PLANT SUCCESSION IN CUT JUNIPER WOODLANDS: 1991-1998

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SUMMARY

We monitored plant succession after tree cutting in grazed and ungrazed western juniper woodlands over an eight year period (1991-1998). Data from ungrazed woodlands span 1991-1997. Data for the grazed woodland in the late development stage were collected during 1991-1993, 1996, and 1998. The study sites were located on Steens Mountain in southeast Oregon. We selected eight 2 acre sized blocks of juniper woodland, and half of each block was cut in August 1991. Both grazed and ungrazed communities (4 blocks each) were rested from domestic livestock grazing in 1992 and 1993. Plots were grazed in the spring during the years 1994-1997 and were rested in 1998. Response trends for understory parameters were similar in grazed and ungrazed cut plots. Total basal cover, density, and biomass of the understory were greater in cut versus woodland treatments. Understory biomass was nearly 9 times greater in the ungrazed cut plots compared to ungrazed woodland in 1993, 1996, and 1997. In grazed plots, understory biomass was nearly 13 times greater in cut versus woodland plots in 1998. In all cut plots, annual grass cover, density, and biomass increased substantially by 1996 but was mainly confined to areas under cut trees (debris zones) and in litter layers around tree stumps. Perennial grasses, primarily squirreltail, preferentially established under juniper debris and around the old stumps. Understory response was not significant until the second year post-cutting (1993) when there were large increases in biomass, density, and cover in cut plots. Delays in understory response in the cut treatment were attributed to environmental conditions and seed production. Dry soil conditions in the spring of 1992 and 1994 contributed to the delay in understory response. The main increases in plant biomass, cover, and density in cut plots coincided with wet periods: the first increase occurring in 1993, and the second increase between 1995 and 1998. Because cutting is expensive, sites for treatment need to be carefully selected. Sites selected for cutting should contain adequate densities of understory perennial grasses. The density of perennial grasses necessary for recovery after cutting is dependent on site potential. A site lacking a perennial grass component and dominated by annual species will likely remain dominated by annual species unless seeded to perennials. The site used in this study probably requires rest or deferment during the growing season until perennial grasses have the opportunity to produce seed and establish seedlings. Grazing in late summer and fall appears permissible because plants are largely dormant during this time.

INTRODUCTION

Succession from sagebrush steppe to western juniper dominated communities has raised concerns over the effects of woodland development on plant community structure, composition, and diversity. Beginning in the late 1800's, western juniper woodlands have increased in density and spatial extent in central and eastern Oregon, northeastern California, and southwestern Idaho (Miller and Wigand 1994). Prior to Euro-American settlement, western juniper was largely confined to areas with shallow rocky soils underlain by fractured bedrock (Burkhardt and Tisdale 1969, Miller and Wigand 1994, Miller and Rose 1995). Recent juniper expansion has occurred on more productive soils occupied by mountain big sagebrush grasslands, riparian zones, and quaking aspen woodlands (Burkhardt and Tisdale 1969, Eddleman 1987, Miller and Rose 1995). Reduced fire frequency is cited as the main factor permitting the expansion of juniper (Burkhardt and Tisdale 1976, Evans and Young 1985, Miller and Wigand 1994). Succession to juniper-dominated communities is accompanied by reductions in understory productivity (West 1984, Vaitkus and Eddleman 1987), cover (Driscoll 1964), and diversity (Burkhardt and Tisdale 1969).

Many juniper dominated communities are relatively stable and resistant to all but the most severe fire conditions. Thus, natural or prescribed fire maybe eliminated as a management tool for restoring understory vegetation due to lack of fuels necessary to carry fires through juniper stands. Understory restoration in many juniper dominated communities is limited to mechanical treatments such as tree cutting.

Tree cutting to remove overstory competition is commonly used in areas occupied by western juniper. Cutting of juniper trees has resulted in greater understory biomass and cover (Vaitkus and Eddleman 1987, Rose and Eddleman 1994). Nonetheless, there is insufficient long term data documenting impacts of cutting in western juniper woodlands on plant community structure, composition, and diversity. Lack of long term ecological databases may hinder or misdirect decision making for understory restoration and commercial use of western juniper woodlands.

