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COMPARISON OF VEGETATION PATTERNS RESULTING FROM BULLDOZING AND TWO-WAY CHAINING ON A UTAH PINYON-JUNIPER BIG GAME RANGE

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ABSTRACT.—Two adjacent mechanically treated pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) big game winter range sites in central Utah were sampled in 1981 to estimate vegetational differences and tree mortality from the two treatments. One site was treated by selectively bulldozing in 1957 and the other was double chained in 1965. Both treatments significantly reduced tree and litter cover, whereas significant increases were found for native grasses and shrubs compared to a nearby untreated site. Juniper cover for the untreated site was 35.5% compared to only 1.4% for the bulldozed area and 4.1% for the two-way chained area. Browse species densities were increased by the mechanical treatments. The use of different mechanical treatments on separate smaller portions of critical areas of big game winter range would help provide: (1) for both long-term and short-term use of a critical wintering area, (2) greater overall productivity and carrying capacity, and (3) greater diversity by creating more edge effect between the differently treated and untreated areas.

Pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) ranges cover roughly 30 million ha in the western United States (West et al. 1975). Since the mid-1950s, mechanical treatment of pinyon-juniper ranges to increase forage production has been extensive (Aro 1975, Phillips 1977, Plummer et al. 1968). Methods used to reduce tree competition include: cabling, one-way chaining, two-way chaining, bulldozing, windrowing, tree crushing, and burning (Arnold et al. 1964, Aro 1975, Plummer et al. 1960, 1968, 1970, Stoddart et al. 1975, Vallentine 1980). This paper evaluates differences in vegetational patterns following bulldozing and two-way chaining and seeding on adjacent sites in central Utah.

STUDY AREA AND METHODS

The study area is a pinyon-juniper big game winter range 2 km east of Holden, Millard County, Utah. Elevation is approximately 1,600 m. The area is classified as an upland stony loam range site. Soils are slightly calcareous with a pH of 6.9. Average yearly precipitation is about 37.5 cm, with most of it coming during the winter months. Slope is relatively constant and averages 7%. The aspect is southwesterly. Before treatment the area supported an open stand of juniper (*Juniperus osteosperma*) with an intermixture of cliffrose (*Cowania stansburiana*), big sagebrush (*Artemisia tridentata*), broom snakeweed (*Xanthocephalum sarothrae*), and some antelope bitterbrush (*Purshia tridentata*). Cheatgrass (*Bromus tectorum*) is the most prominent understory species on the control site. Other grasses and forbs are infrequent and produce little forage (Christensen et al. 1964).

The bulldozed site is owned and managed by the Utah Division of Wildlife Resources, and the two-way chained site is federally owned and managed by the USDI Bureau of Land Management (BLM). Bulldozing was used to eliminate trees while minimizing disturbance to cliffrose and big sagebrush on Utah Division of Wildlife Resources land (Christensen et al. 1964). These two shrub species are considered important winter browse for big game animals.

The nine species seeded on the bulldozed site, listed in Table 1, were either broadcast seeded or hand seeded into the depressions left by uprooted juniper trees (Plummer et al. 1960). Only crested wheatgrass (*Agropyron cristatum*) was seeded on the BLM site; 9 kg/ha of seed was applied during the chaining operation. Grazing has varied on the bulldozed site since treatment. It was rested from

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TABLE 1. Percent cover by species on bulldozed and two-way chained sites and adjacent untreated pinyon-juniper ranges. Amount of broadcasted seed is for the bulldozed site only.

