Pinyon-juniper chaining and seeding for big game in central Utah

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Abstract

Vegetation and soils were evaluated on 5 different-aged, mechanically treated and seeded pinyon-juniper sites and compared to adjacent untreated areas. Plant cover was significantly changed after treatment: trees were reduced from 26 to 6% total ground cover; shrubs were increased from 2 to 8% ground cover; and herbaceous plants increased from 2 to 13% ground cover. Annuals and perennial forbs were 75% of the total plant cover on the 2-year-old site, perennial grasses and shrubs dominated the plant cover (52 to 83%) on three, 14- to 20-year-old sites, while shrubs and trees combined for 84% of the plant cover on the 24-year-old site. Two *Agropyron* grass species showed good establishment and persistence after seeding. Seeded forbs contributed about 5% of the total plant cover on the 2-year-old treated site and they declined on older treated sites. Seeding of shrubs was only successful on sites where the shrub species was already present in the understory naturally. Seeding of nonnative shrub seed did not produce stands. Even though tree cover was reduced after treatment, total tree density was not. Shrub density increased from an average of 800 plants/ha on untreated areas to 2,750 plants/ha on treated areas. Juniper mortality during mechanical treatment varied from 60 to 91% and was related to the percentage of trees estimated to be 60+ years old ($r = 0.97$) and with the number of trees greater than 5 cm in stem diameter ($r = 0.71$) on the adjacent untreated sites. Big game pellet group counts were not different between untreated and treated sites, suggesting that big game make use of these treated areas because of increased forage and browse and in spite of reduced security cover.

Key Words: revegetation, tree mortality, woodland structure, pioneer species, competition

The pinyon-juniper (*Pinus* spp.—*Juniperus* spp.) woodland type covers from 17 to 32.5 million ha in the southwestern United States (Kuchler 1964, West et al. 1975). More than 25% of Utah's land area is dominated by pinyon-juniper, which often suppresses growth of understory shrubs, grasses, and forbs. Big game populations in Utah use the pinyon-juniper type extensively for winter range (Plummer et al. 1968). During the severe winter of 1948–1949, poor winter range contributed to losses of up to 42% in some deer herds, while other deer herds with good winter range had losses comparable to those occurring during a moderate winter. Because of such losses the Utah Division of Wildlife Resources in cooperation with the USDA Forest Service's Intermountain Research Station initiated a program to improve depleted big game winter range. Such improvements involved mechanical tree removal and artificially seeding adapted grass, forb, and shrub species to increase forage production (Plummer 1958, Plummer et al. 1960, 1968, 1970).

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Average tree kill with cabling or chaining ranges from 40 to 80% (Arnold et al. 1964, Aro 1971, 1975, Parker 1971). In the Great Basin, Phillips (1977) noted that chaining reduces tree overstory by nearly 100% and that the majority of trees observed on chained areas are those that survived the chaining. There is little evidence on most sites of rapid invasion by young trees establishing from seed (Stevens 1987). Reduction of tree cover by mechanical methods reduces competition for light, soil nutrients, and moisture (O'Rourke and Ogden 1969) and stimulates understory browse and grass growth (Arnold et al. 1964, Phillips 1977, Plummer et al. 1968). An early study in Utah (Plummer et al. 1970) estimated that total understory production before treatment of several pinyon-juniper sites was 22 kg/ha. Ten years after 2-way chaining and seeding with 4 grasses and 3 legumes, total production increased to 1,912 kg/ha on grazed areas and 1,717 kg/ha on ungrazed areas.

Despite increases in forage production, some problems associated with pinyon-juniper treatment for big game include: (1) a 5-to 10-year rejuvenation period before some of the slower growing browse species become available; and (2) loss of security cover for big game animals if large open tracts of land (greater than 250 m wide) are treated. In an attempt to alleviate such problems researchers recommend clearing small, localized areas, or long, narrow, contoured strips from 30 to 200 m in width and seeding desirable species in the openings (Minnich 1969, Phillips 1977, Short et al. 1977, Short and McCulloch 1977).

