UNDERSTORY DYNAMICS IN A CUT JUNIPER WOODLAND (1991-1997)

Jon D. Bates, Richard F. Miller, and Tony J. Svejcar

SUMMARY

In this study we assessed understory dynamics after tree cutting in a western juniper woodland during a 7-year period (1991-97). Community dynamics monitored were understory cover, biomass, diversity, and density. The study site was on Steens Mountain in southeast Oregon. After cutting, significant treatment differences were observed for most of the understory response variables measured. Cover, density, and biomass of the understory were generally greater in the cut treatment than compared to the uncut woodland. Understory biomass was nearly 9 times greater in the cut treatment than in the uncut woodland in 1993, 1996, and 1997. Perennial grass biomass was 13 times greater in the cut treatment compared to the woodland in 1997. Annual grass cover, density, and biomass increased substantially in 1996, but was generally confined to areas under cut trees (debris zones) and around the old stumps. Perennial grasses, primarily squirreltail, preferentially established under juniper debris and around the old stumps. Total ground cover was nearly twice as great in the cut compared to the uncut treatment in 1993 and 1997. Understory response did not become significant until the second year post-cutting (1993), when there were large increases in biomass, density, and cover. 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 productivity and plant densities on-site occurred in two stages, the first increase occurring in 1993, and the second increase between 1995 and 1997. Because cutting can be expensive, sites for treatment need to be carefully selected and should contain adequate densities of understory perennial grasses. The density of perennial grasses necessary for recovery after cutting depends 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 from grazing during the main growing season until perennial grasses have the opportunity to produce seed and establish seedlings. Grazing in late summer and fall is permissible since plants are largely dormant during this time. Burning in the first few years after cutting will, in most cases, generate heat fluxes into soils that will kill perennial grasses under and adjacent to debris. Thus, it is generally recommended that burning of debris be deferred until fuel loads are diminished through the decomposition of juniper litter, usually a minimum of 5 to 10 years.

INTRODUCTION

The recent expansion of western juniper (*Juniperus occidentalis* spp. *occidentalis* Hook.) woodlands in central and eastern Oregon, northeastern California, and southwestern Idaho, has raised concerns over the effects of tree-canopy development on plant community structure, composition, and diversity (Miller and Wigand 1994). Prior to settlement in the late 1800s, western juniper was primarily confined to areas with shallow rocky soils underlain by fractured bedrock (Burkhardt and Tisdale 1969, Miller and Wigand 1994, Miller and Rose 1995). The expansion of juniper has been in deeper more productive soils characterized by mountain big sagebrush grasslands, riparian zones, and aspen woodlands (Burkhardt and Tisdale 1969, Eddleman 1987, Miller and Rose 1995). Reduced fire frequency is cited as the main factor causing 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).

Natural or prescribed fire is largely eliminated as a management tool for restoring understory vegetation in many woodlands because of lack of fuels necessary to carry fires through juniper stands. Consequently, understory restoration in many juniper-dominated communities may be limited to mechanical treatments such as tree cutting or chaining.

Tree cutting is commonly used to restore understory productivity in areas occupied by western juniper. The cutting of trees in western juniper woodlands (Vaitkus and Eddleman 1987, Rose and Eddleman 1994) and pinyon-juniper woodlands in Nevada (Everett and Sharrow 1985) removes overstory interference and leads to greater understory biomass and cover. Nonetheless, there is insufficient quantitative and qualitative evidence documenting the impact of cutting in western juniper woodlands on plant community structure, composition, and diversity. Increasing interest in juniper wood products may accelerate cutting in this ecosystem. There is concern that lack of a good ecological database will hamper or misdirect decision making for understory restoration and commercial use of western juniper woodlands.

In this study we assessed understory dynamics after tree cutting in a western juniper woodland. Over a 7-year period (1991-97) understory cover, biomass, and density were monitored.

MATERIALS and METHODS

Study Site

The study site was on Steens Mountain in southeast Oregon. Elevation at the site is 5000 ft, and aspect is west-facing with a 22-percent 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. Juniper canopy cover averaged 24 percent and tree density averaged 92 trees/ac. Bare ground accounted for 74 percent of the area and rill erosion was evident throughout the site. In the early 1900s this site was used as wintering grounds for domestic sheep. Since the late 1940s the site has been moderately grazed in the early spring by cattle.

The understory was dominated by Sandberg's bluegrass, comprising about 75 percent of total understory perennial-plant cover. Other species characteristic of the site were bottlebrush squirreltail, bluebunch wheatgrass, Thurber's needlegrass, basalt milkvetch, and pale alyssum. Based on remnant plants, soils, elevation, and aspect, we judged the plant community prior to juniper encroachment to be mountain big sagebrush/Thurber's needlegrass.

