Sagebrush Steppe Ecology & Management – Research Progress Report 2008

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Influence of Long-Term Livestock Grazing Exclusion on the Response of Sagebrush Steppe Plant Communities to Fire

Kirk W. Davies, Tony J. Svejcar, and Jon D. Bates

For more information see: Davies, K.W., T.J. Svejcar, and J.D. Bates. *IN PRESS.* Interaction of historical and non-historical disturbances maintains native plant communities. Ecological Applications

Summary

Ecosystem management directed at restoring historical disturbance regimes may be inappropriate under modern conditions. Moderately grazing sagebrush plant communities with livestock, though not part of the historical disturbance regime, increased the tolerance of the perennial herbaceous vegetation to fire and promoted resistance to cheatgrass invasion. However, mimicking the historical disturbance regime of minimal large herbivore pressure and periodical fire promoted cheatgrass invasion. This study suggests that moderate levels of livestock grazing may be critical to protecting sagebrush plant communities and wildlife dependent on them.

Introduction

Historical disturbances are often considered a requirement to maintain native plant communities and this has resulted in the reconstruction of historical disturbance regimes to direct ecosystem management. However, some ecosystems have experienced irrevocable changes in environmental conditions and biotic potentials that could potentially alter the response of the plant community to disturbance. For example, climate change or invasive plants may result in different plant community response to disturbance than would be expected under historical conditions.

Livestock grazing of plant communities that did not evolve with large numbers of herbivores is generally considered negative, because livestock grazing was not part of the historical disturbance regime. These plant communities are not expected to be tolerant of livestock grazing pressure (Fleischner 1994, Noss 1994, Belsky and Blumenthal 1997, Jones 2000). In contrast to this assumption, light to moderate utilization by domestic livestock has been demonstrated to have minimal impacts on sagebrush plant communities (Manier and Hobbs

2006, Rickard 1985). However, the influence of grazing or not grazing prior to fire in these plant communities is unexplored.

We evaluated the impacts of grazing and not grazing prior to fire in Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) plant communities. Understanding the impacts of different disturbance patterns on Wyoming big sagebrush plant communities is important because most of these plant communities are grazed by domestic livestock, at risk of burning, and provide valuable habitat for wildlife. With the introduction of exotic annual grasses such as cheatgrass (*Bromus tectorum*), the impact of returning Wyoming big sagebrush plant communities to their historical disturbance regime of periodic fire without domestic livestock conditions is unknown under modern conditions.

Methods

The study was conducted on the Northern Great Basin Experimental Range (NGBER) in southeastern Oregon about 56 km west of Burns, Oregon. Treatments were: 1) ungrazed unburned, 2) ungrazed burned, 3) grazed unburned, and 4) grazed burned and were applied at three different sites. Ungrazed treatments were implemented with the erection of 2 ha grazing exclosures in 1936. Data collected in 1937 revealed no differences in the density of herbaceous vegetation between inside and outside the exclosure. Cheatgrass was not present inside or outside the exclosures in 1937. The grazed treatments were areas adjacent to the exclosures and had moderate livestock grazing (30-40% of available forage used) until 1990. Native herbivores had access to the exclosures. Prescribed burns were applied in the fall of 1993. Average fine fuel loads were 689 $\mathrm{kg \cdot ha^{-1}}$ in grazed treatments and 793 $\mathrm{kg \cdot ha^{-1}}$ in ungrazed treatments. Vegetation characteristics were sampled in 2005, 2006, and 2007 (12, 13, and 14 years post-burning).

Results

Cover

The interaction between burning and grazing influenced the cover of all herbaceous functional groups ($P < 0.01$; Fig. 1). Sandberg bluegrass cover decreased with burning and protection from grazing amplified this decrease ($P < 0.01$). Large perennial bunchgrass cover was greatest in the grazed burned treatment and lowest in the ungrazed burned treatment ($P < 0.05$). Although generally increased with burning, cheatgrass cover was more than 8.6-fold greater in the ungrazed burned treatment than any of the other treatments (*P* < 0.01). Similarly, annual forb cover, predominantly introduced annual forbs, was greatest in the ungrazed burned treatment (P < 0.05), while perennial forb cover was lowest in this treatment (P < 0.05). Moss cover was lowest in the ungrazed burned treatment and highest in the ungrazed unburned treatment (P < 0.05; Fig. 2). Burning decreased Wyoming big sagebrush cover and increased green rabbitbrush (*Chrysothamnus viscidiflorus*) cover (*P* = 0.01 and < 0.01, respectively). Grazing did not influence sagebrush cover (*P* = 0.43), but slightly increased rabbitbrush cover (*P* = 0.05).

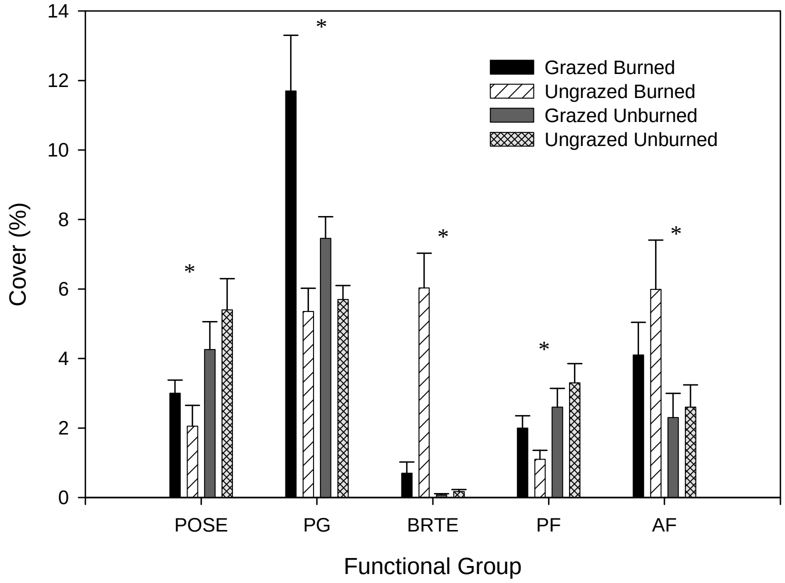

Figure 1. Functional group cover (mean + S.E.) of the treatments averaged over 2005, 2006, and 2007 at the Northern Great Basin Experimental Range. POSA = Sandberg bluegrass, PG = tall perennial bunchgrass, BRTE = cheatgrass, PF = perennial forb, and AF = annual forb. Ungrazed = livestock excluded since 1936, Grazed = moderately grazed by livestock until 1990, Burned = prescribed fall burned in 1993, and Unburned = no prescribed burning. Asterisk (*) indicates significant interaction between grazing and burning treatments for that functional group (*P* < 0.05).

Density

Large perennial bunchgrass, cheatgrass and green rabbitbrush densities were influenced by the interaction of burning and grazing (P < 0.01; Fig. 3). Large perennial bunchgrass density was lowest in the ungrazed burned treatment and highest in the grazed burned treatment with an approximately 1.9-fold difference between the two treatments (P < 0.01; Fig. 2). Burning decreased perennial bunchgrass density in the ungrazed treatment but did not influence bunchgrass density in the grazed treatment. Cheatgrass density was 15-fold greater in the ungrazed burned treatment (P < 0.01), than the other treatments which did not differ in density (P < 0.01). Perennial forb density was decreased by burning (P < 0.01), but was not influenced by grazing (P = 0.36). Burning generally increased green rabbitbrush density (P < 0.01); however the increase in density was largest in the ungrazed treatment.

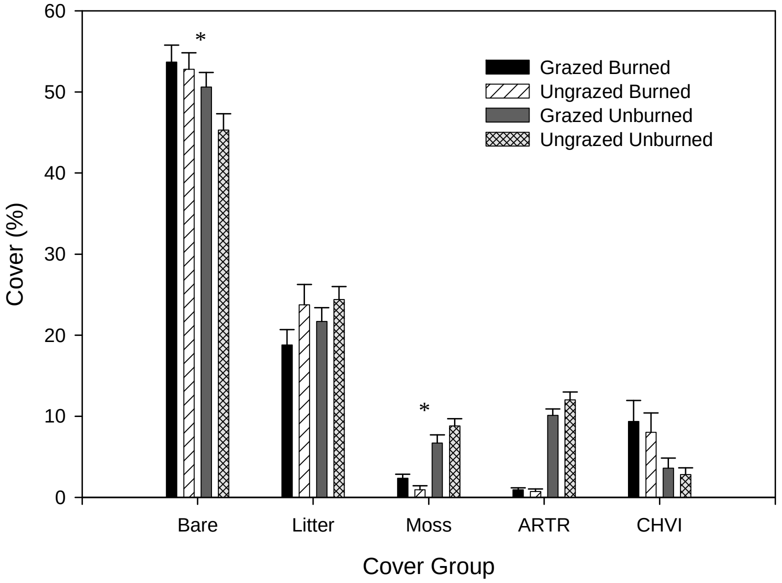

Figure 2. Shrub species, litter, and moss cover and bare ground (mean + S.E.) of the treatments averaged over 2005, 2006, and 2007 at the Northern Great Basin Experimental Range. Bare = bare ground, ARTR = Wyoming big sagebrush, and CHVI = green rabbitbrush. Ungrazed = livestock excluded since 1936, Grazed = moderately grazed by livestock until 1990, Burned = prescribed fall burned in 1993, and Unburned = no prescribed burning. Asterisk (*) indicates significant interaction between grazing and burning treatments for that cover group (*P* < 0.05).

Biomass

Large perennial bunchgrass production generally increased with burning (P < 0.01; Fig. 4). Bunchgrass production increased more with burning in the grazed compared to the ungrazed treatment (P < 0.01). Burning the grazed treatment increased perennial bunchgrass production 1.6-fold (P < 0.01). Cheatgrass biomass production increased more than 49-fold greater in the ungrazed burned treatment than in the other three treatments (P < 0.01). Perennial forb biomass production decreased 3-fold when the ungrazed treatment was burned (P < 0.01). Biomass production of annual forbs increased with burning (P < 0.01). However, the annual forb production was lowest in the ungrazed unburned treatment and highest in the ungrazed burned treatment (P < 0.01). In the ungrazed burned treatment, cheatgrass produced more biomass than all the perennial herbaceous vegetation combined (P < 0.01). Combining cheatgrass and annual forb production reveals that annuals produced 2.8-fold more biomass than perennial herbaceous vegetation in the ungrazed burned treatment (P < 0.01). The ungrazed burned treatment was the only treatment to produce more annual than perennial herbaceous vegetation biomass.

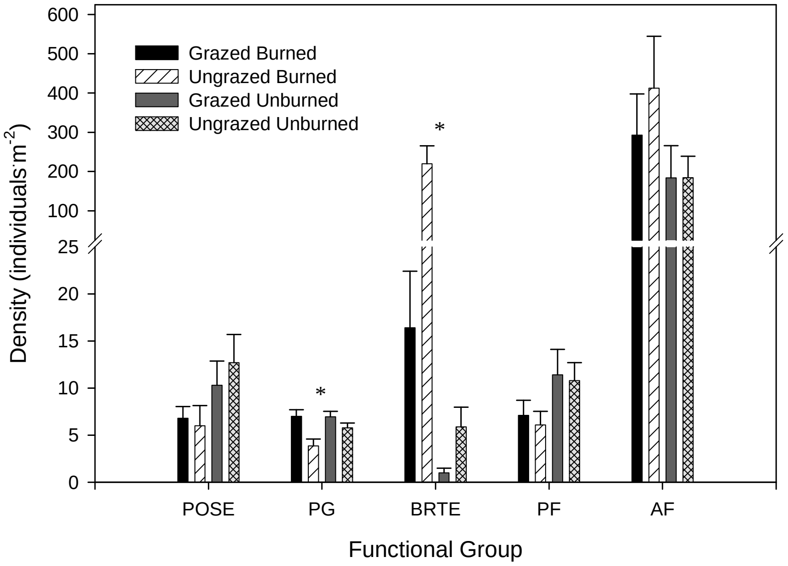

Figure 3. Functional group density (mean + S.E.) of the treatments averaged over 2005, 2006, and 2007 at the Northern Great Basin Experimental Range. POSA = Sandberg bluegrass, PG = tall perennial bunchgrass, BRTE = cheatgrass, PF = perennial forb, and AF = annual forb. Ungrazed = livestock excluded since 1936, Grazed = moderately grazed by livestock until 1990, Burned = prescribed fall burned in 1993, and Unburned = no prescribed burning. Asterisk (*) indicates significant interaction between grazing and burning treatments for that functional group ($P < 0.05$).

Discussion

Moderate levels of grazing by livestock in these plant communities increased the ability of the native herbaceous plants to tolerate fire and thus, prevented cheatgrass invasion. The invasion of the ungrazed treatment following fire has probably changed the future disturbance regime of those communities. The invasion of cheatgrass often increases fire frequency due to an increase in the amount and continuity of fine fuels. The invasion of cheatgrass and, subsequently, the altered future disturbance regime will negatively impact sage-grouse, pygmy rabbits, and other sagebrush obligate wildlife species.

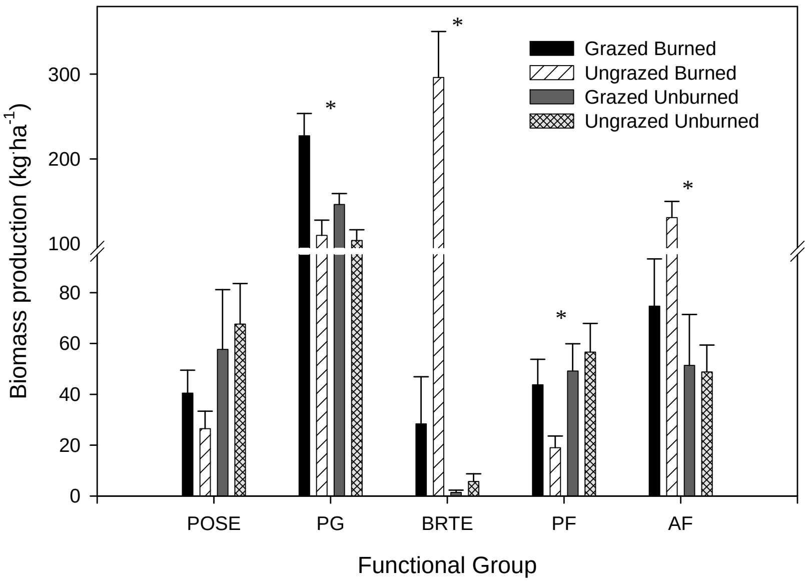

Figure 4. Functional group biomass production (mean + S.E.) of the treatments averaged over 2005, 2006, and 2007 at the Northern Great Basin Experimental Range. POSA = Sandberg bluegrass, PG = tall perennial bunchgrass, BRTE = Cheatgrass, PF = perennial forb, and AF = annual forb. Ungrazed = livestock excluded since 1936, Grazed = moderately grazed by livestock until 1990, Burned = prescribed fall burned in 1993, and Unburned = no prescribed burning. Asterisk (*) indicates significant interaction between grazing and burning treatments for that functional group ($P < 0.05$).

Moderate grazing probably mediated the impacts of fire because it reduced the amount of fine fuel. Less fuels, especially around perennial bunchgrasses, probably increased the survival of native herbaceous perennial vegetation. Mortality of perennial bunchgrasses would potentially open the plant community to cheatgrass invasion.

Though domestic livestock grazing was not part of the historical disturbance regime of these plant communities, it may now be needed because of new pressures from invasive plants and climate change. However, individual circumstances will dictate the value of emulating historical disturbance regimes for maintaining native plant communities. In our specific example, the historical disturbance regime of Wyoming big sagebrush plant communities is estimated to have consisted of a 50-100+ year fire return intervals (Wright and Bailey 1982; Mensing et al. 2006) and lacked large herbivore grazing pressure (Mack and Thompson 1982). Emulating this disturbance regime for Wyoming big sagebrush plant communities did not produce the expected effect of shifting the dominance from shrubs to native forbs and perennial grasses. Long-term protection from livestock grazing followed by fire resulted in substantial cheatgrass invasion and a large increase in non-native forbs.

Conclusions

Preventing grazing in Wyoming big sagebrush plant communities weakened the ability of the perennial herbaceous vegetation to tolerate fire. This could be the result of accumulation of fuels or a loss of adaptations important to tolerating disturbances. Low to moderate livestock grazing appears to be beneficial to the long-term sustainability of Wyoming big sagebrush plant communities and sagebrush obligate wildlife species.

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Shrub Microsite Influences Post-fire Perennial Grass Establishment

Chad S. Boyd and Kirk W. Davies

Summary

Density, height, and reproductive status of seeded perennial grass species were greater in burned Wyoming big sagebrush subcanopy microsites than in burned interspace microsites. Nonnative seedlings established more successfully than native seedlings.

Introduction

Establishment of desired vegetation is often needed after wildfires to restore ecosystem function and prevent invasion by exotic species. The probability of success when establishing desirable vegetation may vary with the spatial arrangement of resources in shrub communities. Shrubs, such as Wyoming big sagebrush, often create resource islands, areas of higher resource concentrations, beneath their canopies(Davies et al. 2007) and burning does not completely eliminate the resource island effect (Davies et al. 2009). The objective of this study was to determine if the success of post-fire seeded perennial grasses differed between interspace and subcanopy microsites.

