Restoration and Management

Introduction

Previous sections in this overview provide strong evidence that western juniper has significantly increased in density and distribution since the late 1800's and if left unchecked can have significant impact on soil resources, plant community structure and composition, water and nutrient cycles, wildlife habitat, and biodiversity. As a result, control of western juniper has been a major concern of land management since the early 1960's. Justifications used for western juniper control include restoration of preinvasion plant communities, increasing forage production and quality, reducing soil erosion, increasing water capture on site, increasing spring and stream flow, improving wildlife habitat, and increasing biological diversity. In the early years, the emphasis on juniper control was to increase forage production for livestock. However, in the last decade the primary justification for juniper control was to enhance proper site function (i.e., capture and store of water, retain soil nutrient capital, restore shrub-steppe communities, etc.).

In the 1960's through the early 1970's chaining and dozing were the most common forms of western juniper control. However, chaining is not currently used on public lands due to high costs and a perception by the public that the treatment has a high disturbance impact on the site. In the late 1970's, the U.S. Bureau of Land Management (BLM) Prineville district began using chainsaws as its primary method of western juniper control. By the 1980's and 1990's this practice became widespread. Research on the effects of western juniper cutting began in the early 1980's and has steadily expanded. Chemical control of western juniper has been tested but have produced mixed results. In the 1990's, the use of prescribed fire to control western juniper greatly increased. The use of mechanical shears and whole tree chipping of western juniper has increased since 2000 in northeastern California (mainly in Modoc and Lassen counties) and south-central Oregon (Lake County) for providing biofuel for power generation at the Honey Lake power plant in Wendell, California.

Since the 1970's various groups have challenged western juniper control treatments based on the limited scientific evidence that supports western juniper removal. Belsky's (1996) review of western juniper treatments demonstrated that some of the justifications for western juniper control were based on anecdotal evidence and were not supported by experimental evidence. Recent and ongoing research has addressed many of the concerns raised about western juniper control, although knowledge gaps in nutrient cycling and hydrologic processes remain.

Until recently, long-term data sets were lacking. Several studies now provide information from treatments that are older than 10 years. Work in central Oregon provides long-term assessments of vegetation response and successional patterns using several treatment methods.

This section is a synthesis of research evaluating the response of plant communities following various western juniper treatments. In "Guidelines for Management" (page 54), we lay out a framework for developing the appropriate action related to western juniper control. A summary of results from research, BLM, and privately administered western juniper treatments in the 1960's and 1970's is provided in Appendixes 2 and 3.

Assessment of Western Juniper Control Justifications

Before presenting a critique of western juniper control practices, we will address some of the specific concerns that have been raised regarding the justifications that are used to support western juniper removal. These responses primarily refer to juniper-dominated stands. Several of the concerns brought up by Belsky (1996) have been addressed in recent and ongoing research, including questions regarding plant community and wildlife response, hydrologic function, and the identification of pre- versus post-settlement woodlands. There remain several areas where additional work is required to better quantify ecosystem response to the current woodland expansion and western juniper control methodologies.

Does western juniper removal restore plant communities?

There are studies that illustrate both successes (Young et al. 1985, Bates et al. 2000, Eddleman 2002d) and failures (Young et al. 1985) of plant community rehabilitation following western juniper treatment. The three key components that will largely influence success or failure are: (1) site selection, particularly pre-treatment understory composition; (2) method(s) used to control western juniper; and (3) follow-up management. The level and speed of community response depends on several factors including post-treatment weather conditions and management, grazing history, site potential (soils and plant community), seed banks, and plant composition prior to treatment. There are still too few studies that allow us to accurately predict plant succession after treating western juniper, particularly when one steady state is transitioning to another. Clear guidelines have not yet been developed when a threshold has been crossed. In several studies, the response of exotic annual grasses exceeded the response of remaining native vegetation or seeded perennials (Young et al. 1985, Vaitkus and Eddleman 1987). Warmer, drier sites, especially south- and west-facing aspects and/or sites below 5,000 ft are likely to have an exotic annual grass component (Eddleman 2002a; EOARC, unpublished data)(see section on weeds). These sites historically were big sagebrush (basin or mountain) with bluebunch wheatgrass and/or Thurber needlegrass as the dominant grass. On these drier sites, many of the original plant species can be restored following western juniper control if at least 2-3 deep-rooted perennial grasses per $10ft^2$ persist on the site. However, exotic annuals will generally remain a part of the community. Restoring system functionality should be the primary goal on these sites, as it is unlikely that the preinvasion plant community composition will fully return. More productive sites at higher elevations and lower elevation sites with northern aspects are usually more resilient, less susceptible to weed invasion, and have a greater potential to return to pre-woodland community characteristics following treatment, compared to more arid sites (Quinsey 1984; Koniak 1985; EOARC, unpublished data). These sites tend to be characterized by mountain big sagebrush, Idaho fescue, and alpine needlegrass. Eddleman (2002d) estimates that one and two perennial grasses per $10ft^2$ are sufficient to allow recovery of these sites following western juniper control.

Does western juniper removal increase forage production and quality?

Productivity of forage species and forage quality can increase after western juniper control, in some cases increasing 8- to 10-fold (Appendix 4)(Young et al. 1985, Vaitkus and Eddleman 1987, Bates et al. 2000). However, the response is primarily driven by pretreatment plant composition and post-treatment management. Crude protein levels of forage species utilized by livestock and wildlife were 50 percent greater in cut versus uncut western juniper woodlands (Bates et al. 2000). Season of available green forage for livestock and wildlife can increase 4–8 weeks for at least the first several years following western juniper control.

Does western juniper removal reduce soil erosion and increase water capture on site?

Recent data on a drier big sagebrush/bluebunch wheatgrass and Thurber needlegrass site indicate that the potential for significant soil erosion and rill formation increases with western juniper dominance (“Hydrology,” page 35). Pierson et al. (2003) measured greater runoff, sediment yields, and rill formation in uncut woodlands compared to cut woodlands. Bates et al. (2000) measured increased water capture and storage on cut western juniper woodlands compared to adjacent uncut woodlands.

Does western juniper removal increase spring discharge and subsurface flow?

There have been no experiments designed to link western juniper control to increased spring or stream flows. Anecdotal evidence has for years suggested that removal of western juniper increases spring flows and water table levels (see “Hydrology”). Climatic fluctuations make it difficult to verify this response. It is our opinion that the relationship between western juniper and subsurface flow is site specific, determined by topography, soils, geology, and amount of precipitation.

