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Ungulate exclusion, conifer thinning and mule deer forage in northeastern New Mexico

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ABSTRACT

The southwestern United States has experienced expansion of conifer species (*Juniperus* spp. and *Pinus ponderosa*) into areas of semi-arid grassland over the past century. The expansion of conifers can limit palatable forage and reduce grass and forb communities. Conifer species are sometimes thinned through hydraulic mulching or selective cutting. We assessed the effects of these treatments on mule deer (*Odocoileus hemionus*) habitat in northeastern New Mexico to determine if conifer thinning improved cover of preferred forage species for mule deer in areas with and without ungulates. We measured plant cover and occurrence of preferred forage species in the summers of 2011 and 2012. An ongoing regional drought probably reduced vegetation response, with preferred forage species and herbaceous cover responding to conifer thinning or ungulate exclusion immediately following treatment, but not the following year. In 2011, areas that received thinning treatments had a higher abundance of preferred forage when compared to sites with no treatment. Grass coverage exhibited an immediate response in 2011, with ungulate exclosures containing 8% more coverage than areas without exclosures. The results suggest that conifer thinning and ungulate exclusion may elicit a positive response, however in the presence of drought; the positive effects are only short-term.

1. Introduction

In the southwestern United States there has been a shift in structure and composition of vegetation communities within the past century, as juniper (*Juniperus* spp.) and ponderosa pine (*Pinus ponderosa*) stands have expanded and tree densities have increased (Belsky, 1996; Jacobs and Gatewood, 1999; Allen et al., 2002; Stoddard et al., 2008). These conifer expansions affect millions of hectares in the western U.S. (O'Rourke and Odgen, 1969; Pieper, 1990; Moore et al., 1999; Ansley et al., 2006). The expansion of juniper and ponderosa pine has had detrimental impacts on grassland systems, reducing herbaceous understory vegetation communities, exposing more bare ground, increasing soil erosion, depleting the soil-stored seed bank and disrupting the hydrological functioning of many sites (Allen et al., 2002; Stoddard et al., 2008). The causes of these conifer expansions are often attributed to anthropogenic factors such as overgrazing and fire suppression, exacerbated by recurring drought (Touchan et al., 1996; Clements and Young, 1997; Jacobs and Gatewood, 1999; Ansley et al., 2006).

Dense juniper and ponderosa stands often represent new stable plant communities that are very resistant to change. In areas of juniper and ponderosa removal, reestablishment of conifers is common where control efforts are not conducted frequently (Gottfried and Severson, 1994; Ansley and Rasmussen, 2005). These forests are often considered undesirable foraging habitat for ungulates due to the poor quality of available forage and lack of palatable understory plants caused by canopy closure and soil degradation (Kufeld et al., 1973; Lutz et al., 2003; Bender, 2006, Bender et al., 2007b) (Table 1). In areas that lack preferred species, Mule deer (*Odocoileus hemionus*) often exhibit low body fat and require larger home ranges to acquire adequate forage to maintain body condition (Boeker et al., 1972; Lawrence et al., 2004; Bender et al., 2007a, 2007b; Parker et al., 2009; Tollefson et al., 2010, 2011).

Selective cutting and hydraulic mulching have been used as restoration techniques aimed at returning areas of juniper and

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Table 1
Preferred grass, sedge, forb and shrub species found at the NRA Whittington Center, 2011–2012. Designation of preference by mule deer follows Kufeld et al. (1973) and Bender (2006).

Growth Form	Family	Species	Annual/Perennial
Graminoid	Cyperaceae	*Carex* spp.	Perennial
		Bouteloua curtipendula	Perennial
		B. eriopoda	Perennial
		B. gracilis	Perennial
		Schizachyrium scoparium	Perennial
Woody	Asteraceae	*Artemisia frigida*	Perennial
		A. ludoviciana	Perennial
	Chenopodiaceae	*Krascheninnikovia lanata*	Perennial
	Fagaceae	*Quercus gambelii*	Perennial
	Rosaceae	*Cercocarpus montanus*	Perennial
Forb	Asteraceae	*Helianthus praetermissus*	Perennial
	Chenopodiaceae	*Bassia prostrata*	Perennial
	Fabaceae	*Melilotus officinalis*	Annual/Perennial
		Psoralidium lanceolatum	Perennial
		Sphaeralcea coccinea	Perennial