The objectives of this study were to evaluate: (1) plant species composition and cover changes between treated and adjacent untreated sites; (2) seeded species establishment and growth on treated areas; (3) mechanical treatment effects on woody plant densities; and (4) the consequences of these changes in relation to big game use. Because differences existed between sites, the study examined similarities and general trends of vegetation change in response to mechanical treatment and seeding, and the influence that management may have had on treated sites.

Study Sites

The areas selected for study are along the western benches of the Pahvant Mountains in Millard County and on the Wasatch Plateau in Sanpete County in central Utah. The Utah Division of Wildlife Resources owns 4 of the study sites. These were treated specifically to increase forage and browse production for big game. A 5th site (Nine Mile) is privately owned and was treated to improve forage production primarily for sheep.

Elevation, aspect, slope, and precipitation were similar on these sites (Table 1). Soils had a thin, light-colored surface horizon, underlain by a subsurface horizon of weathered parent material derived from limestone, sandstone, and shale. The soils were moderately calcareous with pH ranging from 6.5 to 7.5. Soil textures were sandy loams, loams, and clay loams.

Vegetation cover before treatment consisted of pinyon pine (*Pinus edulis* Engelm.), Utah juniper (*Juniperus osteosperma* (Torr.) Little), Gambel oak (*Quercus gambelii* Nutt.), and infrequent and scattered grasses, forbs, and shrubs in the understory

(Plummer et al. 1970). Native shrubs that occurred in woodland openings were big sagebrush (*Artemisia tridentata* Nutt.), black sagebrush (*Artemisia nova* A. Nels), true mountain mahogany (*Cercocarpus montanus* Raf.), bitterbrush (*Purshia tridentata* (Pursh) DC.), cliffrose (*Cowania mexicana* D. Don), and broom snakeweed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby). Browse species had been overgrazed by livestock and big game and were in a state of low vigor at the time of treatment (Plummer et al. 1970). Cheatgrass (*Bromus tectorum* L.) was typically the most prominent understory species.

Mayfield, Nine Mile, Corn Creek, and Hilltop were chained 1-way, aerially seeded, then chained in the opposite direction in the late fall of 1960, 1967, 1967, and 1979, respectively, with 41 kg chain links (Table 1). The Pioneer site was first seeded, then cabled 1-way in October 1957. Cabling was used on this site because large numbers of big sagebrush and cliffrose were present in the understory and this method does less damage to these desirable understory species than chaining (Plummer et al. 1968). Seeded species and seedling rates are shown in Table 2 along with their relative cover on each treated site in 1981.

Management policy of the Utah Division of Wildlife Resources is to graze rehabilitated big game winter ranges with cattle during the spring to reduce grass and forb cover, thereby enhancing browse production for wintering big game. Grazing animal and stocking rate varied among the sites studied (Table 1).

Sampling Methods

Study sites were sampled during July and August of 1981 along 4 randomly located transects of 300 m each that were placed perpendicular to the edge of treated areas. One half, or 150 m, extended into the native, untreated woodland and 150 m into the treated area. Quadrats (1 m^2) were placed at 5-m intervals (240 quadrats per site) along the transect to estimate total ground cover by plants and individual plant species cover. A modified Daubenmire (1959) technique with 7 cover classes was used to estimate vegetation cover. Relative cover of different plant life forms and seeded species was calculated as a percent of total ground cover by plants for each untreated and treated area on each site.

Density of trees and shrubs was evaluated by using 50-m^2 circular plots. The enlarged plot was centered on every 3rd quadrat along the transect (80 plots per site). Every shrub and tree within the plot was identified and its stem diameter measured at 10 cm above ground. The largest stem of each shrub was measured if it had multiple stems.

