In cooperation with Bureau of Land Management—Bishop California Field Office

Evaluating the Effects of Pinyon Thinning Treatments at a Wildland Urban Interface

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Evaluating the Effects of Pinyon Thinning Treatments at a Wildland Urban Interface

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Abstract

This study evaluated the short-term effects of thinning methods for pinyon pine woodlands at two sites in the southwestern Great Basin. Both cut/pile/burn and mastication treatments were equally effective at reducing the target fuels which were mature, live pinyon trees. Application costs though differed substantially, with the cut/pile/burn technique being less expensive. Thinning treatments increased the abundance of herbaceous vegetation, although in some cases the strength of the increase was constrained by the level of pre-treatment tree dominance. Increases in perennial grass cover and density in response to thinning were usually greatest at lower levels of pre-treatment pinyon dominance, whereas native annual forb density and cover responded fairly equally along the tree-dominance gradient. Shrub abundance declined in response to pre-treatment tree dominance and the response to thinning treatments appeared more subtle than for herbaceous vegetation. Shrub cover within the control decreased slightly during the 3 post-treatment years, while it increased slightly within both thinning treatments. The response of slower-growing plants such as shrubs will need to be evaluated during future years to determine differences between thinning treatments. Species richness within the two thinning treatments steadily increased relative to the control over the course of the 3 years following treatment. Species richness was also consistent across the pinyon-dominance gradient, which suggests

that the ability for vegetation to recover at this location may not be significantly limited by a lack of seed availability or lack of species diversity within highly tree-encroached shrublands. Cover of herbaceous live fuels (perennial and annual forbs and grasses) and live woody fuels (live shrubs and trees) were also similar between the two thinning treatments and higher than the control. The greatest difference in fuel structure between the two fuel treatments appeared to be dead woody fuel loads—mastication clearly resulted in greater fine fuel loads (1–100 hour fuels) as well as the shredded woody particles. The stimulation of live herbaceous cover—especially at lower pre-treatment pinyon dominance—may have important implications for fire spread by enhancing the continuity of surface fuels, especially during dry years.

Background and Purpose

Woodlands dominated by pinyon pine (*Pinus* spp.) and/or juniper (*Juniperus* spp.) occupy over 30 million ha of the western United States (West 1999), while only 3 million ha were occupied prior to the late 1800s (Miller et al. 1999). This 10-fold expansion of pinyon-juniper range may have only just begun since it currently occupies less area than climatic conditions seem to allow (Miller et al. 2000). The historic range and density of pinyon-juniper never reached its climatic potential because natural disturbances, especially wildfire, prevented trees from encroaching into adjacent shrublands. Historic fire regimes throughout the western US were substantially altered following European-American settlement during the 1900s, and pinyon-juniper/sagebrush fire regimes were changed because of direct fire suppression and reductions in surface fuels caused by livestock grazing (Miller and Rose 1999). A shift from sagebrush-dominated to pinyon-juniper–dominated vegetation caused by fire exclusion can result in loss of habitat for sagebrush-dependent wildlife, decreased species diversity, depleted soil seed banks, decreased aquifer recharge, and increased soil erosion rates (Koniak and Everett 1982, Reid et al. 1999, Davenport et al. 1998, West 1999, Miller et al. 2000).

As sagebrush-steppe has converted to pinyon-juniper woodlands, fire regimes have shifted from moderate intensity surface fires with moderate return intervals (~50 years) to high intensity crown fires with longer return intervals (>100 years). Changes in vegetation composition, fuel structure, and fire regime are generally characterized as shifts in fire regime condition class (FRCC). Historical, pre-settlement or otherwise "natural" conditions are classified as FRCC1, while moderate and high departures from historical conditions are classified as FRCC2 and FRCC3, respectively (Hann and Bunnell 2001).

In stands where encroaching woodlands are relatively young—having established since the mid-1900s—tree cover is low and surface fuels may still carry low to moderate intensity surface to passive crown fires. If early-succession woodland stands begin to dominate a sagebrush-steppe community, it is categorized as FRCC2—the community moderately deviates from historic natural fuel and fire regime characteristics. The potential is often relatively high for restoring FRCC2 areas back to their pre-invasion state by using tree thinning and without the need to actively re-vegetate sagebrush-steppe species. Where invading woodlands are relatively old—having established before or soon after the beginning of the 1900s—tree cover is high, whereas cover and seed bank densities of shrubs, grasses, and herbs are low. In these closed-canopy woodlands, fire does not propagate easily, except under extreme fire weather conditions, which typically results in intense crown fires that endanger rural communities and have undesirable effects on soils and plants (Miller et al. 2000). The potential may be relatively low for FRCC3 landscapes to return to pre-invasion conditions following tree thinning, especially without actively re-vegetating sagebrush-steppe species.

Various thinning treatments have been used to reduce density and cover of pinyon and juniper, and ultimately shift FRCC2 and FRCC3 sagebrush ecosystems to historical FRCC1 conditions, but their effects have been poorly documented and are difficult to predict. This lack of predictability makes many land managers wary of embarking on expensive thinning projects that could potentially have undesirable side effects. The existing information void also complicates the environmental review and approval process and can stall fuels reduction projects in the planning phase. Prudent land management requires that expensive, broad-scale landscape manipulations should be studied and evaluated first to identify the best prescription to correct the problem before obligating significant resources to treatments that may do more environmental harm than good. Thus, there is a significant management need across the United States for fuel management prescriptions that can effectively restore FRCC1 fuel and fire regime characteristics while minimizing negative ecological side-effects.

One of the primary concerns about thinning treatments is that they cause significant amounts of disturbance, which may promote the dominance of non-native plants such as cheatgrass (*Bromus tectorum*) (Brooks and Pyke 2001). In some cases, invasive plants create new fuel conditions and alter fire regimes (D'Antonio and Vitousek 1992, Brooks et al. 2004). Cheatgrass is prevalent in the pinyon-juniper/sagebrush-steppe ecotone, especially in disturbed areas. There is a very real concern that efforts to restore shrub-steppe to FRCC1 conditions may increase cheatgrass dominance, promote recurrent fire, and push landscapes into non-native annual grasslands.