Winter and spring periods typically are cool and moist, while summers are warm and dry. Over the past 30 years, water year (October 1 - Sept. 30) precipitation at Malheur National Wildlife Refuge weather stations, located 16 miles southwest (elev. 4265 ft) and 18 miles northwest (4100 ft) of the site, averaged 11 and 9.8 inches, respectively. 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, montmorillonite, frigid, Lithic Argixerolls.

Experimental Design

The experimental design was a randomized complete block with 4 blocks (replicates) and 2 treatments, cut and uncut juniper woodland. Replicates were 2 acres in size and were selected for similarities in overstory/understory density and cover. Measurements of baseline vegetation characteristics were made before tree cutting in July 1991. Half of each replicate was 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 during the study.

Understory Sampling Procedures

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

Understory biomass was sampled at peak standing in 1992, 1993, 1996, and 1997. Biomass was sampled at 10-ft intervals, in 10.75-ft^2 quadrats, along two 150-ft randomly selected transects in cut and uncut woodland replicates. Vegetation was clipped to a 1-inch stubble height. Understory plant density was measured using 1 x 2-ft quadrats (1991-97). Basal cover of perennial plants was measured along five 100-ft line transects in each cut and uncut replicate in 1991, 1992, 1993, 1994, and 1997. Along the transects, ground cover provided by trees, duff layers, and cut trees were also measured. Canopy/ground cover was estimated visually in the 1 x 2-ft quadrats in 1993 and 1997.

Cover and density of plants was also zonally delineated. In uncut woodlands, plant cover and density was measured in interspace and canopy (under trees) zones. In the cut treatment, zones were the interspaces, canopies (around the old stumps), and debris locations (under cut trees).

RESULTS

Understory Dynamics

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. After cutting, there were significant treatment differences for most of the understory-response variables measured. Cover, density, and biomass of the understory were generally significantly greater in the cut treatment than compared to the uncut woodland (Tables 1-3).

Understory biomass was nearly 8 times greater in the cut treatment than in the uncut woodland in 1997. Density, cover, and biomass of all species groups (except Sandberg's) have increased steadily in the cut treatment between 1992 and 1997. Sandberg's bluegrass cover and biomass increased between 1991 and 1993 in the cut treatment. However, by 1997 cover and biomass of Sandberg's bluegrass declined dramatically in the cut treatment. In the uncut woodland, biomass increased between 1993 and 1996-97. There has, however, been no corresponding change in the density and cover of plants.

The increase in annual grass has mainly been confined to areas under cut trees (debris zones) and around the old stumps (Fig 1). Perennial grasses, primarily squirreltail, have also preferentially established under juniper debris and around the old stumps. Densities of perennial species in the different zones are shown in Fig 2.

Except for one year (1995) annual forb density has been greater in the uncut versus the cut treatment (Table 2). Annual forbs in the cut treatment have been larger, as evidenced by there greater biomass value in 1997. The lower annual forb density in the cut treatment was a result of lower densities of pale alyssum compared to the uncut treatment. Densities and cover of all other annual forb species tended to increase and were greater in the cut treatment than in the uncut treatment.

Total ground cover was nearly twice as great ($P < 0.01$) in the cut compared to the uncut treatment in 1993 and 1997. In 1997 ground cover in the cut treatment totaled 56 percent (juniper slash, 18 percent; duff and other litter, 20 percent; interspace herbaceous canopy cover, 18 percent) compared to 29 percent in the uncut treatment (juniper trees and duff, 24.5 percent; interspace herbaceous canopy cover, 4.5 percent).

DISCUSSION

Western juniper suppressed the herbaceous understory in the woodland community. Understory plants in the cut treatment responded to juniper removal with increased productivity, plant density, and cover (basal and canopy). Bates (1996) found that the removal of juniper reduced belowground interference, thus increasing the availability of soil water and nitrogen (N) for uptake by understory plants. Similar increases in soil water, N availability, and understory production have been documented after removal of western juniper in northeastern California (Evans and Young 1985), and after cutting of pinyon-juniper woodlands in Nevada (Everett and Sharrow 1985).

Understory response was largely determined by species assemblages present on the site before to juniper cutting. About 80 percent of the species identified during the study were observed prior to cutting. Succession in the cut treatment has been dominated by the perennial grasses although we have seen a substantial increase in density, biomass, and cover of annual grass (cheatgrass and Japanese brome) during the past 2 years. Evidence from our study indicates juniper woodland dominance reduces the species diversity of understory plants (Bates 1996). When tree interference was removed the number of herbaceous species identified increased by 80 percent, and species diversity was increased by 60 percent.