Does western juniper removal improve wildlife habitat?

Western juniper can be an important habitat element for many wildlife species if a healthy understory of shrubs and grasses is maintained. Maintaining low densities of western juniper on portions of the landscape, resulting in increased structural diversity, will increase the abundance, diversity, and richness of avian and mammal populations in the shrub-steppe. Western juniper cutting has resulted in higher capture rates of small mammals than in adjacent woodlands (Willis and Miller 1999). Closed canopy woodlands also supported lower numbers and diversity of avian species than adjacent treated woodlands (EOARC, unpublished data). On cut plots in Grant County, Oregon, numbers and diversity of avian species were greater on the cut plots where slash remained compared to adjacent closed woodlands (Miller et al. 1999b). However, wildlife response will be highly dependent on vegetation response following treatment.

Does western juniper removal increase biological diversity?

In many cases, biological diversity of herbaceous plants increases following a reduction of western juniper. Increased diversity primarily results from increased emergence of perennial and annual forbs following cutting or fire in western juniper (Bates et al. 2000; EOARC, unpublished data). The effect of western juniper on species diversity may be site dependent (Miller et al. 2000) and cutting may reduce diversity on sites in poor conditions (Young et al. 1985), particularly where cheatgrass or medusahead may become dominant following treatment.

Mechanical Treatments

Chainsaw cutting

The most common method used to control western juniper in recent years has been cutting with chainsaws. Costs for cutting western juniper on BLM lands (based on 2004 bids) ranged from $36 to $80/acre. Though information gaps persist, chainsaw cutting of trees has been the most thoroughly researched method of western juniper control (Appendix 2). Tree cutting has been researched in two of the five Oregon ecological provinces where significant western juniper woodlands are present; these were the High Desert (Steens Mountain vicinity) and John Day (sites in Prineville vicinity and Grant County). Other ecological provinces where western juniper is present but treatments have not been assessed are the Klamath, Mazama, and Snake River provinces. The John Day Province is slightly warmer in the winter with growing seasons beginning 2–4 weeks ahead of the High Desert Province. Weedy annuals, especially at lower elevations and on drier sites, have been more of a concern in woodlands of the John Day Province compared to the High Desert. The High Desert Province has colder winters and shorter growing seasons, and exotic annuals have posed less of a problem following restoration efforts. Research emphasis in the two provinces has differed. Research in the John Day Province has focused on woodland cutting, effects of slash dispersal, and seeding of perennial species. Research in the High Desert Province has centered on combinations of cutting and prescribed fire, post-treatment grazing, and has emphasized natural regeneration rather than seeding. For these reasons we will discuss research results from each province separately.

John Day Ecological Province

Studies in central Oregon have assessed long-term (more than 10 years) post-treatment vegetation dynamics with emphasis on (1) assessing shrub and herbaceous response to western juniper removal on different plant community types, and (2) combining western juniper cutting and slash treatments with seeding of native cultivars and introduced perennial grasses.

Eddleman (2002d) evaluated shrub/herbaceous response after western juniper cutting on three different sites (low sagebrush, basin big sagebrush, and mountain big sagebrush) during an 18-year period. Uncut woodland plots showed little change in herbaceous composition but there were measurable decreases in density and cover of shrubs at the low sagebrush and basin big sagebrush sites. Cut treatments had large increases in shrub and perennial grass cover and density on all three sites. Early response (2 years after cutting) on these sites demonstrated the potential to increase herbaceous biomass by nearly 300 percent on the shallow-soil sites (low sagebrush) and by 100 percent on deeper soil sites (Vaitkus and Eddleman 1987). The initial increase in biomass was composed of cheatgrass but sites are presently dominated by perennial grasses (Eddleman 2002d). In a second study, perennial forb and grass cover in cut plots was 14 percent, compared to 8 percent in adjacent uncut closed woodlands (Eddleman and Miller 1999).

On many post-settlement woodlands in central Oregon perennial grasses have been depleted and seeding is necessary following western juniper cutting to avoid site dominance by annual grasses. Use of western juniper slash to provide a favorable micro-environment for perennial grass seedling establishment has been evaluated (Eddleman 2002b). Scattering western juniper slash was proven to be a successful method for establishing broadcast-seeded species on a basin big sagebrush/Thurber needlegrass-type site in average to above-average precipitation years. However, in dry years, slash covering had no effect on seedling establishment. After 13 years, seeded grasses that responded favorably to slash cover were Goldar bluebunch wheatgrass, Tegmar intermediate wheatgrass *(Agropyron intermedium),* and Rush wheatgrass *(Agropyron elongatum).* Because of the cost of scattering slash (up to $250/acre) this method should only be considered on highly erodable soils and slopes.

Roller punching to scarify soils followed by broadcast seeding and scattering of slash has also been successfully used to establish perennial grass species (Eddleman 2002 a, c). In dry years, roller punching and slash covering more than 50 percent of the treated area appears to be most beneficial for seedling establishment. In wet years, roller punching with surface slash covering between 0 and 25 percent of the area appears to be adequate for seeded species response.

Eddleman (2002) suggested that for seedings to be successful in the province, precipitation between November and January should exceed 5 inches, with none of the three months individually being below 1.7 inches precipitation. By evaluating moisture conditions over this period, managers could delay seeding until February if conditions were favorable.

Western juniper control in ponderosa pine communities was assessed to determine western juniper influences to pine growth (Rose and Eddleman 1994). Cutting of western juniper increased understory production by 50 percent after 2 years but did not result in increased pine growth. There may have been a lag response by the pine to the cutting treatment; trees may have adjusted to reduced competition by expanding root systems and leaf area. This study also took place in above-average precipitation years, which may have masked treatment differences. To accurately assess pine response to western juniper removal would necessitate extending the study period beyond the two years used here.

High Desert Ecological Province

Studies in the High Desert Ecological Province have assessed short and long-term (10 years) treatment responses with emphasis on (1) shrub and herbaceous response to cutting and prescribed fire, and (2) effects of cutting on the nitrogen cycle and hydrologic function.

