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Vegetation Response to Mowing Dense Mountain Big Sagebrush Stands

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Abstract

A decrease in fire frequency and past grazing practices has led to dense mountain big sagebrush (*Artemisia tridentata* Nutt. subsp. *vaseyana* [Rydb.] Beetle) stands with reduced herbaceous understories. To reverse this trend, sagebrush-reducing treatments often are applied with the goal of increasing herbaceous vegetation. Mechanical mowing is a sagebrush-reducing treatment that commonly is applied; however, information detailing vegetation responses to mowing treatments generally are lacking. Specifically, information is needed to determine whether projected increases in perennial grasses and forbs are realized and how exotic annual grasses respond to mowing treatments. To answer these questions, we evaluated vegetation responses to mowing treatments in mountain big sagebrush plant communities at eight sites. Mowing was implemented in the fall of 2007 and vegetation characteristics were measured for 3 yr post-treatment. In the first growing season post-treatment, there were few vegetation differences between the mowed treatment and untreated control ($P > 0.05$), other than sagebrush cover being reduced from 28% to 3% with mowing ($P < 0.001$). By the second growing season post-treatment, perennial grass, annual forb, and total herbaceous vegetation were generally greater in the mowed than control treatment ($P < 0.05$). Total herbaceous vegetation production was increased 1.7-fold and 1.5-fold with mowing in the second and third growing seasons, respectively ($P < 0.001$). However, not all plant functional groups increased with mowing. Perennial forbs and exotic annual grasses did not respond to the mowing treatment ($P > 0.05$). These results suggest that the abundance of sagebrush might not be the factor limiting some herbaceous plant functional groups, or they respond slowly to sagebrush-removing disturbances. However, this study suggests that mowing can be used to increase herbaceous vegetation and decrease sagebrush in some mountain big sagebrush plant communities without promoting exotic annual grass invasion.

Resumen

Una disminución en la frecuencia del fuego y anteriores practicas de pastoreo han llevado a la formación de montículos densos de artemisa de la montaña (*Artemisia tridentata* Nutt. subsp. *vaseyana* [Rydb.] Beetle) y la reducción del estrato herbáceo. Para revertir esta tendencia, con frecuencia se aplican tratamientos para reducir la artemisa y aumentar la vegetación herbácea. La remoción mecánica de la artemisa es el tratamiento comúnmente usado, sin embargo, no hay información detallada de la respuesta de la vegetación al chapoleo. Específicamente, se necesita información para determinar sí aumentos proyectados en pastos perennes y hierbas se posibles y como pastos exótico anuales responden al tratamiento de chapoleo. Para responder esta preguntas, evaluamos la respuesta de la vegetación al tratamiento de chapoleo in comunidades de plantas de gran artemisa de montaña en ocho sitios. El chapoleo fue implementado en el otoño de 2007 y las características de la vegetación fueron medida tres años post-tratamiento. En la primera época de crecimiento de post-tratamiento hubo pocas diferencias en la vegetación entre el tratamiento de chapoleo y el control ($P > 0.05$). La cobertura de artemisa se redujo de 28% a 3% con el chapoleo ($P < 0.001$). Para la segunda época de crecimiento post-tratamiento los pastos perennes, hierbas anuales y el total de la vegetación herbácea fueron generalmente mayores en el tratamiento de chapoleo que en el control ($P < 0.05$). El total de la producción de la vegetación herbácea aumento 1.7 a 1.5 veces con el tratamiento de chapoleo en la segunda y tercer época de crecimiento respectivamente ($P < 0.001$). Sin embargo, no todos los grupos funcionales de plantas aumentaron con el chapoleo. Las hierbas perennes y pastos exóticos anuales no respondieron al tratamiento de chapoleo ($P > 0.05$). Estos resultados sugieren que la abundancia de artemisa puede no ser el factor limitante de algunos grupos funcionales de plantas herbaceas o que ellas responden lentamente al disturbio de la remoción de la artemisa. Sin embargo, este estudio sugiere que el chapoleo puede ser usado para aumentar la vegetación herbácea y disminuir la artemisa en algunas comunidades de plantas de gran artemisa de montaña sin promover la invasión de pastos anuales exóticos.

Key Words: annual grass, *Artemisia tridentate*, brush management, disturbance, forage, range improvements

INTRODUCTION

The sagebrush (*Artemisia* L.) ecosystem occupies over 62 million hectares in western North America (Tisdale et al. 1969; Küchler 1970; McArthur and Plummer 1978; Miller et al. 1994; West and Young 2000). It provides critical habitat for many wildlife species and constitutes a major forage base for western livestock operations (Connelly et al. 2000; Crawford et al. 2004; Davies et al. 2006; Davies and Bates 2010a, 2010b). Historically, periodic wildfires removed sagebrush from the plant communities, resulting in increased herbaceous vegetation (Wright and Bailey 1982; Miller and Rose 1999). However, with European settlement, fire-return intervals have been lengthened in some mountain big sagebrush (*A. tridentata*

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Nutt. subsp. *vaseyana* [Rydb.] Beetle) plant communities (Miller and Rose 1999; Miller and Heyerdahl 2008) causing, in combination with past grazing practices, an increase in sagebrush and reduction in the herbaceous component (West 1983; Miller et al. 1994; Miller and Rose 1999). Herbaceous vegetation generally decreases as sagebrush increases because of competition for limited resources (Rittenhouse and Sneva 1976).

