Rangeland Ecol Manage 67:455–467 | September 2014 | DOI: 10.2111/REM-D-13-00090.1

Region-Wide Ecological Responses of Arid Wyoming Big Sagebrush Communities to Fuel Treatments

David A. Pyke,[1] Scott E. Shaff,[2] Andrew I. Lindgren,[2] Eugene W. Schupp,[3] Paul S. Doescher,[4] Jeanne C. Chambers,[5] Jeffrey S. Burnham,[7] and Manuela M. Huso[6]

Authors are [1]Supervisory Research Ecologist, [2]Ecologist, [6]Supervisory Research Statistician, US Geological Survey, Forest & Rangeland Ecosystem Science Center, Corvallis, OR 97331, USA; [3]Professor and [7]Ecologist, Wildland Resources Department and the Ecology Center, Utah State University, Logan, UT 84322, USA; [4]Professor, Department of Forest Ecosystems and Society, Oregon State University, Corvallis, OR 97331, USA; and [5]Research Ecologist, US Department of Agriculture, Forest Service, Rocky Mountain Research Station, Reno, NV 89512, USA.

Abstract

If arid sagebrush ecosystems lack resilience to disturbances or resistance to annual invasives, then alternative successional states dominated by annual invasives, especially cheatgrass (*Bromus tectorum* L.), are likely after fuel treatments. We identified six Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* Beetle & Young) locations (152–381 mm precipitation) that we believed had sufficient resilience and resistance for recovery. We examined impacts of woody fuel reduction (fire, mowing, the herbicide tebuthiuron, and untreated controls, all with and without the herbicide imazapic) on short-term dominance of plant groups and on important land health parameters with the use of analysis of variance (ANOVA). Fire and mowing reduced woody biomass at least 85% for 3 yr, but herbaceous fuels were reduced only by fire (72%) and only in the first year. Herbaceous fuels produced at least 36% more biomass with mowing than untreated areas during posttreatment years. Imazapic only reduced herbaceous biomass after fires (34%). Tebuthiuron never affected herbaceous biomass. Perennial tall grass cover was reduced by 59% relative to untreated controls in the first year after fire, but it recovered by the second year. Cover of all remaining herbaceous groups was not changed by woody fuel treatments. Only imazapic reduced significantly herbaceous cover. Cheatgrass cover was reduced at least 63% with imazapic for 3 yr. Imazapic reduced annual forb cover by at least 45%, and unexpectedly, perennial grass cover by 49% (combination of tall grasses and Sandberg bluegrass [*Poa secunda* J. Presl.]). Fire reduced density of Sandberg bluegrass between 40% and 58%, decreased lichen and moss cover between 69% and 80%, and consequently increased bare ground between 21% and 34% and proportion of gaps among perennial plants > 2 m (at least 28% during the 3 yr). Fire, mowing, and imazapic may be effective in reducing fuels for 3 yr, but each has potentially undesirable consequences on plant communities.

Key Words: *Bromus tectorum*, resistance and resilience, fire, mowing, tebuthiuron, imazapic

INTRODUCTION

Sagebrush ecosystems are prevalent in the western United States, covering nearly 500 000 km^2 (Miller et al. 2011). Within the sagebrush biome, Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) communities occur on the most arid and some of the least productive lands. Shifts among community phases within reference states were historically driven by infrequent fires (around 100 yr; Baker 2011; Miller et al. 2011). These fires likely burned in mosaics, where fires removed woody species and shifted burned plant communities from shrub grassland mixtures to perennial grasslands with scattered sagebrush (Miller et al. 2011). After fires, cool-season bunchgrasses tended to dominate herbaceous component, whereas forbs likely were only minor components (generally less than 10% cover) within reference or relic communities (Franklin and Dyrness 1988; Miller et al. 2011).

Historical fire dynamics have been disrupted by land uses and introductions of fire-adapted plants. Since Euro-American settlement, livestock grazing supplanted fire as the most pervasive driver of community dynamics within Wyoming big sagebrush communities. Historically, these lands experienced inappropriate grazing practices that tended to shift plant communities from shrub-grass codominance to largely shrub-dominated communities with a minor component of perennial grass (Mack 1986; Knapp 1996; Miller et al. 2011). Introductions of invasive annual grasses such as cheatgrass (downy brome, *Bromus tectorum* L.) in the late 1800s quickly led to cheatgrass dominance of interspaces among perennial plants and to reductions in biological soil crusts that once dominated these positions within communities (Miller et al. 2011). Infilling of spaces between perennial plants led to a continuous fuel source that changed fire dynamics within these communities, substantially reducing intervals between fires (Brooks et al. 2004; Link et al. 2006; Miller et al. 2011).

Land managers are concerned about reducing the extent of wildfires, because fires threaten wildlife habitat and increase

This is Contribution Number 84 of the Sagebrush Steppe Treatment Evaluation Project (SageSTEP), funded by the US Joint Fire Science Program (05-S-08), the Bureau of Land Management, the National Interagency Fire Center, the Great Northern Land Conservation Cooperative, and the US Geological Survey.

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Correspondence: David A. Pyke, US Geological Survey, Forest and Rangeland Ecosystem Science Center, 3200 SW Jefferson Way, Corvallis, OR 97331, USA. Email: david_a_pyke@usgs.gov

Current address: Jeffrey S. Burnham, Washington Dept of Fish and Wildlife, Yakima, WA 98902, USA.