Methods

This study was conducted in the Wyoming big sagebrush alliance approximately 65 km east of Burns, Oregon within a 13,000 ha area that was burned by wildfire in July of 2007. The five study sites were drill seeded with a seed mix that included 4.5 kg/ha (PLS) of crested wheatgrass (*Agropyron cristatum* L.), 2.2 kg/ha of Siberian wheatgrass (*Agropyron sibiricum* (Wild.) Beauv.), 2.25 kg/ha of bluebunch wheatgrass, 1.12 kg/ha of Secar bluebunch wheatgrass (*Elymus wawawaiensis* J. Carlson & Barkworth), 0.56 kg/ha of Great Basin wildrye (*Leymus cinereus* (Scribn. & Merr.) A. Love), and 0.56 kg/ha of Sandberg bluegrass (*Poa secunda* J. Presl).

In October of 2008, we identified five burned sites that had supported sagebrush at the time of burning. Sagebrush subcanopy microsites were associated with persistent dead woody material and were characterized by a blackened soil surface (Fig. 1); “persistent” indicated a sagebrush base with below-ground plant parts still anchoring it in place. We grouped seeded species and labeled *Agropyron* as “non-native” and the remaining genera as “native”.

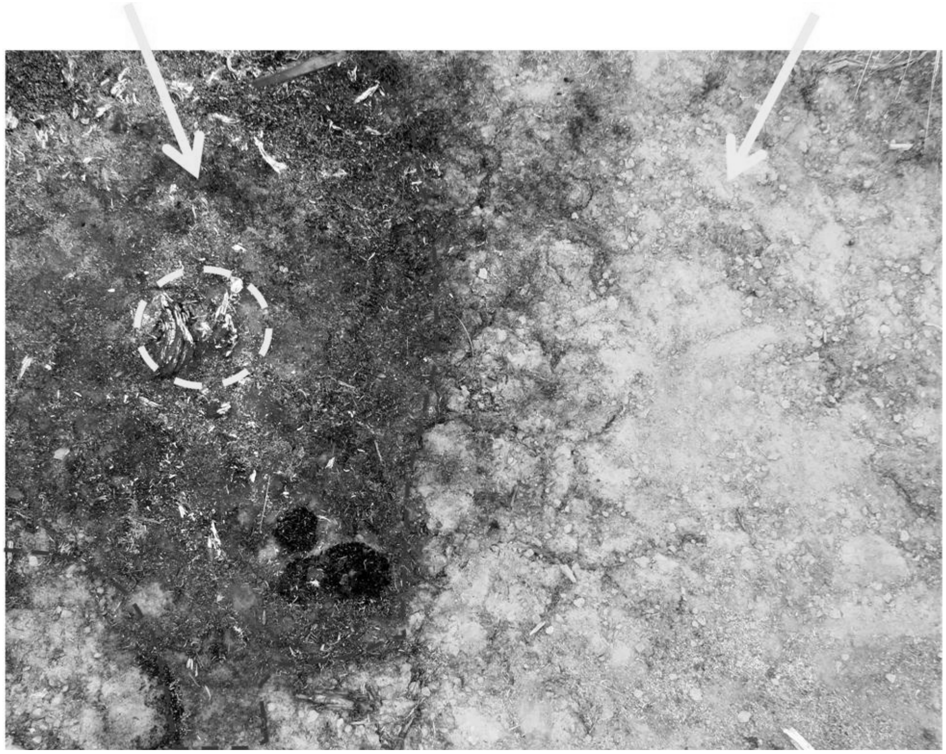

Figure 1. Following fire, areas within the sagebrush subcanopy appeared as blackened (left arrow) as compared to interspace areas (right arrow). Contiguous black areas were used to define subcanopy microsites and contiguous non-blackened areas were defined as interspace. Residual stump of original sagebrush is within dotted circle at left.

Results

Non-natives dominated the perennial grass seedling population ($P < 0.001$) based on density with 1.91 seedlings/0.2 m^2 (+/-0.49) compared to 0.25 seedlings/0.2 m^2 (+/-0.14) for natives. Density of non-native seedlings in subcanopy microsites (average = 3.3 seedlings/0.2 m^2 +/-0.34) was about six times higher ($p < 0.001$) than interspace microsites (average = 0.51 seedlings/0.2 m^2 +/-0.11, Fig. 2). For native seedlings, density at subcanopy microsites (average = 0.48 seedlings/ 0.2 m^2 +/-0.25) was 24 times higher ($P = 0.016$) than interspace microsites (0.02 seedlings/0.2m^2 +/-0.01, Fig. 2). In contrast to density, native and non-native seedlings had similar performance with respect to height ($P = 0.995$), but seedling height varied by microsite ($P < 0.001$). Seedling height for subcanopy microsites (across species) averaged 25.63 cm (+/-1.95) compared to 11.48 cm (+/-1.02) for interspace microsites (Fig. 2). In subcanopy microsites, a higher percentage of plots ($P < 0.001$) contained non-native reproductive seedlings (28% +/-4.9) compared to natives (3.0% +/-2.0, Fig. 2). The percent of subcanopy microsite plots containing native reproductive seedlings did not differ from the percent of interspace microsite plots containing native (*P* = 0.447) or non-native (*P* = 0.447) reproductive seedlings (Fig. 2). No reproductive seedlings were found within interspace microsites.

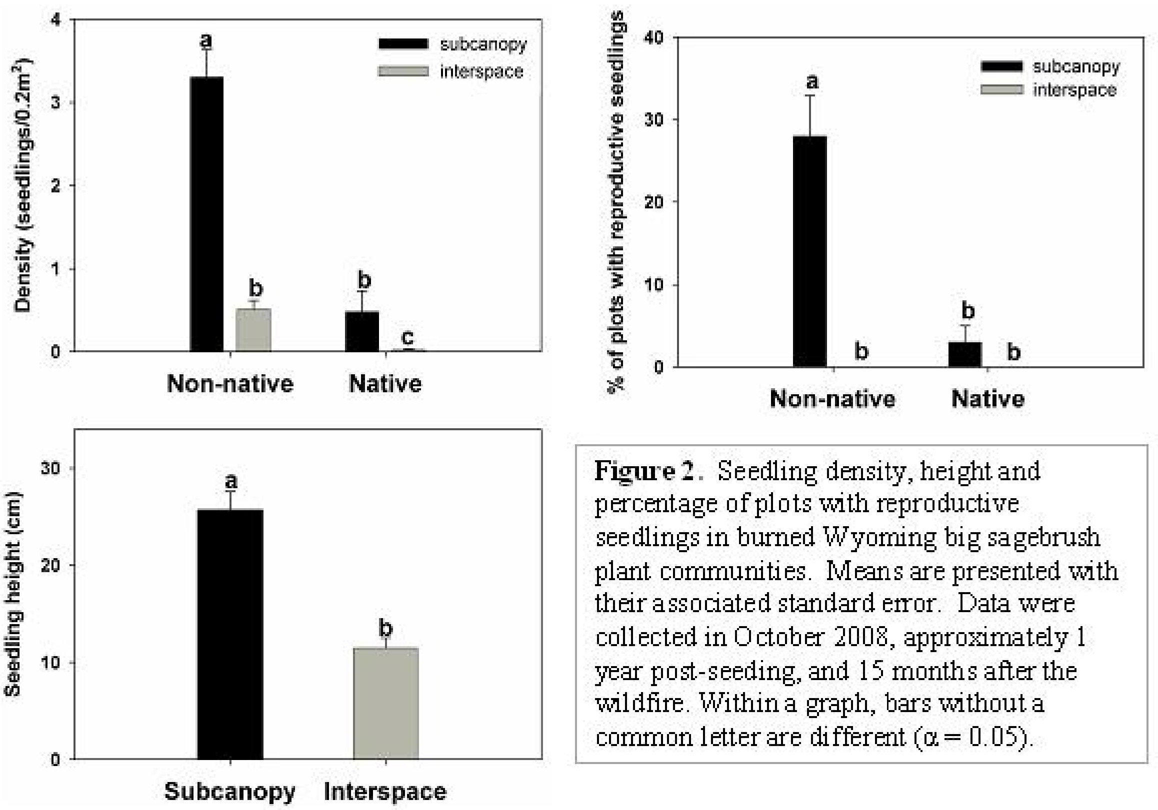

Figure 2. Seedling density, height and percentage of plots with reproductive seedlings in burned Wyoming big sagebrush plant communities. Means are presented with their associated standard error. Data were collected in October 2008, approximately 1 year post-seeding, and 15 months after the wildfire. Within a graph, bars without a common letter are different ($\alpha = 0.05$).

Discussion

Subcanopies were more conducive microsites for establishment and performance of perennial grasses seeded after wildfire. The 6 and 24-fold difference in density of introduced and native perennial bunchgrass, respectively, between burned subcanopies and burned interspaces, along with increases in height and reproductive effort of subcanopy seedlings, suggests that shrubs have significant influence on the spatial success of revegetation efforts. Our results are consistent with the idea that spatial heterogeneity of environmental and soil characteristics created by shrubs produces spatial heterogeneity in seedling success.

Our data also indicate that non-native perennial bunchgrasses were over seven times more likely to establish than native perennial bunchgrasses. Competition between non-native and native perennial bunchgrasses may have contributed to the limited establishment of native perennial bunchgrasses in our study. Clearly our work implies that with application of a native/non-native seed mix, non-native perennial bunchgrasses are more likely to be successful than native perennial bunchgrasses in revegetation of semi-arid sagebrush sites after wildfires. Increased success and lower cost have bolstered use of non-native perennial grasses compared to natives perennial grasses in post-fire rehabilitation of Wyoming big sagebrush communities (Eiswerth et al. 2009), particularly where the threat from annual grass invasion is high.

Conclusions

Shrub microsites exert a post-fire influence on community assembly and the heterogeneity of revegetation success as demonstrated by the greater establishment and performance of post-fire seeded perennial grasses (based on seedling density, height, and reproductive effort) in subcanopy compared to interspace microsites. Non-native perennial grasses were more successful (based on density and reproduction) than native perennial grasses and thus, non-native grasses may need to be included in seed mixes were the probability of establishing native species low and there is a need to revegetate to prevent erosion or invasive plant invasion. Our research suggest that determining the mechanism that facilitate greater establishment in burned subcanopy microsites may provide valuable information to revegetate sagebrush communities after fire.

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Microsite and Herbaceous Vegetation Heterogeneity after Burning Sagebrush Steppe

Kirk W. Davies, Jonathan D. Bates, and Jeremy J. James

For more information see: Davies, K.W., J.D. Bates, and J.J. James. 2009. Microsite and herbaceous vegetation heterogeneity after burning *Artemisia tridentata* steppe. Oecologia 159:597-606.

Summary

Wyoming big sagebrush creates resource islands and heterogeneity in plant communities. Burning appeared to reduce, but not eliminate the influence of resource islands on herbaceous vegetation within woody plant-dominated communities. This may have significant implications for community assembly and diversity.

Introduction

Arid and semi-arid ecosystems are often characterized by high levels of bare ground interspersed by distinct patches of vegetation. Woody vegetation, such as sagebrush, may facilitate the growth of other species under their canopies by creating microenvironments that are favorable for vegetation growth. There is limited information detailing the changes that occur between the interspace and subcanopy zones after a fire removes the woody vegetation. Existing information suggests that burning may reduce the soil heterogeneity between interspace and subcanopy zones. This may have significant implications for community assembly and diversity as plant diversity is positively correlated with soil heterogeneity.

The objective of this study was to determine the influence of fire on microsite and herbaceous vegetation spatial heterogeneity in woody vegetation (Wyoming big sagebrush)-dominated plant communities. We hypothesized that: 1) microsite and herbaceous vegetation differences exist between zones and prescribed burned (former) zones and 2) former subcanopy and interspace zones differ in microsite and herbaceous vegetation characteristics.

Methods

This study was conducted at the Northern Great Basin Experimental Range (NGBER), in southeastern Oregon about 56 km west of Burns, Oregon. Six sites (blocks) with varying soils and herbaceous vegetation dominance, composition, cover, density and biomass production were selected for the experiment. Prior to prescribed burning, the sites were determined to be late seral Wyoming big sagebrush-dominated plant communities based on criteria in Davies et al. (2006). Tall tussock perennial bunchgrasses dominated the understory and exotic annual grasses were only a minor component (< 0.1% cover) of the plant communities. One half of each block was prescribed burned in October 2002.

Relative humidity, air and soil temperature, and photosynthetically active radiation (PAR) measurements and soil surface texture were recorded in each zone and former zone per site. Soil pH, total carbon, total nitrogen, water content and organic matter in the upper 15 cm (water content also in the15-30 cm) of the soil profile from each zone and former zone per site were determined. Vegetation parameters measured were herbaceous cover, biomass, density, photosynthetic rate, carbon and nitrogen isotope ratios, and carbon and nitrogen content.

Results

Micro-environment and Soil Characteristics

Maximum daily soil temperatures varied between subcanopies and burned subcanopies ($P < 0.01$) and between burned subcanopies and burned interspaces ($P < 0.05$); however, it did not vary between interspaces and burned interspaces ($P = 0.09$). Burned subcanopies were on average 15.7 and 3.2˚C warmer than subcanopies and burned interspaces, respectively.

Soil organic matter, pH, total carbon, and total nitrogen were greater in burned subcanopies than burned interspaces ($P < 0.05$). Soil organic matter, total carbon, and total nitrogen did not differ between subcanopies and burned subcanopies or between interspaces and burned interspaces ($P > 0.05$). Across the growing season burned subcanopies generally had greater NO_3^- and NH_4^+ concentrations than burned interspaces. Burned subcanopies also had greater NO_3^- and NH_4^+ concentrations than subcanopies ($P < 0.01$), but NO_3^- and NH_4^+ concentrations did not differ between interspaces and burned interspaces ($P > 0.05$).

Soil water content (0-15 cm) varied by sampling date ($P < 0.01$), but did not differ between burned subcanopies and burned interspaces, between interspaces and burned interspaces, or between subcanopies and burned subcanopies ($P > 0.05$) (Fig. 3). Soil water content (15-30 cm) did not vary between burned subcanopies and burned interspaces, between interspaces and burned interspaces, or between subcanopies and burned subcanopies ($P > 0.05$).

Vegetation

Tall tussock perennial grass, Sandberg bluegrass, perennial forb, annual grass, annual forb, total herbaceous, litter, and moss cover and bare ground did not differ between burned subcanopies and burned interspaces (*P* > 0.05). Tall tussock perennial grass, Sandberg bluegrass, annual grass, litter, and moss cover were greater in subcanopies than burned subcanopies (*P* < 0.05). Litter and Sandberg bluegrass cover were greater in interspaces than burned interspaces (*P* < 0.05), but tall tussock perennial grass, annual grass, perennial forb, bare ground, total herbaceous, and moss cover did not differ between interspaces and burned interspaces (*P* > 0.05).

Tall tussock perennial grass and total perennial grass (tall tussock perennial grass and Sandberg bluegrass) densities were greater in burned subcanopies than burned interspaces (*P* = 0.04 and 0.03, respectively). Tall tussock perennial grass, total perennial grass, and Sandberg bluegrass densities did not differ between subcanopies and burned subcanopies or between interspaces and burned interspaces (*P* > 0.05).

Herbaceous functional groups and total herbaceous biomass production did not differ between burned subcanopies and burned interspaces (*P* > 0.05). Annual grass and Sandberg bluegrass biomass production was greater in subcanopies than burned subcanopies and tall tussock perennial grass and perennial forb biomass production was less in subcanopies than burned subcanopies (*P* < 0.05). Annual grass and Sandberg bluegrass biomass production was greater in interspaces than burned interspaces and perennial forb and tall tussock perennial grass biomass production was less in interspaces than burned interspaces (*P* < 0.05).

Discussion

Burning appeared to reduce the influence of resource islands on herbaceous vegetation within woody plant-dominated communities. Prescribed burning of Wyoming big sagebrush-bunchgrass communities decreased microsite and herbaceous vegetation heterogeneity within a stand. The structural diversity created by Wyoming big sagebrush canopies was removed with burning but burning did not completely eliminate the heterogeneity of resource concentrations created by the sagebrush. Burning eliminated or greatly reduced micro-environmental differences between subcanopies and interspaces. Soil resource differences, however, were common after burning. Herbaceous vegetation characteristics differed between intact and burned locations, suggesting that burning alters the spatial heterogeneity of herbaceous vegetation created by woody vegetation. The effects of prescribed burning on herbaceous vegetation cover and production were depended on functional group and location. The heterogeneity in herbaceous vegetation characteristics was largely eliminated with burning; except that perennial herbaceous density differences remained. Density differences between burned subcanopies and burned interspaces were probably an artifact of prior densities and not the result of significant differences in resource availability to herbaceous vegetation.

Our results suggest that disturbances that remove woody vegetation reduced microsite and herbaceous vegetation heterogeneity within plant communities but do not completely remove the resource island effect.

Conclusions

Burning appears to largely eliminate micro-environmental differences between subcanopies and interspaces and thus, decreases herbaceous vegetation heterogeneity within plant communities. However, burned subcanopies and burned interspaces differed in soil resources, which may promote heterogeneity of vegetation composition and productivity over time. Burning does not eliminate the resource island, but may reduce its affects on herbaceous vegetation. However, seedling establishment may vary between burned subcanopies and burned interspaces due to the difference in soil resources. This study demonstrates the importance of woody vegetation to heterogeneity in plant communities and that resource islands exist even after disturbances have removed the woody vegetation, which probably influences diversity and community assembly.

Post-fire Succession in Big Sagebrush Steppe with Livestock Grazing

Jonathan D. Bates, Edward C. Rhodes, Kirk W. Davies, and Robert N. Sharp

For more information see: Bates, J.D., E.C. Rhodes, K.W. Davies and R. Sharp. 2009. Postfire succession in big sagebrush steppe with livestock grazing. *Rangeland Ecology & Management* 62: 98-110.