In dense sagebrush stands, sagebrush-reducing treatments might be necessary to decrease sagebrush in order to increase herbaceous vegetation (Connelly et al. 2000; Olson and Whitson 2002; Crawford et al. 2004; Beck et al. 2009) and biodiversity (Johnson et al. 1996). Prescribed fire often is used to remove sagebrush (Harniss and Murray 1973; Peek et al. 1979; Davies et al. 2007); however, mechanical treatments might be preferable in some situations because they do not pose a risk of fire escape (Mueggler and Blaisdell 1958; Urness 1979), and sagebrush dominance can be reduced without completely removing sagebrush from the plant community (Davies et al. 2009a). Complete elimination of sagebrush from plant communities with fire can have substantial long-lasting negative impacts on sagebrush-associated wildlife species (Beck et al. 2009) and, considering that more than 350 sagebrush-associated plants and animals have been identified as species of conservation concern (Suring et al. 2005; Wisdom et al. 2005), mechanical treatments might become increasingly prevalent.

Although treatments that reduce sagebrush often result in 2-fold to 3-fold increases in herbaceous vegetation (Harniss and Murray 1973; Wambolt and Payne 1986; Davies et al. 2007), these responses are not always realized when sagebrush is reduced with mechanical treatments (Davies et al. 2011a). Disturbances that remove sagebrush also can decrease the resistance of the plant community to exotic plant invasion (Prevéy et al. 2010). Thus, increases in herbaceous vegetation following sagebrush-reducing treatments might be primarily exotic annual grasses (Stewart and Hull 1949; Davies et al. 2009b). Exotic annual grass invasion is concerning because it can promote frequent wildfires that create a grass-fire cycle to the detriment of native vegetation (D'Antonio and Vitousek 1992; Brooks et al. 2004). However, the threat of invasion appears to vary by sagebrush plant community type. For example, Wyoming big sagebrush (*A. tridentata* Nutt. subsp. *wyomingensis* [Beetle & A. Young] S.L. Welsh) plant communities appear to be at a much greater risk of converting to near-monocultures of exotic annual grass compared to mountain big sagebrush plant communities (Miller and Eddleman 2000; Chambers et al. 2007; Davies et al. 2011b). Although less likely, exotic annual grass invasion can be a threat to mountain big sagebrush plant communities after disturbance (Bates et al. 2005; Condon et al. 2011).

Evaluations of the response of mountain big sagebrush plant communities to mechanical treatments are limited. Mountain big sagebrush plant communities are one of the most productive and diverse sagebrush plant communities (Davies and Bates 2010a, 2010b); thus, this information is critically needed. In mountain big sagebrush plant communities in Utah, Dahlgren et al. (2006) reported that forbs increased, whereas grasses remained the same when sagebrush was reduced with either a Lawson aerator or a Dixie harrow. In contrast, Mueggler and Blaisdell (1958) reported an increase in grasses with railing and rotobeating treatments in western Idaho in what were probably mountain big sagebrush plant communities, although the big sagebrush subspecies at their study sites was not reported. Mueggler and Blasidell (1958) also measured an increase in forbs. Thus, results have not been consistent across mechanical treatments and ecoregions. The applicability of these studies to mountain big sagebrush plant communities in other ecoregions, as well as other mechanical treatments, such as mowing, is unknown. These studies also often have grouped perennial and annual forbs together (Mueggler and Blaisdell 1958; Dahlgren et al. 2006), and perennial and annual grasses together (Mueggler and Blaisdell 1958), thereby limiting the ability to anticipate individual plant functional group response to treatments. For example, with the increase in invasive annual grasses in sagebrush communities (Chambers et al. 2007), valuable information on the influence of treatments on invasibility would be lost when perennial and annual grasses are grouped together. More detailed vegetation measurements from additional ecoregions are needed to build a knowledge base to determine the response of mountain big sagebrush plant communities to mechanical treatments.

To help fill this knowledge gap, we evaluated the response of eight mountain big sagebrush plant communities to mowing treatments in southeastern Oregon. Our hypotheses were: 1) herbaceous vegetation biomass, cover, and density would increase with the reduction of sagebrush with mowing, 2) with annual vegetation initially increasing, but 3) then decreasing as perennial herbaceous vegetation increased in subsequent years.