Stem diameters were related to tree age by regression analysis after cutting and counting the growth rings of 20 different-sized juniper trees on each untreated and treated site. These trees were cut near the transects on each site. One growth ring was taken to equal 1 year's growth. Juniper mortality was calculated by estimating the age of the trees (by their measured stem diameter). We assumed the juniper density and age structure was the same between untreated areas and treated areas (before the treatment was applied). Those trees on the treated area that were estimated to be older than the length of time since treatment were considered to have survived the mechanical treatment. Those trees that were estimated to be younger than the length of time since treatment were those that were assumed to reinvade the site by seed. Juniper mortality was determined by calculating the density of trees in the untreated area that were present when the mechanical treatment was done and comparing it to the density of trees older than the length of time since treatment on the treated area.

Relative big game use of these areas was estimated by counting pellet groups within the enlarged plot. A pellet group was counted when a minimum of 15 pellets were found together and when the group was determined to be from the current year (Ferguson 1955). Some investigations have reported problems with pellet group counts as an index to mule deer habitat preferences (Collins and Urness 1981, Neff 1968). Nevertheless, due to time and survey money constraints of this study, pellet group data were used to estimate and compare relative big game use on untreated vs treated areas.

Soil samples were taken after vegetation sampling was completed to a depth of 25 cm at every 10th quadrat (16 samples per site) to determine if vegetational differences were related to soil factors. Soil samples were analyzed for 10 nutrients. Phosphorus, K, Ca, Mg, and Na were extracted by ammonium acetate, while Zn, Fe, Mn, and Cu were determined with DTPA-TEA (Black 1965). Percent N (Kjeldahl method), soil texture (hydrometer method), and pH (pH electrode on 1:1 soil:water paste) were also determined.

Vegetation and soil data were analyzed by analysis of variance to determine significant differences for these parameters on untreated and treated areas across all sites. Duncan's multiple mean comparison test was used to determine significant differences across sites on the untreated and treated sites (Steel and Torrie 1980).

Results and Discussion

Species Composition and Relative Cover

With few exceptions, plant life form composition (annual grasses and forbs, perennial grasses, perennial forbs, shrubs, and trees) on untreated areas was relatively similar for all sites (Table 3). Trees contributed most of the cover while annuals, grasses, forbs, and shrubs were present in small amounts. Total ground cover by plants on untreated areas averaged 31% with about 90% of that ground cover accounted for by tree canopies.

Relative cover of the different plant life forms changed significantly on treated sites when compared to adjacent untreated areas (Table 3). Added together, relative cover of annuals and perennial forbs was 75% on the 2-year-old treated site but decreased to less than 15% on older treated sites. This concurs with Tausch and Tueller (1977) and others (Barney and Frischknecht 1974, Tausch 1973) who reported annuals and perennial forbs dominate treated sites for 1 to 2 years following treatment with gradual replacement by grasses, shrubs, and trees. The annual and perennial forbs (e.g., *Descuriana sophia* (L.) Webb, *Bromus tectorum, Verbascum thapsus* L., *Verbena hastata* L., *Viguiera ciliata* (Robins. and Greenm.) Blake) observed on our 2-year-old treated site were weedy species that invade quickly after soil disturbance.

Perennial grasses and shrubs dominated the 14- to 20-year-old treated sites (Nine Mile, Corn Creek, and Mayfield). Shrub cover was significantly greater on treated compared to untreated areas and tended to increase as the length of time since treatment increased. The Pioneer site (24-year-old, cable-treated site) supported the greatest shrub and tree cover and lowest perennial grass cover compared to any other site. The cable did not disturb the shrub and tree components as much as double-chaining. Therefore, shrub expansion and tree development may have hindered grass establishment on this site. Our records show limited livestock grazing on Pioneer during the 20 years after treatment, but it is possible that grazing pressure reduced grass cover from 1978 through 1981. Cattle were present on the site when vegetation sampling was conducted. The relative amount of cover contributed by trees on these sites was reduced from 87 to 22% after treatment. Actual ground cover by trees on treated sites ranged from 0.5% on the 2-year-old chained site to 18% on the 24-year-old cabled area.