Summary

Moderately grazing one growth cycle after prescribed fire did not slow the recovery of herbaceous plant communities in Wyoming big sagebrush steppe. This study suggest that a standard rule of waiting two growing seasons after fire to return livestock grazing is not always necessary. However, it does not suggest that livestock grazing can always be reinstated the first year after fire.

Introduction

Fire has been a natural and prescribed disturbance of big sagebrush communities that temporarily shifts vegetation from shrub-grass co-dominance to grass dominance. A typical management policy adopted on publicly administered rangelands of the Intermountain Region is that following prescribed burning or wildfire, rangelands are rested from livestock grazing for a minimum of two years (Bureau of Land Management 2007). Post-fire defoliation and grazing study results suggest that the timing, use, and duration of grazing of burned rangelands are more important than a specific period of rest after fire. In 2001, we developed a study to evaluate post-fire herbaceous recovery of sagebrush steppe in eastern Oregon, as influenced by season of grazing.

Methods

This study was conducted at the Northern Great Basin Experimental Range, 56 km west of Burns, Oregon. The effects of cattle grazing to post-fire recovery of herbaceous vegetation were evaluated during four growing seasons. Five 12.6 ha blocks were established in 2001. Within each block, six 2.1-ha plots were randomly assigned to the treatments. All treatments were replicated 5 times. The treatments were 1) Summer 1, grazed the first 2 years after fire in August

2003 and 2004; 2) Summer 2, grazed the second and third summer after fire in August 2004 and 2005; 3) Spring 1, grazed the second and third spring after fire in May 2004 and 2005; 4) Spring 2; grazed the third spring after fire in May 2005, which is equivalent to many current postfire grazing programs; 5) Burn, no grazing after fire; and 6) Unburned, not burned or grazed. Prescribed burning was completed in late September and early October 2002. Grazing was managed to remove 40-50% of herbaceous standing crop in all grazed treatments.

Results

Herbaceous Standing Crop and Annual Yield

The first year after burning (2003), standing crop was greater in the Unburned treatment than all burned treatments (grazed and not grazed). By the third growing season (2005), herbaceous standing crop was greater in all the burned treatments (grazed and not grazed) than the Unburned treatment (Fig. 1). In contrast to standing crop results, differences among the burn-grazed treatments and the Burn treatment were less apparent for total herbaceous and perennial grass yields in 2005 and 2006 (Figs. 2A and 2B).

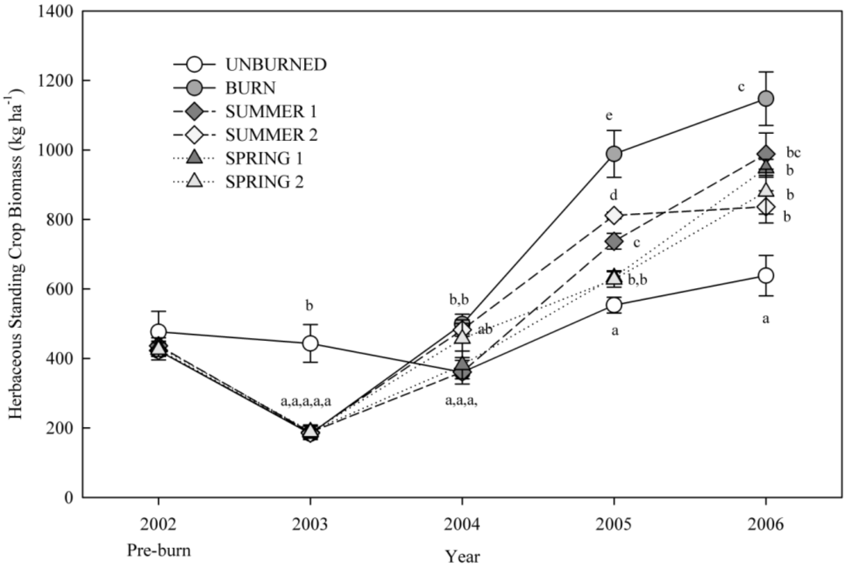

Figure 1. Herbaceous standing crop (kg · ha^{-1}) for the burn–grazing treatments (Burn, Spring 1, Spring 2, Summer 1, Summer 2) and unburned treatment in Wyoming big sagebrush steppe, Northern Great Basin Experimental Range, Oregon, June 2001–2006. Values represent means ± one standard error. Different letters indicate significant differences ($p < 0.05$) among the treatments within year.

Functional Group Canopy Cover, Density and Species Presence

After the first year post fire, perennial grass cover increased with burned (grazed or ungrazed) treatments; however, unlike annual yield, cover values did not differ from the Unburned treatment (Fig. 3A). Annual forb cover was greater in burned (grazed and ungrazed) treatments than in the Unburned treatment from the 2nd through 4th year after fire (2004-2006; Fig. 3D). Sandberg bluegrass (*Poa secunda* J. Presl.) increased in all treatments in 2003 ($p < 0.05$); but had returned to pretreatment levels by 2005.

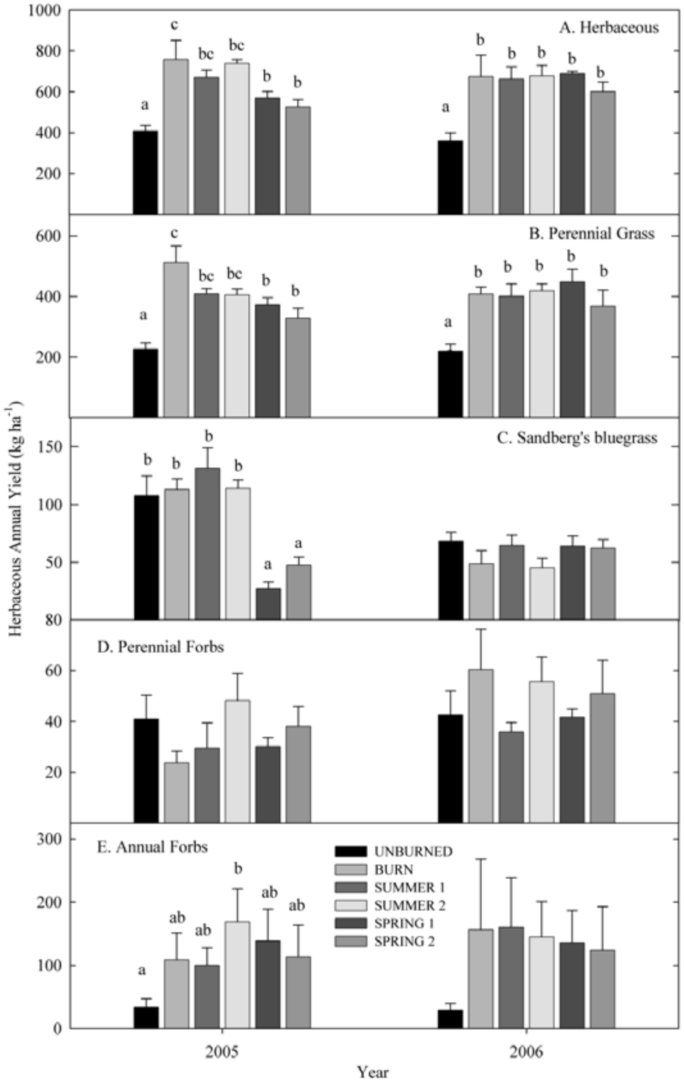

Figure 2. Annual yield values (kg · ha^{-1}) for **A**, herbaceous, **B**, perennial bunchgrasses, **C**, Sandberg's bluegrass, **D**, perennial forbs, and **E**, annual forbs for the burn–grazing treatments (Burn, Spring 1, Spring 2, Summer 1, Summer 2) and unburned treatment in Wyoming big sagebrush steppe, Northern Great Basin Experimental Range, Oregon, June 2005–2006. Values represent means ± one standard error. Different lowercase letters indicate significant differences ($p < 0.05$) among the treatments within year.

Ground Cover

The first year after burning (2003), herbaceous cover was greater in the Unburned than all burned treatments than all burned treatments (grazed and ungrazed). By the second growing season after fire (2004) herbaceous cover was not different among the treatments and by 2005 and 2006, cover was greater in all the burned treatments than the Unburned treatment (Fig 4A); primarily as a result of greater annual forb cover (Fig. 3D).

Moss and other biotic crust increased in the Unburned treatment between 2002 and 2004 and remained 3.5-4 times greater than the burned treatments (grazed and ungrazed; Fig. 4B).

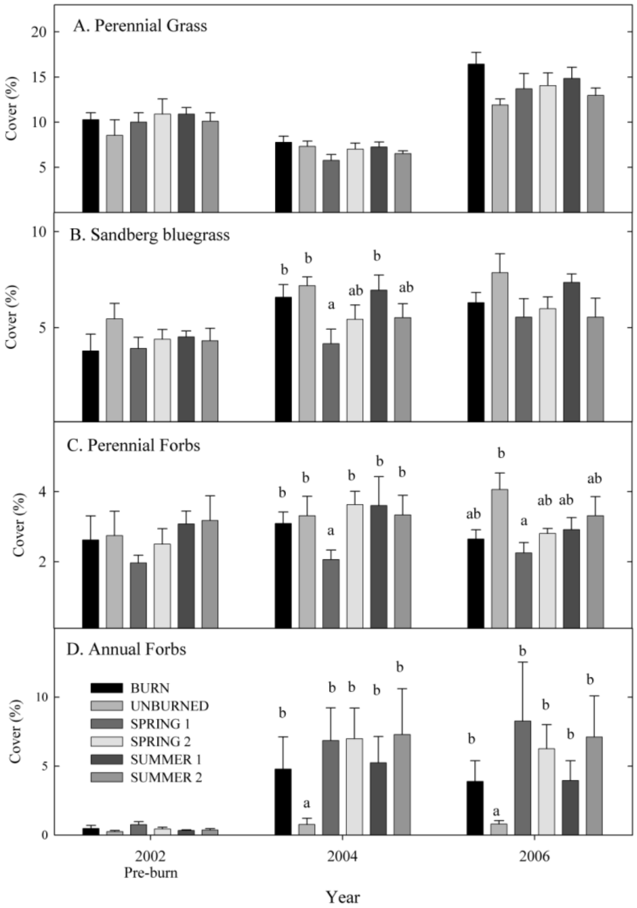

Figure 3. Canopy cover values (%) for the burn–grazing treatments (Burn, Spring 1, Spring 2, Summer 1, Summer 2) and unburned treatment in Wyoming big sagebrush steppe, Northern Great Basin Experimental Range, Oregon, June 2002, 2004, and 2006. **A**, Perennial bunchgrasses, **B**, Sandberg's bluegrass, **C**, perennial forbs, and **D**, annual forbs. Values represent means ± one standard error. Different lowercase letters indicate significant differences ($p < 0.05$) among the treatments within year.

Discussion

Livestock grazing during the first several years after prescribed fire in the big sagebrush steppe has often been considered to be incompatible with herbaceous recovery. This study suggests that moderate grazing, following completion of the 1st growth cycle after prescribed fire, does not limit herbaceous recovery in Wyoming big sagebrush steppe.

The response of herbaceous vegetation after fire, whether grazed or not grazed, was comparable to results from other postfire (prescribed and wildfire) studies in big sagebrush systems. Herbaceous cover, standing crop, and annual yields in the Burn and burn-grazed treatments equaled or exceeded the unburned treatment by the 2nd (2004) or 3rd (2005) year after fire. The increases in annual yield (perennial grasses and annual forbs) were likely influenced by a combination of sagebrush removal and favorable postburn growing conditions (e.g. above-average precipitation) between 2004 and 2006. Another factor for the rapid and progressive herbaceous response was a lack of mortality among bunchgrass species, indicating a fire of low severity.

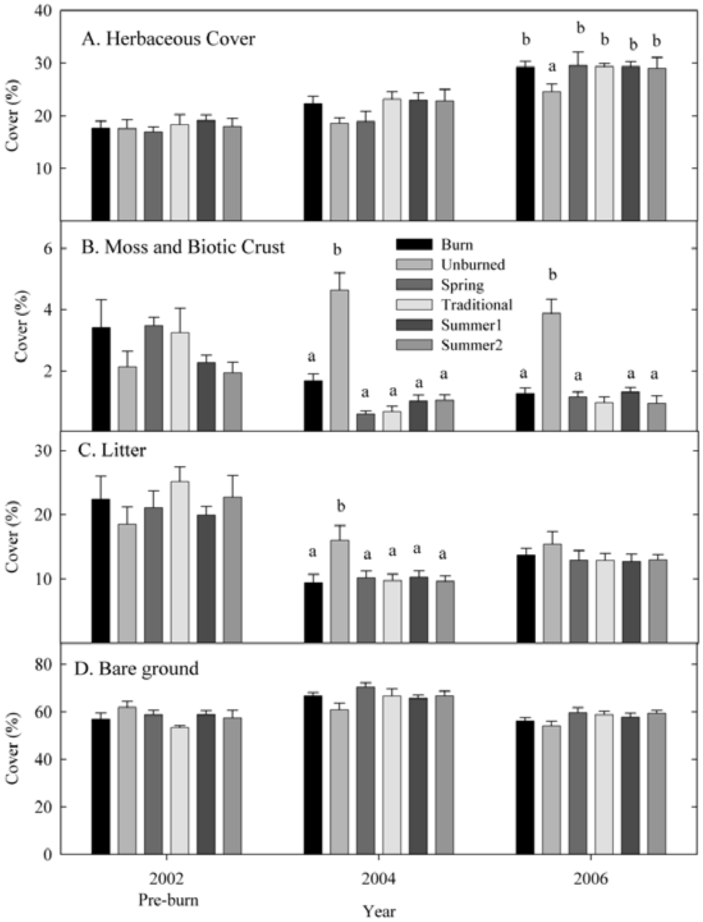

Figure 4. Ground cover values for the burn–grazing treatments (Burn, Spring 1, Spring 2, Summer 1, Summer 2) and unburned treatment in Wyoming big sagebrush steppe, Northern Great Basin Experimental Range, Oregon, June 2002, 2004, 2006. **A**, Herbaceous, **B**, soil surface litter, **C**, moss and biotic crust, and **D**, bare ground and rock. Values represent means ± one standard error. Different lowercase letters indicate significant differences ($p < 0.05$) among the treatments within year.

Our results indicate that burning can successfully stimulate herbaceous native species and not induce an increase of cheatgrass with or without grazing. This study suggests that burning Wyoming big sagebrush communities may not increase the abundance or yield of perennial forbs. The lack of perennial forb response may result from the high survival of perennial grasses, which recovered quickly after the fire, as well as the large increases in pale alyssum.

Conclusions

This study demonstrated that properly applied livestock grazing one growth cycle after prescribed fire did not slow the recovery of herbaceous plant communities in Wyoming big sagebrush steppe and that requiring grazing rest the first 2 yr after fire to encourage herbaceous recovery may not be necessary in all situations. Nevertheless, the results and interpretations of this study must be considered under the conditions it was conducted. The trials were performed on a distinct big sagebrush site, with fires causing minimal, if any, mortality to perennial bunchgrasses; with a lack of a significant weed presence; and with strictly controlled grazing protocols. One or more of these elements will vary in other situations generating a host of post-fire recovery scenarios. Study plots were small and we managed to obtain uniform grazing use. Our study has only provided a short-term herbaceous response to grazing after fire in sagebrush steppe. Management should not be hasty in disregarding past recommendations for grazing rest after fire in sagebrush steppe; however, mounting evidence also indicates that post-fire grazing decisions can be applied more flexibly to meet vegetation recovery goals. However, this is the first study of spring grazing in sagebrush steppe after fire, and the trials only evaluated defoliation during vegetative and early boot stages of growth of the larger perennial bunchgrasses. At this point, grazing sagebrush steppe in the spring during the first 2 yr after fire should be applied cautiously until additional information becomes available.

References

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Influence of Mowing Wyoming Big Sagebrush on Wildlife Winter Habitat

Kirk W. Davies, Jonathan D. Bates, Dustin D. Johnson, and Aleta M. Nafus

For more information see: Davies, K.W., J.D. Bates, D.D. Johnson, and A.M. Nafus. *IN PRESS*. Influence of mowing *Artemisia tridentata* ssp. *wyomingensis* on winter habitat for wildlife. Environmental Management DOI 10.1007/s00267-008-9258-4.

Summary

All sagebrush structural characteristics were recovering from mowing; however, some characteristics appear to require ~ 20 yrs to become fully recovered. The reduction in sagebrush from mowing is of a concern for sagebrush obligate and facultative wildlife species, especially in their winter habitat.

Introduction

Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) communities occupy vast potions of the western United States and provide important habitat for wildlife and forage for domestic livestock. Mowing is commonly implemented in this community in an attempt to improve wildlife habitat, increase forage production for livestock and create fuel breaks for fire suppression. However, information about the influence of mowing on the winter habitat for wildlife is lacking. This information is critical because many wildlife species depend on Wyoming big sagebrush plant communities for winter habitat and consume significant quantities of sagebrush at this time. The nutritional quality of sagebrush is important for the many wildlife species whose winter diets have a high sagebrush component including sage-grouse, pronghorn, and mule deer. Mechanical treatment may increase the number of younger sagebrush in a stand as younger, smaller sagebrush plants are more likely to survive. Juvenile Wyoming big sagebrush leaves have been found to contain higher crude protein content than more mature plants (Wambolt 2004). Additionally, there is a lack of information describing the recovery of Wyoming big sagebrush after mowing and the impacts of mowing on stand structure.