METHODS

Study Area

We evaluated the response of mountain big sagebrush plant communities to mowing on the Hart Mountain National Antelope Refuge (lat 42°21′16″N, long 119°22′54″W). The study sites were located on the east side of Hart Mountain at elevations ranging from 2 013 to 2 166 m above sea level. Hart Mountain is a fault-block mountain in southeastern Oregon with a less steep slope on the eastern side and a steep slope dropping to the Warner Valley on the western side. Slopes at the study sites were relatively flat to 7°, and aspects varied from north to south. Annual precipitation averaged between 400 to 510 mm, depending on the site (USDA-NRCS 1998). Most of the precipitation occurs in the winter as snow and summers are relatively hot and dry. Annual precipitation was 66%, 87%, and 101% of the long-term average in 2008, 2009, and 2010, respectively (Eastern Oregon Agricultural Research Center, unpublished data, 2010). Livestock had been excluded from the 112 503 hectare refuge since the mid-1990s. Wildlife utilization was not measured, but probably is limited due to low numbers of ungulates in the area. A general lack of observations of wildlife use also suggests that utilization was low. Plant communities prior to treatment were dominated by mountain big sagebrush with an understory of perennial grasses and forbs. Prior to treatment, sagebrush, perennial grass (excluding Sandberg bluegrass [*Poa secunda* J. Presl]), and perennial forb cover averaged 28%, 19%, and 12%, respectively. Common perennial grasses included Columbia needlegrass (*Achnatherum nelsonii* [Scribn.] Barkworth), prairie junegrass