Establishment of Seeded Species

Relative cover of seeded species varied across the sites from 15% on the 2-year-old site to 72% on the 21-year-old site (Table 2). Crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.) was found

Table 1. Summary of characteristics of 5 study sites in central Utah.

Characteristic	Study site: Pioneer	Mayfield	Corn Creek	Nine Mile	Hilltop
Elevation (m)	1770	2010	1680	1950	1920
Aspect	SW	SW	W	SW	SW
Ave slope (%)	6	12	9	8	10
Ave precip (cm)	37	32	35	32	33
Range site class	Upland stoney loam	Upland stoney loam	Upland stoney loam	Upland shallow loam	Upland shallow loam
Year treated	1957	1960	1967	1967	1979
Treatment method	Cabled and seeded	Double-chain and seeded	Double-chain and seeded	Double-chain and seeded	Double-chain and seeded
Size of treated area (ha)	810	345	292	492	30
Grazing animal	Cattle	Cattle	Cattle	Sheep	None
Stocking rate (ha/animal unit)	1978–81=1.5	1965–79=5.6 1980–81=0	1972–78=5.0 1979–81=0	1967–81=2.5	1979–81=0
Length of grazing (days)	30	55	45	60	None

Table 2. Seeding rate (kg/ha) of the major species seeded at the time of treatment and the relative amount of cover (% of total ground cover by plants) for these seeded species in 1981 on treated pinyon-juniper ranges in central Utah.

	Study site: Pioneer		Mayfield		Corn Creek		Nine Mile		Hilltop	
Seeded species	Rate (kg/ha)	Rel Cov (%)	Rate (kg/ha)	Rel Cov (%)	Rate (kg/ha)	Rel Cov (%)	Rate (kg/ha)	Rel Cov (%)	Rate (kg/ha)	Rel Cov (%)
Agropyron cristatum	1.6	3.1a[1]	2.4	21.8ab	4.7	28.3b	6.2	17.8ab	1.8	4.4a
Agropyron intermediu	.5	.2[2]	.6	1.0	1.9	5.1	3.1	5.9	.9	6.0
Bromus inermis			2.3	10.6b	1.2		2.1	.3a		
Elymus junceus			1.2	5.1	1.1		2.0	3.1	.9	
Medicago sativa	.1		1.8		.8	.1	1.0	.2	2.7	.9
Melilotus officinale			1.2		.4		.6	.1	.9	1.4
Sanguisorba minor			.6		.4		.5		.9	2.5
Artemisia tridentata	.1	31.8a	.6	1.2b	.4	17.1ab	.5	1.5b	.9	
Artemisia nova				16.1b	.1		.1	4.1a		
Atriplex canescens	.2		.1	.1	1.1		.7	.2	.9	
Chrysothamnus nauseosus	.1				.4		.6	.2	.5	
Cowania stansburiana	.1	15.7	.1		.1	15.0	.1		.2	
Purshia tridentata	.3		.1		.1	.1	.1	.1	.2	
Totals[3]										
Seeded grasses	2.6	3.9b	7.0	50.2a	9.7	33.9ab	14.3	27.1ab	3.6	10.5ab
Seeded forbs	.1		3.6		2.0	.1	1.5	.3	5.0	4.8
Seeded shrubs	.8	47.6a	.8	22.1ab	2.3	32.2ab	1.9	6.0b	2.9	
Total of seeded species[3]	3.5	51.5a	11.4	72.3a	14.0	66.2a	17.7	33.4ab	11.4	15.3b

[1]Cover values for each species across sites with the same letter are not significantly different at $p<0.05$.
[2]Where no letter appears, the cover values for that species are not significantly different.
[3]Totals include other seeded species which were seeded (<0.1 kg/ha).

Table 3. Total plant cover (% ground cover by all plants) and relative cover (% of total plant cover) by different plant life forms on untreated (Unt) and treated (Trt) big game ranges in central Utah.