Some thinning methods such as mastication reduce woody plant material into small wood chips leaving them as mulch on the ground, and this mulch has been shown to reduce the dominance of cheatgrass (Wolk and Rocca 2009). This reduced dominance of cheatgrass may be the result of increased soil carbon from the mulch which leads to reduced soil nitrogen levels that inhibits growth of invasive plants. Alternatively, the mulch may significantly shade the soil surface and inhibit seed germination and seedling growth. Regardless of the mechanism, reduced dominance of invasive plants such as cheatgrass can lead to increased density, cover, and diversity of native species, which could provide an additional benefit of tree thinning treatments.

Land managers at the BLM Bishop Field Office have a significant need to thin woodlands dominated by pinyon to reduce fire hazards at wildland urban interface areas, restore historical fuelbed conditions, and promote native plant species diversity while minimizing positive effects on cheatgrass. However, before they implement large-scale thinning treatments they need information to reliably determine the best methods to achieve their goals. Specifically, recommendations are needed on management approaches to effectively restore tree-dominated FRCC2 and FRCC3 sagebrush-steppe landscapes (high intensity, long return interval crown fires) to FRCC1 conditions (moderate intensity and return interval surface fires). Approaches should also minimize the subsequent dominance of cheatgrass, which has the potential to replace one fuel hazard (dense trees) with another (continuous fine fuels), and potentially shift the landscape into another FRCC2 or FRCC3 situation (mixed intensity, short return interval, fast-moving surface fires). In addition, ideal treatments should also promote native plant dominance and diversity.

Project Objectives

The purpose of this project was to establish a fire management experiment and demonstration site that addressed significant local knowledge gaps hindering the management of pinyon woodland fuels within lands managed by the BLM Bishop Field Office. The need for this information is not unique to the Bishop Field Office, or even adjacent Inyo National Forest lands, but rather is typical of information needed by federal, state, and other land managers throughout the Intermountain West. The specific objectives of the project were to:

1. Establish demonstration sites to illustrate the effects of cut/pile/burn, mastication, prescribed fire treatments on the vegetation community and fuelbed structure.
2. Compare the implementation costs of cut/pile/burn and mastication treatments.

3. Compare the immediate effects of pinyon thinning treatments on their target fuel types, standing live pinyon fuels.

4. Compare the short-term effects of pinyon thinning treatments on cheatgrass abundance during the first 3 post-treatment years.

5. Compare the short-term effects of pinyon thinning treatments on native plant communities during the first 3 post-treatment years.

6. Compare the short-term effects of thinning treatments across a range of initial pinyon cover (where trees are just beginning to invade sagebrush-bitterbrush steppe to where trees have reached canopy closure).

7. Compare the short-term effects of pinyon thinning treatments on live herbaceous fuel characteristics.

8. Compare the short-term effects of pinyon thinning treatments on litter and duff fuel characteristics.

9. Compare the short-term effects of pinyon thinning treatments on woody fuel characteristics.

Methods

Study Area

This study was conducted in the southwestern Great Basin at two sites in the Bodie Hills of Mono County, CA at elevations ranging from 2,100–2,600 m (figure 1). One site—Rancheria Gulch—was used to evaluate the effects of cut/pile/burn versus mastication treatments on vegetation community and fuelbed structure. Another site—Trench Canyon—was established for the same purposes, except that prescribed fire was also included as a treatment. Using prescribed fire at the Rancheria Gulch site was not feasible because of its proximity to human developments. Both sites were located in areas characterized by a wide range of initial pinyon cover (10-80% cover).

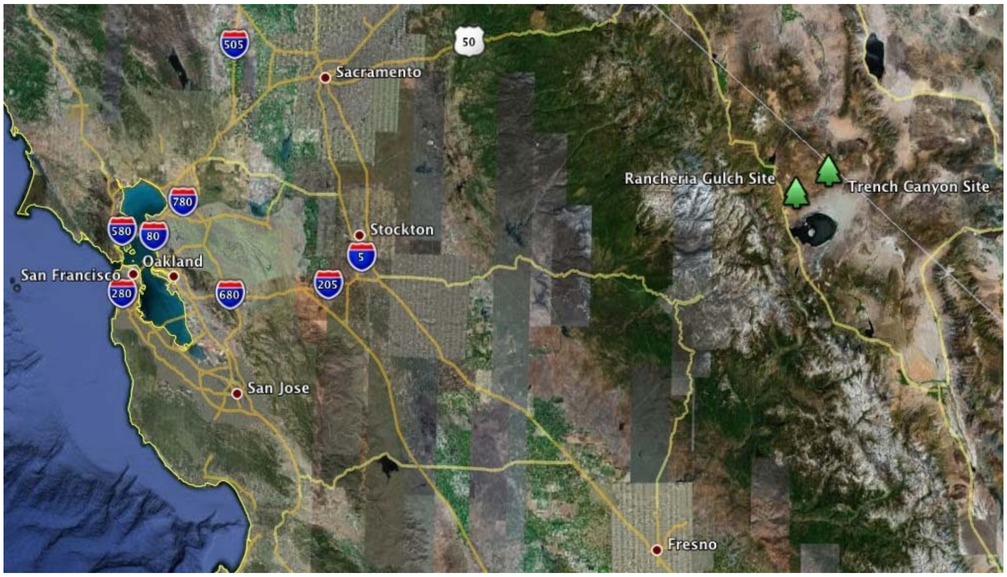

Figure 1. Locations of study sites.

Annual precipitation in the study area averages 40 cm with summer temperatures ranging between 15–32 ºC and winter temperatures ranging between -9–2 ºC. Soil parent material in the study area is comprised primarily of tertiary volcanics with granitic and calcareous inclusions and soil textures range from rocky to loamy.

A fire regime condition class assessment for the Bodie Hills area was recently completed by The Nature Conservancy on behalf of the BLM Bishop Field Office (Provencher et al. 2009). This assessment found that the distribution of vegetation succession classes within montane sagebrush-steppe deviates substantially from historic natural conditions (table 1). Historically, over 85% of montane sagebrush-steppe was comprised of vegetation in early- to mid-succession classes, which consisted of herbaceous-dominated vegetation (following fire and other disturbances) through shrub-dominated vegetation (the result of shrub re-establishment and growth). Late-succession classes where conifers began to establish, mature, and eventually dominate the community occurred naturally within only 15% of the community. Currently in the Bodie Hills, almost half of the montane sagebrush-steppe community is comprised of mature sagebrush stands, while another 38% is classified as uncharacteristic—succession classes which rarely occurred naturally. This substantial deviation in the distribution of succession classes means that the montane sagebrush-steppe community in the Bodie Hills can be categorized as FRCC3.