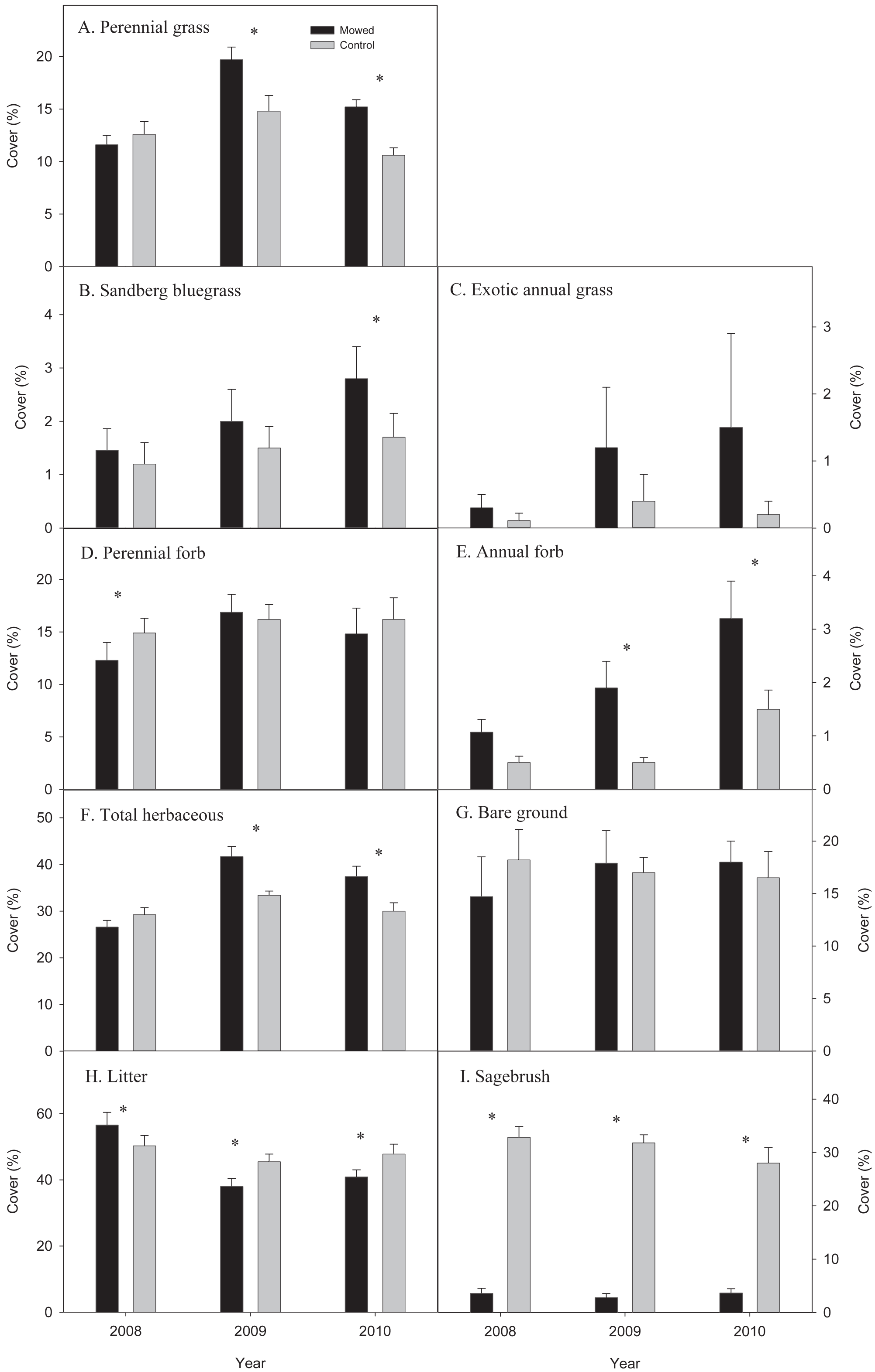

Figure 1. Vegetation, litter, and bare ground cover (mean + SE) in mowed and untreated controls in mountain big sagebrush plant communities in southeastern Oregon in the first 3 yr post-treatment. Asterisk (*) indicates significant difference ($P \leq 0.05$) between treatments in that year.

(*Koeleria macrantha* [Ledeb.] Schult.), bottlebrush squirreltail (*Elymus elymoides* [Raf.] Swezey), Idaho fescue (*Festuca idahoensis* Elmer), bluebunch wheatgrass (*Pseudoroegneria spicata* [Pursh] Á. Löve), Thurber's needlegrass (*Achnatherum thurberianum* [Piper] Barkworth), mountain brome (*Bromus marginatus* Nees ex Steud.), Sandberg bluegrass, and other bluegrass species (*Poa* spp. L.). Common perennial forbs included milkvetches (*Astragalus* spp. L.), yarrow (*Achillea millefolium* L.), hawksbeard (*Crepis* spp. L.), paintbrushes (*Castilleja* spp. Mutis ex L. f.), fleabanes (*Erigeron* spp. L.), biscuitroots (*Lomatium* spp. Raf.), ragwort (*Senecio integerrimus* Nutt.), and lupines (*Lupinus* spp. L.).

Experimental Design and Measurements

Response to mowing in mountain big sagebrush plant communities was evaluated using a randomized complete block design with eight blocks (sites). Blocks varied in location, topography, soils, and vegetation characteristics. Prior to mowing, treatment plots within blocks were determined to have uniform vegetation (see below for description of sampling method). Sagebrush, perennial grass, perennial forb, Sandberg bluegrass, exotic annual grass, and annual forb cover and density did not vary between treatments prior to mowing ($P > 0.05$). Treatments were either mowed or an untreated control. Treatments were randomly assigned to 0.4 ha (50 m × 80 m) plots within each block. Mowing was applied in September 2007 with a John Deer 1418 rotary cutter (Deere & Company, Moline, IL) set to cut at a 20-cm height above the soil surface. Mowed shrubs were not removed from plots. Response variables were herbaceous biomass production, cover, and density, sagebrush cover and density, bare ground, and litter cover.

Response variables were measured in each plot prior to treatment and in early July of 2008, 2009, and 2010. Sagebrush canopy cover was measured using the line intercept method (Canfield 1941) on four, parallel 50-m transects, spaced at 20-m intervals. Sagebrush density was measured by counting all the shrubs rooted inside 2 m × 50 m belt transects, positioned on each of the four, 50-m transects used to measure sagebrush cover. Herbaceous canopy cover and density, bare ground, and litter cover were measured by species inside 40 cm × 50 cm frames (0.2 m^2) located at 3-m intervals on each 50-m transect (starting at 3 m and ending at 45 m), resulting in 15 frames per transect and 60 frames per plot. Herbaceous biomass (aboveground) was determined by clipping by plant functional group from 5 randomly located 1 m^2 frames per plot. Harvested herbaceous biomass was oven-dried at 50°C until reaching a consistent weight, and then current year's growth was separated from previous years' growth and weighed to determine annual biomass production.

Statistical Analyses

We used repeated measures analysis of variance (ANOVA) using the mixed models procedure (Proc Mix) in SAS v.9.1 (SAS Institute Inc., Cary, NC) to determine the influence of mowing on response variables across years. Fixed variables were treatment and time since treatment (year) and their interactions. Random variables were blocks (sites) and block by treatment interactions. Covariance structures used in the repeated measures ANOVAs were selected using the Akaike's Information Criterion (Littell et al. 1996). Treatment effects also were analyzed using ANOVAs in each year of the study, because the response of sagebrush communities often varies significantly by time since disturbance (Harniss and Murray 1973; Davies et al. 2007). Data were tested for normality using the univariate procedure in SAS v.9.1 (Littell et al. 1996). Data that violated assumptions of normality were log-transformed. All figures present original data (i.e., nontransformed). Response variable means were reported with standard errors. Differences between means were considered significant at alpha ≤ 0.05. For analyses, herbaceous cover, density, and biomass were grouped into functional groups: Sandberg bluegrass, perennial grass, exotic annual grass, perennial forb, and annual forb. Sandberg bluegrass was treated as a separate functional group from the other perennial grasses because it is smaller in stature and its phenological development occurs earlier than other perennial grasses. Sandberg bluegrass also responds differently to management and disturbances than other perennial grasses (Robertson 1971; Davies et al. 2007).