Understory dynamics in western juniper woodlands were assessed under grazed and ungrazed conditions after tree cutting. Cover, biomass, and density of understory species were monitored over a seven year period after cutting in 1991.

MATERIALS & METHODS

Study Site

The study site was on Steens Mountain in southeast Oregon. Elevation at the site 5000 ft and aspect is west facing with a 22% slope. Full occupancy of the site by juniper was indicated by the limited leader growth on juniper trees and low herbaceous cover. Mountain big sagebrush was largely eliminated from the site with only a scattering of old decadent shrubs remaining. On ungrazed plots juniper canopy cover averaged 25% and tree density averaged 119 trees ac^{-1}. On grazed plots juniper cover averaged 24% and tree density was 92 trees ac^{-1}. Bare ground was 97% in intercanopy zones and rill erosion was evident throughout the site.

The understory was dominated by Sandberg bluegrass, which constituted about 75% of total understory perennial plant cover. Other species characteristic of the site were bottlebrush squirreltail, bluebunch wheatgrass, Thurber needlegrass, basalt milkvetch, and pale alyssum. Perennial grasses on grazed plots were primarily of bluebunch wheatgrass and squirreltail. Perennial grasses on ungrazed plots were primarily of Thurber needlegrass and squirreltail.

Water year (October 1 - Sept. 30) precipitation at Malheur National Wildlife Refuge weather stations located 16 miles southwest at 4265 ft elevation and 18 miles northwest at 4100 ft elevation, have averaged 11 and 9.8 in. over the past 30 years. Soils on the site are 16 to 20 inches deep, rocky, and are clay loam in texture. Soils are underlain by a welded ash tuff of rhyolite/rhyodacite composition which blocks root penetration. Soils were classified as clayey-skeletal, smectitic, frigid, Lithic Argixerolls.

Experimental Design

Ungrazed Plots - The experimental design was a randomized complete block with 4 blocks (replicates) and 2 treatments, cut and uncut juniper woodland. Replicates were 0.8 ha (2 acres) in size and were selected for similarities in overstory/understory density and cover. Measurements of baseline vegetation characteristics were made prior to tree cutting in July 1991. Trees in half of each block were cut with chainsaws in August 1991. All cut juniper trees were left in place, a standard range improvement practice in eastern Oregon. Post-treatment measurements of understory characteristics began in April 1992. Livestock were excluded from the site from 1992 through 1998.

Grazed Plots - The experimental design was a randomized complete block with 4 blocks and 2 treatments, cut and uncut juniper woodland. Replicates were 0.8 ha in size. Pre-treatment vegetation characteristics were made prior to tree cutting. Trees in half of each block were cut in August 1991. Post-treatment measurements of understory characteristics began in April 1992. Livestock were excluded from the site in 1992, 1993, and 1998. Plots were grazed in the spring from 1994-1997 by 100-400 cow/calf pairs in the spring. Plots were in a pasture of about 200 acres and access was available to hay meadows below the site. The duration of use was approximately three weeks each year from late April to May 15.

Understory Sampling

Understory measurements were basal cover (perennial plants), canopy cover, density, and biomass. Understory plants were measured by species (except biomass) but are organized into five functional groups to simplify presentation of the results. The functional groups are Sandberg bluegrass, perennial bunchgrasses (e.g. Thurber needlegrass, bluebunch wheatgrass, squirreltail), perennial forbs, annual grasses, and annual forbs.

Biomass was sampled at 10 ft intervals using 10.75 ft^2 quadrates along two 150 ft transects in cut and uncut woodlands. Vegetation was clipped to a 1 in. stubble height. Understory plant density and canopy/ground cover was measured using 2 ft^2 quadrates. Basal cover of perennial plants was measured along five 100 ft line transects in 1991-93 and along four 150ft transects in 1994, 1997, and 1998. Transect length and number were changed in 1994 to conform with understory sampling protocols that are being used in other juniper woodland projects.

Sampling in the plots was conducted as follows:

Ungrazed Plots

Biomass: 1992, 1993, 1996, 1997.

Density: 1991-1997.

Basal Cover: 1991-1994, 1997.

Canopy Cover: 1993, 1994, 1997.

Grazed Plots

Biomass:1992, 1993, 1996.