Methods

The study area encompassed 350,000 ha in the High Desert Ecological Province (Anderson et al. 1998) in eastern Oregon. Wyoming big sagebrush was mowed at various locations across the study area zero, two, four, and six years prior to sampling. Six sites per post-treatment time interval were randomly selected for sampling. Each mowed plot was blocked with an adjacent untreated (control) plot. Each blocked treated and control plot had uniform soil and topography. Mechanical treatments were implemented in September and October with a John Deere 1418 rotary cutter (Deere & Company, Moline, IL, USA). Sagebrush was mowed at 20 cm height above the soil surface. Response variables include Wyoming big sagebrush cover, density, and leaf nutritional quality.

Results

Cover and Density

Wyoming big sagebrush cover and density were lower in the mowed treatments than the controls in every post-treatment time interval ($P < 0.01$and $P < 0.05$, respectively; Fig. 1). Recovery of Wyoming big sagebrush cover and density were positively correlated to the amount of time since the mowed treatment ($P < 0.01$; Fig. 2a, b). Wyoming big sagebrush cover increased from 11% to 41% of the control as recovery period increased from 0-6 years and density in the mowed plots was 75% of that in the untreated control plots by the 6th year post-treatment.

CP, ADF and NDF

Crude protein (CP) concentration in Wyoming big sagebrush leaves was greater in the mowed compared to control treatments in all post-treatment time intervals ($P < 0.05$), except for the winter immediately after treatment ($P = 0.09$). Averaged across the 6, 4, and 2 years since treatment, CP was 15.7 ± 0.26% and 14.0 ± 0.13% in the mowed and control treatments respectively. Acid detergent fiber (ADF) was less in the mowed treatments in all post-treatment time intervals ($P < 0.05$), except for the winter immediately after treatment ($P < 0.10$). Averaged across the six, four, and two years since treatment, ADF was 21.3 ± 0.22% in the mowed treatment and 22.3 ± 0.17% in the control treatment. Neutral detergent fiber (NDF) did not differ between treatments in any of the post-treatment time intervals ($P > 0.05$).

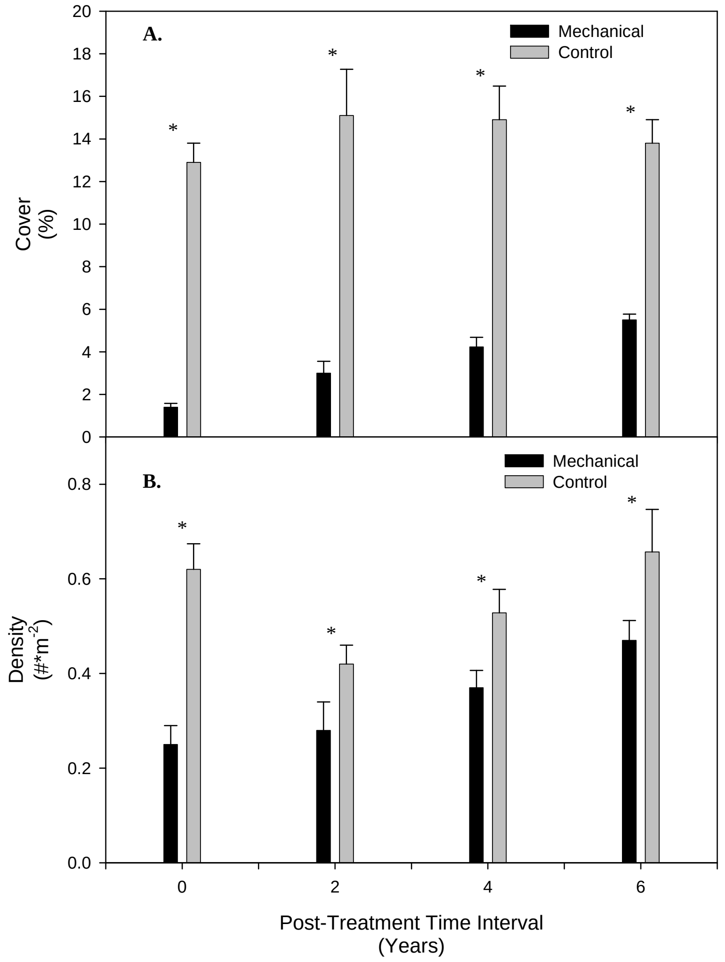

Figure 1. Sagebrush cover (A.) and density (B.) (mean + SE) in the roto-cut compared to the control treatment in 0, 2, 4, and 6 years post-treatment. Asterisk (*) indicates significant difference between means ($P < 0.05$) at the post-treatment time interval.

Discussion

Mowing of Wyoming big sagebrush decreased all measured stand structural characteristics for greater than 6 years post-treatment. However, all measured stand characteristics were recovering. Density of Wyoming big sagebrush was almost fully recovered in the mowed treatment after 6 years, whereas cover was still less than half of the control treatment. Assuming the current rate of recovery, Wyoming big sagebrush density and cover will be fully recovered in ~ 9.7 and 18.7 years post-treatment, respectively. Other than the winter immediately after treatment, mowing appears to slightly increase the nutritional value of Wyoming big sagebrush plants. However, the increase in CP and decrease in ADF from mowing is probably not biologically significant. Whether or not increases in CP from mowing Wyoming big sagebrush

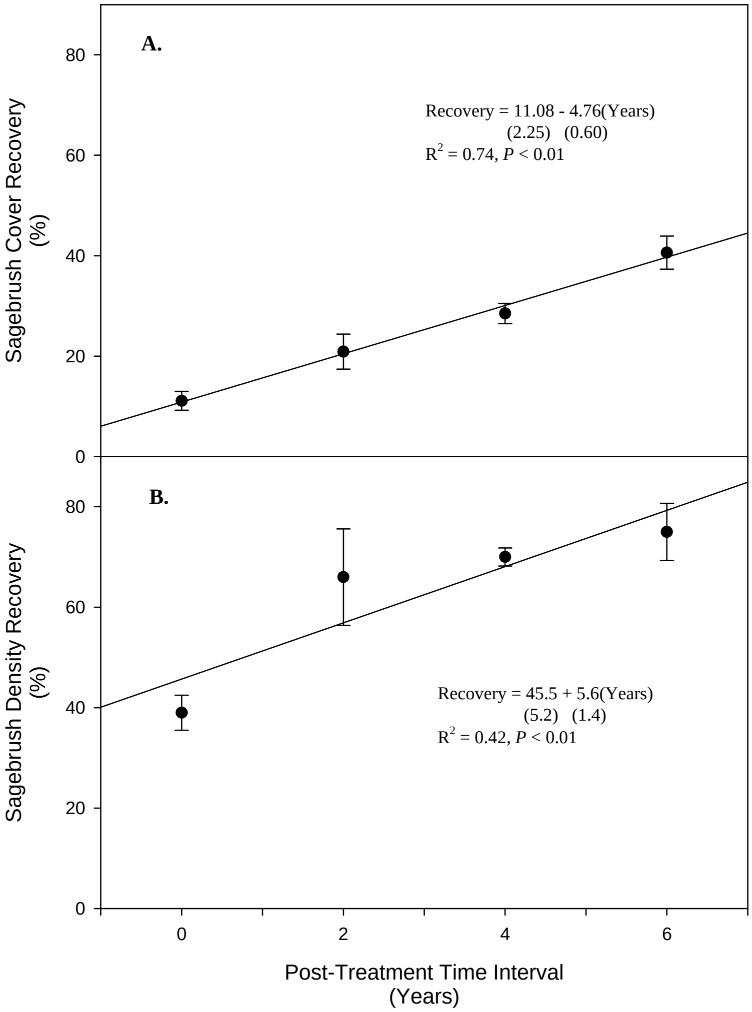

Figure 2. Recovery of sagebrush cover (A.) and density (B.) (Mean ± SE) in the roto-cut treatments at 0, 2, 4, and 6 years post-treatment. Recovery is the percent the treated plots are of the control plots. Recovery regression is based on individual block differences.

are biologically significant might depend on the amount of Wyoming big sagebrush consumed and the quality of other forage ingested. However, there may not be any advantage to wildlife species for which the majority of their diet is big sagebrush because there is a high nutritional quality in untreated Wyoming big sagebrush and the increases in nutritional quality as a result of mowing may not be offset by the large reduction of Wyoming big sagebrush with mowing.

Conclusions

Mowing influences stand structure by decreasing Wyoming big sagebrush cover and density. These effects are not permanent because of evident Wyoming big sagebrush recovery in all measured characteristics. Caution should also be exercised when considering mowing treatments because our results suggest that mowing reduces the cover and volume of Wyoming big sagebrush for ~ 20 years. Although mowing Wyoming big sagebrush increases its leaf nutritional quality, it is doubtful that this is biologically significant enough to offset the negative impacts of long-term reductions in sagebrush for most wildlife species. A distinct benefit of mowing Wyoming big sagebrush to sagebrush obligate wildlife during the winter is lacking and this study suggests that mowing in winter habitat could have significant negative impacts for almost 20 years post-treatment. Furthermore, with the decline in Wyoming big sagebrush-dominated landscapes; reducing Wyoming big sagebrush might exasperate the plight of sagebrush obligate and near-obligate wildlife species. Thus, we advise caution in the mowing of Wyoming big sagebrush because of its negative impacts on winter habitat for a variety of sagebrush obligate and facultative wildlife species

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Herbaceous Productivity in Wyoming Big Sagebrush Associations

Jon Bates, Kirk W. Davies, and Georjanna Pokorney

Summary

This study quantified forb and other herbaceous production dynamics in 37 Wyoming big sagebrush associations in southeast Oregon over a 6-year period (2003-2008). Associations were identified by dominate grass species and included bluebunch wheatgrass, Thurber's needlegrass, bluebunch wheatgrass-Thurber's needlegrass, Idaho fescue, and needle-and-thread associations.

Introduction

Herbaceous standing crop in the sagebrush steppe varies greatly across years and has been linked to the amount of precipitation received during the winter and early spring. In sagebrush steppe, forage production tends to be positively correlated with higher crop year (Sept. – May) precipitation, but other interactive factors are also important. Temperature, timing of precipitation, soil characteristics, and soil nutrient availability also influence herbaceous production on annual basis. In this study, herbaceous production was evaluated on 37 Wyoming big sagebrush sites in southeast Oregon over a 6-year period. The purpose of the study was to develop a better understanding of long-term herbaceous production dynamics and potentials in Wyoming big sagebrush associations. Particular emphasis has been placed on forb production. Forb production dynamics has received limited attention in studies on big sagebrush steppe. Forbs are important to many wildlife species, including pronghorn antelope and sage-grouse.

Methods

Sites were located in south east Oregon which included the High Desert, western Snake River, and northern Humboldt Ecological Provinces (Fig. 1). All 37 sites were Wyoming big sagebrush associations and in high seral ecological condition. Associations were identified by dominate bunchgrass species as: Wyoming big sagebrush/bluebunch wheatgrass (*Artrwy8/Agsp*); Wyoming big sagebrush/Thurber's needlegrass (*Artrwy8/Stth*); Wyoming big sagebrush/Idaho fescue (*Artrwy8/Feid*); Wyoming big sagebrush/needle-and-thread (*Artrwy8/Stoc*); Wyoming big sagebrush/bluebunch wheatgrass-Thurber's needlegrass (*Artrwy8/Agsp-Stth*) and Wyoming big sagebrush/Idaho fescue -Thurber's needlegrass (*Artrwy8/Feid-Stth*). All sites were in high ecological condition, comprising a balance of Wyoming big sagebrush, perennial grasses, and forbs. Cheatgrass was present on most sites but was a minor component of total vegetation cover and production.

Results

Production was highly variable across years in all associations. Annual precipitation (Sept-August) was a poor predictor of production with an adjusted R^2 of about 24% using a standard linear equation. A better correlation might have been achieved by comparing production to Sept-June precipitation. In addition, we only used one precipitation station (Burns, Oregon) to compare against herbaceous production covering much of southeast Oregon. There is likely to be considerable differences in precipitation across southeastern Oregon annually. In the future we will gather precipitation data to correlate with herbaceous yield on a more local basis.

Perennial bunchgrasses made up the largest proportion of total production in all plant associations (46-87%; Table 1). Functional groups that expressed the greatest production variability among years were Sandberg's bluegrass, annual grass and annual forbs. The variability expressed by these functional groups is in response to soil water availability with dry years resulting in low production and wet years with greater production. Perennial bunchgrasses and forbs were more consistent in production year to year. Perennial forbs out produced Sandberg's bluegrass in all years of the study in all associations, except the *Artrwy8/Stoc* association.

Production of perennial bunchgrasses was approximately 50% (range 30-72%) of standing crop during the six year period. Production of Sandberg's bluegrass was about 64% (range 40-90%) of standing crop during the study.

Densities of perennial herbaceous species differ among associations (Fig 1). The *Artrwy8/Feid* association has the highest densities of perennial grasses and perennial forbs. Sandberg's bluegrass densities were greatest in *Artrwy8/Agsp, Artrwy8/Feid,* and *Artrwy8/Stth* associations. The *Artrwy8/Stco* association had the lowest densities of Sandberg's bluegrass and perennial forbs.

Table 1. Wyoming big sagebrush production and standing crop in eastern Oregon by plant association (2003-2008). Standing crop for perennial bunchgrasses and Sandberg's bluegrass is equivalent to: production + standing biomass remaining from previous year's growth. Standing crop of other functional groups does not differ from production. Values are in pounds per acre and percent (%) of total production.

	Perennial Bunchgrass	Sandberg's bluegrass	Perennial Forb	Annual Grass	Annual Forb	Total
Artrwy8/Feid						
Production	247.8 ± 32.9	54.2 ± 13.8	87.1 ± 12.6	0.3 ± 0.2	11.7 ± 4.7	401.1 ± 60.8
% of total	62.4%	12.6%	22.4%	0.1%	2.5%	
Min	143.2	15.9	63.1	0.0	3.0	253.8
Max	367.4	76.1	145.4	2.8	33.8	649.3
Standing Crop	426.2 ± 34.0	73.1± 13.8	Same as production	Same as production	Same as production	598.4 ± 49.6
Artrwy8/Agsp						
Production	223.3 ± 27.7	51.7 ± 13.8	76.8 ± 9.3	14.4 ± 3.7	16.9 ± 6.3	383.0 ± 55.0
% of total	59.0%	12.8%	20.5%	3.6%	3.9%	
Min	136.5	20.3	46.5	3.6	3.8	210.9
Max	318.9	114.3	116.8	24.9	45.7	617.9
Standing Crop	434.0 ± 27.8	72.6 ± 11.6	Same as production	Same as production	Same as production	614.9 ± 43.2
Artrwy8/Agsp-						
Stth	183.4 ± 23.8	47.3 ± 10.7	77.9 ± 8.2	14.0 ± 5.1	16.9 ± 6.3	355.0 ± 49.8
Production	52.3%	12.7%	23.0%	3.8%	3.9%	
% of total	101.5	17.3	54.6	1.4	8.4	191.8
Min	284.2	80.0	101.5	30.6	70.6	556.9
Max	339.6 ± 18.4	65.5 ± 8.0	Same as production	Same as production	Same as production	530.6 ± 37.7
Standing Crop						
Artrwy8/Stco						
Production	273.9 ± 39.8	9.9 ± 2.6	5.4 ± 0.8	28.1 ± 7.2	13.0 ± 6.3	330.4 ± 43.9
% of total	82.7%	2.8%	1.8%	9.3%	3.4%	
Min	192.3	1.3	3.2	13.0	1.8	221.4
Max	445.2	17.0	7.1	61.3	42.8	522.4
Standing Crop	446.6 ± 33.8	14.7 ± 3.4	Same as production	Same as production	Same as production	507.9 ± 36.5
Artrwy8/Feid-Stth						
Production	133.8 ± 16.3	54.6 ± 13.1	60.5 ± 13.6	7.6 ± 3.3	32.7 ± 11.8	291.2 ± 39.9
% of total	46.0%	19.9%	20.8%	2.6%	11.2%	
Min	87.4	19.9	23.7	0.6	4.7	159.4
Max	184.0	106.6	114.7	19.1	88.9	455.1
Standing Crop	280.7 ± 32.5	73.6 ± 13.3	Same as production	Same as production	Same as production	455.1 ± 45.6
Artrwy8/Stth						
Production	133.9 ± 16.3	36.5 ± 9.2	50.0 ± 7.4	9.5 ± 2.0	20.8 ± 8.2	250.6 ± 38.2
% of total	54.3%	14.1%	20.5%	3.9%	7.2%	
Min	101.7	15.9	29.4	2.8	6.5	176.24
Max	207.6	76.1	74.7	13.3	57.5	428.9
Standing Crop	262.9 ± 16.8	51.6 ± 8.2	Same as production	Same as production	Same as production	394.5 ± 34.5

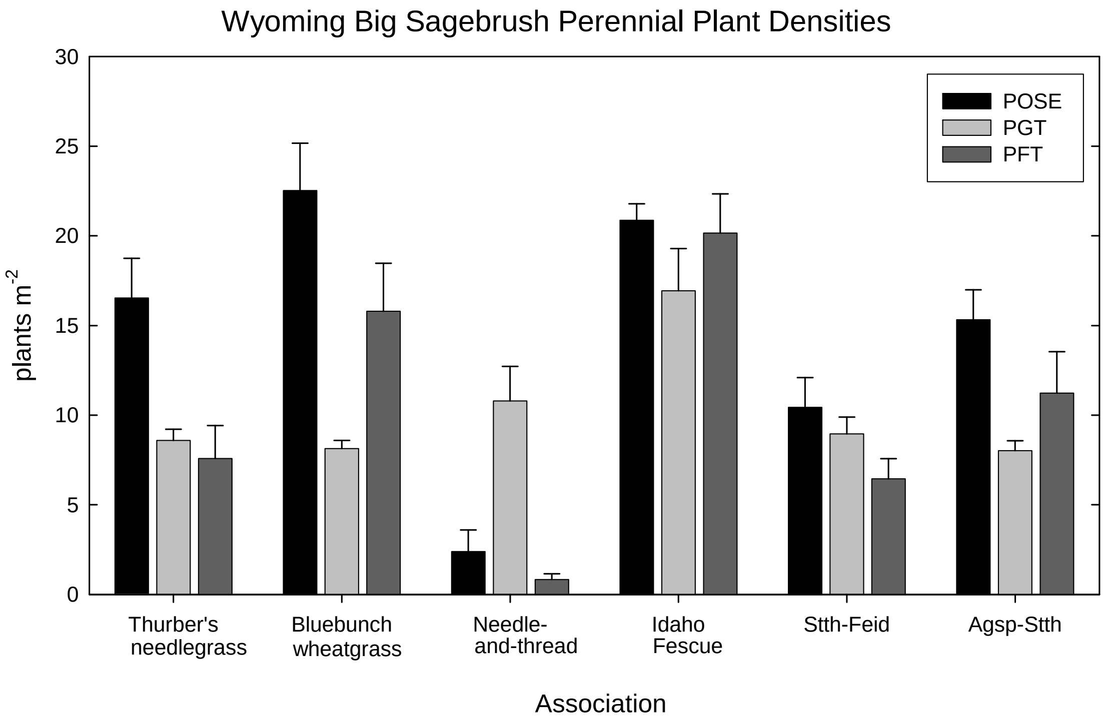

Figure 1. Density of perennial herbaceous plants in Wyoming big sagebrush associations, southeast Oregon. Data is in means + 1 standard error.