The increase in annual grass in the 5th and 6th year post cutting was not expected. In other western juniper woodlands, annual grass, especially (cheatgrass), have dominated immediately after tree removal by cutting (Vaitkus and Eddleman 1987), fire (Quincey 1984), and herbicide application. Dominance by cheatgrass may diminish over time as perennial grasses begin to assert themselves (Evans and Young 1985). In our study the increase in annual grass in 1996-97, we attributed to two factors. First, the past several winters (1995-96, and 1996-97) 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 stumps suggest that these areas not only provide good seedbeds for annual grass, but may also provide other benefits such as greater soil nutrient or water availability. Soil moisture levels were determined to be significantly greater under juniper debris than in the interspaces (Bates et al. 1998). We did not measure increases in available soil N in debris or canopy zones in 1992 and 1993. 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, thus benefitting the annual grasses in canopy and debris locations. Though cover of perennial grasses was not high in debris and canopy zones, there has been a substantial increase in perennial grasses density in these locations even under competition with cheatgrass. It will be interesting to see if these plants will develop and begin competing more effectively with annual grasses in these locations.

Understory response did not become significant until the second year post-cutting (1993), when there were large increases in biomass, density, and cover. Other studies in pinyon-juniper woodlands have shown delays of one-to-several years before the understory fully responds to removal of tree interference (Barney and Frischknecht 1974, Tausch and Tueller 1977, Everett and Ward 1984, Vaitkus and Eddleman 1987, Rose and Eddleman 1994). After 1993, it has taken several additional years for perennial grasses densities to increase and biomass levels to approach the site's potential.

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 productivity and plant densities on the site occurred in two stages: the first increase occurring in 1993, and the second increase between 1995 and 1997. For many locales, 1993 was the wettest year on record in eastern Oregon. Growing-season moisture conditions prevailing in 1995-97 have been conducive to increased productivity and seedling establishment on the cut treatment.

MANAGEMENT IMPLICATIONS

The cutting of juniper reduces below-ground interference for water and soil nutrients, thereby resulting in increased understory cover, biomass, density, and diversity. 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 during periods of drought. However, the wide variability in site characteristics across the western juniper ecosystem will also influence understory response to juniper-control projects. North-facing aspects and sites with deeper soils will respond to treatment more quickly than sites with shallow soils or with southern exposures.

Because cutting can be expensive (about $.50/tree), sites for treatment need to be carefully selected. Sites selected for cutting should contain adequate densities of understory perennial grasses. A site lacking a perennial grass component and dominated by annual species will likely remain dominated by annual species unless seeded to perennials. Seeding adds an additional cost and may not be successful if drought conditions prevail. The density of perennial grasses necessary for recovery after cutting is dependent on site potential. On our site, perennial grass density prior to cutting was low, at about 2 plants/m^2 (about 10 ft^2). This density was adequate for perennial grasses to dominate the understory post-cutting. However, other sites may differ in their requirements for perennial grass recovery.

Grazing management on cut sites also requires careful consideration. The site used in this study probably requires rest during the main growing season until perennial grasses have the opportunity to produce seed and establish seedlings. Grazing in late summer and fall is permissible because plants are largely dormant during this time. We found that grazing (unplanned) on two cut plots during late summer and fall in 1992 and 1993 did not retard understory recovery on the study site.

On our site there was a definite correlation between juniper debris and annual grass cover and biomass. Removal of cut junipers is an option to reduce the amount of annual grass that may become established in debris zones. However, 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 very effective at removing juniper debris. When should debris be burned? Burning in the first years after cutting will, in most cases, generate heat fluxes into soils that will kill perennial grasses under and adjacent to debris. Thus, it is generally recommended that burning of debris be deferred until fuel loads are diminished by the decomposition of juniper litter, usually a minimum of 5 to10 years. There are several other reasons that would 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 competition from annual grasses. In addition, observations on this site and others in central Oregon (Lee Eddleman, pers. communication) indicate that debris left in place is effective at reducing soil erosion. 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 see if burning debris can be done in the first year or two post-cutting without harming the perennial grass component by scheduling burns under very specific conditions. Adequate conditions include, dormant grasses (fall and winter), and high soil and litter moisture content to reduce heat flux into the soil. Results from this study are several years away.