RESULTS

Cover

Perennial grass, total herbaceous, and litter cover varied by the interaction between treatment and year ($P < 0.001$). Bare ground and the cover of the other plant functional groups did not vary by the interaction between treatment and year ($P > 0.05$). Perennial grass cover was not different between the control and mowed treatment in 2008 (Fig. 1A; $P = 0.378$). In 2009 and 2010, perennial grass cover was 1.3-fold and 1.4-fold greater in the mowed treatment compared to the untreated control, respectively ($P < 0.001$). Sandberg bluegrass cover did not vary between treatments when all years were combined ($P = 0.157$); however, when years were analyzed individually, it was 1.6-fold greater in mowed compared to the control in 2010 (Fig. 1B; $P = 0.019$). In 2008 and 2009, Sandberg bluegrass cover did not vary between treatments ($P = 0.590$ and 0.210, respectively). Exotic annual grass cover did not differ between the treatments when all years were analyzed together or when years were analyzed individually (Fig. 1C; $P > 0.05$). Perennial forb cover did not vary by treatment when all years were combined for analysis ($P = 0.258$). In 2008, perennial forb cover was 1.2-fold greater in the untreated control than the mowed treatment (Fig. 1D; $P = 0.045$). In 2009 and 2010, perennial forb cover did not vary between treatments ($P = 0.570$ and 0.247, respectively). Annual forb cover was greater in the mowed compared to the control treatment when all years were included in the analysis ($P = 0.009$). In 2008, annual forb cover did not differ between treatments (Fig. 1E; $P = 0.232$). In 2009 and 2010, annual forb cover was 3.8-fold and 2.1-fold greater in the mowed treatment compared to the control, respectively ($P = 0.009$ and $P = 0.003$, respectively). Total herbaceous cover did not vary by treatment in 2008 (Fig. 1F; $P = 0.180$). In 2009 and 2010, total herbaceous cover was approximately 1.2-fold greater in the mowed treatment than the control ($P < 0.001$ and $P = 0.001$, respectively). Bare ground did not differ between the treatments when all years were used in the analysis or in individual years (Fig. 1G; $P > 0.05$). Litter cover was greater in the mowed than the untreated control in 2008 (Fig. 1H; $P = 0.009$) and in 2009 and 2010 it was greater in the control compared to the mowed treatment ($P = 0.001$ and $P = 0.002$, respectively). Sagebrush cover was between 7.6-fold and 11.4-fold greater in the untreated control than the mowed treatment in all post-treatment years (Fig. 1I; $P < 0.001$).

Density

Perennial grass, Sandberg bluegrass, annual grass, perennial forb, and sagebrush density did not vary by the interaction