Table 1. Succession class composition of montane sagebrush-steppe community in the Bodie Hills (from Provencher et al. 2009).

Succession Class	Historic Composition %	Current Composition %
A. Early: 0–10% cover of mountain sagebrush & shrubs; >50% grass/forb cover	20	<1
B. Mid-Open: 11–30% cover of mountain sagebrush & shrubs; >50% herbaceous cover	50	7
C. Mid-Closed: 31–50% cover of mountain sagebrush & shrubs; 25–50% herbaceous cover, <10% conifer sapling cover	15	49
D. Late-Open: 10–30% cover of mid-sized conifers; 25–40% cover of mountain sagebrush & shrubs; <30% herbaceous cover	10	6
E. Late-Closed: 31–80% cover of full-sized conifers; 6–20% shrub cover; <20% herbaceous cover	5	<1
U. Uncharacteristic: various classes, including tree-encroached and annual-grass invaded vegetation	0	37

Experimental Design

At the Rancheria site, two thinning treatments (cut/pile/burn and mastication) and an untreated control were evaluated. The mastication treatments were applied during the fall of 2006 using a Recon Bull Hog® masticator (figure 2). The cutting and piling part of the cut/pile/burn treatment was conducted in fall 2006 by hand crews using chain saws. The piles were left in place for one year to allow the material to sufficiently dry and subsequently burned in the winter of 2007. Thinning treatments targeted all tree size classes for removal, although 11 of the most mature trees in a plot were left standing for aesthetic reasons. There were a total of 29 experimental plots (~1 ha/plot), with 10 in each of the 2 thinning treatments and 9 control plots. The experimental plots were also arranged along a gradient of pinyon pine dominance.

Figure 2. Masticating equipment.

Initially at the Trench Canyon site, the methodology and timing of the treatments were the same as at the Rancheria site, but with a total of 18 plots—6 in each of the cut/pile/burn, masticate, and control treatments—arranged along a gradient of pinyon tree dominance. In our original study plan, we proposed to measure how fire behaved within cut/pile/burn, masticated, and untreated control plots two years after the thinning treatments were applied. However, the fuelbeds in the thinned plots never developed to the point that fire could readily carry through them within the first two post-treatment years. We therefore decided instead to burn the untreated control plots during fall 2008, thus creating a third type of thinning treatment for evaluation. We then characterized vegetation and fuel conditions at the site in summer of 2009, so measurements were made 3 years post-treatment for the masticate and cut/pile/burn treatments, but 1 year post-treatment for the fire treatment. This limits the short-term comparisons that can be made between all the three treatments, but will provide the opportunity for longer-term comparisons in future years.

These two demonstration sites can be used to monitor long-term effects of the thinning treatments. They will also serve as places were field trips can be conducted to visually observe how the plant community and fuelbed characteristics evolve over time. Because the two sites differed in some of their initial conditions (see Study Area above), they must be considered as separate case studies comparing different sets of thinning treatments.

Plant Community Sampling

Within each 1-ha treatment plot at the Rancheria Gulch site, we established 3 sampling plots for quantifying vegetation community structure. A sampling plot consisted of a 20 m × 50 m plot based on the modified-Whittaker sampling design (Stohlgren et al. 1995). Each modified-Whittaker plot included five 1-m2 subplots for measuring plant species density and richness; plus two 10-m2 subplots, one 100-m2 subplot, and the entire 1000-m2 plot for quantifying species richness at additional spatial scales. Vegetation cover was measured using a point intercept technique, with 100 total points spaced 0.5 m apart running along a 50-m edge of the modified-Whittaker plot. Post-treatment vegetation measurements were made for 3 years following treatment (summers of 2007, 2008, and 2009). Pre-treatment tree cover was measured in 2005 and was calculated by measuring crown-diameters of individual trees within a 5m× 30m subplot within each modified-Whittaker subplot.

Fuelbed Sampling

Fuel structure at the Rancheria Gulch and Trench Canyon sites was measured at one location within each treatment plot. A fuel structure plot consisted of two, 25-m long Brown's-style transects (Brown et al. 1982) for quantifying downed woody fuel loads; five, 1 m × 1 m subplots for measuring the cover and depth of surface fuels (litter, duff, standing herbaceous and shrub material, and masticated wood particles); a 100-m2 circular subplot for measuring the characteristics of smaller-sized trees (<10 cm diameter at root collar); and a 500-m2 circular subplot for measuring the characteristics of larger-sized trees (≥10 cm diameter at root collar). Tree characteristics included diameter at root collar, health, height, crown base height, live crown ratio, and crown diameter. Fuel measurements were made in the summer of 2009.

Data Analyses

Measures of vegetation abundance, which included canopy cover and density of individuals, were grouped into nativity/life-cycle/life-form categories (e.g. native annual forbs, native perennial grasses, alien annual grasses, etc.). Vegetation community diversity was assessed using multi-scale species richness and species evenness (calculated from species abundance based on density). Variables describing surface fuel characteristics included cover/depth of litter, duff, and masticated material; standing live and dead herbaceous vegetation; standing live and dead woody vegetation; and 1-, 10-, 100-, and 1000-hour fuel loads.

We statistically analyzed most responses using Bayesian hierarchical models, which included random effects (such as sub-samples nested within treatment plots) and experimental fixed effects (thinning treatment, pre-treatment pinyon dominance, time, and interactions of thinning with the pinyon dominance and time). The RJAGS package (Plummer 2009) for the R statistical software system (R Development Core Team 2008) was used to calculate probability distributions for model parameters using Markov Chain–Monte Carlo sampling. If the interval that encompassed 95% of the density of a parameter's probability distribution (i.e. the 95% credible interval) did not include 0, the parameter was deemed highly statistically significant. We considered parameters having credible intervals excluding 0 at slightly lower densities (90–94%) as marginally significant. Models used non-informative priors for all parameters. The predicted values plotted in figures were also generated from Markov Chain–Monte Carlo sampling and were the median value of the distribution.