Basin big sagebrush/Thurber needlegrass-bluebunch association (1991–2003)

Vegetation response: Cutting trees in a western juniper-dominated basin big sagebrush/Thurber needlegrass-bluebunch community in 1991 resulted in significant increases in herbaceous cover and biomass in the first 2 years following treatment (Bates et al. 2000). Vegetation response was minimal the first year following cutting. In the second growing season herbaceous cover increased nearly nine-fold (329 lb/acre) in the cut woodlands compared to adjacent uncut woodlands (38 lb/acre). Early successional response indicates restoration requires patience as it may take several years for understory species to respond to the removal of western juniper, particularly during dry periods. Plant diversity was significantly higher in the cut compared to uncut woodlands.

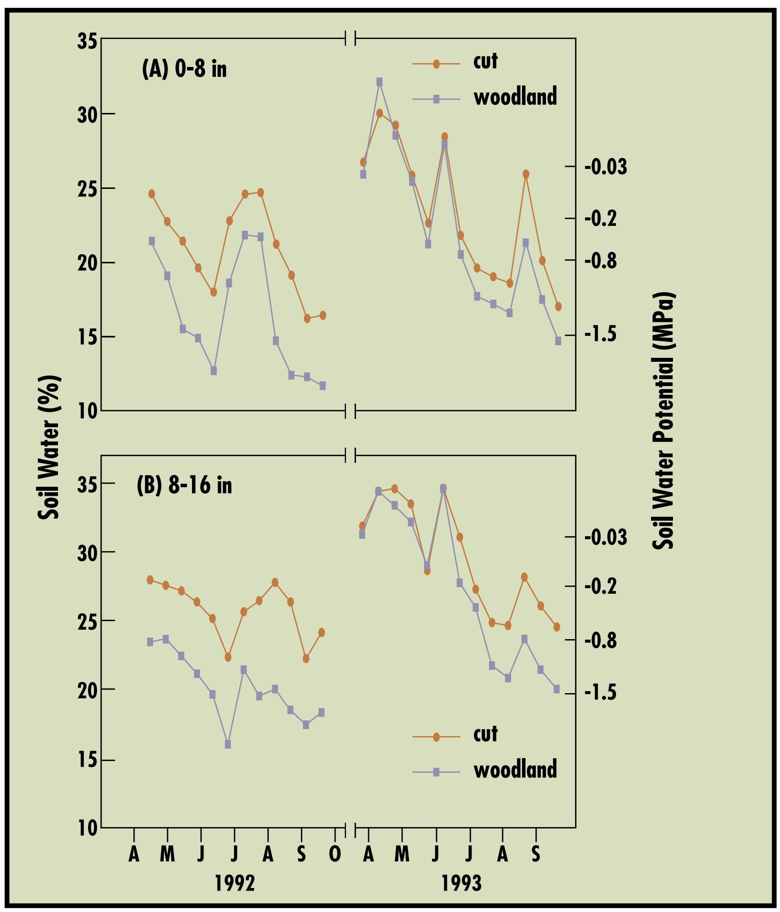
These same plots were measured again in 1994, 1997, 1998, and 2003. Perennial grass density increased between 233 and 300 percent (from 2–3 plants/10ft^2 to 10–14 plants/10ft^2) compared to uncut woodland. Cheatgrass and Japanese brome *(Bromus japonicus)* began increasing in 1994 and increased exponentially in 1997 and 1998 in the cut plots (Bates et al. 2000; EOARC, unpublished data). The increase in annual grasses was mainly confined to litter deposition areas under cut trees and around old stumps. Increases in annual grass in areas of western juniper litter deposition have been observed in studies in central Oregon and in south-facing mountain sagebrush/bluebunch wheatgrass communities on Steens Mountain. Since 1997, annual grass biomass has decreased (from 240 lbs/acre in1997 to 65 lbs/acre in 2003) (EOARC, unpublished data). Native perennial grasses remained the dominant component in the understory (from 550 lbs/acre in 1997 to 890 lbs/acre in 2003).

Soil water: Cutting resulted in increased soil water content and plant water availability the first two growing seasons after cutting (Figs. 33, 34) (Bates et al. 2000). Retaining western juniper debris on site reduced evaporative loss of soil water.

Soil erosion and runoff: Runoff, sediment yields, and rill erosion formation were significantly reduced 10 years (2001) following cutting when compared to adjacent uncut woodlands (refer to hillslope runoff and erosion in "Hydrology," Figs. 29, 30).

Understory response to cutting juniper in four mountain big sagebrush/Idaho fescue sites in various stages of woodland succession (Phases II and III) was evaluated on Steens Mountain in the 1990's (EOARC, unpublished data). Perennial grasses and shrubs were the major functional groups that responded to the cutting treatments. Perennial grass cover in cut late-successional woodlands doubled 5 years after treatment. In closed canopy and mid-successional woodlands there was little change in perennial grass and other understory cover during the same five year

Figure 33. Seasonal soil water potential at 0–8 and 8–16 inches soil depth for cut and uncut western juniper woodland on basin big sagebrush/Thurber needlegrass plant association on Steens Mountain, Oregon (Bates et al. 2000).

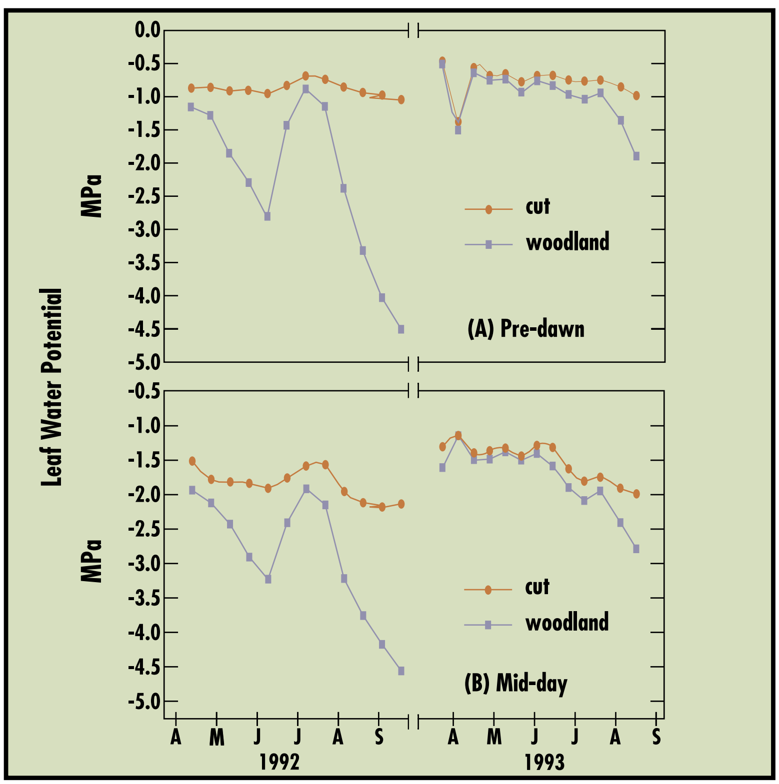


period. In all treated areas shrub cover increased significantly and bare ground declined. In northeastern California, bitterbrush leader growth was two to three times greater in western juniper communities where tree cover had been thinned to 5 percent compared to adjacent unthinned woodlands with tree cover of 30–50 percent.