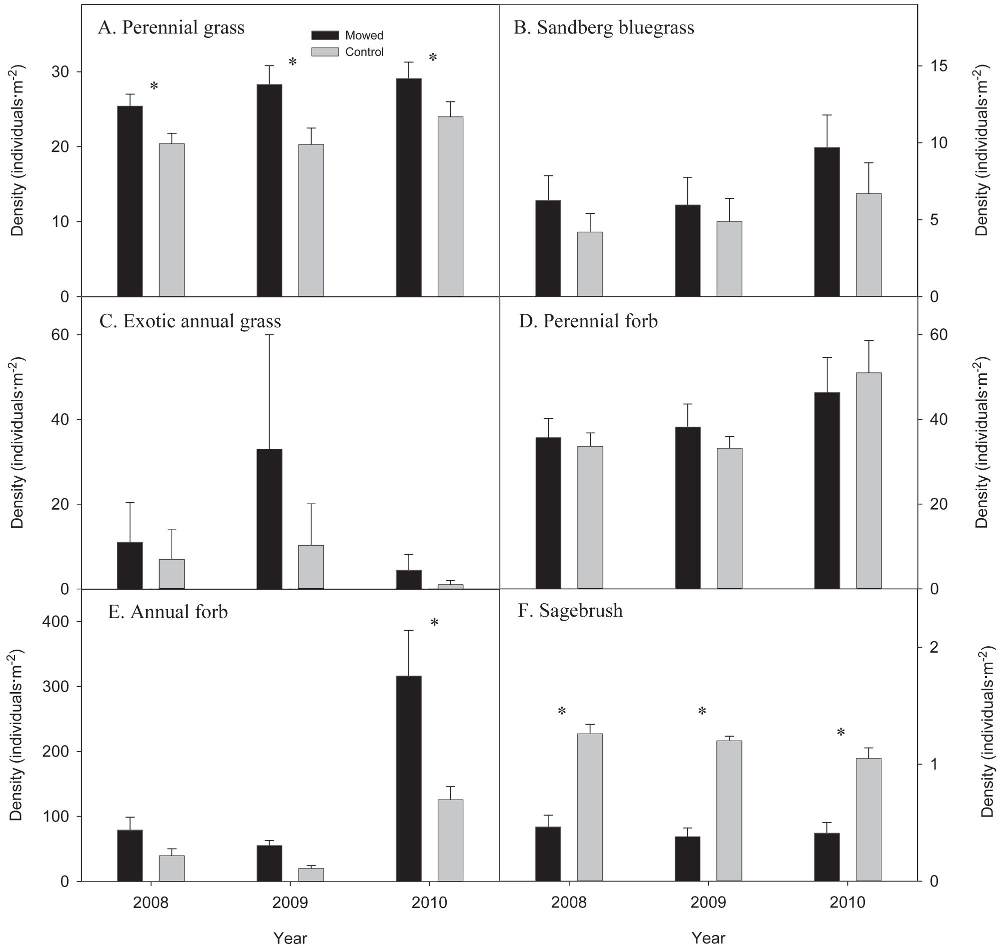

Figure 2. Vegetation density (mean + SE) in mowed and untreated controls in mountain big sagebrush plant communities in southeastern Oregon in the first 3 yr post-treatment. Asterisk (*) indicates significant difference ($P \leq 0.05$) between treatments in that year.

between treatment and year ($P > 0.05$), whereas annual forb density did vary by the interaction ($P = 0.016$). Perennial grass density was greater in the mowed than the control when all years were included in the analysis (Fig. 2A; $P = 0.007$). In 2008, 2009, and 2010, perennial grass density was 1.2-fold, 1.4-fold, and 1.2-fold greater in the mowed compared to the control, respectively ($P = 0.044$, $P = 0.002$, and $P = 0.042$, respectively). Sandberg bluegrass, annual grass, and perennial forb density did not differ between treatments in individual years or when all years were analyzed together (Fig. 2B–D; $P > 0.05$). Annual forb density was not different between treatments in 2008 and 2009 (Fig. 2E; $P = 0.332$ and $P = 0.388$, respectively). In 2010, annual forb density was 2.5-fold greater in the mowed compared to the control treatment ($P < 0.001$). Sagebrush density was less in the mowed compared to the control treatment (Fig. 2F; $P < 0.001$). In 2008, 2009, and 2010, sagebrush density was 2.6-fold, 2.2-fold, and 2.1-fold greater in the control than the mowed treatment, respectively ($P < 0.001$).

Biomass

Perennial grass and total herbaceous biomass varied by the interaction between treatment and year ($P < 0.001$ and $P = 0.002$, respectively). The other plant functional groups did not vary by the interaction between treatment and year ($P > 0.05$). Perennial grass biomass did not differ between treatments in 2008 (Fig. 3A; $P = 0.485$), whereas in 2009 and 2010 it was 2.5-fold and 1.9-fold greater in the mowed compared to the control ($P < 0.001$). Sandberg bluegrass, annual grass, and perennial forb biomass production did not vary between the treatments when years were analyzed together or individually (Fig. 3B–D; $P > 0.05$). Annual forb biomass production was greater in the mowed than the control treatment when all years were analyzed together ($P = 0.016$). When years were analyzed individually, annual forb biomass did not differ between treatments in 2008 and 2009 (Fig. 3E; $P = 0.200$ and $P = 0.185$, respectively). In 2010, annual forb biomass was 2.8-fold greater in the mowed compared to the control ($P = 0.008$). Total herbaceous biomass did not differ between treatments in 2008 (Fig. 3F; $P = 0.512$). In 2009 and 2010, total herbaceous biomass production was 1.7-fold and 1.5-fold greater in the mowed than the control, respectively ($P < 0.001$).

DISCUSSION

Herbaceous vegetation biomass, density, and cover generally either did not respond or increased in response to mowing. Several herbaceous plant functional groups did not increase