Density: 1991-1993, 1998.

Basal Cover: 1991-1993, 1998.

Canopy Cover: 1993, 1998.

RESULTS

Understory Succession - Ungrazed Plots

Pre-cutting - Baseline measurements made before cutting in July 1991 indicated there were no differences in basal cover (Table 1) of herbaceous perennials or in understory plant density (Table 2) between plots that were left as woodlands and plots that were selected to be cut.

Post-cutting - *Sandberg bluegrass* - Cover (Table 1) and biomass (Table 3) of bluegrass increased between 1991 and 1993 in cut plots. Bluegrass cover and biomass were greater in cut versus woodlands during 1992 and 1993. By 1997, there were no differences between cut and woodland plots in cover, density (Table 2), and biomass. In cut plots cover and biomass of bluegrass declined dramatically between 1993 and 1997.

Table 1. Ungrazed Plots - Understory perennial plant basal cover (%) in cut and woodland treatments (1991-93 and 1997). Different letters denote significant differences for each species group in each year.

Species Group [1]	Treatment	1991	1992	1993	1997
Sandberg Bluegrass	Cut	1.4 ± 0.3 a	1.5 ± 0.4 a	2.8 ± 0.4 a	1.1 ± 0.2 a
	Woodland	1.2 ± 0.2 a	1.1 ± 0.2 a	1.2 ± 0.1 b	1.1 ± 0.1 a
Perennial Grasses[2]	Cut	0.9 ± 0.2 c	0.9 ± 0.2 d	2.6 ± 0.3 d	3.5 ± 0.3 d
	Woodland	0.8 ± 0.2 c	0.4 ± 0.1 c	0.4 ± 0.1 c	0.2 ± 0.1 c
Perennial Forbs	Cut	0.4 ± 0.1 g	0.4 ± 0.2 h	0.5 ± 0.2 h	0.3 ± 0.1 g
	Woodland	0.3 ± 0.1 g	0.1 ± 0.1 g	0.1 ± 0.1 g	0.1 ± 0.1 g
Total Cover	Cut	2.6 ± 0.4 y	2.8 ± 0.3 z	5.9 ± 0.3 z	4.8 ± 0.3 z
	Woodland	2.3 ± 0.3 y	1.7 ± 0.2 y	1.7 ± 0.3 y	1.5 ± 0.3 y

[1] Units are percent crown cover (%).

[2] Perennial grasses in this category are the taller tussock grasses, including bluebunch wheatgrass, Thurber' needlegrass, and squirreltail.

Perennial Bunchgrasses - In cut plots, the basal cover, density, and biomass all steadily increased between 1991 and 1997 (Tables 1-3). Perennial grass density increased by nearly 700%, basal cover increased by 350%, and biomass increased (1992 vs. 1997) by 2700%. In 1997, perennial grass biomass was 12 times greater in cut plots compared to woodlands. Basal cover and density of perennial grasses have been significantly greater in cut plots versus the woodlands in all years post-cutting. Perennial grasses, primarily squirreltail, preferentially established under juniper debris and around the old stumps (Bates et al 1998). In woodland plots perennial grass biomass increased between 1993 and 1997. However, basal cover of grasses has declined in woodlands over the same period.

Perennial Forbs - Perennial forb basal cover and density has not differed between treatments. However, in all years forb biomass was consistently greater in cut plots compared to woodlands (Table 3).

Annual Grasses - There was a distinct lag in annual grass (cheatgrass and Japanese brome) response to cutting. Densities of annual grasses did not differ in 1992 or 1993 between treatments. Annual grass density began increasing in 1994 and 1995 in cut plots. By 1996 and 1997 cover, density, and biomass of annual grasses increased exponentially in cut plots (Tables 1-3). The increase in annual grass has mainly been confined to areas under cut trees and around the old stumps (Bates et al. 1998).

Annual Forbs - Except for one year (1995) annual forb density has been significantly greater in woodland versus cut plots (Table 2). Annual forbs are larger in cut plots as evidenced by their greater biomass value in 1997 (Table 3). The lower annual forb density in cut plots results from lower densities of pale alyssum compared to woodlands (Bates et al. 1999).