Juniper cutting and debris burning in basin big sagebrush/Thurber needlegrass associations (1997–2002)

Prescribed burning of juniper debris was applied the first and second winters after juniper cutting and were compared to unburned cut plots (EOARC, unpublished data). Conditions under which burning was prescribed were that a) soils were frozen and/or wet (near field capacity); b) suspended juniper litter was dry, and c) herbaceous plants were largely dormant. Burning debris under these conditions successfully removed most of the juniper litter except for large branches and tree boles. Impacts to understory vegetation present beneath burned juniper debris were minimal. There was little measurable loss of established perennial grass species. Comparisons made between burned (1st and 2nd year burns) and unburned debris piles showed no differences after 4 years post-treatment in perennial grass density and cover, or presence of annual grass. Burned areas had significantly higher densities and larger individuals of annual and perennial forbs than unburned debris. Adjacent to this site debris piles were burned with dry soils in the winter and death of perennial grasses was significant compared to unburned debris the first year (EOARC, unpublished data). In central Oregon, Eddleman (unpublished data) reported fall burning of juniper slash under hot dry conditions resulted in a decline in native perennial grasses and large increases in cheatgrass.

Figure 34. Leaf water potential at pre-dawn (least water stressed) and mid-day (most water stressed) for single trees remaining in the cut plots and uncut western juniper woodland on a basin big sagebrush/Thurber needlegrass plant association on Steens Mountain, Oregon. Leaf water potential is an index of soil water availability in the rooting zone (Bates et al. 2000).



Summary

A major advantage of cutting is the high degree of control in the treatment application. Managers can select specific types of trees to cut or not cut (e.g., old-growth trees should be left on site for wildlife habitat). Unlike prescribed fire, treatment boundaries are predictable and potential liability is thus reduced. Cutting can be conducted almost year-round as long as access is not constrained by weather, road conditions, special land designations (e.g., wilderness study areas) and extreme fire conditions restricting chainsaw use. Cutting is not limited by terrain roughness as are heavy machinery applications. The only area of concern is that leaving cut trees on site can present a fuel load problem for several years following treatment. This is of particular concern in the urban interface, in woodlands that are adjacent to forested plant communities such as ponderosa pine forest where juniper tree densities are high, and where the understory has a significant cheatgrass or medusahead component. Primary disadvantages of cutting compared to fire are costs, limited size of area treated, and minimal control on small trees, which often require a follow-up treatment.

Cutting and leaving trees currently (2004) costs $36–80/acre. The higher cost reflects additional expense incurred when working where terrain is steep and not readily accessible from roads. However, costs increase to as much as $250/acre if cut trees are limbed and slash is scattered. Because of high costs, scattering slash should only be considered on sites with high erosion potential and where broadcast seeding is the only option for replanting. Scattering of slash may be partially achieved without cost by making western juniper cuts open to the public for firewood cutting.

The results indicate that restoration of woodland sites requires patience. Studies in western juniper and in piñon-juniper woodlands have shown delays of one to several years before the understory fully responds to removal of tree interference, especially when growing conditions are not favorable (Barney and Frischknecht 1976, Tausch and Tueller 1977, Vaitkus and Eddleman 1987, Bates et al. 2000). Even in wet years, a lack of significant understory response the first year after cutting may be expected. Existing plants require time to grow new roots and tillers and new plants need time to establish (Bates et al. 2000).

Heavy machinery

Heavy machinery used to control juniper species in the Intermountain West has included: bulldozers to push trees over; bulldozers pulling anchor chain or steel cable through stands to uproot trees; and various mechanical cutting and grinding devices mounted on dedicated logging equipment, such as feller-bunchers, excavators, front-end loaders, and farm-forestry tractors. Disturbance of the soil surface can vary from minimal to high depending on soil conditions, which include soil moisture content, soil texture, frozen or unfrozen ground, and tight turns by heavy equipment. Controlled research designs assessing plant response to western juniper removal by heavy machinery are limited to two studies.

Young et al. (1985) compared wood harvesting to mechanical clearing using a bulldozer on a relatively dry site in northeastern California. Without weed control the main herbaceous response was composed mostly of exotic annual grasses. Weed control using atrazine and drill seeding of perennials following mechanical clearing was the most successful treatment. Perennial production steadily increased and exceeded annual grass production by the fourth growing season after treatment. Wood harvest successfully removed trees but generated high levels of litter, which reduced the effectiveness of weed control measures and prevented establishment of an adequate perennial component.

Leckenby and Toweill (1983) seeded several chained western juniper communities in southcentral Oregon near Silver Lake with mixed results. They did not provide information on the success of the chaining in removing western juniper competition, however the area was primarily composed of large trees that were successfully removed (R.F. Miller, personal observation). Chained areas had successful establishment of introduced crested and Siberian wheatgrasses *(Agropyron cristatum* and *A. sibericum)* but other species contained in the seed mix rarely established. Seeded species did not establish on untreated woodlands.

Additional results describing mechanical treatment in western juniper woodlands can be found in workshop reports (Appendix 3). These results cover chaining projects in the Klamath Falls region and in central Oregon in the 1960–1980's. Formal research designs were not applied and follow-up monitoring was not adequate to assess long term treatment affects. Chaining has not occurred on public lands since the 1970's in Oregon or on private lands since the early 1980's.