Manuscript received 6 June 2013; manuscript accepted 9 July 2014.

exotic species. Fuel management within Wyoming big sagebrush communities has several purposes (Pyke 2011). Reduction in woody plant dominance, most often represented by sagebrush, reduces fire intensity and severity. Fuel breaks that provide anchor points for fire suppression or allow fire managers to compartmentalize fires in smaller blocks are typical fuel treatment objectives (D. Havelina, Bureau of Land Management, National Interagency Fire Center, Boise, ID, USA, pers. comm.). In addition, fuel treatments along roads or travel corridors reduce the potential for fire spread into adjacent sagebrush communities, and reductions of annual grasses may decrease fire spread and size. In addition, there may be a release of fire-adapted perennial plants, increasing the opportunity for restoration of important species.

Fuel manipulations within Wyoming big sagebrush communities may be risky when cheatgrass is present, even if cheatgrass is not dominant before treatments. Prescribed fires potentially increase N availability (Rau et al. 2011), which may favor those cheatgrass seedlings from which seeds escape the fire and germinate (Miller et al. 2013). Mowing tends to reduce woody plant cover and may thin woody plant density if mowing heights are low (Davies et al. 2011; Hess and Beck 2012). However, with lower mowing height and more undulating soil surfaces, there is a risk of soil disturbance. This may create vegetation voids and safe sites for cheatgrass establishment and growth. In spite of this, shifts from cheatgrass-dominated to perennial-plant–dominated communities with adequate time indicate that some of these communities may have sufficient resilience to recover (Allen-Diaz and Bartolome 1998; Rew and Johnson 2010). Shrub reductions through chemical thinning with tebuthiuron modify fuel structure as dead plants or branches lose their leaves to the litter layer while increasing herbaceous plants that are released from competition (Olsen and Whitson 2002). Imazapic may have the potential for multiple years with reduced annual grass cover, thus likely reducing fine fuels after other fuel treatments are applied (Vollmer 2005; Davidson and Smith 2007), but other studies warn of death to or reduced cover of desirable herbaceous plants (Baker et al. 2009; Elseroad and Rudd 2011).

Most previous studies of sagebrush community dynamics consist of case studies within a local area on a single ecological site or across many locations with divergent dominant species; this may limit comparability (Allen-Diaz & Bartolome 1998; West and York 2002; Davies et al. 2011; Beck et al. 2012). To our knowledge, no one has attempted to apply consistent fuel-management techniques throughout a geographic region with the use of treatments and replicated sites with similar ecological potentials. Fuel treatments tend to disturb perennial bunchgrasses less than shrubs in the short term (Pyke et al. 2010); therefore adequate cover of perennial bunchgrasses may compensate for the loss of shrub cover after fuel treatments. Without adequate perennial bunchgrass cover, death of sagebrush individuals may increase spatial distances among perennial plants, leading to a potential increase in cheatgrass cover (Reisner 2010; Reisner et al. 2013). We wished to determine if pretreatment spatial distances of perennial plants might influence the posttreatment plant or soil surface responses after fuel treatments. In addition, we evaluated the impact of a factorial combination of fuel treatments (prescribed fire, mowing, tebuthiuron, and no treatment, with and without applications of imazapic) on biomass, cover, and density of major plant species or life forms (Wyoming big sagebrush, perennial grasses, annual and perennial forbs, and cheatgrass) as well as important land health indicators (cover of mosses and lichens, and of bare mineral soil) over 3 yr.

We addressed the following specific questions relating to the application of fuel treatments on relatively intact Wyoming big sagebrush-grassland communities across six sites in the northern Intermountain West: 1) what is the effect of fuel treatments on the cover, biomass and density of native perennial plants and on the invasive annual grass, cheatgrass; 2) can variance in responses be reduced by including the number or size of basal gaps among perennial plants; 3) do responses change over the first 3 yr after treatments; and 4) what is the effect of fuel treatments on indicators previously shown as being positively related to cheatgrass cover?

We anticipated that treatment applications would affect differentially not only species relative dominance (cover and biomass), but also the size and distribution of gaps among perennial vegetation and the cover of biological soil crusts. We hypothesized that prescribed fire would be the most disruptive to the community, because it not only temporarily reduces sizes of surviving plants, but it also kills some plants, creating space for surviving plants to expand and new plants to recruit. If communities are resilient, surviving perennial plants should increase their size relative to untreated areas, reducing indicators of potential cheatgrass expansion (interperennial plant gaps and bare soil). Three years is a typical monitoring and research period for tracking vegetation dynamics after treatments for drawing short-term conclusions; therefore, we examined these dynamics and report these initial findings.

METHODS

Our experiment was conducted on the seven locations of the SageSTEP 'sage-cheat' experiment (see map in McIver and Brunson 2014). The Roberts Idaho location was removed from analysis and will not be discussed further for two reasons: 1) a poor burn throughout the fire treatment; and 2) a wildfire that burned the majority of the location in the fourth year of study. Soils at the six remaining locations ranged from silty to coarse–loamy textures at elevations between 270 m in the Columbia Plateau of Washington to 1 800 m in the Great Salt Lake area of Utah (Table 1). Because of delayed timing of the fire treatment at Moses Coulee, this treatment was treated as missing for Moses Coulee, and was accounted for by the use of a maximum likelihood estimation in the analysis. Locations occurred in four states (Nevada, Oregon, Utah, and Washington) and covered five major land resource areas (Columbia Basin, Columbia Plateau, Malheur High Plateau, Owyhee High Plateau, and Great Salt Lake) (US Department of Agriculture, Natural Resources Conservation Service [USDA NRCS] 2006) and three Level III Ecoregions (Columbia Plateau, Northern Basin and Range, Central Basin and Range) (US Environmental Protection Agency [US EPA] 2011). None of these locations had burned in the last 50 yr, based on fire records from land owners. Cattle grazing (moderate utilization) was halted at least one growing season before treatments were applied. Grey