	Study site: Pioneer		Mayfield		Corn Creek		Nine Mile		Hilltop	
Characteristic	Unt	Trt	Unt	Trt	Unt	Trt	Unt	Trt	Unt	Trt
Total plant cover	46a[1]	44a	36a	29a	21ab	30a	24a	17ab	28a	15b
Annuals	2c	6b	0c	1b	5c	10b	2c	8b	2c	34a
Perennial grasses	1c	8b	4c	54a	5c	36ab	4c	33ab	1c	19ab
Perennial forbs	0c	2b	2c	4b	2c	3b	0c	2b	1c	35a
Shrubs	9b	43a	11b	29a	14b	38a	1b	19a	1b	9a
Trees	88a	41b	81a	12b	74a	13b	93a	38b	95a	3b

[1]Values for each characteristic across sites with the same letter are not significantly different at $p<0.05$.

Table 4. Soil characteristics on untreated (Unt) and treated (Trt) pinyon-juniper ranges in central Utah. All nutrient concentrations except N are reported in mg/kg.

	Study site									
	Pioneer		Mayfield		Corn Creek		Nine Mile		Hilltop	
Characteristic	Unt	Trt	Unt	Trt	Unte	Trt	Unt	Trt	Unt	Trt
% Sand	39a[1]	37b	37a	33b	46a	45b	46a	41b	46a	44b
% Clay	26[2]	26	31	33	23	26	24	27	28	29
pH	6.5b	6.2b	7.2a	7.2a	7.2a	7.2a	7.3a	7.2a	7.2a	7.2a
P	36a	37a	11b	10b	10b	10b	8b	18b	17b	8b
K	301	272	194	309	224	240	263	218	208	251
Ca	6756b	4230b	10408a	10866a	10356a	10025a	10908a	11275a	12083a	13333a
Mg	381	368	367	433	281	281	525	575	308	366
Na	44b	46b	60a	60a	59a	57a	65a	64a	65a	67a
Zn	1.6	1.6	1.2	1.1	1.3	1.5	1.0	.8	.9	1.1
Fe	76	80	41	92	61	82	70	88	13	15
Mn	62	81	32	84	60	77	65	61	14	11
Cu	1.1b	1.2b	1.4a	1.0b	1.0b	1.0b	.7c	.9bc	.6c	.6c
% N	.2	.1	.2	.5	.3	.2	.2	.2	.2	2

[1]Mean values across sites with the same letter are not significantly different at $p<0.05$.
[2]Where no letters appear, the values for that nutrient across sites are not significantly different.

on all treated sites and was most prevalent on intermediate-aged sites. Intermediate wheatgrass (*Agropyron intermedium* (Host) Beauv.) also established and persisted on these sites. Smooth brome (*Bromus inermis* Leyss.) and Russian wildrye (*Elymus junceus* Fisch.) established and persisted on the Mayfield and Nine Mile sites. Alfalfa (*Medicago sativa* L.), yellow sweetclover (*Melilotus officinale* (l.) Lamb.), and small burnet (*Sanguisorba minor* Scop.), all biennial or perennial forbs, were present in the greatest amounts on the 2-year-old treated site. These species have been known to persist and maintain themselves after seeding (Plummer et al. 1968), but they were found only in scarce amounts on the 14-year-old sites (Table 2).

Soil analysis revealed several significant differences between soils of untreated and treated areas, and between sites (Table 4). Sand content was significantly lower on treated compared to untreated areas. Soils at Pioneer were lower in pH and Ca, and higher in P than the other sites. A soil pH of 6.5 on this site may have released greater amounts of P and K for plant uptake. These 2 nutrients have been shown to be limiting to juniper growth (Bunderson et al. 1985). Differences in texture and other nutrients showed no specific trends and were not consistent with any particular vegetation characteristic (Leonard et al. 1987).

Woody Plant Density

Juniper density after treatment was significantly lower on only 2 of the 5 sites (Table 5) (Rippel et al. 1983). Pinyon density was reduced by treatment on 2 out of 3 sites where it was found. Gambel oak, a prolific root sprouter, can spread after mechanical treatment. Gambel oak response to mechanical treatment varied across our sites.