Chaining has been used extensively in the past to control piñon-juniper woodlands throughout the Intermountain West (Stevens and Monsen, 2004). Currently Utah's Division of Wildlife Resources is the only agency continuing to use chaining to control piñon-juniper. Their main treatment goal is to improve big game habitat by increasing shrub and herbaceous production. Chaining practices in Utah are typically combined with seeding of native and/or exotic perennials. Research studies of chaining in Utah and Arizona indicate that two-way[16] chaining is highly successful in reducing piñon-juniper competition and encouraging increased productivity and cover of shrub and herbaceous species (seeded and unseeded treatments). Success of removing trees depends on age and size structure of the stand. Trees greater than 60 years and/or with stem diameters exceeding 2 inches are most easily controlled. Damage to the shrub and herbaceous layer is usually light to moderate. Follow-up treatment is necessary to remove saplings. Although chaining and seeding have generally proven successful when properly applied, this method is expensive with costs ranging from $60 to $200/acre (Chadwick et al. 1999). Herbaceous seed is usually broadcast prior to single chaining or between chainings (two-way chaining), which allows seed to be covered. This increases success on sites where broadcasting seed on bare ground usually is unsuccessful.

The use of equipment to mechanically shear or cut western juniper is common in the southwestern portion of its range, especially in northeastern California (Lassen and Modoc counties) and parts of eastern Oregon. Major users of this type of equipment in northeastern California and south-central Oregon (Lake County) are subcontractors who supply juniper chips to a biomass power plant in Wendell, California. The equipment is also used for land clearing for residential and commercial developments, especially in central Oregon, and rangeland habitat improvement in other locations.

[16] Two-way chaining is the practice of pulling an anchor chain twice over the landscape, with the second chaining pulled perpendicular to the first chaining.

Summary

Depending on the type of machinery used, mechanical treatment can be selective (single tree treatments) to landscape in size. Operators can control where and when to treat sites and liability is low compared to fire prescriptions. Heavy equipment use may be limited by rough terrain and tends to be expensive. The primary concern associated with heavy machinery use for western juniper control is the disturbance to soils and existing understory vegetation, particularly if post treatment recovery is dependent on species present on a site. Disturbance of the soil surface can vary from minimal to high depending on soil conditions (e.g., soil moisture, frozen or unfrozen ground, tight turns by heavy equipment, etc.). Higher levels of surface disturbance can increase opportunities for weed establishment and temporarily increase erosion potential. However, disturbance of the soil may also be beneficial if applied properly when seeding is required (Bruce Roundy, Professor of Range Ecology, Brigham Young University, Provo Utah, communication). In Utah, surface soil disturbance by chaining has been shown to increase establishment success of seeded species. Additional research and monitoring is necessary to properly assess the impacts that heavy machinery have on soil compaction and erosion, and damage to understory species. Soil type, plant composition, time of year, and weather conditions will influence the effect of heavy machinery on a particular site.

Fire

The use of prescribed fire to control western juniper has increased since 1990. A few controlled studies have evaluated post-fire succession or quantified fuel load characteristics required to conduct successful burns in developing western juniper woodlands. The primary factors that will influence post-burn response are plant composition and seed pools prior to treatment, ecological site (site potential), fire severity and extent, pre-and post-fire climate conditions, and post-treatment management.

Plant composition and seed pools

Important biotic factors driving post-fire succession are plant composition prior to treatment, individual species' response to fire, and existing seed pools. The abundance of desirable and undesirable species and their ability to tolerate fire will largely determine post-fire succession. Summaries of plant species' responses to fire are provided by Wright et al. (1979), Bunting (1984), and Miller and Eddleman (2001). Climate conditions and fire severity also influence recovery rates and become more important as communities approach thresholds. In the preventative stage (Fig. 21, Phases I and II, page 25) successful site recovery and predictability of response is high when plant communities contain an abundance of native species prior to burning. The initial response to fire of plant communities in relatively good condition is typically increased cover, density, and biomass of perennial grasses and perennial and annual forbs. However, this initial response is accompanied by a decrease of litter and woody plant cover, resulting in more bare ground (Quinsey 1984; Koniak 1985; EOARC, unpublished data). As developing woodland communities approach the transition between Phase II and III, or deep-rooted perennial grasses decline to fewer than 1– 2/10ft^2, it is more difficult to predict post-fire succession. The risk of failure also increases if weedy exotic species are present (see section on weeds). Increases of introduced annuals are usually not significant unless the site is in poor condition and there are few native species present to respond (Quinsey 1984, Koniak 1985). Once a community shifts to Phase III and/or native perennial grasses are no longer present in the understory, return to the pre-invasion community is unlikely without major and usually costly restoration inputs. In fully developed woodlands, desirable native species and seed pools become depleted, which potentially limits recovery after fire (Erdman 1970, Koniak and Everett 1982, Miller et al. 2000). As communities shift into the restoration stage (Figs. 21, 22c, pages 27–28) and abundance of understory vegetation and fuels become limiting, prescribed fire alone is no longer a viable management tool.

Two prescribed burns were conducted in productive mountain sagebrush sites during the late 1990's in the central Oregon pumice soil zone and in northeastern California. Western juniper woodland succession varied between Phase I and II across both sites. In the central Oregon burn, cover of bluebunch wheatgrass increased 274 percent and Idaho fescue increased 22 percent above preburn levels by the third year after fire (EOARC, unpublished data). Perennial forb cover, which is typically low on these pumice soils, did not respond significantly after fire. In the northeastern California burn, cover of Idaho fescue initially decreased by 25 percent the first year following fire and by the third year post-burn was 40 percent greater than preburn levels (Appendix 4)(EOARC, unpublished data).

Quinsey (1984) compared response of burned woodlands among dry (basin big sagebrush/Thurber needlegrass) and moist (basin big sagebrush/ Idaho fescue-bluebunch) plant communities on the Crooked River National Grasslands, Oregon. Differences in grazing history, time after fire, and preburn vegetation characteristics (degree of stand closure and understory composition) among the burns discounted developing any cause and effect relationships. However, several patterns in plant response were observed. First, dry warm sites are prone to increases in cheatgrass cover, and it appears that shrub and tree reestablishment take longer than on moist sites. Second, on wetter cooler sites, recovery of shrubs and perennial herbaceous plants occurred more rapidly and annual grasses did not compete well.