ponderosa expansion to their original grassland-savanna ecotypes (O'Rourke and Odgen, 1969; Covington et al., 1997; Jacobs and Gatewood, 1999; Ansley and Rasmussen, 2005; Bates and Svejcar, 2009). Active forest thinning and restoration projects are becoming more common in juniper and ponderosa zones in the Midwest, Southwest, and the West (Severson and Boldt, 1977; Gibbs et al., 2004; Ansley and Rasmussen, 2005; Coultrap et al., 2008). Thinning of juniper and ponderosa can result in increased forage availability, affecting habitat use by mule deer (Gibbs et al., 2004). Immediate increases in herbaceous production and cover are often observed after thinning, though over the longer term (e.g., 7 years or more) production and cover can begin to decrease as conifers re-establish if treatments are not reapplied (Ansley and Rasmussen, 2005; Coultrap et al., 2008).

Ungulate exclusion can help elucidate the effect of herbivores on vegetation and has been used to assess the impacts of white-tailed deer (*Odocoileus virginianus*) (Ross et al., 1970; Webster et al., 2005; Goetsch et al., 2011) and livestock (Thaxton et al., 2010). Exclusion has also been used to reduce the intensity of browsing on plant communities in an attempt to increase herbaceous production and community diversity in areas of high ungulate densities (Webster et al., 2005; Goetsch et al., 2011) or where invasive ungulates have become problematic (Thaxton et al., 2010). Following ungulate exclusion there is often an increase in juvenile plants, especially forb species, and plant production and diversity. However, areas that are exposed to higher than average ungulate densities for extended periods of time often experience long-term effects that dictate how the community responds following the removal of grazing pressure due to seed bank degradation and increasing prevalence of invasive species (Webster et al., 2005; Thaxton et al., 2010; Goetsch et al., 2011).

To evaluate the impact of conifer removal on mule deer forage resources, we measured herbaceous response (herbaceous cover and herbaceous plant species richness) during the summers of 2011 and 2012 in areas that were subjected to confer thinning and areas that did not receive thinning treatments (control). Ungulate exclosures were constructed in both areas, with unfenced control plots paired with each exclosure. We hypothesized that areas which received conifer thinning would experience an increase in herbaceous cover and herbaceous plant species richness. We further hypothesized that areas of ungulate exclusion would experience an increase in herbaceous cover and herbaceous plant species richness due to the removal of grazing pressure. Lastly, we hypothesized that areas of thinning and ungulate exclusion would display the largest increases in cover and richness.

2. Material and methods

2.1. Study area

The NRA Whittington Center (WC; 36° 47′ N, 104° 30′ W), near the city of Raton, in Colfax County, in north-eastern New Mexico covers over 12,950 ha of semi-arid grassland and forest, and ranges in elevation from 2037 to 2400 m. Vegetation at the WC is similar to plant communities elsewhere in northeastern New Mexico (Armentrout and Pieper, 1988). Lower elevations (2000–2,300 m) are mostly grasslands and include species such as blue grama (*Bouteloua gracilis*), sideoats grama (*Bouteloua curtipendula*), little bluestem (*Schizachyrium scoparium*), and sand dropseed (*Sporobolus cryptandrus*). Fringed sagebrush (*Artemisia frigida*), winterfat (*Krascheninnikovia lanata*), and Gambel's oak (*Quercus gambelii*) are also common. At higher elevations (above 2300 m) the vegetation is dominated by Rocky Mountain juniper (*Juniperus scopulorum*), one-seed juniper (*Juniperus monosperma*), pinyon pine (*Pinus edulis*), ponderosa pine and Douglas fir (*Pseudotsuga menziesii*). The boundaries of the WC are fenced by three-strand barbed wire that has excluded livestock grazing since 1973 (Hild and Wester, 1998). Elk (*Cervus canadensis*), pronghorn (*Antilocapra americana*), mule deer, black bears (*Ursus americanus*) and mountain lions (*Puma concolor*) are also present.

The climatic conditions at the WC depend on aspect and elevation. The temperature varies throughout the year with high and low averages of 28.0° C and 12.9° C in July to 7.1° C and −7.3° C in January. Average annual precipitation on the WC is approximately 414 mm (SD = 110 mm), with the majority (62%) occurring between May and August (NOAA Weather Station COOP ID 297280; http://www.wrcc.dri.edu/).