Species	Treatment			Seeding rate[1] (kg/ha)
	Untreated	Bulldozed	Two-way	
ANNUALS				
Bromus tectorium	1.33[a*]	3.85[a]	2.97[a]	
Total all annual species	1.33[a]	4.05[a]	3.31[a]	
GRASSES				
Agropyron cristatum	0.00[a]	0.19[a]	4.96[b]	1.59[2]
Agropyron spicatum	0.00[a]	8.74[b]	1.68[a]	
Agropyron tricophorum	0.00[a]	2.54[b]	0.00[a]	0.55
Poa secunda	0.41[a]	2.01[a]	0.79[a]	
Total all grass species	0.46[a]	13.68[c]	8.31[b]	
SHRUBS				
Artemisia tridentata	2.43[a]	10.92[a]	5.95[a]	0.13[2]
Cowania stansburiana	3.00[a]	4.24[a]	3.68[a]	0.01[2]
Xanthocephalum sarothrae	0.42[a]	2.55[a]	9.65[b]	
Total all shrub species	5.85[a]	18.17[b]	19.40[b]	
TREES				
Juniperus osteosperma	35.47[a]	1.42[b]	4.10[b]	
Quercus gambelii	6.64[a]	2.64[a]	0.00[a]	
Total all tree species	42.11[a]	4.06[b]	4.10[b]	

*Values in the same row with different letters are significantly different at $P < .05$.
[1]Other seeded species were *Agropyron intermedium* (.48), *Medicago sativa* (0.08), *Atriplex canescens* (.17), *Chrysothamnus nauseosus* (.14), and *Purshia tridentata* (.34). The seeding rate for two-way chained site was *Agropyron cristatum* at 9 kg/ha.
[2]Some of the seed was hand-seeded into the depressions.

grazing from 1961 to 1962 and 1964 to 1965, but when grazed the stocking rate was 3.0 ha/per animal unit (AU) from 10 May to 15 June. Since treatment the two-way chained site has had a stocking rate of 4.5 ha/per animal unit (AU) from 1 May to 15 June. Both areas have been grazed by cattle throughout the study periods.

Treated areas were sampled by a single transect running across both treatments. This transect was 800 m long, with 400 m within each treatment. A second transect of 400 m was used to sample a nearby untreated area that was used as a control. Meter-square quadrats were placed at 10 m intervals along the transect. Total plant cover and cover by species were estimated using a variation of Daubenmire's (1959) cover class estimation technique. The variation consisted of adding a smaller cover class, 0% to 1%, so that the cover of small plants would not be overestimated. Percent cover of bare ground, litter, and rock were also estimated at each quadrat.

Density of trees and shrubs was evaluated by the use of a circular plot with an area of 50 m^2. This enlarged plot was centered on every third quadrat along the transect. In each enlarged plot, every shrub and tree was identified and assigned to a height and stem diameter class. Diameter of all trees was measured at 10 cm aboveground, and the largest stem of each multistemmed shrub was measured at approximately the same height. At least five juniper trees were cut near each transect and aged by growth rings. Regression analysis was used to correlate stem diameter with age. Evaluated parameters include: changes in species cover and composition, changes in tree and shrub density, and tree mortality resulting from treatment. Swept pellet group transects were used to indicate big game activity within the areas of treatment.

Composite soil samples were taken to a depth of 25 cm at every tenth quadrat along the transect. Soil texture, pH, and soluble salts were determined. Soils were also analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, sodium, zinc, iron, manganese, and copper content.

RESULTS AND DISCUSSION

Total plant and litter cover were significantly reduced by both treatments when compared to the control (Table 2). However, total plant, bare ground, litter, and rock cover

TABLE 2. Percent cover of surface characteristics on bulldozed and two-way chained sites and adjacent untreated pinyon-juniper ranges.

Characteristic	Treatment		
	Untreated	Bulldozed	Two-way
Total plant cover	48.87[a]*	37.90[b]	35.48[b]
Bare ground	25.08[a]	27.07[a]	33.12[a]
Litter	27.22[a]	15.33[b]	16.59[b]
Rock	4.47[a]	3.37[a]	3.19[a]
Lifeform cover:			
Annual species	1.33[a]	4.05[a]	3.31[a]
Forb species	.11[a]	1.04[a]	.36[a]
Seeded grass species	.00[a]	2.73[a]	5.78[a]
Native grass species	.46[a]	10.95[c]	2.53[b]
Seeded shrub species**	5.43[a]	12.43[a]	9.64[a]
Native shrub species	.42[a]	2.64[b]	9.76[c]
Tree species	42.11[a]	4.06[b]	4.10[b]