Total ground cover - Ground cover was nearly twice as great in cut compared to woodland plots in 1993 and 1997. In 1997, ground cover in the cut treatment totaled 56% (juniper slash, 18%; duff and other litter, 20%; interspace herbaceous canopy cover, 18%) compared to 29% in the uncut treatment (juniper trees and litter, 24.5%; interspace herbaceous canopy cover, 4.5%).

Understory Succession - Grazed Plots

Pre-cutting - Baseline measurements in July, 1991 did not show any major differences plant cover (Table 4) or density (Table 5) between plots that were left as woodlands and plots that were selected to be cut. Perennial forb density and cover were slightly greater in woodland versus cut plots.

Post-cutting - *Sandberg bluegrass* - Cover (Table 4) and biomass (Table 6) of bluegrass increased between 1991 and 1993 in cut plots and were greater in cut versus woodlands.

Table 2. Ungrazed Plots - Understory density (1991-1997) in cut and woodland treatments. Different letters denote significant treatment differences for each species group in each year. In the cut treatment there were significant increases in perennial grass and annual grass densities particularly between 1994 and 1997.

Species Group [1]	Treatment	1991	1992	1993	1994	1995	1996	1997
Sandberg Bluegrass	Cut	8.0 ± 0.6 a	10.4 ± 1.1 a	11.1 ± 1.2 a	8.6 ± 0.7 a	5.9 ± 0.4 a	6.4 ± 0.2 a	9.8 ± 1.1 a
	Woodland	7.7 ± 0.7 a	10.4 ± 0.9 a	9.2 ± 0.9 a	13.3 ± 1.4 b	8.6 ± 0.5 b	11.5 ± 1.3 b	11.1 ± 0.6 a
Perennial Grasses	Cut	2.6 ± 0.3 d	2.2 ± 0.3 e	3.7 ± 0.4 e	5.1 ± 0.2 e	7.5 ± 0.9 e	10.0 ± 0.4 e	15.1 ± 1.4 e
	Woodland	2.1 ± 0.3 d	1.6 ± 0.2 d	1.9 ± 0.3 d	1.9 ± 0.4 d	2.2 ± 0.3 d	2.1 ± 0.5 d	1.7 ± 0.3 d
Perennial Forbs	Cut	0.4 ± 0.2 g	1.0 ± 0.4 g	1.7 ± 0.4 g	1.9 ± 0.3 g	2.9 ± 0.5 h	4.0 ± 1.5 h	4.5 ± 0.4 h
	Woodland	0.6 ± 0.3 g	0.6 ± 0.3 g	2.0 ± 0.3 g	1.2 ± 0.3 g	1.7 ± 0.4 g	1.9 ± 0.5 g	1.6 ± 0.3 g
Annual Grasses	Cut	0.5 ± 1.2 r	2.2 ± 1.1 r	3.7 ± 5.3 r	30.1 ± 3.7 s	77.0 ± 11.1 s	570.0 ± 61.0 s	442.0 ± 64.0 s
	Woodland	1.1 ± 3.4 r	2.5 ± 2.5 r	2.8 ± 2.7 r	3.4 ± 3.1 r	2.1 ± 1.2 r	5.9 ± 2.8 r	6.7 ± 2.7 r
Annual Forbs	Cut	12.6 ± 4.2 y	9.4 ± 2.3 y	40 ± 18 y	100 ± 18 y	139 ± 9 z	65 ± 6 y	207 ± 32 y
	Woodland	14.2 ± 1.4 y	83.5 ± 34 z	125 ± 43 z	174 ± 40 z	59 ± 14 y	102 ± 22 z	286 ± 37 z

[1] Units are number of plants per m^2 (or number of plants per 10.75 ft^2).

Table 3. Ungrazed Plots - Understory biomass (lb/ac) in cut and woodland treatments (1992-93 and 1996-97). Different letters denote significant differences for each species group in each year.