Western juniper cutting and prescribed fire combinations

As woodland development enters Phase III, fine fuels and ladder fuels are not sufficient to carry a fire with the necessary intensity to kill western juniper trees. Recently BLM managers have experimented with partial cutting of western juniper (usually one-fourth to one-half of the western juniper trees on a site) to develop sufficient fuel loads to carry fires. These methods have thus far proven successful in mountain sagebrush grassland, aspen, and riparian communities. The number of trees cut should be the minimum required to create ladder fuels to carry the fire. Increasing the number of trees cut increases costs and the potential to sterilize the soils, kill native bunchgrasses, and provide open sites for weed encroachment.

Burning in aspen for juniper control

Fire is an effective tool for restoring aspen communities that have been encroached upon by western juniper. However, the wet nature of aspen communities can create problems in applying prescribed fire. In northeastern California, western junipers greater than 13 ft in height were cut in the fall and left in an aspen stand. Fire was applied to the stand the following fall. The fallen western juniper trees carried fire through the stand, killing all western junipers and aspen trees (EOARC, unpublished data). In the third year post-fire aspen sucker density (3–10 ft tall) was 6,000 stems/acre compared to the pre-burn densities of 300 stems/acre (most of which were 18 inches tall with browsed terminal stems). The burn was rested from livestock use the first 3 years after treatment and there was little elk or deer use.

Partial cutting of western juniper to develop fuel loads to carry fire was used in aspen stands in Kiger Canyon on Steens Mountain, Oregon, in 2001 (Bates et al. 2004). Partial cutting involved felling one-third to one-half of the mature western juniper trees in decadent aspen stands. Tree canopy cover was more than 60 percent, shrub cover less than 1 percent, and perennial herbaceous cover was less than 15 percent. Prescribed fire included fall burning (October 2001) using helicopter-dropped "ping-pongs" and spring burning (April 2002) using drip torches. Partial cutting and fall burning was effective at removing remaining live western juniper trees (Bates et al. 2004). Aspen resprouting varied depending on the condition of the stand prior to treatment. Resprouting on cut and fall-burned plots ranged from 50 stems/acre to over 5,000 stems/acre by the second year post treatment. Cutting may not necessarily be required when fall burning is applied. In several cases, fires were ignited in untreated stands where sufficient fuel provided by dead-fallen aspen trees was present to kill 80–100 percent of the encroaching western juniper. Resprouting in fall-burned plots ranged from 100 stems/acre to over 4,900 stems/acre. Fires were hot in both cut and uncut burned treatments and herbaceous and shrub layers were negatively affected. Understory response has primarily been limited to annual and perennial forbs and resprouting shrubs, included western snowberry and wax currant. Discounting cover provided by aspen, bare ground has exceeded 95 percent in the two growing seasons after fire was applied. However, the importance of fire in stimulating some species was evidenced by emergence in all heavily burned plots of long-sepaled globemallow *(Iliamna longisepala)*, which is considered a rare species in the area.

Partial cutting (May 2001) followed by spring burning (April 2002) was less successful than was fall burning at removing remaining western juniper trees and seedlings. Aspen resprouting ranged from 240 stems/acre to over 2,400 stems/acre. Spring burns were cool and caused little damage to understory species. Soils were partially frozen, saturated, and there was still snow cover in shaded areas at the time of burn application. Shrub and understory composition remained largely unchanged after fire and there was no increase in bare ground.

Post-treatment management and disturbance

Post-treatment management should be part of the planning process. Introduction of livestock after burning in western juniper woodlands has not received adequate scrutiny but is one of the most important decisions resource managers and livestock owners must make. Grazing can be considered a form of disturbance that affects the rate and trajectory of plant community recovery following fire. Typically 2 years of grazing rest is prescribed following fire. This requirement has never been tested experimentally. Decisions regarding livestock reintroduction should be made based upon the response of vegetation following treatment. With slow community recovery, rest may be required beyond the standard 2-year time frame. Reintroduction of livestock within the first 2 years post-fire should not be rejected if recovery proceeds rapidly. Sites that respond rapidly may not be negatively affected by deferring grazing until after the growing season (August or later) within the first 2 years post-fire. Considerations for livestock grazing after western juniper treatment are discussed in a later section of this chapter.

Summary

There are several conclusions that can be drawn from fire research in western juniper woodlands.

- A positive plant community response after fire increases with site condition, site potential, and when the community is still in the early stages of western juniper woodland development.
- Predicting response is lowest when a site is approaching the threshold between Phases II and III.
- Risk of weed invasion and treatment failure after fire will increase with site aridity and warmer temperature regimes. Prediction of outcomes and achievement of desirable responses generally increase along a gradient of increasing moisture and decreasing temperatures in sagebrush plant communities.
- Post-fire climate conditions can influence recovery rates of plant communities and successional dynamics (e.g., plant composition).
- Climatic conditions prior to fire can affect recovery by influencing seed pools.
- The complexity (patchiness and shape) and size of a fire will also influence the potential seed rain from within and outside the fire boundary.
- Fire severity will influence plant response and seed pools within the boundary of the fire.

Chemical

Tebuthiuron and picloram are the herbicides that have received the most attention for western juniper control. Aerial application of tebuthiuron pellets applied at rates of 2.2 and 4.4 lb/acre, was unsuccessful in controlling western juniper in eastern Oregon (Britton and Sneva 1981). Although western juniper was not eliminated, the understory was significantly reduced. Thus aerial application is not a recommended practice. On an adjacent site, individual tree treatments with tebuthiuron were effective in killing trees less than 6.5 ft tall. The lack of effective western juniper control was likely due to site selection. The plant community was a low sagebrush type with heavy clay soils; clays in the surface horizon bind up the chemical, decreasing its infiltration through the soil profile and decreasing its availability for root uptake by western juniper. This study is a good example of the necessity of picking sites that will respond to treatment. Even if western juniper had been removed by some other method, the herbaceous response would be minimal as it was a low sagebrush community with low site potential.

Picloram applied to individual trees around canopy driplines was highly effective at controlling western juniper in northeastern California on a basin big sagebrush site (Young et al. 1985). Perennial grass response was limited primarily because of the increased dominance of cheatgrass and medusahead. Attempts were made to treat annual grasses with atrazine and then seed with a perennial mix. Weed control was generally unsuccessful because litter accumulations and physical constraints imposed by standing dead trees limited herbicide application and drill seeding of perennial species.