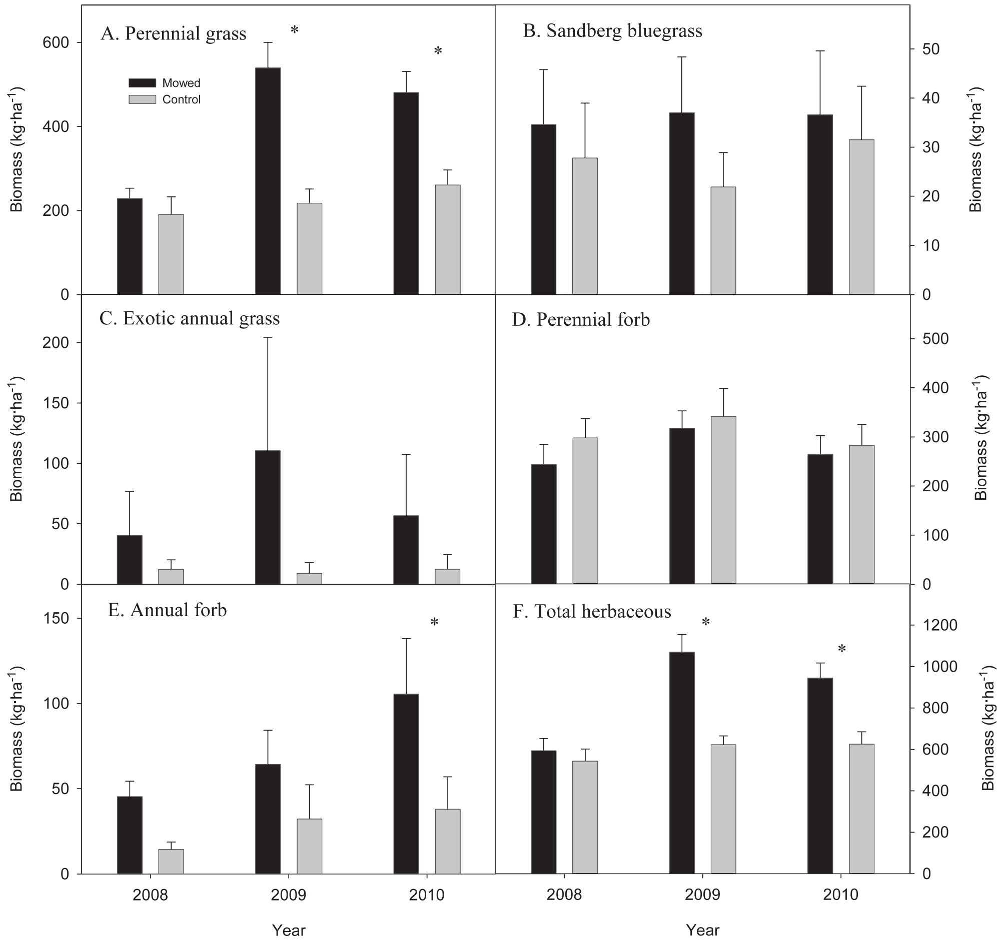

Figure 3. Vegetation biomass production (mean + SE) in mowed and untreated controls in mountain big sagebrush plant communities in southeastern Oregon in the first 3 yr post-treatment. Asterisk (*) indicates significant difference ($P \leq 0.05$) between treatments in that year.

with mowing; thus, the assumption that the herbaceous plants would increase with sagebrush reduction treatments was, at least partially, incorrect. This questions whether dense mountain big sagebrush stands suppress the nonresponsive, plant functional groups or if only certain groups can respond relatively rapidly to the decrease in sagebrush. Also, in contrast to what was predicted, results were not based on life cycles. Not all annual vegetation initially increased as hypothesized and similarly perennial herbaceous plant functional groups varied in their responses.

Plant functional groups that did respond positively to mowing had relatively substantial increases. For example, perennial grass production almost doubled and annual forb production approximately tripled in response to mowing treatments by end of the study. The increases in perennial grasses and annual forbs caused large increases in total herbaceous vegetation. The increase in perennial grass generally did not occur until the second growing season, suggesting that there was a lagged response to mowing. In contrast to our results, Dahlgren et al. (2006) and Davies et al. (2011a) did not measure increases in perennial grasses with mechanical sagebrush control treatments. However, Dahlgren et al. (2006) reduced sagebrush cover to 18.8% and 14.6% with a Dixie harrow and Lawson aerator, respectively. In our study, we reduced sagebrush cover to 3.3% with the mowing treatment. Davies et al. (2011a) treated Wyoming big sagebrush plant communities, which are less productive and probably respond differently to treatments than mountain big sagebrush plant communities (Davies and Bates 2010a, 2010b). Thus, the contrasts in results with these studies were probably due to different levels of sagebrush reduction and different plant communities.

The increase in the cover, density, and biomass of annual forbs with mowing is similar to results from other studies where sagebrush was reduced (e.g., Rhodes et al. 2010; Davies et al. 2011a). Increases in the annual forb component could be important to maintaining functional diversity in the plant community (Davies et al. 2010). The increase in annual forbs also might be important because forbs are nutritious forage for wildlife (Gregg et al. 2008). Annual forb response also might have been even greater if perennial grasses had not increased. Bates et al. (2011) reported that annual and perennial forbs largely dominated postfire plant communities when there were severe fire effects to perennial grasses.