Wyoming big sagebrush/bluebunch wheatgrass and Wyoming big sagebrush/Idaho fescue

The *Artrwy8/Agsp* (Fig 2; Table 1) and *Artrwy8/Feid* (Fig 3; Table 1) were the most productive associations. Cheatgrass on the *Artrwy8/Agsp* tended to be a small component of production though on 3 of the 13 sites cheatgrass had the potential to comprise 20% of total production in a high moisture year. Cheatgrass and other annual grasses, such as six-week fescue, were minor components or not present in the *Artrwy8/Feid.* Consequently production of annual grass was low on the *Artrwy8/Feid* association. Perennial forb production, as a percentage of the total, in these two associations varied between 17-32% across years.

Soils on the *Artrwy8/Agsp* associations were variable. Great groups consisted of Duriargids, Haploargids, Petrocalcids, Argixeroll, and Calcixerolls. Soil great groups in the *Artrwy8/Feid association consisted of* Aridic Argixeroll and Pachic Agrixerolls.

Wyoming big sagebrush/Thurber's needlegrass and Wyoming big sagebrush/Idaho fescue - Thurber's needlegrass

These were the least productive of all associations (Fig 4 and Fig 5; Table 1). However, both associations produced the highest values and percent of total production for annual forbs.

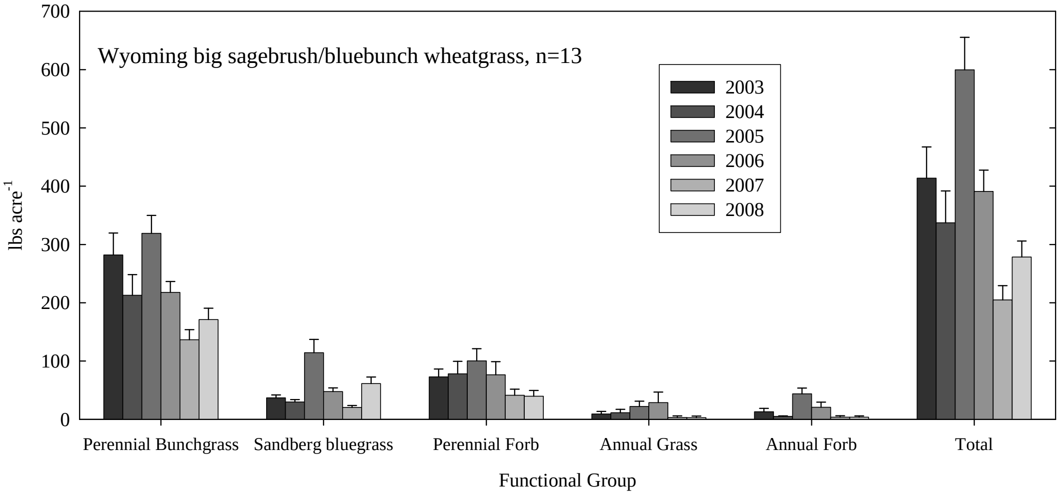

Figure 2. Production (2003-2008) on Wyoming big sagebrush/bluebunch wheatgrass association, southeast Oregon. Data is in means + 1 standard error.

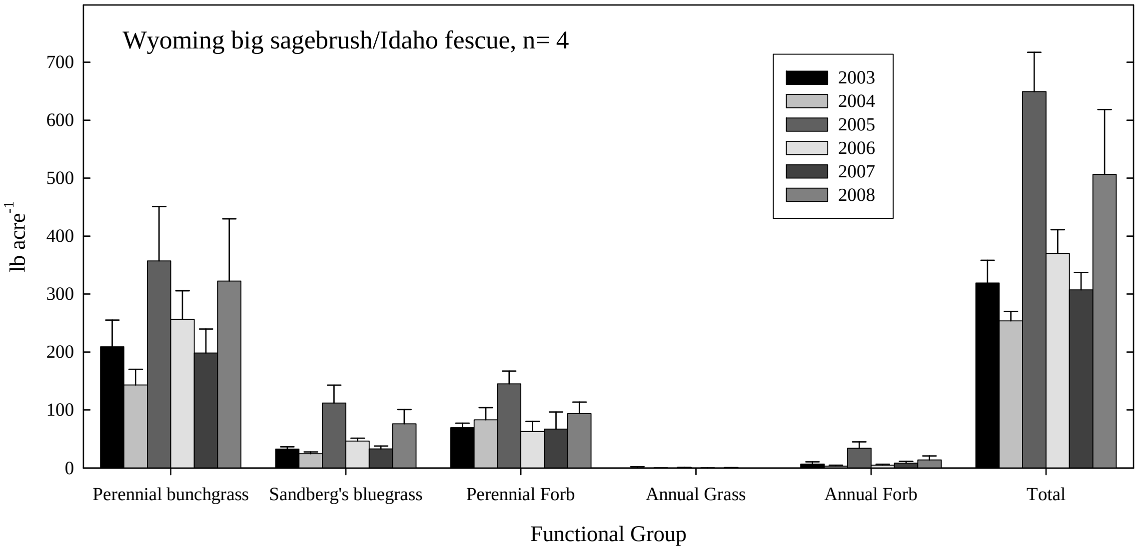

Figure 3. Production (2003-2008) on Wyoming big sagebrush/Idaho fescue association, southeast Oregon. Data is in means + 1 standard error.

Annual forb production, as a percentage of the total, in these two associations varied between 3% in dry years and 13% in high precipitation years. Cheatgrass and other native annual grass production were low and never comprised more than 8% of total production. Perennial forb production, as a percentage of the total, in these two associations varied between 15-37% across years.

Soils described to the Great group on the *Artrwy8/Stth* association included Haploargids, Argidurids, Petrocalcids, and Haplocambids. Soils described to the great group on the *Artrwy8/Feid-Stth* association were Durixerolls.

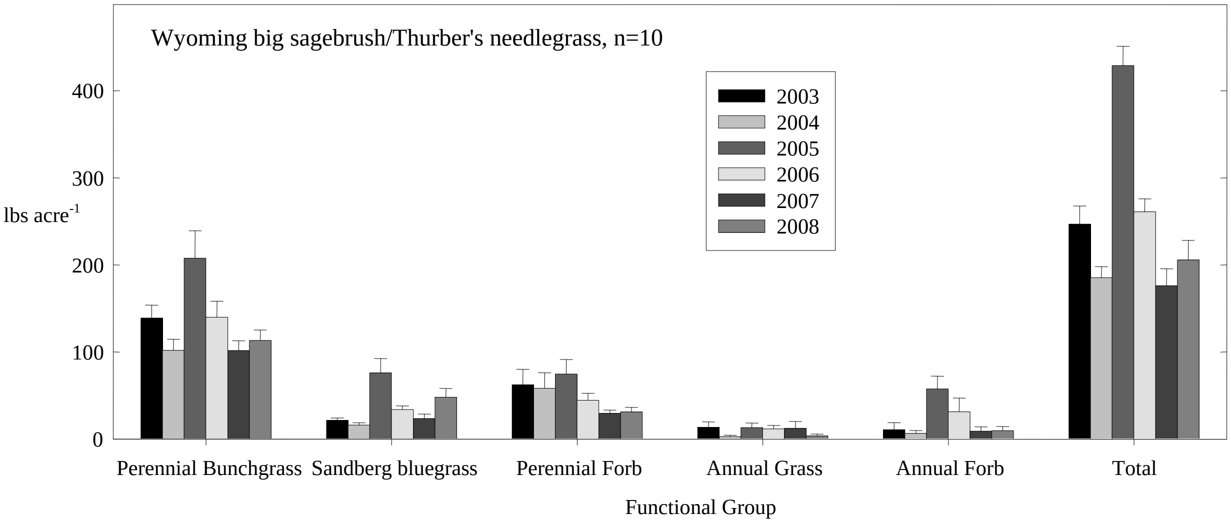

Figure 4. Production (2003-2008) on Wyoming big sagebrush/Thurber's needlegrass wheatgrass association, southeast Oregon. Data is in means + 1 standard error.

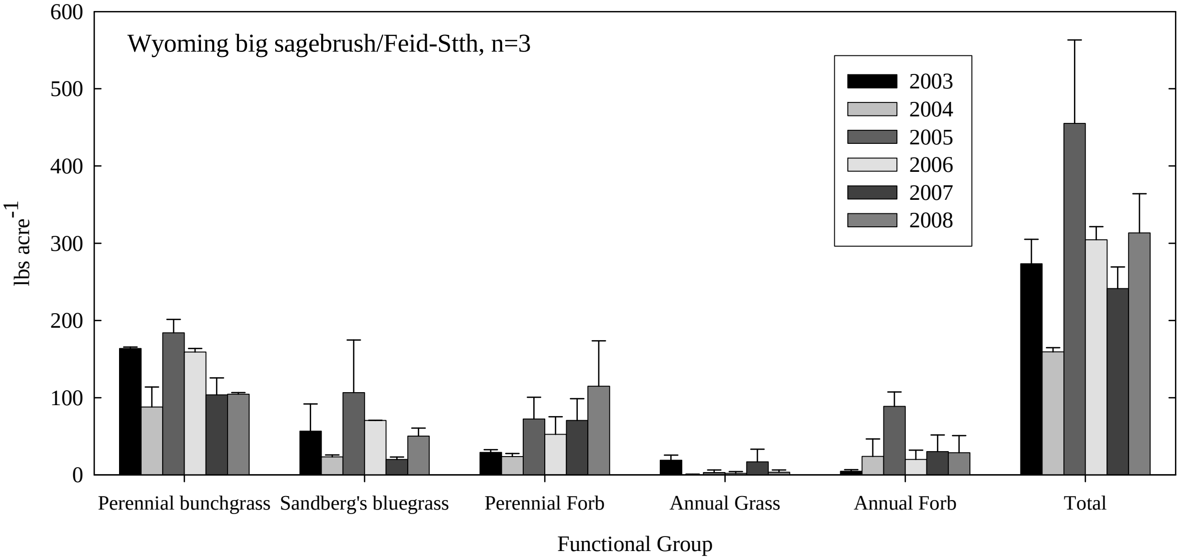

Figure 5. Production (2003-2008) on Wyoming big sagebrush/Idaho fescue-Thurber's needlegrass wheatgrass association, southeast Oregon. Data is in means + 1 standard error.

Wyoming big sagebrush/bluebunch wheatgrass-Thurber's needlegrass

This association generally has good perennial forb production. Perennial forb production in the *Artrwy8/Agsp-Stth* association is similar to the *Artrwy8/Agsp* (Fig 7; Table 1) and

Artrwy8/Feid. Perennial forb production, as a percentage of the total, in the *Artrwy8/Agsp-Stth* association varied between 16-31% across years.

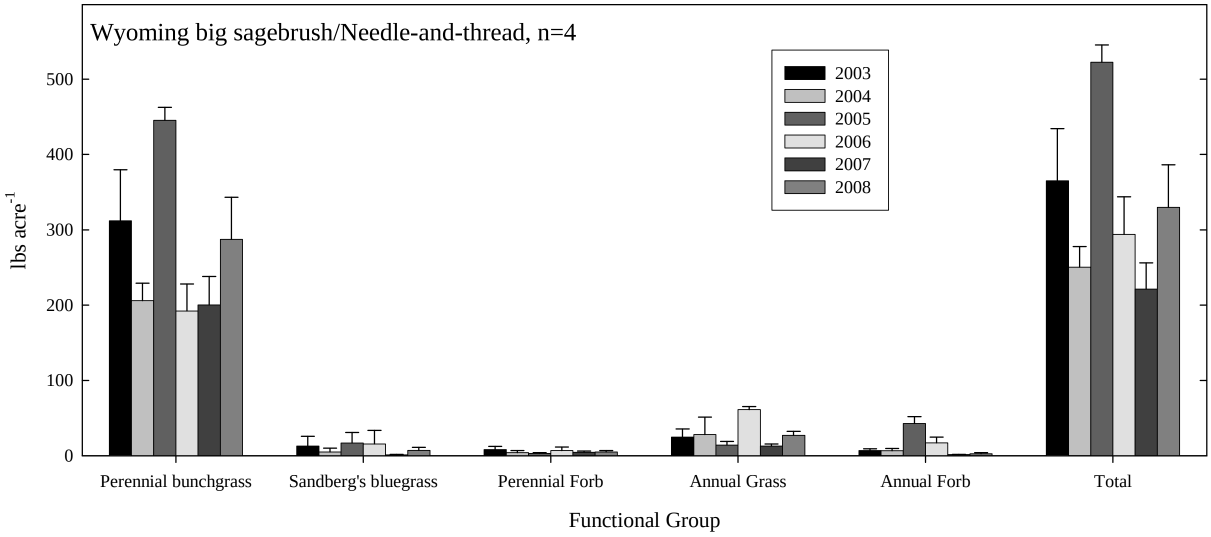

Figure 6. Production (2003-2008) on Wyoming big sagebrush/Needle-and-thread wheatgrass association, southeast Oregon. Data is in means + 1 standard error.

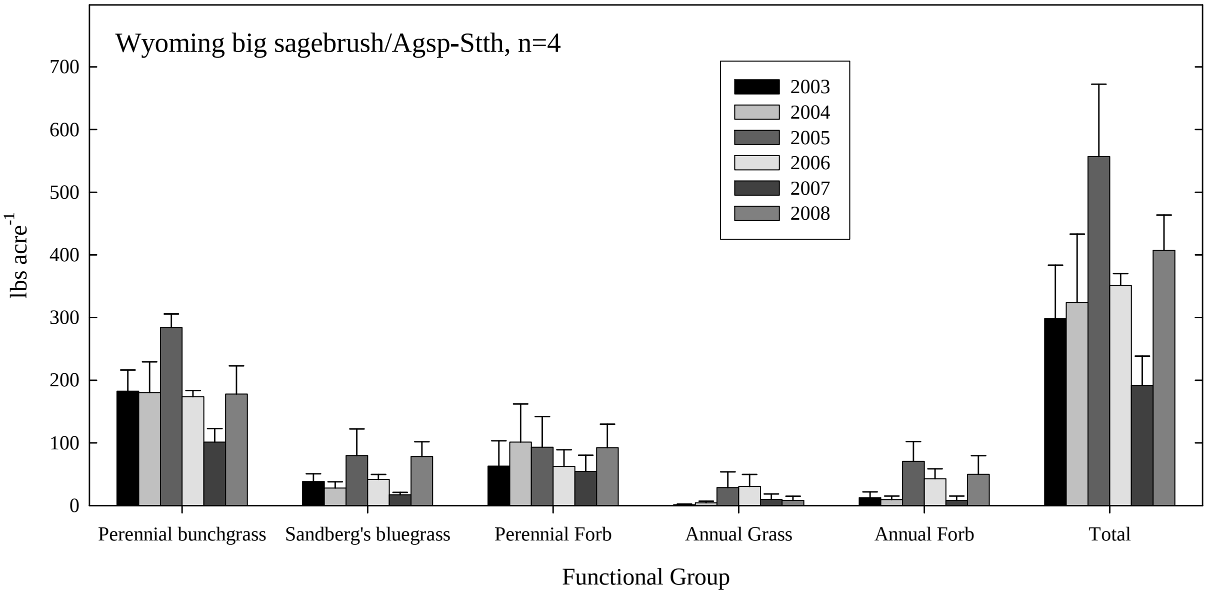

Figure 7. Production (2003-2008) on Wyoming big sagebrush/ bluebunch wheatgrass association-Thurber’s needlegrass association, southeast Oregon. Data is in means + 1 standard error.

Competitive Perennial Grass Impedes the Spread of an Invasive Annual Grass

Kirk W. Davies, Aleta M. Nafus, Roger L. Sheley

Summary

Creating competitive vegetation barriers by establishing desert wheatgrass (*Agropyron desertorum*) around the edge of medusahead (*Taeniatherum caput-medusae*) infestations slowed the spread of the infestations into surrounding non-infested plant communities.