Our models also specified the most appropriate statistical distribution for each response variable. A Poisson distribution was used for density and richness responses since they are always integer counts ≥ 0. A binomial distribution was used for cover values, which were expressed as the total number of point intercepts versus the number of total points. The binomial-based models also included parameters to account for possible over-dispersion in the response variable, which can occur because cover points are clustered in space along sampling transects.

Key Findings

Thinning Approaches

The cost for mastication treatment was $738 per acre, while the cut/pile/burn treatment costs totaled $439 per acre ($339 per acre for contractors cutting and piling, plus ~$100 per acre for BLM employees burning the piles). However, since the thinning treatments were applied on small-scale study plots, they are not representative of typical costs. For recent management-scale mastication treatments conducted by Bishop BLM, costs range from ~$400 per acre for low tree encroachment, ~$600 per acres for moderate tree encroachment, and ~$800–1000 per acre for high tree encroachment. Management-scale cut/pile/burn treatment costs range from ~$150 per acre for low tree encroachment, ~$350 per acre for moderate tree encroachment, and ~$600 per acre for high tree encroachment for the cutting and piling, plus ~$60 per acre for burning. BLM's planning costs are not included in these estimates; however, planning effort is similar for the different thinning techniques and levels of tree encroachment.

Plant Community Responses at Rancheria Gulch

Trees

Both thinning treatments significantly reduced tree cover during the initial 3 post-treatment years (figure 3). Note that the remaining tree cover in the masticate treatment appeared to slowly inch higher during the 3 years sampling period, although the change was not statistically significant.

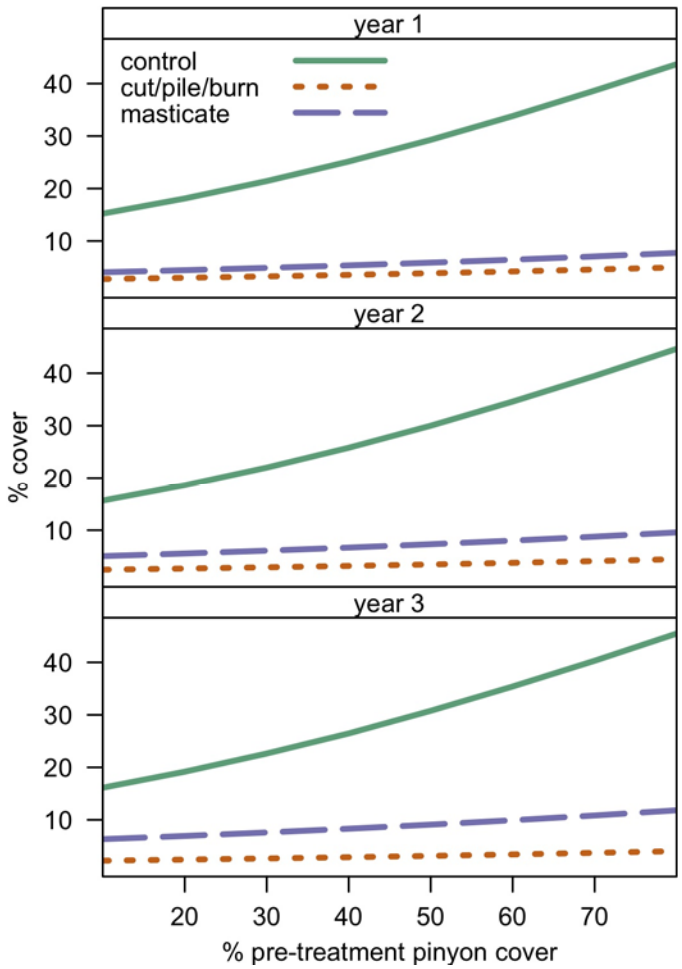

Figure 3. Tree cover.

Shrubs

Both thinning treatments significantly altered shrub cover during the 3 post-treatment years (figure 4). The simple effect of time was significantly negative; however, positive mastication × time and cut/pile/burn × time effects offset the decrease, indicating that shrub cover declined over time only within the control but remained stable or increased slightly within the two thinning treatments. There was a marginally significant negative pre-treatment tree cover effect in all treatments.

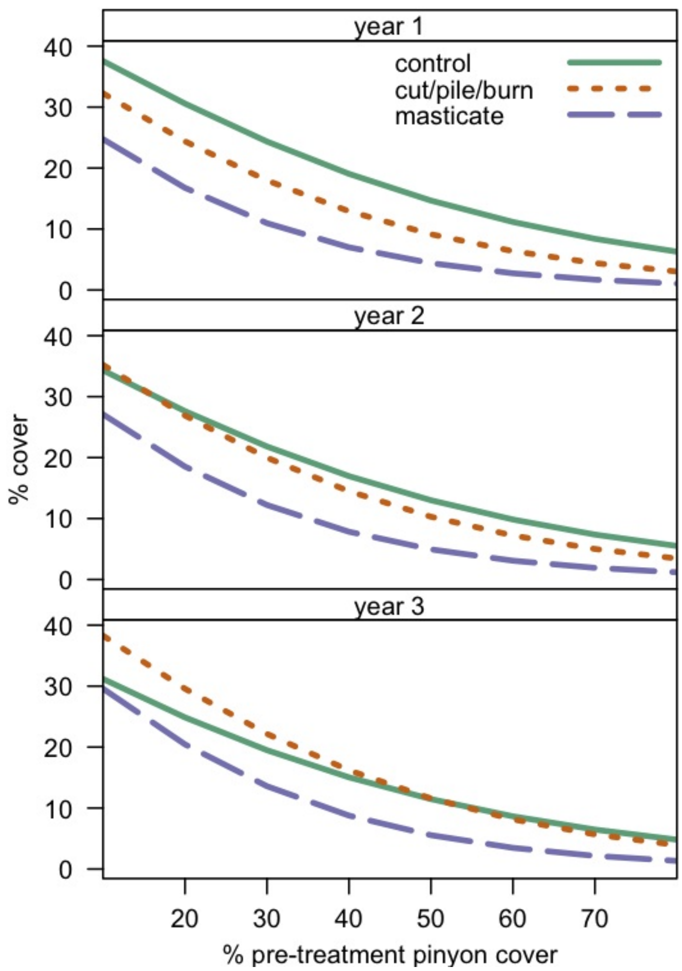

Figure 4. Shrub cover.