We found no evidence that exotic annual grasses would become problematic after mowing mountain big sagebrush plant communities. Other studies (Bates et al. 2005; Condon et al. 2011) reported that exotic annual grasses can be a problem in mountain big sagebrush plant communities after disturbance. Unlike to our study, Bates et al. (2005) and Condon et al. (2011) evaluated postfire response in mountain big sagebrush plant communities encroached by western juniper (*Juniperus occidentalis* Hook.) or singleleaf pinyon (*Pinus monophylla* Torr. and Frém.) and Utah juniper (*Juniperus osteosperma* [Torr.] Little), respectively. These plant communities had much lower postdisturbance perennial grass densities than measured in our study. The greater density of perennial grasses in our treated plots probably limited the exotic annual grass response. High perennial grass abundance limits the ability of exotic annual grasses to establish in sagebrush communities (Davies 2008). More severe disturbances that reduce perennial grasses might make these mountain big sagebrush plant communities more susceptible to exotic annual grass invasion. Mowing does not appear to reduce perennial grass abundance, and therefore might be a prudent choice for reducing sagebrush in mountain big sagebrush plant communities at risk of postdisturbance exotic annual grass invasion.

Similar to many other shrub removal studies (Sturges 1983, 1993; Berlow et al. 2003; Davies et al. 2007), we measured a considerable increase in herbaceous vegetation with a reduction in sagebrush. Mountain big sagebrush plant communities with dense sagebrush overstories probably are suppressing herbaceous vegetation production. Treatments that reduce sagebrush in these communities can increase forage for livestock and increase herbaceous vegetation cover. In our study, forage production was approximately doubled by the second year after mowing mountain big sagebrush plant communities. Although there generally was not an increase in herbaceous vegetation the first growing season after mowing, we did not find any evidence of negative impacts of mowing on herbaceous vegetation. We are in agreement with Mueggler and Blaisdell (1958), who did not report any negative impacts to herbaceous vegetation when applying rotobeating or railing treatments to reduce sagebrush.

One potential negative effect of mowing mountain big sagebrush was the amount of sagebrush that was reduced. If the only goal was to increase herbaceous vegetation, large reductions in sagebrush would not be of concern. However, if the purpose was to increase herbaceous production and simultaneously provide high quality habitat for sage-grouse (*Centrocercus urophasianus*), the reduction in sagebrush was extreme (based on recommendations in Connelly et al. 2000) to be applied across large areas. However, mowing might be acceptable if applied to relatively small areas within large continuous sagebrush-dominated landscapes (Dahlgren et al. 2006). There exists a tradeoff between too much cover ($> 25\%$) in the untreated areas and not enough cover ($< 4\%$) in the mowed areas to best meet the habitat needs for some sagebrush-associated wildlife. However, the short-term negative impacts of reduced sagebrush cover can be mediated in the long-term as sagebrush cover increases in the mowed areas.

Our results also demonstrate the importance of separating perennial and annual functional groups for analyses. Perennial forbs did not respond, other than a slight decrease in cover in the first post-treatment growing season, to the mowing treatment, but annual forbs increased substantially. Important response differences to mowing between perennial and annual forbs would have been missed if they had been grouped together. Similarly, perennial grasses increased with mowing in our study, whereas annual grasses did not differ between treatments. Our results suggest that important response differences between annual and perennial herbaceous plant functional groups might have been missed with previous studies in mountain big sagebrush communities (e.g., Mueggler and Blaisdell 1958; Dahlgren et al. 2006).

MANAGEMENT IMPLICATIONS

Mowing mountain big sagebrush plant communities resulted in an almost 2-fold increase in herbaceous vegetation and reduced sagebrush cover from approximately 28% to 3% cover. Increases in perennial grasses with mowing could increase forage for livestock; however, the large reduction in sagebrush cover could negatively impact some sagebrush-associated wildlife species if applied to large areas as long as sagebrush cover remains low. As sagebrush cover increases in treated areas, sagebrush-associated wildlife may benefit from less dense sagebrush stands. Thus, there could be a tradeoff between sagebrush cover that is greater than optimal for some sagebrush-associated wildlife (and that might be suppressing herbaceous vegetation in untreated dense stands) and not enough sagebrush cover for sagebrush-associated wildlife immediately after mowing. Our study does not, however, provide enough information to predict the long-term recovery of sagebrush. In areas of critical habitat for sagebrush-associated wildlife, mowing large areas should be avoided because of the potential for adverse effects on their populations (Connelly et al. 2000; Dahlgren et al. 2006). Although mowing dense mountain big sagebrush plant communities elicited a positive response from some plant functional groups and did not promote exotic annual grass invasion, several plant functional groups did not respond to mowing. For example, our study did not provide any evidence that mowing would increase perennial forbs. Long-term evaluation is needed to evaluate if a lagged response might exist, especially for the species that would have to be recruited from seed. Because increases in herbaceous vegetation seem to be specific to only a few functional groups, careful consideration of whether mowing dense mountain big sagebrush stands will meet management objectives is needed.

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