Species Group	Treatment	1992	1993	1996[2]	1997[2]
Sandberg Bluegrass	Cut	10.2 ± 1.0 a	165 ± 21 b	N.A.	36 ± 7 a
	Woodland	9.1 ± 1.6 a	41 ± 5 a		41 ± 5 a
Perennial Grasses[3]	Cut	16.6 ± 2.9 e	169 ± 25 e	N. A.	492 ± 65 e
	Woodland	7.1 ± 2.9 d	9 ± 3 d		41 ± 12 d
Perennial Forbs	Cut	13.8 ± 5.4 h	21 ± 6 h	N. A.	111 ± 10 h
	Woodland	0.4 ± 0.2 g	3 ± 1 g		28 ± 12 g
Annual Grasses	Cut	1.1 ± 0.5 j	5.0 ± 1.0 k	N. A.	211 ± 16 k
	Woodland	0.2 ± 0.2 j	0.5 ± 0.2 j		2 ± 1 j
Annual Forbs	Cut	N. M.	N. M.	N. A.	20 ± 2.6 s
	Woodland				0.7 ± 0.2 r
Total Biomass	Cut	41.7 ± 5.1 z	359 ± 35 y	931 ± 211 y	931 ± 85 y
	Woodland	16.6 ± 4.3 y	33 ± 5 z	91 ± 24 z	110 ± 29 z

[2] Biomass values in 1996 and 1997 include both current years production and standing dead material from previous years growth. Current years production in 1996 and 1997 is about 70% of the biomass values shown.

[3] Perennial grasses in the this category are the taller tussock grasses, including bluebunch wheatgrass, Thurber needlegrass, and squirreltail.

N. M. - not measured.

N. A. - not separated by species group.

Table 4. Grazed Plots - Understory perennial plant basal cover (%) in cut and woodland plots (1991-93 and 1997). Different letters denote significant treatment differences for each species group in each year.

Species Group[1]	Treatment	1991	1992	1993	1998
Sandberg Bluegrass	Cut	1.0 ± 0.1 a	0.9 ± 0.2 b	1.7 ± 0.3 b	0.7 ± 0.1 a
	Woodland	1.2 ± 0.1 a	0.8 ± 0.2 a	0.8 ± 0.2 a	0.5 ± 0.1 a
Perennial Grasses	Cut	0.4 ± 0.1 c	0.5 ± 0.1 d	1.6 ± 0.3 d	1.8 ± 0.1 d
	Woodland	0.6 ± 0.1 c	0.2 ± 0.1 c	0.2 ± 0.1 c	0.1 ± 0.0 c
Perennial Forbs	Cut	0.1 ± 0.0 g	0.3 ± 0.2 g	0.2 ± 0.0 g	0.1 ± 0.0 g
	Woodland	0.3 ± 0.1 h	0.2 ± 0.1 g	0.2 ± 0.1 g	0.1 ± 0.0 g
Total Cover	Cut	1.5 ± 0.1 y	1.8 ± 0.4 y	3.5 ± 0.3 z	2.7 ± 0.2 z
	Woodland	2.0 ± 0.2 y	1.2 ± 0.2 y	1.3 ± 0.1 y	0.7 ± 0.1 y

[1] Units are percent crown cover (%).

Table 5. Grazed Plots - Understory density (plants m^{-2}) in 1991-93 and 1998 in cut and woodland plots. Different letters denote significant treatment differences for each species group in each year.

Species Group[1]	Treatment	1991	1992	1993	1998
Sandberg Bluegrass	Cut	7.0 ± 0.8 a	7.8 ± 1.2 a	8.1 ± 1.0 a	7.1 ± 1.6 a
	Woodland	6.7 ± 1.4 a	7.0 ± 1.1 a	7.6 ± 1.4 a	6.9 ± 1.6 a
Perennial Grasses	Cut	3.5 ± 0.3 a	3.0 ± 0.3 b	3.0 ± 0.4 b	10.1 ± 0.2 b
	Woodland	2.9 ± 0.4 a	1.8 ± 0.2 a	1.6 ± 0.3 a	2.3 ± 0.4 a
Perennial Forbs	Cut	0.9 ± 0.1 a	2.4 ± 0.5 a	2.4 ± 0.4 a	5.2 ± 1.7 a
	Woodland	1.6 ± 0.4 b	2.5 ± 0.3 a	2.5 ± 0.5 a	3.1 ± 0.7 a
Annual Grasses	Cut	0.8 ± 0.3 a	2.0 ± 0.8 a	1.8 ± 0.6 a	547.0 ± 46.0 b
	Woodland	2.4 ± 1.9 a	10.8 ± 9.4 a	8.8 ± 7.1 a	10.1 ± 2.2 a
Annual Forbs	Cut	8.9 ± 1.3 a	97 ± 24 a	98 ± 24 a	266 ± 41 a
	Woodland	8.2 ± 1.5 a	293 ± 128 b	272 ± 81 b	527 ± 92 b

[1] Units are number of plants m^{-2} (or number of plants 10.8 ft^{-2}).