Shrub density within the cut/pile/burn treatment increased over time (significant cut/pile/burn × time effect) compared to the masticate and control treatments, and there was significant negative pre-treatment tree cover effect in all treatments (figure 5).

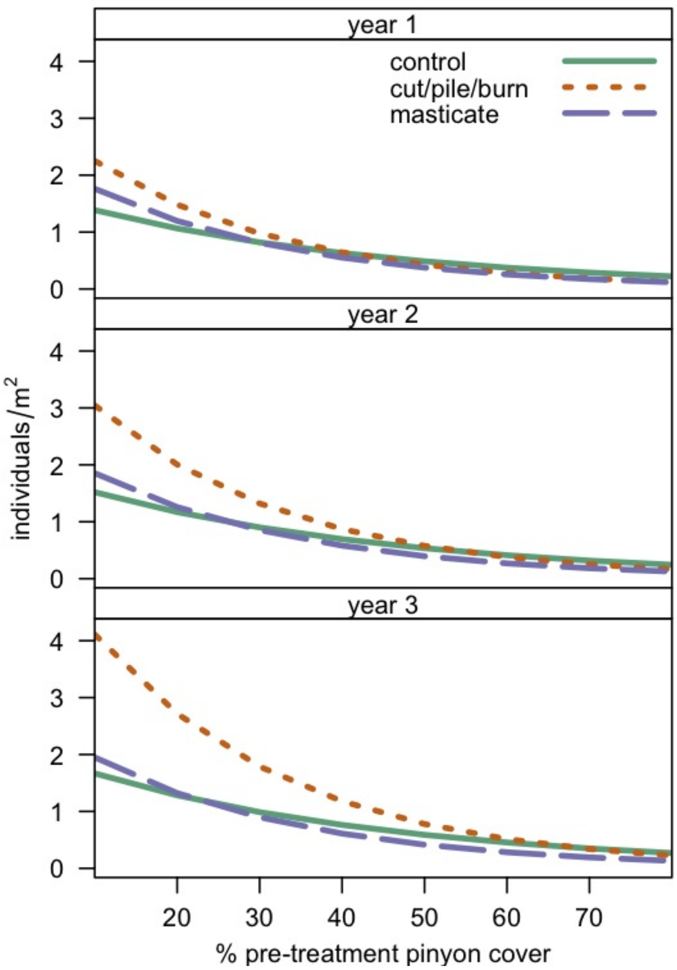

Figure 5. Shrub density.

Perennial Grasses

Perennial grass cover exhibited marginally-significant responses to both thinning treatment × time effects, with higher densities within the thinning treatments versus the controls, especially by the third post-treatment year (figure 6).

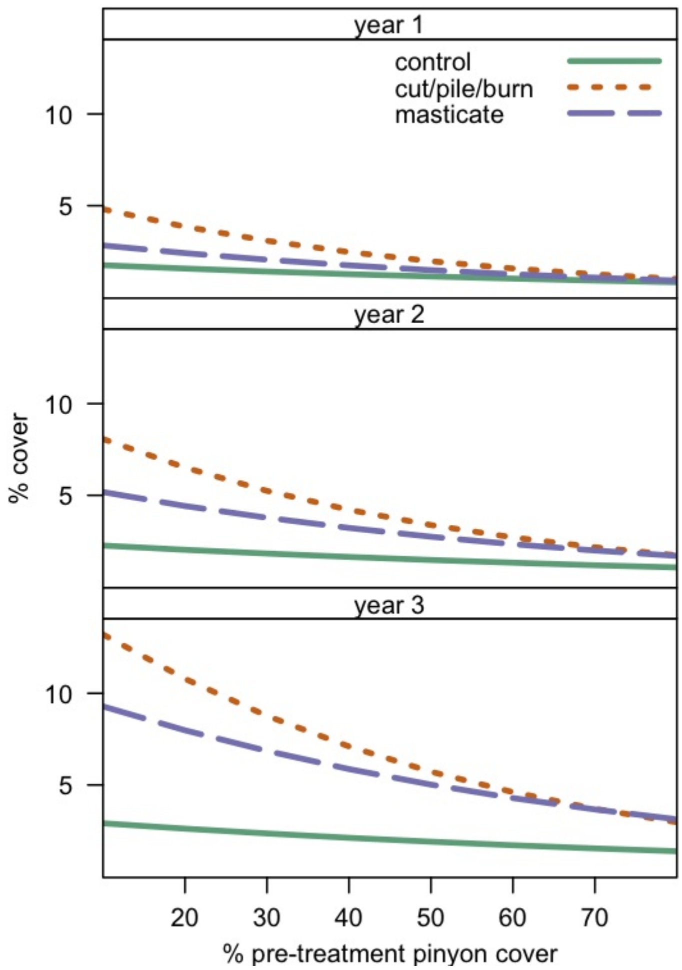

Figure 6. Perennial grass cover.

The simple cut/pile/burn treatment effect was significant—generally leading to higher perennial grass densities—but the treatment significantly interacted with time and tree cover (figure 7). The highest densities were within the cut/pile/burn at low tree cover in the first year, but the treatment effect gradually declined during the next two seasons. Both thinning treatment × tree cover effects were significantly negative while the simple tree cover effect did not statistically differ from 0, indicating that perennial grass densities declined with increasing pre-treatment tree cover within the thinning treatments but were fairly constant within the control.