Introduction

Invasive plants are decreasing biodiversity, reducing productivity, degrading wildlife habitat and altering ecological functions of wildlands around the world. Restoration of plant communities invaded by exotic plant species is expensive, rarely successful, and may exacerbate the negative impacts of the invaders. Thus, efforts should be directed at preventing exotic plant invasions. Davies and Sheley (2007) demonstrated that maintaining neighboring vegetation taller than the invasive plant species could potentially reduce invasive plant propagule pressure by limiting dispersal of invasive plant seeds. In addition to reducing propagule pressure, the establishment of competitive vegetation may increase the biotic resistance of the plant community immediately adjacent to established infestations thereby increasing the distance between invasive plants and plant communities at risk of invasion.

To investigate the potential for competitive vegetation to reduce the spread of invasive plants, we evaluated the ability of the competitive perennial bunchgrass, desert wheatgrass (*Agropyron desertorum* (Fisch. ex Link) Schult.) to reduce the establishment and spread of the exotic annual grass, medusahead (*Taeniatherum caput-medusae* (L.) Nevski).

Methods

This study was conducted in the northwest foothills of Steens Mountain in southeast Oregon about 65 km southeast of Burns, OR. Soils are a complex of different series with 20-35% clay content and moderate to high shrink-swell potential. Twelve sites were selected along medusahead invasion fronts. Each site was divided into two treatments 1) established desert wheatgrass (vegetation barrier) and 2) undisturbed control. Desert wheatgrass was drill seeded at 11 $kg \cdot ha^{-1}$ in a 15 X 6 m band in front of the medusahead invasion in 3 growing seasons prior to medusahead spread measurement. In July 2008, herbaceous plant cover and density were measured along 4 transects spaced at 2 m intervals and along a transect located 4 m from the barrier, all parallel to the invasion front. Nutrient supply rates of potassium, phosphorus and inorganic nitrogen were also measured for each treatment plot.

Results

In the Competitive Vegetation Barrier

Medusahead and total annual grass cover were more than 7.1 and 2.7- fold greater in the control treatment than in the desert wheatgrass treatment ($P < 0.01$ and $P = 0.04$, respectively; Fig. 1A). Annual forb cover was greater in the control treatment than in the desert wheatgrass seeded treatment but desert wheatgrass cover was greater in the seeded than control treatment ($P = 0.01$ and $P < 0.01$, respectively). Medusahead and annual grass density were ~7.8 and 2.8-fold greater in the control compared to desert wheatgrass treatment ($P = 0.01$ and 0.04, respectively; Fig. 1B). Desert wheatgrass density was greater in the seeded treatment than control treatment ($P < 0.01$). Potassium concentrations were ~2-fold greater and ammonium concentrations were approx. 15-fold greater in the control than desert wheatgrass seeded treatments (Fig. 2).

Beyond the Competitive Vegetation Barrier

Medusahead cover and density was less in plant communities protected by a barrier of established desert wheatgrass than unprotected plant communities (a 42-fold and 47-fold difference, respectively; $P < 0.01$; Fig. 3).

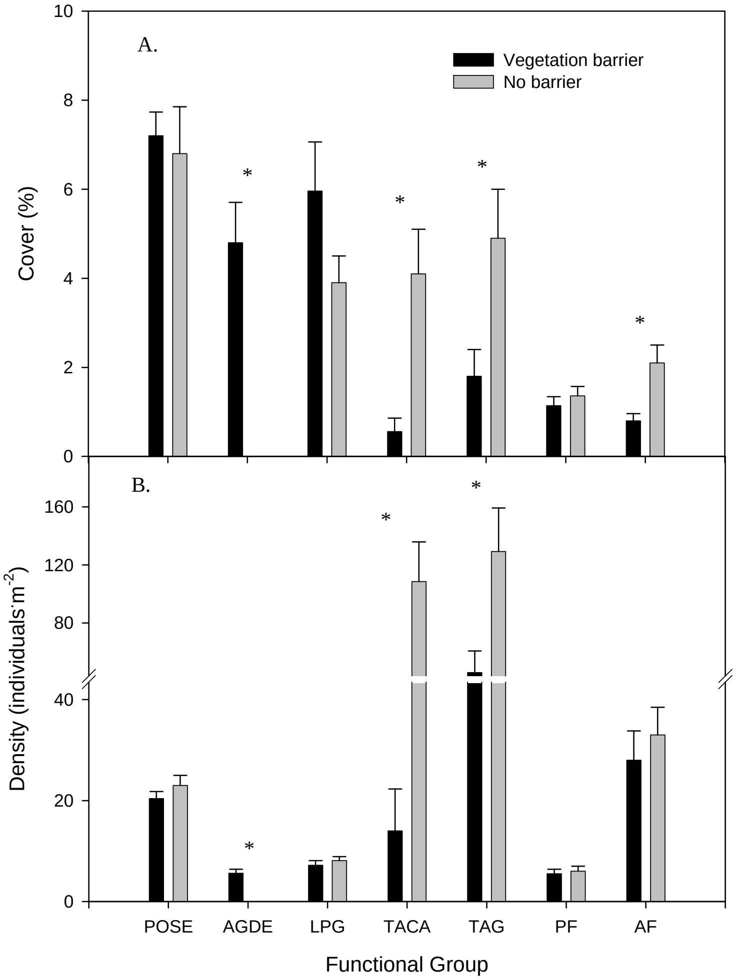

Figure 1. Cover (A.) and density (B.) of plant functional groups in the competitive vegetation barrier (established desert wheatgrass) and no barrier treatments (mean + S.E.). POSE = Sandberg bluegrass, AGDE = desert wheatgrass, LPG = large perennial bunchgrass, TACA = medusahead, TAG = total annual grass, PF = perennial forb, and AF = annual for. Asterisk (*) indicates significant difference between treatments ($P < 0.05$).

Discussion

Establishing competitive plants around infestations can reduce the spread of invasive plants by increasing the biotic resistance of the plant community to invasion and limiting the dispersal of invasive plant seeds into adjacent non-invaded plant communities. In this study, lower soil nutrient concentrations and less medusahead cover and density in the crested wheatgrass areas suggest that the establishment of crested wheatgrass increased the biotic resistance of these plant communities to invasion. The 40-fold greater presence of medusahead in plant communities without a crested wheatgrass barrier between them and the medusahead invasion demonstrates the effectiveness of a competitive vegetation barrier at reducing the spread of invasive plants into

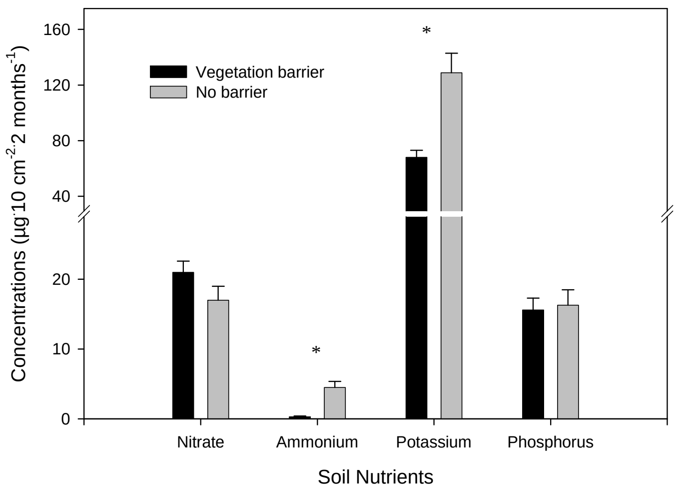

Figure 2. Soil nutrient concentrations in the competitive vegetation barrier (established desert wheatgrass) and no barrier treatments (mean + S.E.). Asterisk (*) indicates significant difference between treatments ($P < 0.05$).

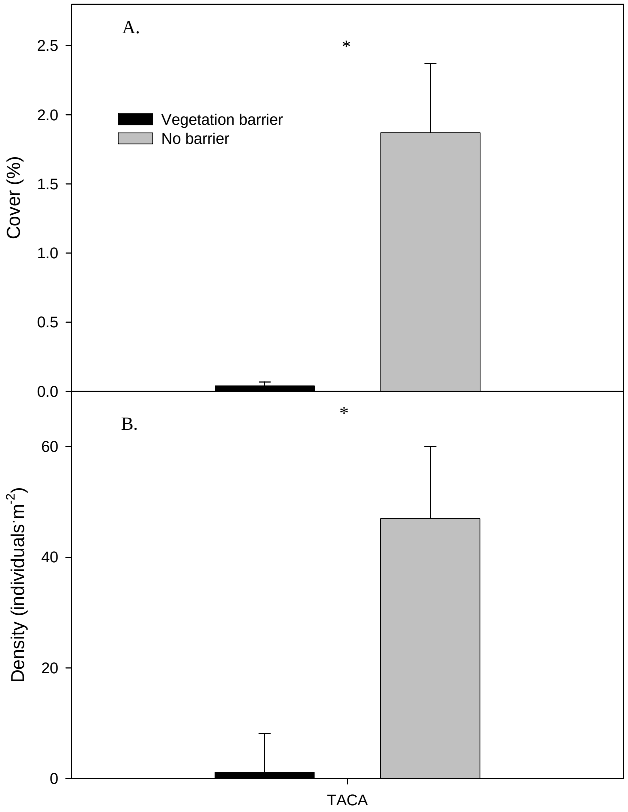

Figure 3. Medusahead (TACA) cover (A.) and density (B.) in the plant communities protected by a competitive vegetation barrier (established desert wheatgrass) and plant communities without a barrier between them and a medusahead infestation (mean + S.E.). Asterisk (*) indicates significant difference between treatments ($P < 0.05$).

surrounding non-invaded plant communities. However, some medusahead seeds were able to establish beyond the barrier. This suggests the effectiveness would be improved by increasing the width of barriers and/or locating them further from the infestation edge to allow better establishment of competitive vegetation prior to experiencing pressure from the invader.   The incorporation of an early detection and eradication program for satellite populations that establish beyond competitive vegetation barriers would also be fundamental to effectively reduce invasive plant spread.

Conclusions

Establishing crested wheatgrass adjacent to medusahead infestations can reduce the spread of medusahead. The establishment of crested wheatgrass appears to increase the biotic resistance of plant communities to invasion and reduce invasive plant propagule pressure in adjacent non-invaded areas. However, some medusahead may establish beyond the crested wheatgrass barrier; thus, integrating crested wheatgrass barriers with other management actions will probably be the most effective strategy to limit the negative impacts of medusahead. Considering the general failure of herbicides to impede the spread of invasive plant species, we suggest, more efforts should focus on increasing the biotic resistance of plant communities to invasion and decreasing invasive plant propagule pressure.

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Linking Nitrogen Partitioning and Species Abundance to Invasion Resistance in Sagebrush Steppe Plant Communities

Jeremy J. James, Kirk W. Davies, Roger L. Sheley and Zachary T. Aanderud

For more information see: James, J.J., K.W. Davies, R.L. Sheley and Z.T. Aanderud. 2008. Linking nitrogen partitioning and species abundance to invasion resistance in the Great Basin. Oecologia 156: 637-648.

Summary

The ability of different functional groups to utilize resources at different times of the year or depths in the soil may increase the invasion resistance of a community. Because of their dominance in the community, perennial bunchgrasses were the most important functional group to limiting the ability of the annual grass, medusahead, to successfully establish in the community.

Introduction

Invasion resistance of a native plant community may be linked to its ability to maintain low levels of limiting resources that would otherwise be available to a potential intruder. Resource partitioning among coexisting species or functional groups may allow more diverse communities to sequester more resources. Resource partitioning among coexisting species might be critical for invasion resistance when physiological or life history traits allow the invader to largely avoid interference from dominant species. For example, perennial bunchgrasses were historically the dominant herbaceous component in the Great Basin, but many of these landscapes have been invaded by the exotic winter annual grasses cheatgrass and medusahead. These annual grasses have higher relative growth rates and rates of root elongation than their perennial counterparts. While it is well known that the timing and duration of biological activity in arid and semi-arid systems is strongly affected by water input, there is evidence suggesting that these systems are also limited by nitrogen and that even small increases in N availability can facilitate the invasion of annual grasses. Even with the potential advantage that annual grasses may have in terms of timing and rate of N capture relative to the historically dominant bunchgrasses, not all communities in the Great Basin are easily invaded and there is some evidence suggesting that N partitioning may be a critical mechanism for invasion resistance in these communities.

Methods

This study was conducted in a sagebrush steppe community 16 km south of Drewsey, Oregon. The herbaceous species selected for this study are representative of the steppe communities in the Great Basin (Tables 1 & 2). Bunchgrasses are the major herbaceous component followed by perennial forbs and annual forbs. Seasonal leaf biomass production, soil inorganic N concentration and gross N transformation rates were measured in April, May and June. To quantify temporal, spatial, and chemical patterns of plant N capture we injected ^{15}N compounds into the soil around naturally established target plants of the seven study species three times (25 April, 23 May and 20 June 2006), at two depths (2-7 and 17-22 cm) and in two chemical forms (NH_4^+ and NO_3^-). To examine how soil water content may influence the pattern of N capture by the study species, a second set of plants were watered with a simulated 25 mm rain event two days prior to the N injections. Removal plots were established at two sites in the community. Four removal treatments were applied at each site including: 1) nothing removed; 2) annual forbs removed; 3) perennial forbs removed; 4) bunchgrasses removed. The functional groups were removed using 6% glyphosate solution. Medusahead was seeded into the plots in the fall of 2005 at 300 seeds m^{-2}

Results

The timing and depth of N capture differed significantly among species (Fig. 1). Forbs and annual grasses acquired a greater proportion of N in April compared to May, while bunchgrasses acquired a greater proportion of N in May compared to April ($P < 0.001$). Forbs acquired a greater proportion of N from the 17-22 cm soil layer than bunchgrasses ($P = 0.006$). Annuals captured more N from shallow soil layers compared to deep soil layers ($P < 0.001$). Nitrogen capture per unit biomass and total N capture by each species declined during the growing season (Figs. 2 and 3; $P < 0.001$). Bunchgrasses, on average, captured more N per unit leaf biomass than forbs ($P = 0.008$) although this appeared to be largely driven by high uptake per unit biomass of Sandberg bluegrass. The total amount of N captured following ^{15}N injection at different times, depths and chemical forms differed significantly among native species ($P < 0.001$; Fig. 3). In all treatments, however, bunchgrass acquired more N than forbs ($P < 0.001$).

Bunchgrass removal was the only treatment that significantly increased medusahead density compared to the intact control plots.

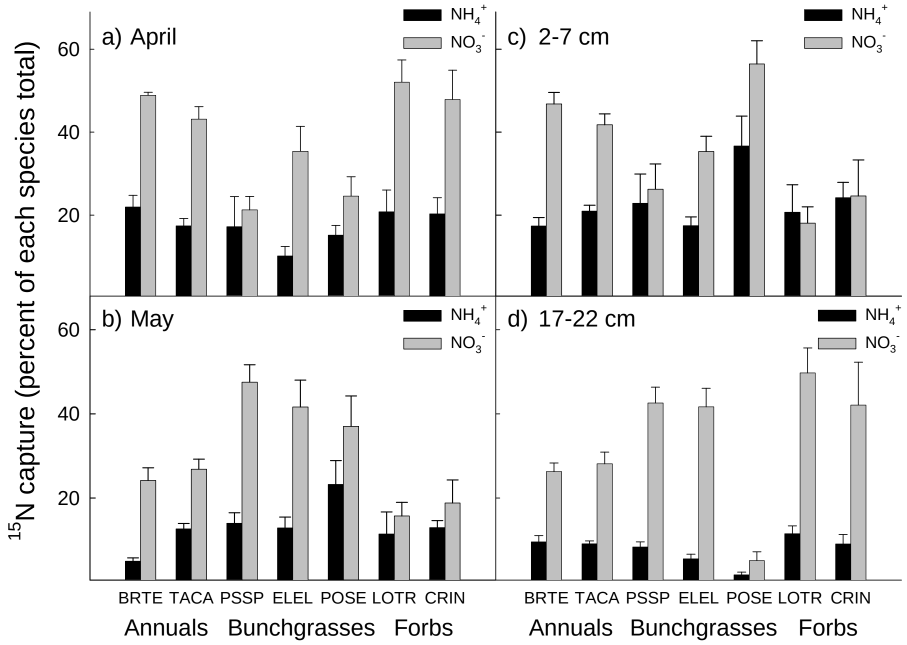

Figure 1. ^{15}N capture by the seven study species as influenced by the time, depth and form of ^{15}N tracer addition. Based on the ANOVA results, panels (a) and (b) show the simple effects of time and N form on species N capture while panels (c) and (d) show the simple effects of depth and N form on species N capture. Plant N capture data are expressed as a percentage of each species total ^{15}N capture. BRTE = Cheatgrass, TACA = Medusahead, PSSP = Bluebunch wheatgrass, ELEL = Squirreltail, POSE = Sandberg bluegrass, LOTR = Nineleaf biscuitroot, and CRIN = Grey hawksbeard. Percentages were calculated individually for each block (mean + SE, *n* = 10).

