Burning and Mowing Wyoming Big Sagebrush: Do Treatments Meet Minimum Guidelines for Greater Sage-Grouse Breeding and Late Brood-Rearing Habitats?

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Abstract—*In the Bighorn Basin of north-central Wyoming, over 100 km² of prescribed burns have occurred since 1980 and over 35 km² of brush mowing has occurred since 2000 in an effort to decrease high density stands of sagebrush, increase herbaceous production, create more diversity in seral stages on the landscape, and reduce conifer encroachment. Many of these treatments were intended to enhance conditions for greater sage-grouse breeding and late brood-rearing habitats. We initiated our study in spring 2008 to compare the relative value of prescribed burning (1990s and since 2000) and mowing to enhance sage-grouse breeding and late brood-rearing habitats within Wyoming big sagebrush (A. t. wyomingensis) communities in the Bighorn Basin. However, it is unclear whether burning or mowing results in vegetation composition and structure that meets guidelines for sage-grouse habitat. In 2008 and 2009 we measured vegetation attributes representing vegetation structure and ecological function afforded to sage-grouse selecting burned and mowed sagebrush habitats for breeding and late brood-rearing. We sampled these attributes at 30 treated sites and 30 paired, untreated reference sites in the Bighorn Basin. Here, we compare the minimum guidelines of Connelly and others (2000) for canopy cover and height of sagebrush and perennial grass in arid sage-grouse*

habitats to conditions measured at our sampling sites. These structural features are useful to compare because they have been identified as critical predictors of greater sage-grouse nest success and chick survival. Perennial grass height (18 cm minimum) and perennial grass canopy cover (15 percent minimum) met the guidelines for breeding and late brood-rearing at reference, burned, and mowed sites. Reference sites met minimum guidelines for sagebrush canopy cover, except for late brood-rearing at reference sites paired with mowed sites on ustic soils. Reference sites only met sagebrush heights for late brood-rearing (40 cm) on reference sites paired with burned sites on aridic soils since 2000 and reference sites paired with 1990 burned sites on ustic soils. Sagebrush canopy cover did not meet the minimum guidelines of 15 percent or 10 percent for breeding or late brood-rearing, respectively, at prescribed burn sites. Minimum sagebrush canopy cover for late brood-rearing, but not breeding habitat was retained at mowed sites. Prescribed burned and mowed sites did not meet the minimum guideline for sagebrush height for breeding (30 cm) or late brood-rearing habitats. Comparisons between values at treated and reference sites indicate that neither perennial grass height nor canopy cover were enhanced through burning or mowing 2–16 years post treatment. Our results suggest two considerations for managers considering burning or mowing treatments intended to enhance Wyoming big sagebrush for sage-grouse. First, while mowing retains minimum levels of sagebrush canopy cover for late brood-rearing, neither mowing nor burning retains sagebrush height within acceptable guidelines for breeding and late brood-rearing. Second, if sagebrush characteristics in untreated communities do not meet the minimum Connelly and others (2000) guidelines, managers should consider how treatments may negatively affect these communities for sage-grouse and consider other practices including no treatment or planting sagebrush where it has been depleted.

INTRODUCTION

Habitat treatments in Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) communities have generally been conducted to restore or enhance sagebrush communities for land health (Hyder and Sneva 1956; McDaniel and others 2005; Watts and Wambolt 1996); watershed improvement (Dugas and others 1998; Hibbert 1983; Wilcox 2002); increasing forage for livestock (Vale 1974); and wildlife habitat enhancement (Crawford and others 2004; Pyle and Crawford 1996; Wambolt and others 2001). The main vegetative objectives of treating sagebrush are to (1) reduce conifer encroachment (Holechek and others 2004), 2) decrease mature stands of sagebrush (Perryman and others 2002), 3) create a more diverse representation of seral stages across sagebrush landscapes (Davies and others 2009), and 4) increase herbaceous cover by reducing competition between the herbaceous understory and sagebrush overstory (Dahlgren and others 2006).

Prescribed burning is conducted frequently by land management agencies to enhance habitat conditions for sage-grouse (Beck and others 2009; Fischer and others 1996; Wambolt and others 2001). The effects of fire on sagebrush communities are of particular importance as fire suppresses recovery of burned basin (*A. t. tridentata*), mountain (*A. t. vaseyana*), and Wyoming big sagebrush because these species do not resprout after fire (Pechanec and others 1965; Tisdale and Hironaka 1981). Prescribed fire can elicit positive short-term (≤ 10 years) response in the herbaceous understory in mountain big sagebrush stands, but it does not elicit short-term positive herbaceous responses in Wyoming big sagebrush or long-term (> 10 years) positive herbaceous responses in Wyoming or mountain big sagebrush (Beck and others 2010). Wyoming big sagebrush is particularly vulnerable to fire because invasion of weedy exotics such as cheatgrass

(*Bromus tectorum*) have led to increasing wildfire frequencies and subsequent loss and degradation of these important communities (Baker 2006).