In 2008 the WC began a series of opportunistic vegetation treatments in an effort to improve habitat conditions for mule deer by thinning juniper on 33 ha in Main Canyon. A hydraulic thinning head attached to an excavator was used to cut and mulch the woody vegetation to its base. This treatment continued in March 2009 and included another 97 ha of juniper and Gambel's oakbrush, creating 130 contiguous ha of treated vegetation in Main Canyon. In April 2010, juniper was thinned in 29 ha of Coal Canyon, again using a hydraulic thinning head. Finally, a private timber company began thinning areas of ponderosa pine, Douglas fir, and white fir (*Abies concolor*) at higher elevations via selective logging in 2010. Logging sites (hereafter referred to as timber) were selected based on ease of access and harvestable tree densities. Trees that were smaller than roughly 50 cm in diameter were cut at the stump and delimbed. Cut limbs were then gathered and left at the site for burning at the discretion of the center. In order to quantify the effect of thinning treatments, we recorded tree density and canopy cover, as well as understory herbaceous plant species richness and mule deer forage resource abundance in each of the thinned and unthinned areas.

2.2. Sampling methods

We sampled two areas (Main Canyon and Coal Canyon) where juniper was thinned through hydraulic mulching and one area (Timber Site) where ponderosa pine was thinned by selective logging. We paired each area with an adjacent, unthinned control. With the addition of the permanent control areas, six permanent experimental areas were established: Main Thinned (juniper thinned by hydraulic thinning in Main Canyon), Main Unthinned (juniper not thinned in Main Canyon), Coal Thinned (juniper thinned by hydraulic thinning in Coal Canyon), Coal Unthinned (juniper not thinned in Coal Canyon), Timber Thinned (ponderosa and other conifers thinned by selective logging at higher elevations), and Timber Unthinned (ponderosa not thinned at higher elevations). In each of the six experimental areas, we randomly placed five replicated exclosures. We used ArcGIS (ESRI, Inc., Redlands, CA) to determine the placement of the exclosures using random selection within polygons of the treatment areas. The exclosures were 5 m × 5 m, and were constructed of 3 m T-posts, which supported 1.2 m field fence and three strands of barbed wire, for a maximum height of 2.46 m, which we accepted as tall enough to prevent elk and mule deer from jumping into exclosures. We placed an additional 30 cm layer of chicken wire at the base of each exclosure to help exclude lagomorphs. We established a 1 m buffer along the inside perimeter of each exclosure to account for possible edge effects. An additional five non-exclosure plots were placed in each area. These plots were marked with pin flags and not fenced, but were used to record the same measurements as the true enclosures, allowing the difference between plant communities with and without ungulates to be quantified. While multiple species, including elk, deer, pronghorn, lagomorphs, etc., had access to the unfenced plots, we focused on evaluating the effects of exclosure and forest thinning on mule deer forage resources because this was the major impetus for WC to conduct the conifer thinning.

Within each exclosure and non-exclosure, herbaceous plant species richness and cover were recorded each year in late June to early July. We determined herbaceous plant species richness by identifying all species present within the 5 m × 5 m plot, including those within the 1 m buffer. Percent cover by species was assessed by adapting the point-intercept method from Herrick et al. (2009). We created a 1 m × 1 m grid inside the buffer, creating an area of 9 m^2 that contained 9 blocks. Within each block we recorded a total of 10 random points (representing soil surface and understory canopy) in each exclosure or non-exclosure, creating a total of 90 sampling points per plot. Plant species from cover estimates were categorized as preferred or non-preferred forage species according to the list provided by Bender (2006), which is a compilation of results found through a literature review and concurs with the results presented by Kufeld et al. (1973). By classifying species as preferred and non-preferred we were able to estimate the coverage of available forage that would be preferentially utilized by mule deer.

We also established five 100 m transects in each of the six areas (thinned and unthinned), and measured tree density and canopy cover in 2011. Tree data were not collected in 2012, because one year was considered insufficient time for tree recovery. We conducted nearest neighbor point-center quarter method every 10 m along each transect to determine tree densities (Chapman, 1976; Cooper, 1961; Etchberger and Krausman, 1997; Bender, 2006). The overall tree density (trees per hectare) of each area was calculated according to Chapman (1976). A spherical densiometer was also used every 10 m along the transects to calculate canopy cover following Chapman (1976).