Discussion

We found strong evidence that coexisting species differ in timing, depth and chemical form of N capture and that this resource partitioning among species can remain consistent under fluctuating environmental conditions. Different functional groups did differ in root distribution by soil depth which meant that some partitioning of soil N by depth did occur. Bluebunch wheatgrass and squirreltail were able to acquire a greater proportion of N at depth than Sandberg bluegrass or forbs which acquired their N from relatively shallow soil layers. The annual grasses accumulated their N from mainly shallow soil layers in May but from deeper layers in April. While neither forbs nor bunchgrasses preferentially utilized the shallow NO_3^- pool in April, the pool most utilized by annual grasses, the forbs and bunchgrasses did have some overlap in N acquisition with the annual grasses. The patterns of overlap differed enough that both forbs and bunchgrasses may be critical to reducing N availability to invasive annual grasses.

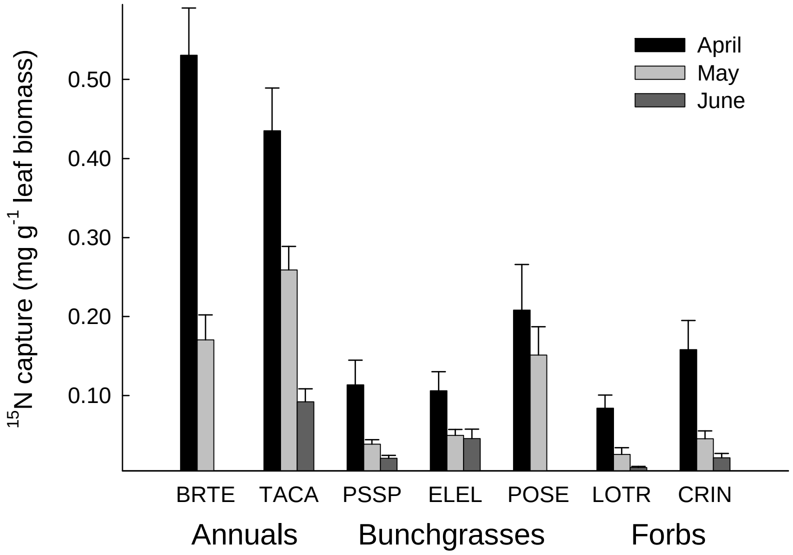

Figure 2. Nitrogen capture per unit biomass by the seven study species following the April, May and June injections. Values are averaged over different depths and chemical form of tracer addition and over the water treatments applied in May and June (mean + SE, *n* = 20 in April and *n* = 40 in May and June). BRTE = Cheatgrass, TACA = Medusahead, PSSP = Bluebunch wheatgrass, ELEL = Squirreltail, POSE = Sandberg bluegrass, LOTR = Nineleaf biscuitroot, and CRIN = Grey hawksbeard.

In agreement with Davies (2008), bunchgrasses were the most important functional group to inhibiting medusahead establishment, consistent with the large amount of N sequestered by this group. Perennial forbs, on the other hand, were relatively minor sinks for N in the community and contributed little to invasion resistance even though forbs acquired most of their N in April, similar to invasive annual grasses. Annual forbs do not appear to influence invasion resistance despite relatively high aboveground biomass production in early spring.

Conclusions

Bunchgrasses were the largest biomass component in the community and they not only sequestered the most N from all soil N pools, but they were the most important functional group to invasion resistance. Although perennial forbs differed from bunchgrasses in patterns of N capture, and both perennial and annual forbs differed from bunchgrasses in patterns of biomass production, the relatively low biomass of these groups limited their contribution to invasion resistance. In systems where coexisting dominants differ in how they harvest resources, it seems likely that resource partitioning will be a key mechanism contributing to invasion resistance.

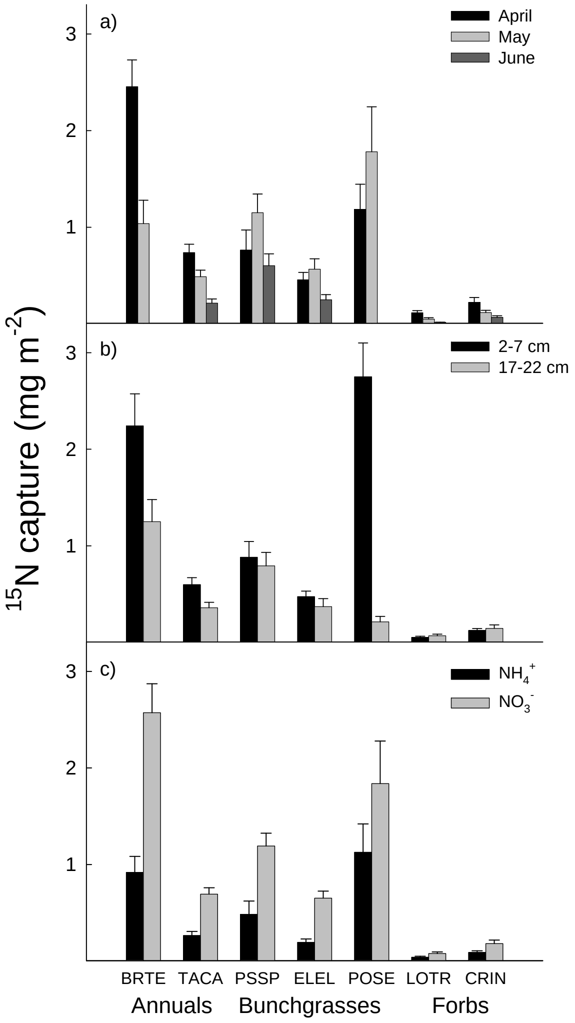

Figure 3. Total N capture by the seven study species as affected by the time (a) depth (b) and form (c) of ^{15}N injections. Values in (a) are averaged over the different depths and chemical form of tracer addition (mean ± SE, *n* = 20). BRTE = Cheatgrass, TACA = Medusahead, PSSP = Bluebunch wheatgrass, ELEL = Squirreltail, POSE = Sandberg bluegrass, LOTR = Nineleaf biscuitroot, and CRIN = Grey hawksbeard.

However, in systems where the bulk of community biomass is determined by one or two species, it seems likely that invasion resistance will mainly be conferred by the resource acquisition traits of the dominant species.

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Promoting Native Vegetation and Diversity in Exotic Annual Grass Infestations

Kirk W. Davies and Roger L. Sheley

For more information: Davies, K.W. and R.L. Sheley. (*IN PRESS*). Promoting native vegetation and diversity in exotic annual grass infestation. Restoration Ecology.

Summary

Restoring a medusahead infested community may be most successful if there is enough remnant native vegetation to eliminate the need for revegetation efforts. Prescribed burning followed by imazapic (Plateau®[1]) application provided the best control of medusahead and resulted in the greatest increases in native vegetation density, cover, and diversity. Native vegetation can be at least partially restored in medusahead infestations by selectively controlling medusahead without implementing seeding treatments.

[1] Mention of a proprietary product does not constitute a guarantee or warranty of the product by USDA, Oregon State University, or the authors and does not imply its approval to the exclusion of other products.

Introduction

Medusahead (*Taeniatherum caput-medusae*) is one of the most problematic of the exotic annual grasses invading rangelands. The invasion of medusahead in native plant communities decreases biodiversity, reduces livestock forage production, degrades wildlife habitat, and alters ecological functions (Davies and Svejcar 2008). Similar to other annual exotic grasses, revegetation of medusahead invaded plant communities is often unsuccessful because seeded vegetation rarely establishes (Young 1992; Monaco et al. 2005). Most research has focused on the most effective treatments to control annual grasses in near-monocultures of exotic annual grasses. Davies and Johnson (2008) suggested that restoration would be more successful in annual grass-invaded communities that still have enough native vegetation to eliminate the need for revegetation efforts.

We expected that fall or spring prescribed burning followed with imazapic application would be the most effective medusahead control treatments and that controlling medusahead would produce a positive response in native vegetation because of a release from medusahead competition and/or suppression that would outweigh any negative impacts of the treatments on the native vegetation.

Methods

The study was conducted in southeast Oregon. The study sites were formerly sagebrush (*Artemisia*) bunchgrass steppe. Treatments were: 1) imazapic (*Imazapic*); 2) spring prescribed burn and imazapic (*Spring Burn-Imazapic*); 3) fall prescribed burn and imazapic (*Fall Burn-Imazapic*); 4) spring prescribed burn (*Spring Burn*); 5) fall prescribed burn (*Fall Burn*); or 6) control (*Control*). The spring prescribed burn was applied in mid-May 2006 and the fall prescribed burn was applied in mid-Oct 2006. Imazapic was applied as Plateau® at 6 oz per acre in mid-Oct 2006 after the fall prescribed burn.

Results

Density

Burning followed by imazapic application resulted in greater bunchgrass density ($P < 0.05$). Medusahead density was greater in the *Control*, *Spring Burn* and *Fall Burn* treatments than in the *Spring Burn-Imazapic*, *Fall Burn-Imazapic* or *Imazapic* treatments ($p < 0.05$). Annual forb density was least in the *Spring Burn-Imazapic*, *Fall Burn-Imazapic*, and *Imazapic* treatments and greatest in the *Spring Burn* treatment ($P < 0.05$).

Plant Species Diversity

The *Spring Burn-Imazapic* treatment (0.80 ± 0.07) had greater diversity than the other treatments ($P < 0.05$) except it was not different from the *Fall Burn-Imazapic* treatment (0.68 ± 0.10) ($P = 0.14$). Plant species diversity did not differ in the *Spring Burn* (0.60 ± 0.07), *Fall Burn* (0.56 ± 0.11), *Imazapic* (0.54 ± 0.08) or *Control* (0.46 ± 0.08) treatments ($P > 0.05$).

Cover

Fall Burn-Imazapic increased perennial bunchgrass cover more than the other treatments ($P < 0.05$; Fig. 1). *Spring Burn-Imazapic* and *Imazapic* treatments had greater perennial bunchgrass cover than *Spring Burn*, *Fall Burn* and *Control* treatments ($P < 0.05$). *Spring Burn-Imazapic* and

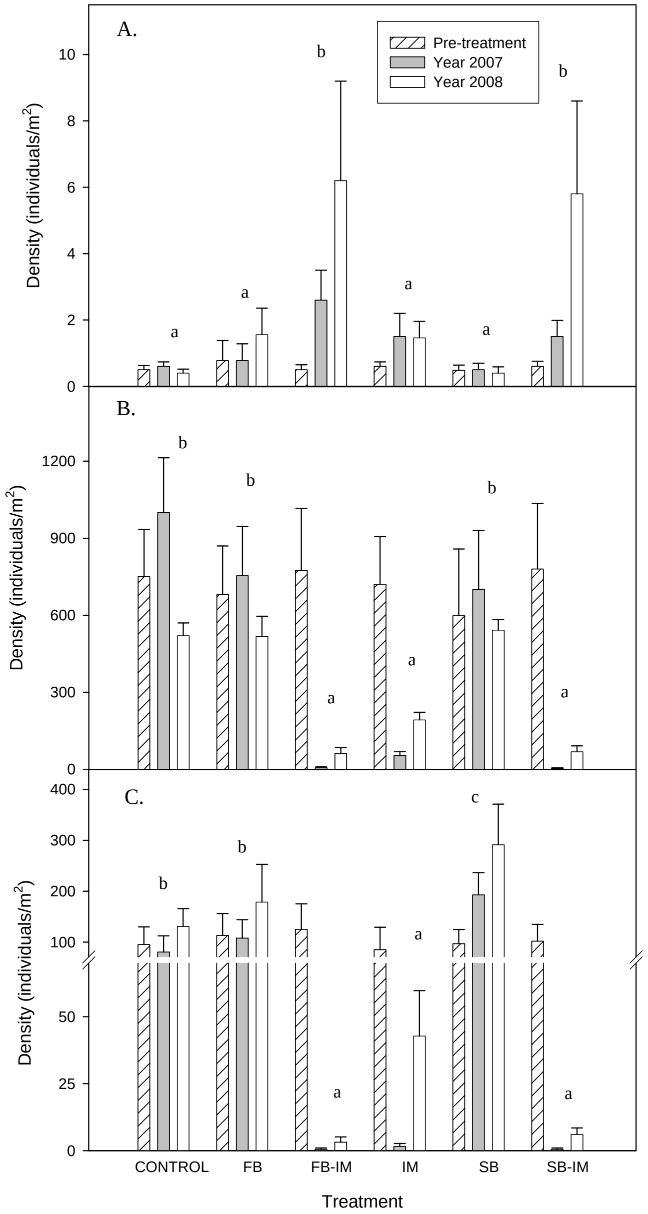

Figure 1. Large perennial bunchgrass (A.), medusahead (B.), and annual forb (C.) densities (mean + S.E.) in the various medusahead control treatments prior to treatment and in 2007 and 2008. Comparisons of treatment effects were only made on post-treatment data. Pre-treatment data is reported to demonstrate that prior to treatment applications plots were similar. Treatments are: CONTROL = control, FB = prescribed fall burn, FB-IM = prescribed fall burn followed with fall imazapic application (87.5 g ai/ha), IM = fall imazapic application, SB = prescribed spring burn, and SB-IM = prescribed spring burn followed with fall imazapic application. Different lower case letters indicate differences between treatments after treatment application ($P < 0.05$).

Fall Burn-Imazapic decreased medusahead cover more than the other treatments ($P < 0.05$; Fig. 3). *Imazapic* reduced medusahead cover relative to *Spring Burn*, *Fall Burn* and *Control* treatments ($P < 0.01$). In 2008, perennial forb cover appears to have increased in the *Spring Burn-Imazapic*, *Fall Burn-Imazapic*, and *Imazapic* treatments while it appears relatively

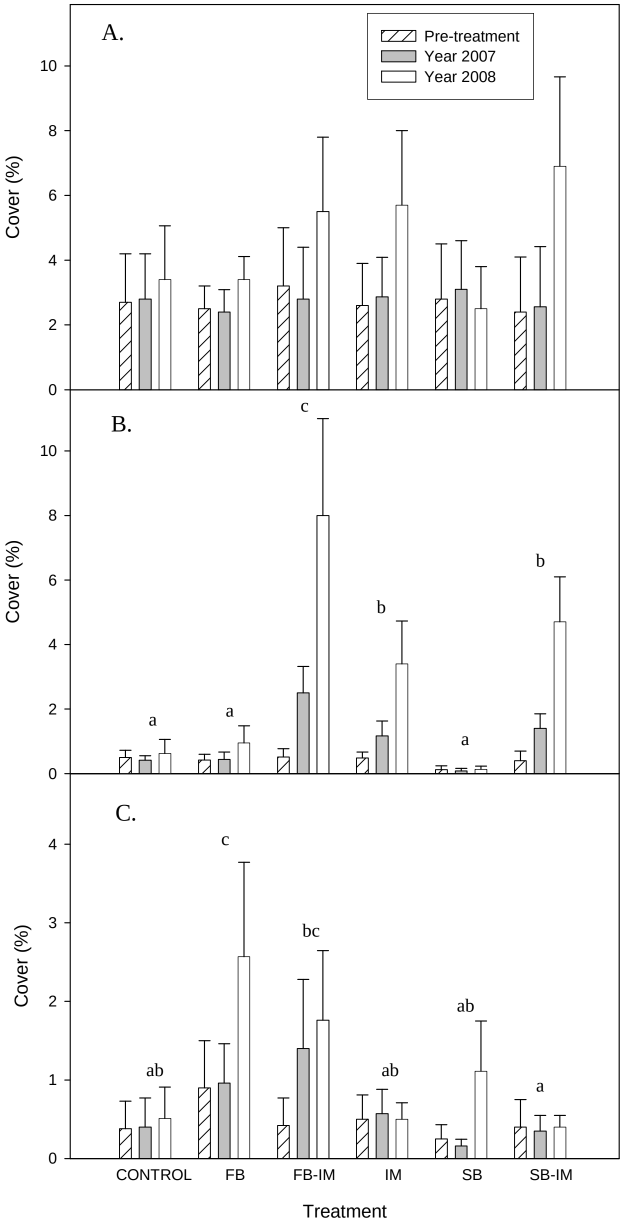

Figure 2. Perennial forb (A.), large perennial bunchgrass (B.), and Sandberg bluegrass cover values (mean + S.E.) in the various medusahead control treatments prior to treatment and in 2007 and 2008. Comparisons of treatment effects were only made on post-treatment data. Pre-treatment data is reported to demonstrate that prior to treatment applications plots were similar. Treatments are: CONTROL = control, FB = prescribed fall burn, FB-IM = prescribed fall burn followed with fall imazapic application (87.5 g ai/ha), IM = fall imazapic application, SB = prescribed spring burn, and SB-IM = prescribed spring burn followed with fall imazapic application. Different lower case letters indicate differences between treatments after treatment application ($P < 0.05$).

unchanged in the *Spring Burn*, *Fall Burn*, and *Control* treatments (Fig. 2). The *Spring Burn-Imazapic*, *Fall Burn-Imazapic*, and *Imazapic* treatments reduced annual forb cover in 2007, but became relatively similar to the *Control* and *Fall Burn* treatment in 2008. The *Spring Burn* was the only treatment to have more annual forb cover in 2007 and 2008 than the *Control* treatment ($P < 0.01$).

