winter sheep grazing to the salt desert shrub community below the critical deer winter range.

The increase in forage production per shrub on chained sites revealed the high degree of intraspecific competition that existed among sagebrush plants in the study area. Shrub density on one-way chained sites was sufficient to outproduce untreated control sites the following year and in each succeeding year of the study. Sites chained two ways did not respond with sufficient browse production to compensate for the additional shrub removal. The second pass reduced sagebrush production to 50 percent of that found on control sites.

The reproductive growth response to sagebrush thinning was not as striking as the vegetative response. A gradual increase in reproductive growth response to sagebrush thinning (both treatments combined) was observed over the 3-year study period. No significant differences were observed in stalk length, weight, or number the first year following treatment. A reproductive response was observed the second year in increased seed stalk lengths and stalk weights. Seed stalk production (number per plant) did not increase until the third flowering period following treatment.

Several factors appeared to be working against sagebrush productivity in the study area. In general, the sagebrush plants were old and decadent. Shrub age averaged 54 years, and the oldest shrubs were close to 100 years in age. Seasonal precipitation patterns, typical of the Colorado Plateau, may have limited the potential for sagebrush production at Nash Wash. Weather data collected at Thompson, UT (16 km from the study site), over the past 30 years, showed that only 55 percent of the annual precipitation was received during the winter (November to May) period. Stations at the Salt Lake City Airport and Fillmore reflected the trend in the Great Basin where approximately 70 percent of the annual precipitation was received during the November to May period. Since winter precipitation is known to influence big sagebrush production (Daubenmire 1975; Elderkin and others 1986), and only 55 percent of the annual precipitation at Nash Wash is received during the winter, shrub health may be vulnerable, especially during drought periods. Drought conditions were exacerbated at Nash Wash, where competition among sagebrush plants was evident. Although not evaluated in this study, the prevalence of cheatgrass, a

Table 7—Browse utilization by mule deer on chained one-way, two-way, and control sites[a].

	Year					
	1989			1990		
Treatment	Leader length	Use	Use index	Leader length	Use	Use index
	cm	*percent*		*cm*	*percent*	
One-way	5.1[a]	67[a]	3.2[ab]	4.7[a]	64[a]	3.2[a]
Two-way	5.4[a]	76[a]	4.1[a]	4.4[a]	67[a]	3.0[a]
Control	2.7[b]	77[a]	2.1[b]	2.2[b]	51[b]	1.1[b]

[a]Values not sharing the same letter superscripts in each column are significantly different at the 0.05 level.

winter annual, could have had a significant impact on sagebrush production and seedling establishment.

Chaining in one direction with a light, unmodified anchor chain, was shown to be an effective treatment for thinning a decadent stand of sagebrush without reducing the carrying capacity for a wintering deer herd. The treatment should be considered with or without artificial seeding, depending on the condition of the herbaceous understory, as a practical method to improve sagebrush health and wildlife habitat on critically important sagebrush ranges. Different results would be expected from chaining one-way with heavier chains, chains modified with rails welded crosswise to the links, or chains pulled in a more aggressive "J" configuration as opposed to the "U" shape maintained during the Nash Wash project.

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