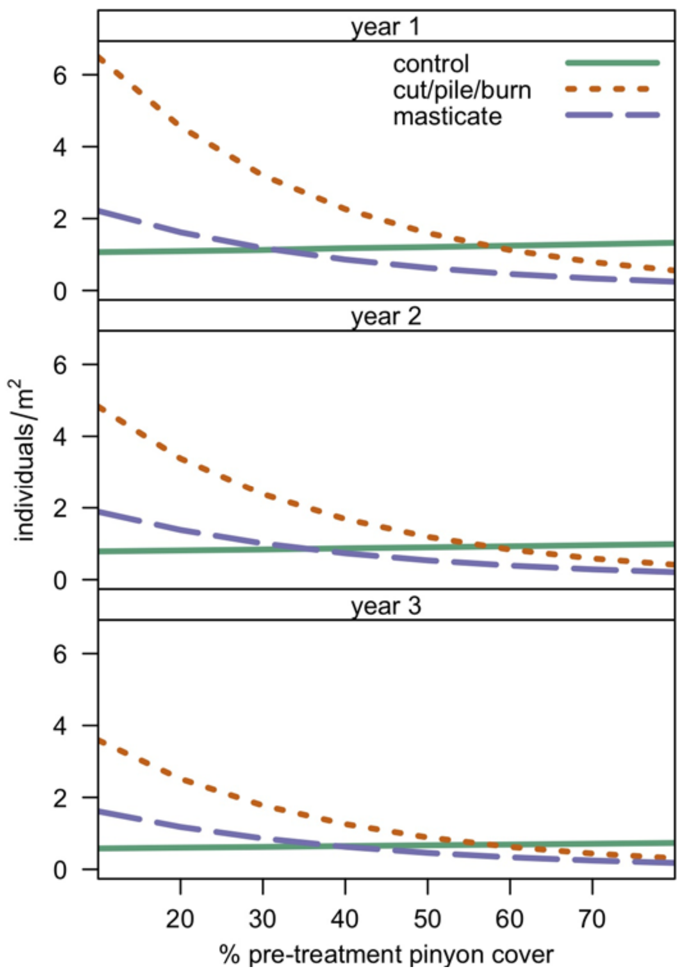

Figure 7. Perennial grass density.

Native Annual Forbs

Native annual forb cover and density were highly variable between years, a direct result of high variability in precipitation. Post-treatment years 1 and 3 were dry while year 2 was wet. The interactions of both thinning treatments with time were significant, with the result being higher densities in the thinning treatments versus the control in year 2 but smaller differences in year 3 (figure 8).

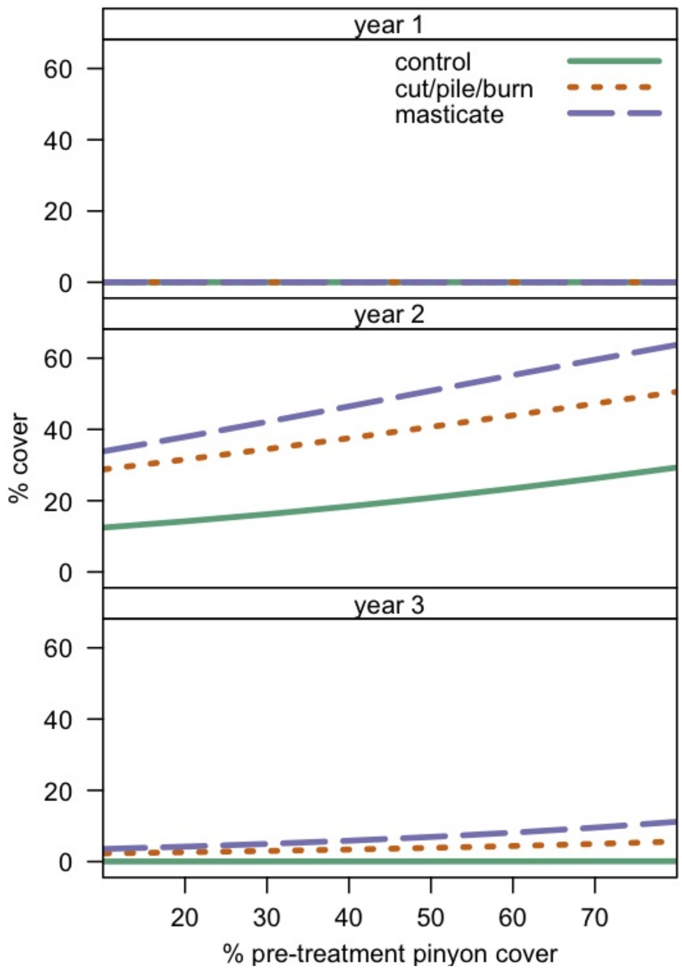

Figure 8. Native annual forb cover.

For native annual forb densities, all model parameters were statistically significant except for masticate × tree cover. The ultimate results were that forb densities in year 2 were highest within the cut/pile/burn treatment while the control and masticate treatment were similar, while in year 3 forb densities within the cut/pile/burn and masticate treatments were both greater than the control (figure 9).

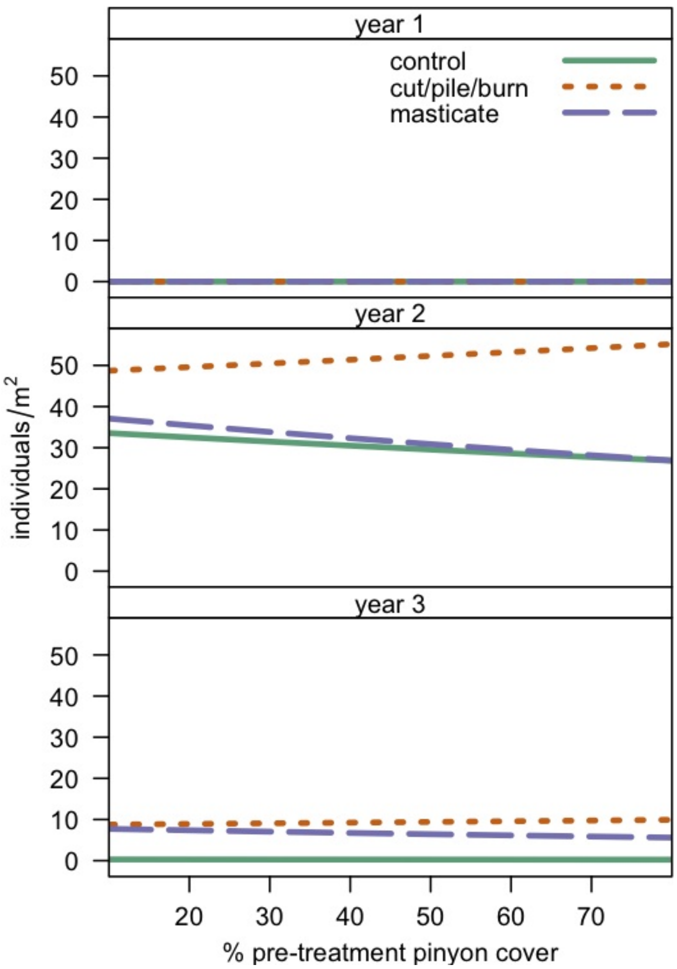

Figure 9. Native annual forb density.