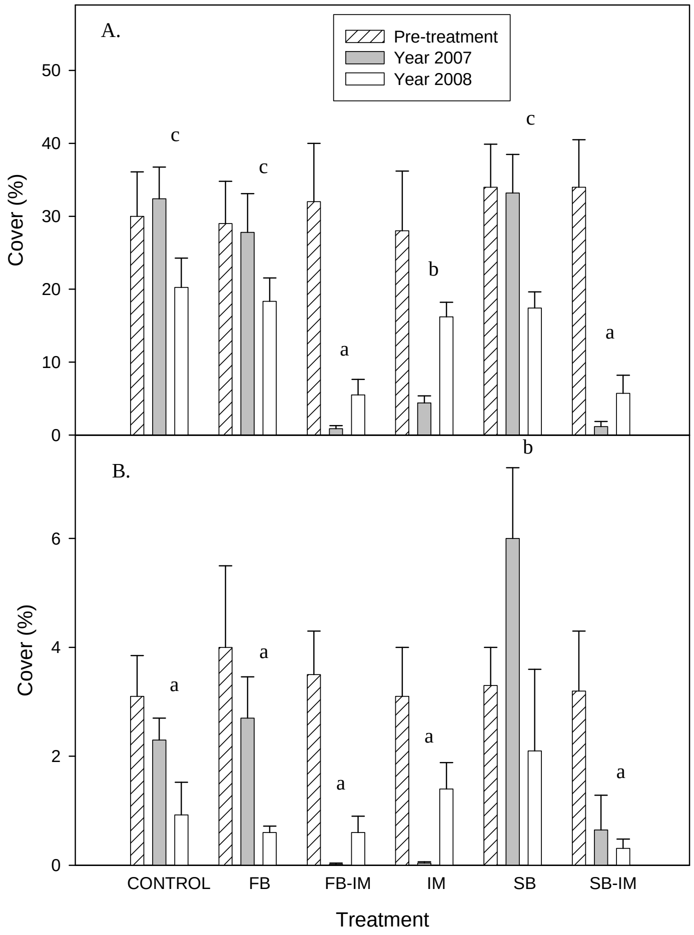

Figure 3. Medusahead (A.) and annual forb (B.) cover values (mean + S.E.) in the various medusahead control treatments prior to treatment and in 2007 and 2008. Comparisons of treatment effects were only made on post-treatment data. Pre-treatment data is reported to demonstrate that prior to treatment applications plots were similar. Treatments are: CONTROL = control, FB = prescribed fall burn, FB-IM = prescribed fall burn followed with fall imazapic application (87.5 g ai/ha), IM = fall imazapic application, SB = prescribed spring burn, and SB-IM = prescribed spring burn followed with fall imazapic application. Different lower case letters indicate differences between treatments after treatment application ($P < 0.05$).

Discussion

Restoration without seeding may be successful in areas with some native plants growing in association with medusahead infestations; however, additional treatments may be necessary to expedite vegetation recovery. Our results demonstrate that native vegetation can be promoted in medusahead infestations by selectively negatively impacting medusahead. However, not all treatments were successful at promoting native vegetation and controlling medusahead. Prescribed burn treatments without imazapic application were ineffective as medusahead control treatments and generally did not promote native vegetation. Prescribed burning treatments combined with imazapic application generally produced the best control of medusahead and the greatest positive response from native functional groups. However, imazapic, either as the sole treatment or in combination with prescribed burning, reduced annual forb cover in the first post-treatment year and density in both years post-treatment. The similarity in life-cycles between annual forbs and medusahead resulted in non-target impacts with the use of a pre-emergence herbicide. Similarities between native plant functional groups and exotic invaders must be carefully evaluated prior to applying treatments to minimize negative non-target impacts.

The increase in large perennial bunchgrasses, which have been demonstrated to be the most important native plant functional group to impede exotic annual grasses invasions (Davies 2008), and plant diversity with prescribed burning and imazapic treatment suggests that these plant communities can be restored, at least partially, when sufficient native vegetation remains in exotic annual grass infestations. The results of this study suggest that by controlling invasive annual grasses and potentially other invasive plant species in plant communities with some native vegetation remaining, the likelihood of failure can be minimized and the high cost of seeding native species can be avoided. However, the gradual increase in medusahead in the second year post-treatment in even the most effective control treatments suggest that further treatments may be needed to ensure continued increases in native vegetation. Though seeding native species appears to not be required, it may improve and hasten recovery.

Conclusions

Plant communities invaded by exotic annual grass that have some residual native perennial vegetation can be at least partially restored with appropriate annual grass control. Prescribed burning prior to imazapic application provided the best control of medusahead and facilitated a generally positive response from the native plant functional groups, with the exception of annual forbs. Considering the numerous failed attempts to reestablish native plants following exotic annual grass control, resources may be more effectively allocated to controlling exotic annual grass infestations with enough native vegetation remaining to eliminate the need for exhaustive restoration, including seeding.

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Attempts to Rehabilitate Medusahead Infested Rangelands

Roger L. Sheley, Brett S. Bingham, and Kirk W. Davies

Summary

The simultaneous application of imazapic and seeding did not provide consistent and reliable establishment of desired species. Considering the seeded species as an entire group, we found little evidence that the combination of imazapic and seeding would provide the best establishment of desired species because all favorable first year effects of treatments on density of desired species had faded by the end of the study.

Introduction

Effective management of medusahead (*Taeniatherum caput-medusae* [L.] Nevski) infested rangeland has been difficult and response to management has been highly variable. Burning has been used to remove medusahead thatch and increase the effectiveness of herbicide treatments. Prescribe burning without herbicide treatment was ineffective at controlling medusahead (Davies and Sheley *IN PRESS*).

Controlling medusahead with burning, imazapic, or their combination is short-term because desirable species are not available to occupy the ecological spaces opened by the control procedure. Perennial grasses may be the most important plant functional group to establish in order to successfully manage medusahead infested rangeland. However, establishing desired species in medusahead dominated areas has proven very difficult.

The need for cost-effective revegetation strategies for medusahead infested rangelands is substantial and unmet. We tested the potential for using the single-entry approach for revegetating medusahead infested rangeland.

Methods

This study was conducted on two sites from 2006 through 2008. The study sites were located about 5 km south of Fossil, Oregon and 8 km north of Spray, Oregon. Treatments included 3 seeding rates (none, medium, high), 2 herbicides (with and without), and 2 burning regimes (burned, not-burned) applied mid-Oct 2006. The treatments (3 x 2 x 2) were factorially arranged and were replicated 4 times in a Randomized-Complete-Block design. Plant density was measured in July 2007 and density and biomass were measured in July 2008. Density of tillers was counted for all grasses except medusahead, which were counted as plants because of their single non-branching stem.

Results

Medusahead

Without imazapic, the density and of medusahead ranged from 750 to 780 plants·m^{-2}, regardless of whether it was burned (Fig. 1a). With imazapic, medusahead density was slightly below half that of control or burning alone. Imazapic plus burn treatments had the lowest medusahead density with 180 plants·m^{-2}. Burning without imazapic yielded the most medusahead biomass (150 g·m^{-2}; Fig. 1b). Treatments with imazapic had lower medusahead biomass than treatments without Imazapic. Combining burning and imazapic yielded the lowest medusahead biomass (48 g·m^{-2}).

Seeded Species

As a group, the influence of imazapic and seeding on seeded species density depended on site and the year the data were collected ($P = 0.04$). By 2008, all treatments produced about the same seeded species density, except the high seeding rate without imazapic. Moderate and high seeding rate combined with burning and imazapic application had a moderately favorable effect on the density and biomass of intermediate wheatgrass and Sherman's big bluegrass. Tiller density of bluebunch wheatgrass increased with imazapic treatments (Fig. 2).

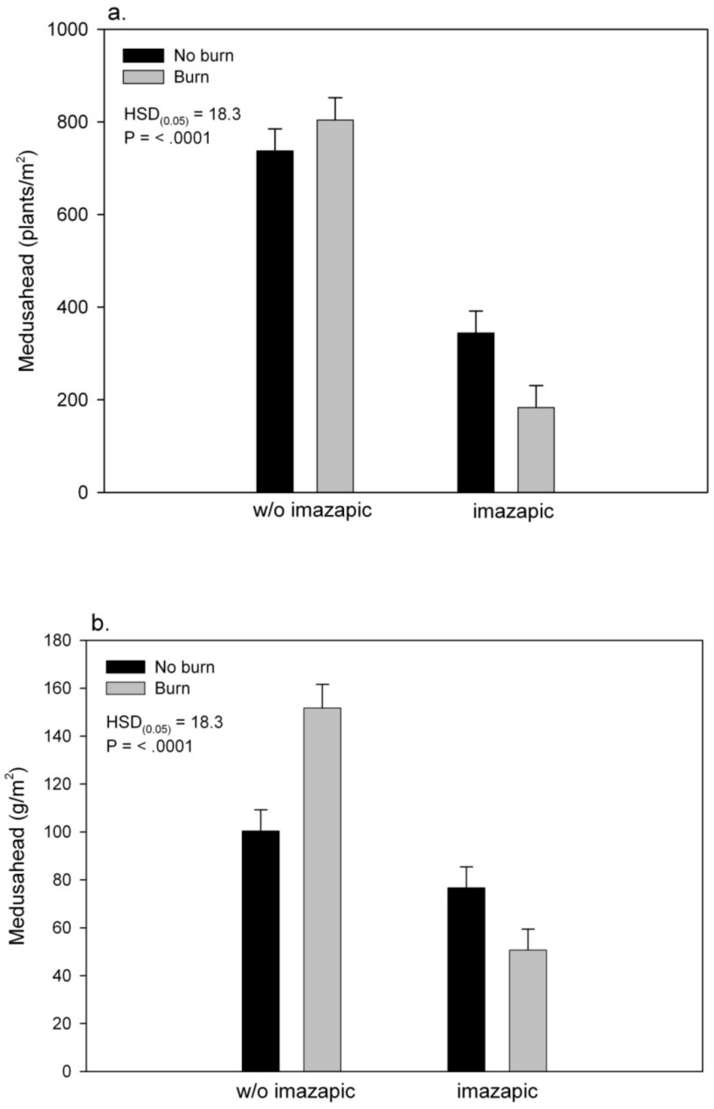

Figure 1. Interaction of burning and herbicide on (a) medusahead density and (b) biomass.

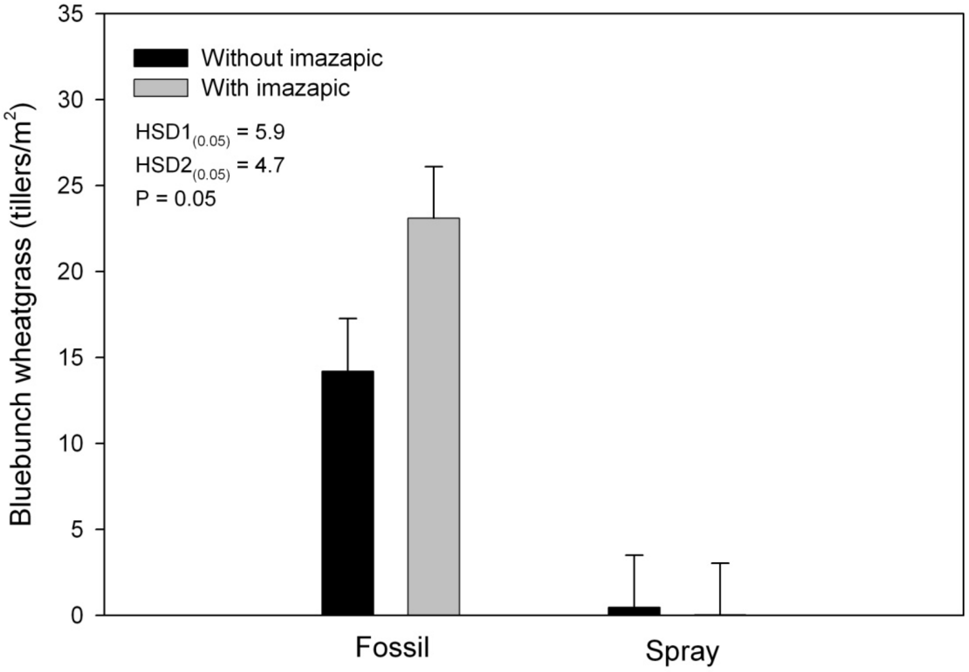

Figure 7. Interaction of herbicide and site on bluebunch wheatgrass tiller density.

Discussion

Successful revegetation is so expensive and the risk of failure is so high that managers are often directed to aim efforts toward situations with potentially greater success, such as prevention or applying herbicides in areas with some residual species that can be released after medusahead control (Davies and Johnson 2008; Davies and Sheley *IN PRESS*). Imazapic has been used as an effective herbicide to control invasive grasses and restore native plants in various regions of the western United States. In order to establish desired species we used a relatively low rate of imazapic (52 g ai/ha) to minimize negative effects of the herbicide on seeded species. However, imazapic applied alone only provided about 50-60% control in this study.

We hypothesized the combination of imazapic and seeding applied simultaneously would provide best establishment of desired species. Considering the seeded species as an entire group, we found little support for this hypothesis because all favorable first year effects of treatments on density of desired species had faded by the end of the study. Medusahead density and biomass were lowest when burning and imazapic were applied together. However, burning prior to the simultaneous application of seeding and imazapic did not assist the establishment of the collected group of seeded species, although it did favor the establishment of intermediate wheatgrass and bluegrass. In this study, there was no solid evidence that higher seeding rates increased seedling establishment.

Conclusions

The need for cost-effective revegetation strategies remains critically important to effective management of rangelands severely infested with medusahead. We found that the simultaneous application of imazapic and seeding did not provide consistent and reliable establishment of desired species. Lack of establishment was probably as result of poor medusahead control and/or injury to desired species by the herbicide. Burning combined with imazapic and seeding provided the best control of medusahead and favored the establishment of intermediate wheatgrass and bluegrass. It is clear that more research needs to be conducted to determine species that are tolerant to higher rates of imazapic if simultaneous seeding and imazapic applications are to become useful in revegetating medusahead infested rangeland.

References

DAVIES, K.W. and D.D. JOHNSON. 2008. Managing medusahead in the Intermountain West is at a critical threshold. *Rangelands* 30:13-15.

DAVIES, K.W. and R.L. SHELEY. (IN PRESS) Promoting native vegetation and diversity in exotic annual grass infestations. *Restoration Ecology*

Other Sagebrush Steppe Research Projects:

Response of herbaceous vegetation to mowing of Wyoming big sagebrush

K.W. Davies

This study is evaluating if mowing Wyoming big sagebrush increases herbaceous vegetation cover, density, and production. Of particular interest is how plant species important in sage-grouse diets are influenced by mowing sagebrush.

Comparing the herbaceous and insect response to mowing and burning of mountain big sagebrush

K.W. Davies & J.D. Bates

Mountain big sagebrush plant communities with greater than 30% cover were either mowed or fall prescribed burned in 2007. The purpose of this study is to determine the impacts of these treatments on herbaceous vegetation and insects that are important to sage-grouse. This study will also compare the impacts of the treatments on long-term recovery of sagebrush and livestock forage production.

Evaluation of assumed benefits of brush management

S. Archer, B. Wilcox, T. Fulbright, K. McDaniel, & K. Davies

This study is evaluation the assumed benefits of brush management to wildlife, watershed function, and livestock. This encompasses brush management across the western United States.

Fire associated mortality of perennial grasses influence on site recovery

K.W. Davies

This study is evaluating the ability of sagebrush-bunchgrass communities to recover after fire at varying mortality rates of perennial grasses.

Influence of long-term livestock grazing exclusion on the accumulation and distribution of plant litter

K.W. Davies, T. Svejcar, & J.D. Bates

This study is comparing the accumulation and distribution of litter between long-term (+70 years) grazing excluded and moderately grazed sagebrush steppe.

Comparison of vegetation characteristics between Wyoming and mountain big sagebrush plant communities

K.W. Davies & J.D. Bates

Little data exists comparing the vegetation characteristics between Wyoming and mountain big sagebrush communities. Especially lacking is a comparison of their value as habitat. This study is comparing vegetation cover, density, diversity, and production in Wyoming and mountain big sagebrush plant communities across southeastern Oregon.

Long-term vegetation dynamics in Wyoming big sagebrush plant communities

J.D. Bates & K.W. Davies

This study is evaluating the fluctuation of vegetation characteristics in Wyoming big sagebrush plant communities over a 10+ year period. The objective is to correlate variation in plant functional groups cover, density, and production with interannual variation in climatic conditions.

Impacts of feral (wild) horses on riparian and adjacent sagebrush steppe uplands

K.W. Davies, C.S. Boyd, & S. Petersen

The impacts of wildhorses on plant communities are relatively unknown because their impacts can rarely be differentiated from domestic livestock use. This study will evaluate the impacts of wildhorses by erecting six riparian and upland exclosures in a 500,000 acre area without domestic livestock use.

Medusahead control with burning and imazapic application in sagebrush steppe

K.W. Davies & R.L. Sheley

Medusahead infestations were treated with spring burning, fall burning, imazapic application, spring burning with imazapic application, and fall burning with imazapic application. The following year perennial grasses were seeded into the treated areas. The control of medusahead and the response of desirable plants are being evaluated among treatments.

Reoccupying medusahead infested sagebrush steppe

K.W. Davies, D.D. Johnson, & A.M. Nafus

This study will determine the density of perennial bunchgrasses require to successfully occupy previously medusahead infested sagebrush steppe plant communities. This study will also compare whether crested wheatgrass or bluebunch wheatgrass plants are more effective at preventing the re-invasion of medusahead.

Revegetation success with wildfire and seeding in medusahead dominated sagebrush steppe

K.W. Davies

In 2007, vegetation characteristics were measure on 19 medusahead dominated sites. Later that year wildfires burned six of those sites. Those sites were seeded with a rangeland drill in the fall of 2007. The purpose of this study is to compare the burned and seeded sites with the untreated sites to determine if wildfire followed by seeding is a viable management option for restoring medusahead invaded sites.

Increase fire frequency with and without grazing affects on productivity and diversity of sagebrush steppe

J.D. Bates, K.W. Davies, & C.S. Boyd

This study will evaluate the impact of increased fire frequency with and without livestock use influence on sagebrush steppe vegetation characteristics.

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