*Values in the same row with different letters are significantly different at $P < .05$.
**Included in the seed mixture were shrub species that also occur naturally on the site. These are shown as seeded in the table so that comparisons could be made between treatments.

were not significantly different between the two mechanical treatments. When these cover categories were compared, no significant differences existed between the two treatments, but visually and structurally they did appear quite different from each other. The treated sites supported significantly greater native grass and native shrub cover than the nearby untreated control site. Comparison between treatments showed that significant cover differences existed for the total of all grass species (Table 1). Crested wheatgrass had greater cover on the two-way chaining, whereas bluebunch wheatgrass (*Agropyron spicatum*) and sandberg bluegrass (*Poa secunda*) both were native and not seeded and exhibited greater cover on the bulldozed site. Pubescent wheatgrass (*Agropyron tricophorum*) showed good establishment and persistence on the bulldozed area.

Crested wheatgrass probably had greater cover because of its higher seeding rate on the two-way site, and the two-way chaining prepared an improved seedbed and covered the seed for better germination and establishment. Crested wheatgrass was also seeded on the bulldozed site, but it did not respond as well as the other two wheatgrasses after the bulldozing treatment. Bluebunch wheatgrass was probably suppressed by crested wheatgrass competition on the two-way chained site. The bulldozed site exhibited greater big sagebrush and cliffrose cover than the chained site, but the cover values were not significantly different between sites.

Juniper density was significantly lower on the bulldozed site (Table 3). There were 42% more trees on the two-way chained area than the bulldozed site. This would indicate that bulldozing to eliminate juniper in this area was probably more effective than chaining because the bulldozed treatment was done eight years previous to the two-way chaining and still had fewer juniper when sampled in 1981. In this study the bulldozing treatment killed 81% of the juniper, whereas double chaining killed only 54% when compared to the nearby control area. Aro (1975) reported a 95% to 100% kill when the trees were windrowed with a bulldozer and burned, whereas double chaining averaged 60% kill. Arnold et al. (1964) stated that double chaining results in a 50% to 80% kill of juniper trees.

Many researchers have noted that a major factor determining actual tree kill from mechanical treatments is the age structure of the juniper stand before treatment (Aro 1975, Skousen 1982, Stevens et al. 1975). Trees on the control area indicated that the stand was relatively young at the time of treatment. Of the trees sampled there, 40% were small, with stem diameters of 5 cm or less when the treatment took place. The presence of these small, flexible trees may explain why the chaining treatment was less effective than bulldozing. No significant differences were found between the sites for cliffrose and big sagebrush densities. Cliffrose cover was higher on the bulldozed site. This anomaly probably arose because surviving plants of

TABLE 3. Tree and shrub densities per hectare on bulldozed, two-way chained, and untreated pinyon-juniper ranges.

Species	Treatment		
	Untreated	Bulldozed	Two-way
TREES			
Juniperus osteosperma	771[a]	428[b]	734[a]
Quercus gambelii	454[a]	719[a]	305[a]
Total trees	1225[a]	1147[a]	1039[a]
SHRUBS			
Artemisia tridentata	1351[a]	2738[a]	1943[a]
Chrysothamnus nauseosus	21[a]	244[a]	30[a]
Cowania stansburiana	429[a]	597[a]	963[a]
Xanthocephalum sarothrae	389[a]	934[a]	5936[b]
Total shrubs	2190[a]	4513[a]	8872[b]

*Values in the same row with different letters are significantly different at $P < .05$.

cliffrose were much larger on the bulldozed site. Two-way chaining appears to have uprooted or broken off all large cliffrose plants (Christensen et al. 1964). Cliffrose plants were intentionally avoided on the bulldozed project. Broom snakeweed was six times more dense on the chained site, suggesting that increased soil disturbance may have allowed this invader species to spread (Arnold et al. 1964). For example, broom snakeweed made up 7% of the shrub cover for the untreated area, 14% of the shrub cover for the bulldozed area, and a high 50% of the shrub cover for the two-way chained area.