Cheatgrass

The abundance of introduced annual grasses—primarily *Bromus tectorum*—was generally low compared to other annual plants, although abundance varied greatly and there were plots with very high abundance. There were no statistically significant effects for cover. The statistical model for density (based on a Poisson distribution) had difficultly converging on a stable solution, possibly because there were a large number of observations with 0 individuals.

The cover and density of plants in all other life-form–life-cycle–nativity categories were minimal and no general trends were observed between thinning treatments.

Species Diversity

Species richness was influenced by most treatment effects and their interactions—all were highly significant except the simple tree cover effect and the interactions between thinning treatments and time. The main response was increased species richness in both thinning treatments, especially by the third post-treatment year (figure 10). There were no significant relationships between species evenness and explanatory variables.

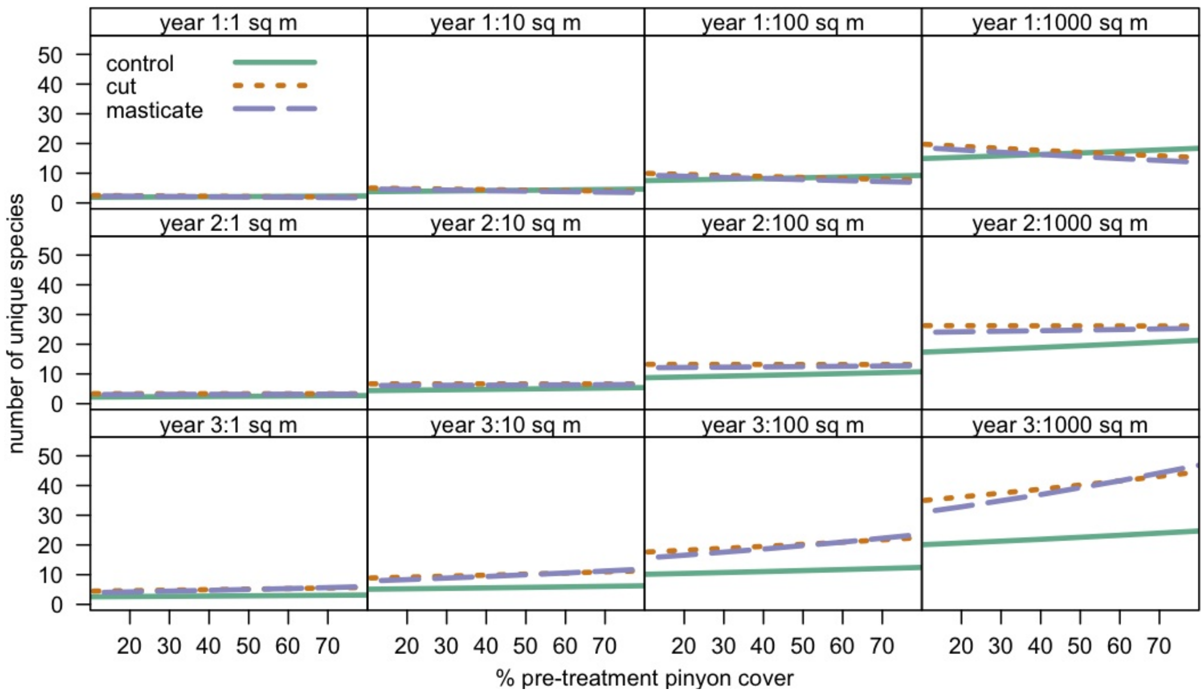

Figure 10. Species richness.

Fuel-bed Responses at Rancheria Gulch

Biomass of fine woody debris (sum of 1-, 10-, and 100-hour fuels) was marginally significantly higher within the masticate treatment (figure 11). Fine woody debris included only solid, completely round wood particles and did not include masticated wood pieces. Coarse woody debris (1000-hr and greater fuels) rarely occurred at the study site.

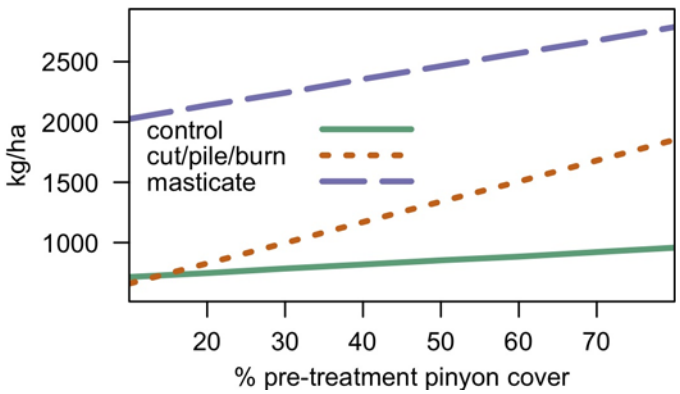

Figure 11. Biomass of fine woody fuels.

The total cover of herbaceous litter significantly responded to thinning treatments and interactions with pre-treatment tree cover, with the result being higher litter cover in both thinning treatments versus the control, especially at lower pre-treatment tree cover (figure 12).

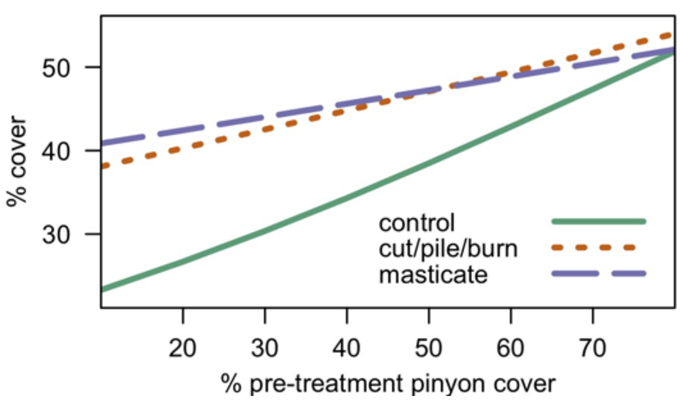

Figure 12. Herbaceous litter cover.