Climatic data were recorded using a portable weather station and data logger (Onset Computer Corp., Bourne, MA) placed at the visitor camping area of the WC, approximately 500 m south of the treatment area in Main Canyon. The data logger was set to record precipitation once every hour. The data were summarized using HOBOware Pro® software and precipitation monthly averages were compared against 30-year historic averages obtained from the National Oceanic and Atmospheric Administration (NOAA Weather Station COOP ID 297280; http://www.wrcc.dri.edu/). Precipitation data for the WC were not available for the period between the first treatment (2008) and the start of vegetation surveys, so we used data collected from the NOAA Weather Station (ID 297280), located in Raton, New Mexico, to determine mean annual precipitation in the time between treatments and surveys.

All data were analyzed by using General Linear Model in JMP (JMP 2011) to compare effects of treatments on plant species response. Normality of the data was tested by Levene's test in SPSS (SPSS 2011). We tested the interaction of the independent variables, Thinning (Thinned vs. Unthinned), Area (Main vs. Coal vs. Timber) and Exclosure (Exclosure vs. non-exclosure), with plot number as a random effect via a Repeated Measures Factorial ANOVA. The dependent variables were tree density, tree canopy cover, herbaceous plant species richness, percent of preferred forage species, and percent herbaceous cover. Significant differences between means were identified with Tukey's HSD for three or more groups or Student's *t*-test when there were two comparable groups to determine respective differences.

3. Results

Both years had lower precipitation than the 30 year historic average (414 mm); 2011 received a total rainfall of 138 mm, and 2012 received a total rainfall of 100 mm (Fig. 1). The year of treatment (2008) and the two subsequent years before vegetation surveys (2009 and 2010), received higher amounts of precipitation (271 mm, 301 mm and 340 mm, respectively) than the survey years (2011 and 2012), but those amounts were still below the 30-year historic average. The effect of thinning on tree density depended on site ($F_{2,24} = 1.678$, $P = 0.017$), with the Main/unthinned site (mean = 860 trees/ha, SE = 182) having more than twice the density of trees as the Main/thinned site (mean = 303 trees/ha, SE = 70; Fig. 2a). Tree density did not differ between thinned and unthinned treatments in the other two sites. The effects of thinning on tree canopy cover also depended on site ($F_{2,24} = 3.05$ $P \leq 0.001$): Timber/unthinned (mean = 78%, SE = 9) had almost twice the canopy cover of Timber/thinned (mean = 47%, SE = 18), but the other two sites did not differ in treatment means (Fig. 2b).

We identified a total of 70 plant species at the NRA Whittington Center, including sedges, succulents, forbs, grasses and woody plants (Table 2). Herbaceous plant species richness was affected by the interaction of year by site ($F_{5,15} = 11.166$, $P = \leq 0.001$) and the interaction of year by thinning ($F_{3,26} = 6.203$, $P = 0.015$). Between 2011 and 2012, herbaceous plant species richness increased, with the Logged site experiencing the greatest increase from an average of 2.8 species per plot (SE = 0.27) to 7.65 individual species per plot (SE = 0.69; Fig. 2c). Herbaceous plant species richness between thinned and non-thinned plots were not different in 2011; both thinned and non-thinned sites underwent an increase in herbaceous plant species richness in 2012. Thinned plots experienced the

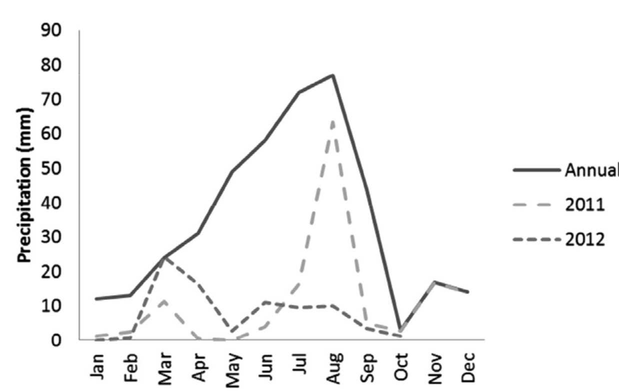

Fig. 1. Comparison of 30-year historic monthly rain average and 2011 and 2012 monthly precipitation (mm) in Raton, New Mexico. Historic average provided by National Climatic Data Center of the National Oceanic and Atmospheric Administration (NOAA ID20937).