Shrub density was significantly higher on 4 out of 5 sites with density increases from 2 to 10 times on treated sites when compared to untreated areas (Table 5). In this study, artificial seeding of shrubs was only successful on sites where the shrub species was already present in the understory naturally. Some shrub species are better adapted to the soils and climate of particular sites (Plummer et al. 1968). Seeding of nonnative shrub seed did not produce stands. Broom snakeweed density probably increased on the treated areas because it is a weedy invader shrub adapted to disturbed sites (Arnold et al. 1964).

Pinyon-Juniper Stand Relations

Mature tree canopies attenuate from 50 to 90% of the light that reaches the outside of the crown, which in turn reduces the light available to the understory (Larcher 1980). Large trees also monopolize basic resources (such as soil moisture and nutrients)

Table 5. Density (plants/ha) of woody plant species on untreated (Unt) and treated (Trt) pinyon-juniper ranges in central Utah.

	Study site									
	Pioneer		Mayfield		Corn Creek		Nine Mile		Hilltop	
Characteristic	Unt	Trt	Unt	Trt	Unte	Trt	Unt	Trt	Unt	Trt
Trees										
Juniperus osteosperma	771a[1]	405bc	442bc	276c	852a	973a	678ab	569ab	586ab	129c
Pinus edulis			503a	121b			606a	352a	149b	10c
Quercus gambelii	2660a	1079ab	389b	1039ab	369b	49b	768ab	280b	139b	9b
Total	3431a	1484b	1358b	1436b	1221b	1022b	2052ab	1201b	874b	148b
Shrubs										
Artemisia tridentata	1351ab	2039a	0c	132c	305bc	1605ab	253bc	244bc	10c	99c
Artemisia nova			99a	1027b			135b	768a		
Cercocarpus montanus			575	332						
Chrysothamnus nauseosus	0[2]	14					9	54		
Cowania stansburiana	108b	533a			149b	334a				
Purshia tridentata			0	22	78	28	0	9		
Gutierrezia sarothrae	389c	1371b	0c	221c	85c	931b	99c	3380a	268c	477b
Total	1848b	3957a	796c	1911b	617c	2898a	496c	4455a	298c	586c

[1]Values within species across sites with the same letter are not significantly different at $p<0.05$.
[2]Where no letters appear, the density values for that species across sites are not significantly different.

and allow only a small amount of these resources to be available to smaller plants in the understory. Mechanical treatment removes most of the large pinyon and juniper trees (Parker 1971) that tie up the basic limited resources at the site. As these larger trees are removed, the resources become available to understory grasses, forbs, and shrubs; but removal of large trees also makes resources available to small trees present in the understory that might not have been uprooted or killed by mechanical treatment. Many of these small trees, which have persisted for long periods in a stunted or depressed condition under the canopy, are released after chaining (Grime 1979). In addition, seeds buried in the soil may germinate in response to the increased quantity and quality of light and soil moisture following canopy removal.

The size and age-structure of pinyon-juniper stands at the time of treatment are important in terms of the success and longevity of mechanical treatments. For example, the Mayfield juniper stand before treatment was an old, even-aged stand with 77% of the trees being 60+ years old (Table 6). The juniper trees on this site were also large with 75% of the trees having stem diameters of greater than 5 cm. Based on this age analysis of the trees in the untreated area, Mayfield was an excellent site for mechanical treatment. According to our analysis, 91% of the trees on the site at the time of treatment were successfully eliminated by double-chaining. Furthermore, age analysis of the trees on the treated area indicates that only 12% of the juniper were older than the length of time since treatment (i.e., older than 20 years old), and juniper establishment from seed was also low (Fig. 1). Good establishment of seeded grasses and shrubs on the Mayfield site has slowed tree establishment and development (Stevens et al. 1975).