Fuelbed Responses at Trench Canyon

Burning consumed nearly all woody surface particles and shrubs and killed most trees but left them standing. Litter cover appeared lower and bare-ground cover higher in the first year following the burn when compared to the 3rd year after the cut/pile/burn and masticate treatments. Basic box-and-whisker plots of responses are show in figure 13. We did not apply any inferential statistical analyses to these variables because thinning treatments differed in their timing (fall 2006 for cut/pile/burn and mastication, and fall 2008 for burning).

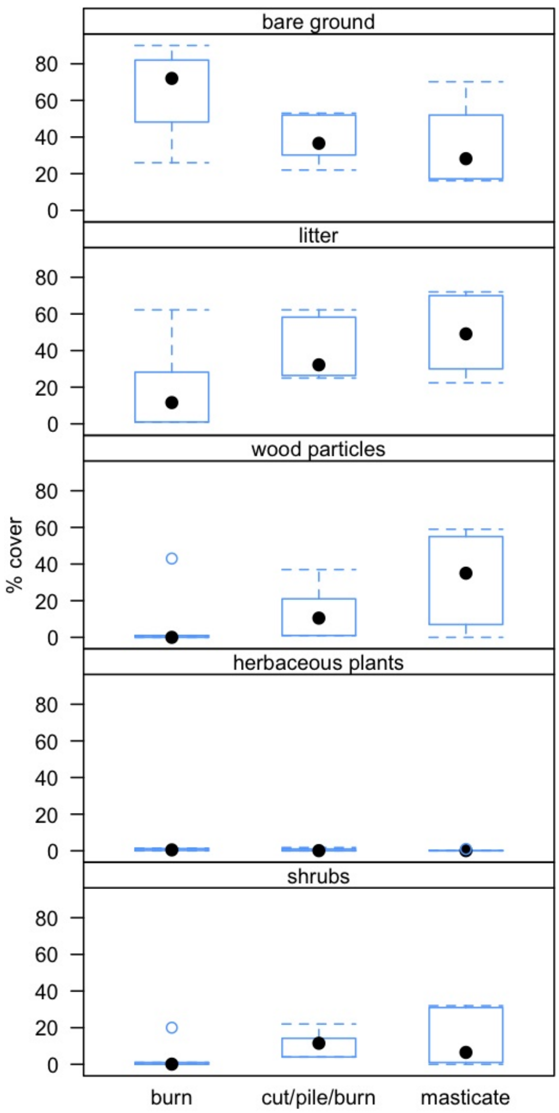

Figure 13. Cover of fuels at Trench Canyon.

Management Implications

Thinning Approaches

Both thinning treatments were equally effective at reducing the target fuels which were mature, live pinyon trees. Application costs though differed substantially, with the cut/pile/burn technique much cheaper even though that technique required chain saw crews consisting of multiple people as opposed to a masticator operated by a single individual.

Vegetation Responses

In general, thinning treatments stimulated the abundance of herbaceous vegetation, although in some cases the strength of the stimulation appeared to be constrained by the level of pre-treatment tree encroachment. Increases in perennial grass cover and density in response to thinning were usually greatest at lower levels of pre-treatment pinyon dominance, while native annual forb density and cover responded fairly equally along the tree-dominance gradient. The rapid recovery of annual forb vegetation in sites with high pinyon abundance didn't appear to be constrained by a lack of seed source, which is a particular concern for managers when applying treatments within highly tree-encroached shrublands. However, our findings suggest a lack of adequate seed sources and/or existing individuals appears to be limiting the initial response of perennial grasses in areas with high tree encroachment. At the higher levels of tree dominance, perennial grass cover within the thinning treatments did start to exceed the control by 3 years post-treatment, while perennial grass density was still similar or slightly lower than the controls. This seems to suggest that the thinning-induced increase in perennial grass cover within areas of high tree dominance is mainly due to an increase in growth of individuals present prior to the treatment, as opposed to an increase due to the recruitment of new individuals.

Shrub abundance exhibited a steep decline in response to tree encroachment and the response to thinning treatments appeared more subtle. Shrub cover within the control decreased slightly during the 3 post-treatment years, while it increased slightly within both thinning treatment. The response of slower-growing plants such as shrubs will need to be evaluated during future years to determine differences between thinning treatments.

Species richness within the two thinning treatments steadily increased relative to the control over the course of the 3 years following treatment, and the response was similar in both thinning treatments. Species richness was also consistent across the pinyon-dominance gradient, which suggests that the ability for vegetation to recover at this location may not be significantly limited by a lack of seed availability or lack of species diversity within highly tree-encroached shrublands. At this location, the distances between phase very low and very high tree-encroached areas are on the order of 100s of meters, which may not be enough to limit seed dispersal into areas of high tree cover.

Fuel-bed Responses

Both thinning treatments equally affected the target fuels, standing live pinyon trees. The cover of herbaceous live fuels (perennial and annual forbs and grasses) and live woody fuels (live shrubs and trees) were also similar between the two thinning treatments and higher than the control. The greatest difference in fuel structure between the two fuel treatments appeared to be dead woody fuel loads—mastication clearly resulted in greater fine fuel loads (1–100 hour fuels) as well as the shredded woody particles. The stimulation of live herbaceous cover—especially at lower pre-treatment pinyon dominance—may have important implications for fire spread by enhancing the continuity of surface fuels, especially during dry years.

Summary of Deliverables

Table 2. Summary of deliverables.

Deliverables	Delivery Dates
FY06 progress report	September 2006
FY07 progress report	Spring 2007
FY08 progress report	September 2008
Integrate preliminary results into NAFRI FIEM course	April, 2006, 2007, 2008, 2009
Fact sheets and other interpretive information	November 2010
Field workshop at the demonstration site	Spring 2009
Final report	November 2010
Project website	December 2010
Peer-reviewed journal articles	2011

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