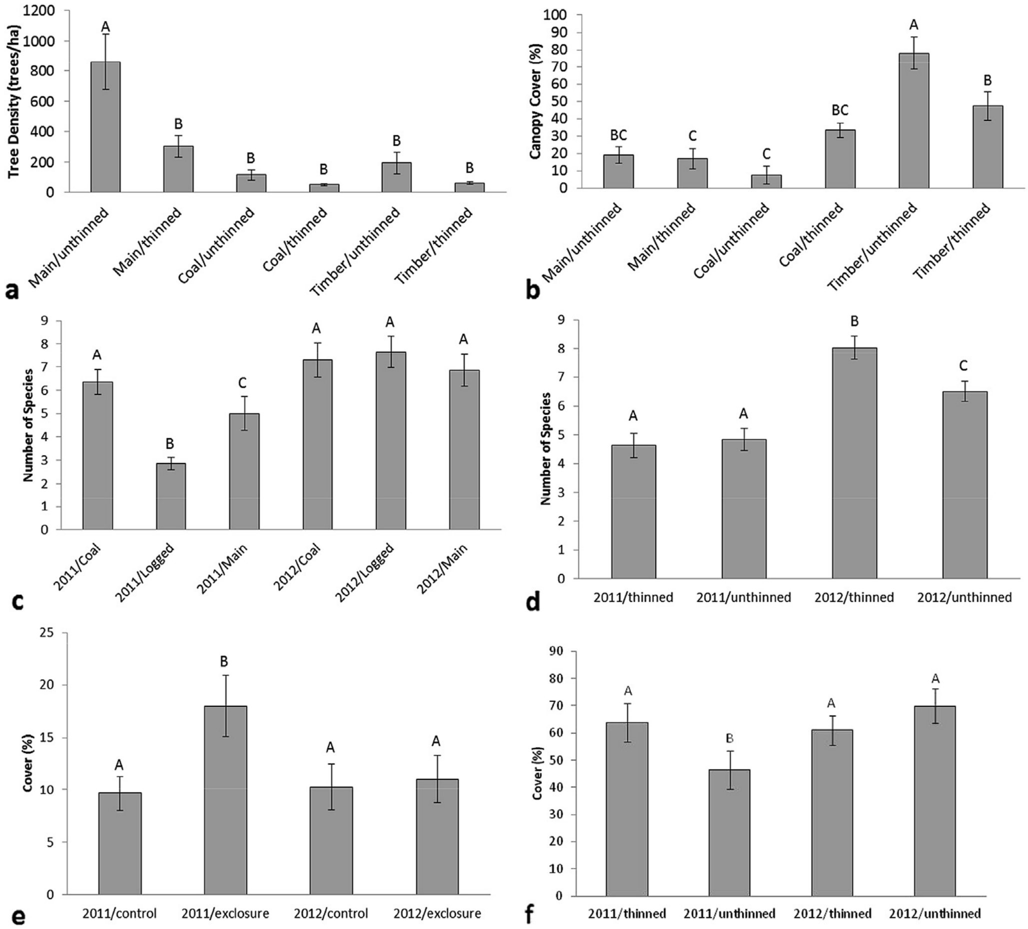

Fig. 2. Effect of area and thinning on tree density in 2011 (a) and (b) overstory canopy cover in 2011, (c) effect of year and site and (d) year and thinning on herbaceous plant species richness, (e) effect of year and ungulate exclosure on grass cover, and (f) effect of year and thinning on preferred forage cover (mean ± S.E.) at the Whittington Center, New Mexico. Means followed by the same letters are not significantly different ($\alpha = 0.05$).

greatest increase from an average of 4.63 plant species per plot (SE = 0.43) to 8.03 species (SE = 0.42) (Fig. 2d).