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

Species Group	Treatment	Basal Cover (%)			
		1991	1992	1993	1997
Sandberg's Bluegrass	Cut	1.4 ± 0.3 a	1.5 ± 0.4 a	2.8 ± 0.4 a	1.1 ± 0.2 a
	Uncut	1.2 ± 0.2 a	1.1 ± 0.2 a	1.2 ± 0.1 b	1.1 ± 0.1 a
Perennial Grasses[1]	Cut	0.9 ± 0.2 a	0.9 ± 0.2 a	2.6 ± 0.3 a	3.5 ± 0.3 a
	Uncut	0.8 ± 0.2 a	0.4 ± 0.1 b	0.4 ± 0.1 b	0.2 ± 0.1b
Perennial Forbs	Cut	0.4 ± 0.1 a	0.4 ± 0.2 a	0.5 ± 0.2 a	0.3 ± 0.1 a
	Uncut	0.3 ± 0.1 a	0.1 ± 0.1 b	0.1 ± 0.1 b	0.1 ± 0.1 a
Total Cover	Cut	2.6 ± 0.4 a	2.8 ± 0.3 a	5.9 ± 0.3 a	4.8 ± 0.3 a
	Uncut	2.3 ± 0.3 a	1.7 ± 0.2 b	1.7 ± 0.3 b	1.5 ± 0.3 b

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

Table 2. Understory density (1991-1997) in cut and uncut woodlands. 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	Treatment	PLANT DENSITY (number/m^2)						
		1991	1992	1993	1994	1995	1996	1997
Sandberg's 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
	Uncut	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[1]	Cut	2.6 ± 0.3 a	2.2 ± 0.3 a	3.7 ± 0.4 a	5.1 ± 0.2 a	7.5 ± 0.9 a	10.0 ± 0.4 a	15.1 ± 1.4 a
	Uncut	2.1 ± 0.3 a	1.6 ± 0.2 b	1.9 ± 0.3 b	1.9 ± 0.4 b	2.2 ± 0.3 b	2.1 ± 0.5 b	1.7 ± 0.3 b
Perennial Forbs	Cut	0.4 ± 0.2 a	1.0 ± 0.4 a	1.7 ± 0.4 a	1.9 ± 0.3 a	2.9 ± 0.5 a	4.0 ± 1.5 a	4.5 ± 0.4 a
	Uncut	0.6 ± 0.3 a	0.6 ± 0.3 a	2.0 ± 0.3 a	1.2 ± 0.3 b	1.7 ± 0.4 b	1.9 ± 0.5 b	1.6 ± 0.3 a
Annual Grass	Cut	0.5 ± 1.2 a	2.2 ± 1.1 a	3.7 ± 5.3 a	30.1 ± 3.7 a	77.0 ± 11.1 a	570.0 ± 61.0 a	442.0 ± 64.0 a
	Uncut	1.1 ± 3.4 a	2.5 ± 2.5 a	2.8 ± 2.7 a	3.4 ± 3.1 b	2.1 ± 1.2 b	5.9 ± 2.8 b	6.7 ± 2.7 b
Annual Forbs	Cut	75.6 ± 13.2 a	9.4 ± 2.3 a	40 ± 18 a	100 ± 18 a	139 ± 9 a	65 ± 6 a	207 ± 32 a
	Uncut	92.2 ± 12.4 a	83.5 ± 34 b	125 ± 43 b	174 ± 40 b	59 ± 14 b	102 ± 22 b	286 ± 37 b

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

Table 3. Understory biomass (kg/ha) in cut and uncut woodlands (1992-93 and 1996-97). To convert values to pounds per acre, multiply by 0.9. Different letters denote significant differences for each species group in each year.

Species Group	Treatment	Biomass(kg/ha)			
		1992	1993	1996[1]	1997[1]
Sandberg's Bluegrass	Cut	11.5 ± 1.0 a	185 ± 24 a	N.S.	41 ± 8 a
	Uncut	10.2 ± 1.7 a	46 ± 5 b		46 ± 6 a
Perennial Grasses[2]	Cut	18.6 ± 3.3 a	190 ± 28 a	N. S.	552 ± 73 a
	Uncut	8.0 ± 3.4 b	10 ± 3 b		45 ± 14 b
Perennial Forbs	Cut	15.5 ± 6.1 a	23 ± 7 a	N. S.	125 ± 11 a
	Uncut	0.5 ± 0.2 b	3 ± 1 b		31 ± 13 b
Annual Grass	Cut	1.2 ± 0.6 a	5.0 ± 1.0 a	N. S.	237 ± 18 a
	Uncut	0.2 ± 0.2 a	0.5 ± 0.2 b		2 ± 1 b
Annual Forbs	Cut	N. M.	N. M.	N. S.	22 ± 2.9 a
	Uncut				0.8 ± 0.3 b
Total Biomass	Cut	46.8 ± 5.7 a	403 ± 39 a	1045 ± 237 a	976 ± 96 a
	Uncut	18.9 ± 4.8 b	37 ± 6 b	101 ± 27 b	124 ± 33 b

[1] 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.
[2] Perennial grasses in the this category are the taller tussock grasses, including bluebunch wheatgrass, Thurber's needlegrass, and squirreltail.
N. M. - not measured.
N. S. - not separated by species group.