Elsewhere, herbicide applications had mixed results at controlling juniper and piñon species. Redberry *(Juniperus pinchotii)* and alligator juniper *(J. depeanna)*, both Southwestern species, have been successfully controlled using dicamba, tebuthiuron, or picloram. However, others have found little control of redberry or alligator juniper using picloram or tebuthiuron particularly when trees exceed 3–10 ft in height. Tebuthiuron application was effective at killing Utah juniper and piñon (single leaf and Rocky Mountain) in old chainings in Utah and across several sites in Arizona and New Mexico when pellets was applied at the base of the tree.

Livestock Grazing Following Western Juniper Treatment

Grazing management following western juniper control requires thorough consideration of when to reintroduce livestock after treatment. Stocking rate, duration, season of use, and how the treatment may influence livestock distribution must be considered when developing follow-up management plans. There are no set prescriptions for reintroducing grazing after western juniper control, and rightly so. Variability in site characteristics (plant association, woodland successional stage, understory composition, soils, and topography), weather, and type and intensity of control method means that no single prescription can be applied with the expectation of successful site restoration. Grazing management must remain flexible, be adaptive to changing conditions, and requires constant reassessment to achieve restoration goals. The primary goal when grazing treated areas is to permit rehabilitation of the sites' ecological functions (particularly hydrologic function and energy and resource capture). In shrub-steppe communities, this is usually best achieved by restoring the system to one dominated by perennial grasses and shrubs. Additional considerations are restoring the structural characteristics of the site, and enhancing resource capture, and improving wildlife habitat.

After western juniper competition has been removed, herbaceous plants will take time to respond. Grazing must be structured to permit short- and long-term successional response. In the short term this necessitates permitting existing plants on site to grow and produce viable seed. Significant seed production tends not to occur until the second or third year after western juniper control. Long-term considerations require that site management permits germination and establishment of new desired individuals. Following western juniper control, some level of grazing rest or deferment will usually be required to achieve restoration goals. The amount of time required for deferment will largely depend upon conditions of the understory prior to treatment, resilience[17] of the site, and climate conditions.

An ongoing study has evaluated herbaceous plant recovery subjected to grazed and ungrazed prescriptions over four growing seasons (1999–2002) after western juniper was chainsaw cut on Steens Mountain, Oregon (EOARC, unpublished data). The study consisted of four treatments: cut grazed, cut ungrazed, woodland grazed and woodland ungrazed. Plots were short-duration grazing by cow-calf pairs for 4–5 days in early spring the first two growing seasons after cutting. Livestock were removed prior to boot stage to minimize grazing impacts to perennial grasses. Plots were not grazed in 2001 and 2002 in order to assess biomass and reproductive responses. Western juniper cutting removed overstory interference and produced significant increases in herbaceous cover, biomass, and seed production when compared to adjacent woodlands. Herbaceous response did not differ between cut-grazed and cut-ungrazed treatments as measured by cover, biomass, and density. However, grazing the cut areas did reduce perennial grass seed production when compared to the cut ungrazed treatment. This site requires rest or deferment the first several growing seasons to provide plants the opportunity to maximize seed crops and enhance opportunities for seedling establishment when environmental conditions are favorable.

Deferring grazing (after the growing season) following a fire is generally a good management practice. Western juniper control by fire will remove most of the existing nonsprouting shrubs and can potentially kill some of the herbaceous component. The level of herbaceous mortality will depend on fire intensity, fuel moisture, and amount of litter buildup. Deferment of grazing to the fall period during the first several growing seasons is probably a minimum requirement if natural recruitment is prescribed, especially in areas with a severely depleted understory. Perennial grass seed production in most cases will not be significant until the second year post-fire. Plants must be allowed time to maximize seed crop and permit seedling establishment on sites where densities of desirable plants have been depleted. Even short grazing prescriptions in early spring are detrimental to perennial grass seed production (EOARC, unpublished data). Burned areas should probably be treated as a new seeding, requiring a minimum 2 years of rest during the growing season and possible deferment in later years.

Chainsaw cutting and proper chemical application will minimally affect understory vegetation. In the case of cutting, treatments typically occupy relatively small areas (a few acres to several hundred acres) located in large pastures, which may be several thousand acres in size. Resting entire pastures until these areas recover may be warranted biologically, but may not be practical from management and forage need perspectives. At the same time, introducing livestock too quickly after western juniper treatments may inhibit understory recovery, particularly on sites with a diminished perennial bunchgrass component and may permit dominance by weedy annuals. Cutting small areas may also result in excessive trailing by livestock in the interspace, resulting in severe utilization on the unprotected plants (Jim Buchanan, Burns, Oregon, BLM, personal communication). Western juniper cutting on this type of area should attempt to coincide with regular pasture rotations so cut areas are rested or deferred in years immediately following western juniper treatment. Grazing in late summer and fall may be permissible as plants are largely dormant during this period.

Heavy machinery will produce varying degrees of disturbance to soil surfaces but grazing management after control will be similar to cutting projects. An additional factor that must be considered in management decisions are grazing and browsing impacts by wild ungulates following western juniper control.

Economics

Little information is available to determine the economic impact of the increasing woodlands throughout the Intermountain West. Several studies have evaluated the response of forage production and big game. However, responses are usually variable depending on site condition, climate, and soils, which makes it difficult to evaluate economic return. It is also difficult to place an economic value on restoring sagebrush grassland ecosystems to proper functioning conditions. And, little has been done to determine the economic values of the possibility of reducing catastrophic fire events. Most economic uses on shrub-steppe grasslands being invaded by western juniper will be marginal at best to justify the costs of juniper removal, and will likely need to be subsidized. The greatest justification for subsidizing woodland control is the restoration of intermountain plant communities to proper functioning condition.

[17] Resilience is the ability of a site to recover to potential native vegetation, which is largely dependent upon site characteristics and climate.

Weeds

Ecology

There has been limited research on the relationships between western juniper expansion and weeds. The primary effect western juniper encroachment has on weeds is modification of the existing plant community. As trees become dominant on a site, shrubs and native herbaceous species in the understory decline, soil nutrient resources become less available, and microclimate is modified. The highest risk levels for weed invasion into pre- and post-settlement western juniper communities are in the warmer (mesic temperature regime) lower elevation sites. The risk for weeds to dominate the understory decreases at higher elevations and is low above 5,000 ft. Larger portions of woodlands are at high risk of weed invasion in the relatively warmer Mazama and John Day ecological provinces than in the High Desert and Humboldt ecological provinces.