Grass cover was affected by the interaction of year by exclosure ($F_{3,26} = 5.217$, $P = 0.025$). There was a significantly higher grass cover in exclosure sites during 2011 (Mean = 18%, SE = 2.89), however the amount of grass cover in exclosures in 2012 decreased (Mean = 11%, SE = 2.26), and was similar to that of control sites in 2012. There was little change between grass cover in control sites from 2011 to 2012 (Mean = 9.67, SE = 1.64 and Mean = 10.3, SE = 2.18, respectively; Fig. 2e).

The percent of preferred vegetation was affected by the interaction of year by thinning ($F_{3,26} = 10.35$, $P = 0.002$). Preferred forage increased in unthinned plots from 2011 to 2012 (Mean = 46.51%, SE = 7.12, and Mean = 69.98%, SE = 6.23, respectively). While the percent of preferred forage in thinned plots increased, the increase was not statistically significant (Fig. 2f).

4. Discussion

Although we expected that thinning of juniper and ponderosa pine would increase herbaceous cover and herbaceous plant species richness, we found inconsistent effects of treatments depending on site and level of herbivory. The altering of tree density and canopy cover was not consistent between sites and did not result in an increase in preferred forage for mule deer in both juniper and ponderosa pine stands. We attribute this result to the opportunistic method of thinning conducted by the site operators. Thinning crews left a higher percentage of other woody plants (pinyon pine and Gambel's oak) standing, and specifically targeted juniper (D. Kramer, personal observation). In 2011, the percent of herbaceous vegetation considered preferred forage for mule deer was approximately 17% higher in sites that were thinned, compared to sites with no treatment. By 2012 the percent of preferred forage species did not differ between thinned and unthinned sites.

Forb and woody cover did not differ a year after treatment between thinned and unthinned sites, although the disruptive nature of the thinning process and the lack of precipitation following the treatment likely limited herbaceous recovery and response. Grass cover was approximately 8% higher within ungulate exclosures than in sites without ungulate fences one year after thinning, however grass cover decreased the following year. This suggests that thinning may have created an immediate opportunity for recovery, but the lack of precipitation limited the ability for grasses to flourish in the second year. More time will be required to adequately evaluate the responses of these vegetation communities to mechanical treatment (Jacobs and Gatewood, 1999; Ansley et al., 2006; Coultrap et al., 2008), even if annual precipitation is at or above historic averages.

By 2012, there was higher herbaceous plant species richness in two of the three thinned sites, but the increase was small with an additional 2.5 species per plot. Soil erosion associated with juniper and ponderosa pine systems may have resulted in the wash out of a

Table 2
Plant species found at the NRA Whittington Center, 2011–2012.

Form	Family	Species	Annual/Perennial
Graminoid	Cyperaceae	*Carex* spp.	Perennial
	Juncaceae	*Juncus tenuis*	Perennial
	Poaceae	*Agropyron cristatum*	Perennial
		Aristida divaricata	Perennial
		A. purpurea	Perennial
		Blepharoneuron tricholepis	Perennial
		Bouteloua curtipendula	Perennial
		B. dactyloides	Perennial
		B. eriopoda	Perennial
		B. gracilis	Perennial
		Bromus japonicus	Annual
		Elymus canadensis	Perennial
		E. elymoides	Perennial
		Muhlenbergia richardsonis	Perennial
		Panicum capillare	Annual
		P. obtusum	Perennial
		Pleuraphis rigida	Perennial
		Poa fendleriana	Perennial
		Schizachyrium scoparium	Perennial
		Sporobolus airoides	Perennial
		S. cryptandrus	Perennial
		S. giganteus	Perennial
Woody	Asteraceae	*Artemisia frigida*	Perennial
		A. ludoviciana	Perennial
	Chenopodiaceae	*Krascheninnikovia lanata*	Perennial
	Cupressaceae	*Juniperus monosperma*	Perennial
		J. scopulorum	Perennial
	Fabaceae	*Robinia neomexicana*	Perennial
	Fagaceae	*Quercus gambelii*	Perennial
	Pinaceae	*Abies concolor*	Perennial
		Pinus edulis	Perennial
		P. ponderosa	Perennial
		Pseudotsuga menziesii	Perennial
	Rosaceae	*Cercocarpus montanus*	Perennial
	Tamaricaceae	*Tamarix ramosissima*	Perennial
Form	Family	Species	Common name
Forb	Amaranthaceae	*Salsola tragus*	Annual
	Asteraceae	*Machaeranthera pinnatifida*	Perennial
		Carduus nutans	Perennial
		Stephanomeria pauciflora	Perennial
		Grindelia squarrosa	Annual/Perennial
		Helianthus praetermissus	Perennial
		Ratibida tagetes	Perennial
		Thelesperma filifolium	Annual/Perennial
		T. megapotamicum	Perennial
	Berberidaceae	*Mahonia repens*	Perennial
	Boraginaceae	*Plagiobothrys* spp.	Annual
	Chenopodiaceae	*Bassia prostrata*	Perennial
	Convolvulaceae	*Convolvulus arvensis*	Perennial
	Fabaceae	*Melilotus officinalis*	Annual/Perennial
		Astragalus flexuosus	Perennial
		Psoralidium lanceolatum	Perennial
	Geraniaceae	*Geranium* spp.	Perennial
	Liliaceae	*Allium geyeri*	Perennial
	Linaceae	*Linum perenne*	Perennial
	Malvaceae	*Callirhoe digitata*	Perennial
		Sphaeralcea coccinea	Perennial
	Onagraceae	*Gaura coccinea*	Perennial
	Papaveraceae	*Argemone hispida*	Perennial
	Polygonaceae	*Polygonum* spp.	Annual
	Rosaceae	*Fragaria virginiana*	Perennial
		Rosa woodsii	Perennial
	Scrophulariaceae	*Castilleja* spp.	Perennial
		Verbascum thapsus	Biennial
	Verbenaceae	*Verbena bracteata*	Annual/Perennial
		V. hastata	Perennial
Succulent	Agavaceae	*Yucca glauca*	Perennial
	Cactaceae	*Cylindropuntia imbricata*	Perennial
		Opuntia spp.	Perennial
		Pediocactus simpsonii	Perennial