Table 6. Percent of juniper eliminated by mechanical treatment on treated areas related to the percent of juniper 40+ and 60+ years old, and greater than 5 cm in stem diameter on adjacent untreated areas.

	Study site				
Juniper trees	Pioneer	Mayfield	Corn Creek	Nine Mile	Hilltop
% eliminated	64	91	68	60	78
% 40+ years old	63	90	53	71	65
% 60+ years old	44	77	40	38	55
% >5 cm	61	75	46	59	74

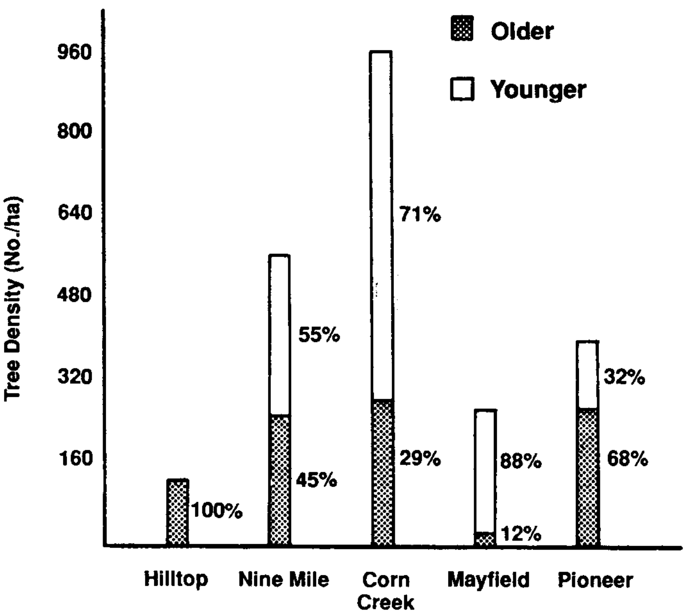

Fig. 1. *Density (No./ha) and percentage of juniper trees that are older (survived the treatment) or younger (emerged since treatment) than the length of time since treatment on pinyon-juniper big game ranges.*

In contrast, the untreated juniper stand at Pioneer revealed a more diverse age structure with approximately 37% of the trees between 0 and 40 years old and 44% greater than 60 years old (Table 6). The trees also were smaller with 39% having stem diameters of 5 cm or less. This site was cabled because numerous plants of cliffrose and big sagebrush were present in the understory, and cabling does less damage to understory plants. Cabling is generally less effective than chaining for eliminating juniper because young, flexible trees bend under the cable (Plummer et al. 1968). Because younger and smaller trees were present at the time of treatment, and because a cable was used, juniper mortality following treatment at the Pioneer site was only 64%. The low juniper mortality on this site is demonstrated by the fact that 68% of the trees in the treated area are older than the treatment date (i.e., older than 24 years) (Fig. 1). However, cabling spared and rejuvenated many of the existing desirable understory shrubs. Juniper mortality during treatment on these sites was related to the percentage of trees 41 years or older ($r = 0.68$) and 61 years or older ($r = 0.97$), and with the number of trees greater than 5 cm in stem diameter ($r = 0.71$) on adjacent untreated areas (Table 6).

A stand analysis should be done for all pinyon-juniper sites that are to be mechanically treated. Evaluating the size and age distribution of the stand would provide an estimate of the percentage of trees expected to be eliminated by the use of a particular weight and type of chain. Therefore, the resource manager may predict pinyon and juniper mortality resulting from a specific mechanical treatment and predict the number of trees that will probably survive the treatment. If the estimate of surviving trees is high, the site may not be suited for mechanical treatment, or some kind of follow-up treatment, such as prescribed burning (Bunting 1987) or herbicides (Johnson 1987), could be done within several years after mechanical treatment.

Regardless of woodland structure and age, treatment technique, or successful establishment of seeded species, some juniper reestablishment will occur. Even so, removing tree competition to allow establishment of seeded species is important to improve forage and browse on pinyon-juniper big game ranges. As tree mortality increases, the potential for establishment of forage and browse species increases, which in turn prolongs the effectiveness of a mechanical treatment. Treatment should always include seeding species that are specifically adapted to the site, meet management objectives, and provide competition to help suppress tree reestablishment (Plummer et al. 1968).