As western juniper begins to dominate a plant community, the understory species decline (Bates et al. 2000, Miller et al. 2000) and soil resources become less available (Bates et al. 2002). The opportunity for weed establishment increases on sites with a depleted shrub and herb layer. However, reduced soil resources on a western juniper-dominated site (Phase III) may limit the abundance of introduced weeds. Weeds can dominate open stands of western juniper. During the early phase of weed invasion, species such as cheatgrass are usually most abundant beneath the south and west side of the tree canopy. On clay soils, however, medusahead can be a dominant understory layer in closed woodlands. In undisturbed closed woodlands weed abundance will fluctuate with climate but will usually have minimal influence on the site; however, the removal of trees will release soil resources (Bates et al. 2002) and result in a release of weedy species (Tausch 1999). Following fire, soil water and available nutrients generally increase, at least for short periods of time (Blank et al. 1994). Increases in nutrients, especially nitrogen, enhance the growth of cheatgrass and increases the period of dominance (McLendon and Redente 1991, Young et al. 1999). Once established, cheatgrass responds rapidly to woodland fires and shifts the seasonality of fire to the more active growing period of native perennials (Whisenant 1990). Repeated fires can simplify vegetation into a homogenous landscape dominated by exotic annuals (Young and Evans 1973, Young 1991). The availability of soil resources following a reduction in tree density can be a predictor of community invasibility (Burke and Grime 1996).

The increase in exotic annuals in piñon and juniper woodlands in Nevada resulted in dramatic increases in fire size and frequency (Young and Evans 1973, Whisenant 1990, Swetnam et al. 1999, Tausch 1999). Recent crown fires in dense piñon-juniper in the southern Great Basin (Tausch 1999, West 1999) have opened up many woodland areas, often causing them to shift from woodland to annual grassland. As western juniper canopies continue to close the potential for high-intensity crown fires will increase.

Weed response following treatment

Barney and Frischknecht (1976) identified a weedy annual stage that peaked within 3 to 4 years after a fire, followed by several stages with differing mixes of perennial grasses, forbs, and shrubs. In Utah, the change in cheatgrass cover was dramatic, ranging from 12.6 percent in 3-year-old burns to less than 1.0 percent in burns older than 22 years. A similar pattern was identified in piñon-juniper woodlands in southwestern Colorado (Erdman 1970). The pattern may be similar with chaining. Working in central Utah, Davis and Harper (1990) measured a high density of both cheatgrass and burr buttercup *(Ranunculus testiculatus)* immediately after chaining on a piñon-juniper site. By the third year after chaining, the density of both species had declined by 85 percent or more compared to the first year post-treatment values. In this study, the density of seeded perennials increased over the 3-year period. In central Oregon, cheatgrass biomass increased 4 to 6 fold (200 lbs/acre) in the first 2 years following western juniper removal by cutting (Vaitkus and Eddleman 1987). However, after 15 years, tree removal resulted in large increases in perennial grasses and a decline in cheatgrass to less than 10 lb/acre (Eddleman 2002d). Similarly a decline in cheatgrass and increase in native perennials 9 years following tree cutting was measured on Steens Mountain in eastern Oregon (EOARC, unpublished data). Cheatgrass accounted for less than 5 percent of the herbaceous biomass following fire on a north aspect at 4,000-ft elevation in the Mazama Ecological Province on Horse Ridge (EOARC, unpublished data). However, on pumice soils at elevations below 3,500 ft with minimal slope, cheatgrass readily invaded stands where western juniper had been cut or burned. In a depleted western juniper woodland in northeastern California, Evans and Young (1985) measured a dramatic increase in cheatgrass (from near 0 to 1,500 lb/acre) after controlling western juniper with picloram pellets. Cheatgrass frequency declined in the treated areas over a 7-year period, but there was a continual increase in frequency of medusahead.

However, medusahead invasion following herbicide control was not a problem where there was good cover of perennial grasses (Young and Evans 1971).

Research shows that weedy annuals, cheatgrass in particular, will usually increase immediately after trees are killed, whether it is by fire, chaining, cutting, or herbicides. Much of the research indicates that this response will be transient, or that it may not even occur. For example, Barney and Frischknecht (1976) pointed out that the annual stage may be by-passed in areas with good cover of perennial herbaceous species prior to burning. In central Oregon, Quinsey (1984) stratified the fire response of western juniper woodlands into dry and moist sites. Dry sites contained cheatgrass prior to burning, and the increase of cheatgrass following treatment persisted for 20 years in some cases. On the moist sites, perennial grasses dominated the unburned vegetation with little cheatgrass present. The moist sites did not have a fire-induced increase in cheatgrass. On the Lava Beds National Monument in northern California, cheatgrass abundance following fire directly related to site and preburn composition (EOARC, unpublished data). Cheatgrass is typically common or dominates sites below 4,500 ft in elevation but is usually less abundant above 4,500 ft, especially on north to northeast aspects.

Species of concern

Cheatgrass, although not yet abundant, had a broad distribution by the late 1800's in the Intermountain West (Stewart and Hull 1949). By the 1920's it represented an important forage resource in Nevada (Young and Evans 1989). In the 1930's the increases in fire frequency that followed cheatgrass became apparent in southern Idaho (Stewart and Hull 1949). Currently cheatgrass has become widespread at the lower elevation woodlands throughout the Great Basin.

Although cheatgrass is the weed species mentioned most frequently in the literature, it certainly is not the only weed of concern in western juniper woodlands. Another species of concern, as mentioned previously, is medusahead. Western juniper woodlands at greatest risk of medusahead invasion are primarily on clay soils. However, there are examples of infestations on medium-textured soils, so it would be a mistake to assume that only clay soils are at risk. There is presently an ongoing invasion of diffuse and spotted knapweeds *(Centaurea diffusa* and *C. maculosa*, respectively) in upland sites and Russian knapweed *(C. repens)* in the moister sites. It is also likely there are other weedy species that are a potential threat but have not yet been recognized.

Summary

Past work suggests weed response following woodland conversion projects will be site-specific and will depend heavily on the initial floristics of each plant community (Everett and Ward 1984, Koniak 1985). The presence of desirable plants is important in reducing the threat of weed invasion. The ecological site (especially where it fits along the gradient of warm-dry to cool-moist), initial floristics, and the stage of woodland development are very important factors that will influence the response of a site following thinning or total removal of trees.