In 1998 there were no differences between cut and woodland plots in cover and density (Table 5) as bluegrass presence declined dramatically between 1993 and 1998 in cut plots.

Perennial bunchgrasses - In cut plots, basal cover (Table 4) and density (Table 5) increased between 1991 and 1998. In woodlands, perennial grass basal cover has declined and in all years was significantly less than cover in cut plots. Density increases in cut plots occurred during the grazing period. Perennial grass density has more than tripled since 1994. Woodland perennial grass density has not changed since 1991 but basal cover has declined by75%.

Perennial Forbs - Perennial forb basal cover and density were not different between treatments. In 1992 and 1993, forb biomass was greater in cut plots compared to woodlands (Table 6).

Annual Grasses - Annual grass response trend has been similar to ungrazed plots. Densities of annual grasses did not differ between treatments in 1992 and 1993. In 1998, annual grass density was 55 times greater in the cut versus woodland treatments. The increase in annual grass density and cover has largely been under cut trees and around old litter zones.

Annual Forbs - In all years annual forb density has been significantly greater in woodland versus cut plots (Table 5). Annual forb canopy cover was greater in cut plots in 1993 and 1998 indicating larger individual plant size.

Table 6. Grazed Plots - Understory biomass (lb/ac) in cut and woodland plots (1992-93 and 1996). Different letters denote significant treatment differences for each species group in each year.

Species Group	Treatment	1992	1993	1996[2]
Sandberg Bluegrass	Cut	11.5 ± 1.6 a	86.5 ± 6.2 b	N.A.[3]
	Woodland	12.7 ± 1.9 a	22.3 ± 3.6 a	
Perennial Grasses	Cut	17.2 ± 2.0 d	106.0 ± 16.0 d	N. A.
	Woodland	3.7 ± 2.0 c	5.6 ± 2.0 c	
Perennial Forbs	Cut	9.1 ± 1.2 h	25.8 ± 4.5 h	N. A.
	Woodland	4.6 ± 1.2 g	5.8 ± 0.8 g	
Annual Grasses	Cut	2.2 ± 1.3 s	9.5 ± 3.3 s	N. A.
	Woodland	0.2 ± 0.2 r	1.1 ± 0.8 r	
Annual Forbs	Cut	N. M.[4]	N. M.	N. A.
	Woodland			
Total Biomass	Cut	39.8 ± 5.1 z	228.2 ± 19.6 z	209.0 ± 37.0 z
	Woodland	20.9 ± 4.3 y	34.8 ± 5.3 y	16.0 ± 3.5 y

[2] Biomass values in 1996 are lower as plots were grazed in the spring (May 1996).
[3] N. A. - not separated by species group.
[4] N. M. - not measured.

Total ground cover and biomass - In 1998, ground cover in the cut treatment was 1.5 times greater in the cut versus woodland treatment. Ground cover totaled 44.6% (juniper debris and litter, 27%; interspace herbaceous canopy cover and litter, 16%; shrub cover, 1.6%) in cut plots compared to 33% in the uncut treatment (juniper trees and litter, 29%; interspace herbaceous canopy cover, 4.0%). It is important to note that interspace cover was over 5 times greater in cut versus woodland plots. Total understory biomass (Table 6) was greater in all years measured in cut versus woodland plots. Results show no increase in biomass in cut plots from 1993 to 1996. This is because in 1996 plots were grazed in the spring. Biomass in 1996 is only a measure of regrowth after grazing, not the actual production capability of the site.

DISCUSSION

Post-cutting Succession

Understory responses from 1991 to 1998 in grazed and ungrazed cut and woodland plots showed similar understory response trends. Unless noted, discussion will focus on cut versus woodland responses.