Only one soil factor was significantly different between untreated, bulldozed, and two-way chained sites (Table 4). Phosphorus concentrations were significantly lower on the bulldozed site than on the untreated or two-way chained areas.

Utah Wildlife Resource conservation officers reported that swept pellet group transects showed big game activity to be two to three times heavier on the bulldozed site than on the two-way chained area. Some years, e.g. 1977, big game use was 13 times heavier on the bulldozed site than on the two-way chained areas (Brent Olsen, data on file).

It has been suggested that the preferential use of the bulldozed site by deer was related to the greater height of the cliffrose. On the two-way chained area, 75% of the cliffrose individuals were under 1 m tall, and all cliffrose plants were under 1.5 m tall. On the bulldozed site, 50% of the cliffrose plants were under 1 m tall, 30% were between 1 and 2 m, and 20% were over 2 m. The deer apparently preferred the bulldozed site where the larger cliffrose plants provided security cover as well as a variety of forage.

Even though the study sites were treated eight years apart, some generalizations are worth noting. Although bulldozing costs are 1.5 to 2 times greater (depending on tree density) than two-way chaining (Bill Davis, personal communication), bulldozing was a practical and effective method for juniper removal on this site. Widemann and Cross (1981) found that bulldozing light to moderate stands of juniper in Texas with a small, low-powered crawler tractor was an economical alternative. Their cost varied from $6 to $50 per ha. The trees on this area did not constitute a closed stand, but the bulldozing treatment left Gambel oak (*Quercus gambelii*), a sprouting species, undisturbed. Bulldozing also allowed minimal disturbance to desired understory species. Cliffrose, an important cover and browse species for big game in this area, was left intact and big sagebrush populations were rejuvenated following treatment and seeding. Because big game showed a two- to threefold preference for bulldozed versus the two-way chained site, restoration projects on pinyon-juniper big game ranges in this area should consider the feasibility of using this method. However, because cliffrose density was increased by double chaining, the two-way chained area should become increasingly more valuable to big game in the future as the cliffrose becomes more mature.

Within areas of critical winter range, it would be advisable to apply different mechanical treatments to different sections of the range. Bulldozed areas could be used by wildlife immediately because the understory is left minimally disturbed (assuming an understory of desirable remnant plants are present for subsequent release and reseeding themselves), whereas

TABLE 4. Soil data on bulldozed, two-way chained, and adjacent untreated pinyon-juniper ranges.

Characteristic	Treatment		
	Untreated	Bulldozed	Two-way
Texture	Clay loam	Loam	Loam
Depth, cm	16.5[a*]	15.0[a]	14.0[a]
pH	6.5[a]	6.8[a]	6.9[a]
Soluble salts, ppm	608.0[a]	590.0[a]	560.0[a]
Phosphorus, ppm	36.2[a]	8.7[b]	27.1[a]
Potassium, ppm	300.7[a]	234.0[a]	228.0[a]
Calcium, ppm	6756.0[a]	9500.0[a]	10075.0[a]
Magnesium, ppm	381.2[a]	300.0[a]	275.0[a]
Sodium, ppm	43.9[a]	86.5[a]	83.0[a]
Zinc, ppm	1.6[a]	1.0[a]	1.6[a]
Iron, ppm	76.0[a]	57.3[a]	37.5[a]
Manganese, ppm	61.5[a]	49.0[a]	33.6[a]
Copper, ppm	1.1[a]	1.0[a]	1.2[a]
% Nitrogen	0.2[a]	0.2[a]	0.2[a]

*Means within rows with the same letter are not significantly different at $P < .05$.

chained areas would become more beneficial as the plant species mature. A regional approach should be developed that would allow areas to be treated by different mechanical techniques (varying degrees of disturbance) while leaving some areas undisturbed for a better balanced use of the resource through time. These combined treatment effects would provide for: (1) both short-term and long-term use of the treated areas by various livestock and wildlife species because of the varying stages of community development that the mechanical treatments induce, (2) greater overall productivity and carrying capacity, and (3) greater edge effect between differentially treated and undisturbed areas.

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