large percentage of the seed bank (Pierson et al., 2007). Contrary to Brockway et al. (2002) who suggested that herbaceous plant species richness can increase in thinned areas, our results agree more with those of Coultrap et al. (2008), who found that juniper removal was unable to increase herbaceous plant species richness and alter community composition in northeastern California. The limited response of herbaceous plant species richness given both mechanical thinning and ungulate exclusion may be a result of long-term high intensity grazing which has been previously documented in areas of heavy deer foraging (Cote et al., 2004; Webster et al., 2005; Thaxton et al., 2010; Goetsch et al., 2011).

Simply conducting mechanical thinning may not be enough to increase production of favorable forage species in areas that have experienced juniper and ponderosa pine stand expansion and densification (Pase, 1958; Jacobs and Gatewood, 1999; Bender, 2006). Although such treatments can be successful, the observed lack of response in our study may be associated with the effects of the ongoing drought and the slow gradual recovery of the herbaceous community, which may take up to 6 growing seasons to recover after treatment (Ansley et al., 2006). A similar situation occurred in north-central New Mexico where drought occurred from 2002 to 2003 and resulted in below average herbaceous production (Bender et al., 2007b).

Climatic events such as drought can have profound effects on ecosystems, altering plant responses (Allen and Breshears, 1998; Breshears et al., 2005). The decrease in production and lack of herbaceous cover were probably directly related to the ongoing severe drought at the site. The exclusion of ungulates reduced plant herbivory, allowing a high percentage of graminoids, forbs and shrubs to grow and persist. In this particular study the drought may have amplified the effects of herbivory by limiting the opportunity for the plant community to produce enough material to meet ungulate off-take. The exclusion of grazers had a more profound effect on the herbaceous community than thinning of both pinyon-juniper and ponderosa pine, however the practicality of large-scale exclusion is limited.

5. Conclusions

In times of below average rainfall, ungulate exclusion may be necessary to elicit a more favorable herbaceous response after conifer thinning. In north east New Mexico, we observed that during drought, ungulate exclusion allowed the grass community to increase in cover after conifer thinning. Ungulate exclusion, though potentially time consuming and expensive, might aid in encouraging an increase in grass community growth, even when conditions might otherwise limit such a response. The shortage of rainfall during this study likely reduced vegetation responses, as has been observed elsewhere (Ansley and Rasmussen, 2005). Treatments to reduce juniper and ponderosa stands should be conducted following years of normal rainfall whenever possible and should involve a thorough management plan prior to treatment.

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