The Utah Division of Wildlife Resources habitat management program provides for livestock grazing on Division-owned lands if it serves as a strategy to benefit wildlife habitat. In most cases, this involves spring grazing by livestock to maintain a proper balance between grasses, forbs, and shrubs on mule-deer winter ranges. Heavy spring grazing by cattle on grasses and forbs on big game winter ranges can accelerate changes toward shrub-dominated communities (Arnold et al. 1964, Plummer et al. 1968). Grazing pressure by livestock or big game may explain why some treated pinyon-juniper areas are quickly dominated by shrubs and trees after mechanical treatment. Heavy grazing by sheep at Nine Mile has increased the density of snakeweed and has helped to accelerate this site toward a tree-dominated community.

Use of Treated Pinyon-Juniper Ranges by Big Game

No significant differences were found for pellet group densities when treated and untreated big game ranges were compared. Our data show that as the unit of time following treatment increased, treated sites showed a trend of increasing numbers of pellet groups per hectare relative to their adjacent untreated areas (Fig. 2). Pellet group data on our sites showed no decline in pellet group density as

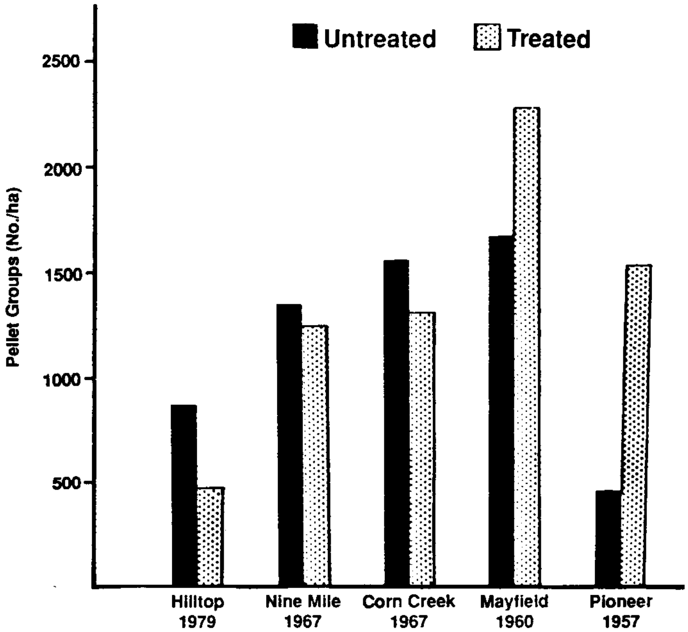

Fig. 2. *Pellet groups (No./ha) on untreated and treated pinyon-juniper big game ranges in central Utah.*

the distance into the treated area increased up to 150 m. Some researchers report that big game use of treated pinyon-juniper sites increased due to greater amounts of forage and browse on the treated area, and their pellet group data support this finding (Minnich 1969, McCulloch 1969, Plummer et al. 1966). Others indicate that treatment has reduced security cover to the extent that big game use declined (Lyon and Jensen 1980, Short et al. 1977, Terrel and Spillett 1975). Phillips (1977) states that young pinyon-juniper chaining projects contribute little to big game until shrubs and trees become established within the treated area (see also Short and McCulloch 1977). Other reports, such as this study, show both higher and lower pellet group densities on treated sites when compared to adjacent untreated areas (Howard et al. 1987, Payne 1981, Phillips 1977). Our experience and research on Utah big game range has shown that big game utilize treated areas as much or more than untreated areas; and, perhaps more importantly, big game use of these treated areas during critical times of the year (i.e., late fall, winter, and early spring) is extended. Because greater amounts of herbs, grasses, and browse are available on treated sites, big game use is enhanced and increases with time as browse and tree species develop in the site.

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