Understory plants in cut plots responded to juniper removal with increased productivity, plant density, and cover (basal and canopy). Removal of juniper reduces belowground competition and increases availability of soil water and nutrients to understory species, which appears to explain understory response after cutting (Bates et al. 1999, Bates 1996).

Species composition after cutting was largely composed of plants present on the site prior to juniper cutting. Thus, initial floristics of a site may be used to predict the general character of post-cutting understory response. However, making quantitative predictions of plant response are more difficult because of several unknowns, including status of seed bank reserves, time since treatment, and post-treatment climate conditions. Sandberg bluegrass and other perennial grasses dominated the understory the first three years of the study. Since 1995 succession in cut plots has continued to be dominated by the perennial bunchgrasses though we have recorded a substantial increase in density, biomass, and cover of annual grasses (cheatgrass and Japanese brome). Bluegrass cover and biomass have declined since 1993. Perennial bunchgrasses and annual grasses seem to have supplanted bluegrass in cut plots.

Until recently, succession in treated woodlands was assumed to progress through a standard pattern beginning with several years of annual dominance followed by a period of perennial grass and forb primacy. This study tends to refute that successional model. Results from our study support the multiple entrance point model (Everett 1987). In our study, pretreatment densities of perennial bunchgrass species (about 2-3 plants 10 ft^{-2}) were sufficient for bunchgrasses to recover and dominate the understory component after cutting. Whether this density value is indicative of an adequate amount of perennial grass to recover on similar sites has not been adequately tested. The results also have shown that annual grasses can become zonal dominates (under cut trees and old canopy areas) several years after removal of the overstory (Bates et al. 1998).

The increase in annual grass in 1996-1998 is attributed to two factors. First, the past several falls and winters (1995-1996, 1996-1997, and 1997-1998) have been relatively warm and wet, ideal conditions for annual grass establishment and growth. Second, the preferential establishment of annual grass under juniper debris and around the old canopy zones suggested that these areas provided good seedbeds for annual grasses and may provide other benefits such as greater soil nutrient or water availability. Annuals tend to respond well to areas of high nutrient availability. We did not measure increases in available soil N in debris or canopy zones in 1992 and 1993 (Bates 1996).

However, by 1996 juniper needles had fallen off cut trees and needle litter on the ground was being incorporated into the soil by decomposition. We suspect that needle litter decomposition resulted in greater soil nutrient release by 1996. Soil moisture levels were determined to be significantly greater under cut juniper debris than in the interspaces (Bates et al. 1998).

Though cover of perennial grasses was not high in debris and canopy zones, there has been a substantial increase in perennial grass density in these locations even under competition with cheatgrass (unpublished file data). It will be interesting to see if overtime perennial grasses will begin competing more effectively with annual grasses in these locations.

An unexpected result was the higher densities of annual forbs in woodlands compared to cut plots (Table 3 and 5). We are unsure why annual forb (primarily pale alyssum) densities were lower in the cut versus woodland plots, considering that soil moisture availability was greater in the cut treatment. Changes in micro-climate, which was not tested, could have negatively affected germination and establishment of annual forbs in cut plots.

In woodland plots, the limited understory biomass response and decrease in perennial basal cover indicated that juniper interference remained strong during wet years. Other resources, such as N, may limit understory plant growth in high moisture years. Nitrogen content was less in understory plants in woodlands compared to plants in cut plots in the wet year, 1993 (Bates et al 1999). Additional research is needed to isolate competitive interactions between the understory and overstory in juniper woodlands in wet and dry years.

MANAGEMENT IMPLICATIONS

The results indicate that the restoration of woodland sites requires patience. It may take one or more years for understory species to respond to the removal of juniper, particularly in dry years. Understory response was subtle and limited in 1992, a dry year. The main increases in plant productivity and plant densities on cut plots occurred in two stages concurrent with wet periods. The first increase occurred in 1993, and the second increase occurred between 1995 and 1998. Across much of eastern Oregon, 1993 was the wettest year on record. Growing season moisture conditions prevailing in 1995-98 were conducive to increased productivity and seedling establishment in cut plots.

However, limited understory response the first year after cutting may not be unusual even in wet years. Studies in pinyon-juniper woodlands have shown delays of 1 to several years before the understory fully responds to removal of tree interference under favorable growing conditions (Barney and Frischknecht 1974, Everett and Ward 1984). It takes time for existing plants to grow larger and new plants to become established.

The increase in herbaceous and litter ground cover in cut plot interspaces is important from a hydrologic standpoint. Research in New Mexico suggests that herbaceous ground cover is more effective at reducing erosion rates than is cover of woody vegetation (Wilcox and Breshears 1994). In the western juniper system, Buckhouse and Mattison (1980) measured greater soil erosion potential in woodland dominated sites than in sagebrush grasslands.

Grazing management on cut sites requires careful consideration. The site used in this study probably requires rest or deferment during the first few growing seasons to provide plants the opportunity to produce seed and permit seedling establishment. Grazing in late summer and fall may be permissible as plants are largely dormant during this time. Grazing (unplanned) on 4 cut plots during late summer and early fall in 1992 and 1993 did not retard understory recovery on these plots.

Comparisons between cut grazed and cut ungrazed plots were not made because sampling did not coincide in the same years since 1993. Plot differences prior to cutting for understory parameters also makes comparisons difficult between cut grazed and cut ungrazed plots. For example, grazed plots had lower perennial basal cover prior to cutting in 1991 than did ungrazed plots. Consequently, there appear to be 3 points that can be developed from grazed and ungrazed cut plot results. *First*, increases in annual grass density, cover, and biomass since 1994 have occurred under both grazed and ungrazed conditions. Removal of grazing did not prevent annual grass development. *Second*, cut ungrazed plots appeared to have had greater increases in perennial grass density. In cut ungrazed plots perennial grass density increased by 575% between 1991and 1997 while in cut grazed plots perennial grass density increased by 333% between 1991 and 1998. *Third*, in both cut ungrazed and cut grazed plots, Sandberg bluegrass cover and biomass had decreased since 1993. Cover and biomass of Sandberg is now similar to levels measured in woodlands. To develop a better understanding of grazing impacts on this site we are currently developing a more controlled grazing/no grazing study on all treatment plots. A fence has been built through the center of all cut and woodland grazed and ungrazed plots (cut and woodland). Half of each plot will be left permanently ungrazed and the other half will be grazed using various prescription grazing criteria. This study is to start in spring 1999.

On our site there was a positive correlation between juniper debris and annual grass cover, density, and biomass. Removal of cut junipers may be an option to reduce the amount of annual grass that may become established under juniper debris. Mechanical removal of debris would add an additional cost to a project and is not cost effective. If juniper becomes profitable as a wood product on a large scale then debris management would not pose a significant concern on cut sites. Burning is also effective at removing juniper debris. However burning debris the first few years after cutting has been observed to generate severe heat fluxes that may kill perennial grasses under and adjacent to debris. Therefore it has been recommend that burning of debris be deferred until fuel loads are diminished by the decomposition of juniper litter, usually a minimum of 5-10 years.

Several other reasons tend to support the argument that burning of debris should be deferred. Results from this study indicate that debris sites are preferred zones for perennial grass establishment even with fairly stiff competition from annual grasses. Burning 5, 10, or 15 years post-cutting still provides land managers plenty of time to remove seedling junipers that become established after treatment. We are currently testing to determine if debris burning can be done in the first year or two post-cutting with the twin objectives of maintaining the perennial grass component and reducing annual grass establishment sites. Burns are scheduled under very specific conditions: perennial grasses must be dormant (fall and winter) and there must be high soil and litter moisture content to reduce heat flux into the soil. Results from this study are several years away.

Cutting of trees on sites similar to the one used in this study will increase forage production and quality, improve watershed characteristics through increased ground cover, and increase plant diversity (Bates et al. 1999). However, variability in site characteristics (soils, aspect, elevation, understory composition) across the western juniper ecosystem will also influence understory response to juniper control. Additional research is required to develop models which assist land managers in predicting understory response and successional pathways after cutting trees in a variety of woodland dominated sites. Because cutting is an expensive management alternative, cutting treatments should only be applied to areas where a good understory response would be expected. Successional models would assist resource managers in targeting those areas where desirable understory vegetation may be successfully restored by juniper cutting.

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