Sagebrush is essential to maintaining native plants and limiting invasion of exotic plants in sagebrush communities (Prevéy and others 2009). This suggests that treatments should be limited to those that do not eliminate or greatly reduce sagebrush. Mowing and other mechanical treatments are seen as alternatives to prescribed burning because they leave smaller live sagebrush plants after treatment (Davies and others 2009), and recovery following burning may take 50–120 years (Baker 2006; Beck and others 2010; Watts and Wambolt 1996). Mowing also leaves residual debris used as cover by sagebrush-obligate wildlife (Dahlgren and others 2006), reduces soil erosion (McKell 1989), and increases snow capture (Sturges 1977). Although mowing leaves residual sagebrush plants and woody debris, it reduces Wyoming big sagebrush cover and volume for about 20 years (Davies and others 2009).

The quality of breeding and late brood-rearing habitats may influence sage-grouse population trends by affecting nest success and juvenile survival (Beck and others 2006; Connelly and Braun 1997; Crawford and others 2004). Quantity refers to the availability and accessibility of habitats, whereas quality is determined by the ability of these habitats to provide conditions and resources adequate for population persistence (Hall and others 1997). The structure and function of sagebrush communities determine the quality of these habitats by providing cover, nutrient cycling, and grouse forage availability and quality. Structural features of perennial grasses and sagebrush, such as cover and height, are used by sage-grouse for protection from predators during breeding and late brood-rearing (Connelly and others 2000; DeLong and others 1995; Gregg and others 1994).

Connelly and others (2000) compiled information from existing studies from approximately 1950 to 2000 to recommend guidelines for managing and restoring sage-grouse habitats. These guidelines are frequently cited by managers as a baseline of information for sage-grouse habitats and are recommended to be adapted to local land conditions and knowledge of local areas. Using the Connelly and others (2000) guidelines for arid sites, we compared the canopy cover and height of sagebrush and perennial grasses at mowed, prescribed burned, and reference sites in the Bighorn Basin of north-central Wyoming, USA for sage-grouse breeding and late brood-rearing habitat. Comparing response variables collected at treated and nearby reference sites provided us a means to better understand how sagebrush-reduction treatments influence key attributes of sage-grouse breeding and late brood-rearing habitats.

STUDY AREA

The Bighorn Basin includes Big Horn, Hot Springs, Park, and Washakie counties in Wyoming and encompasses 32,002 km^2 of north-central Wyoming. The Bighorn Basin is bordered by the Absoraka Mountains to the west, Beartooth and Pryor Mountains to the north, Bighorn Mountains to the east, and Bridger and Owl Creek Mountains to the south. The average valley elevation is 1,524 m (1,116 m minimum) and is composed of badland topography and intermittent buttes. The Bighorn Basin is semi-arid with average annual precipitation ranging from 12.7–38.1 cm. Dominant land uses in the sagebrush areas between agricultural lands and forest lands in the Bighorn Basin include livestock grazing; limited bentonite mining, with most current extraction occurring in lower elevation saltbush desert; and oil and gas extraction.

Native flora include perennial grasses such as bluebunch wheatgrass (*Pseudoroegneria spicata)*, blue grama (*Bouteloua gracilis*), and needle and thread (*Hesperostipa comata*); shrubs such as mountain big sagebrush, spineless horsebrush (*Tetradymia canescens*), and Wyoming big sagebrush; and forbs and subshrubs including buckwheat (*Eriogonum* spp.), milkvetch (*Astragalus* spp.), prairie sagewort (*A. fridida*), and Western yarrow (*Achillea millefolium*). Invasive, exotic species in the Bighorn Basin include cheatgrass, Japanese brome (*B. japonicus*), Canada thistle (*Cirsium arvense*), leafy spurge (*Euphorbia esula*), hoary cress (*Cardaria draba*), knapweed (*Centaurea spp.*), and toadflax (*Linaria spp.*).

Since 1984, the USDI–Bureau of Land Management has conducted 156 prescribed burns (100 km^2 burned) and 55 mowing treatments (36 km^2 mowed) in big sagebrush communities to reach vegetation management objectives, including enhancing habitat conditions for sage-grouse. By comparison, 91 wildfires have burned 520 km^2 of sagebrush since 1980.

METHODS

We established 100-m^2 plots within 30 treated sites and 30 paired, untreated sites defined by combinations of soil group, age since treatment by decade, and treatment type. We refer to these combinations as chronosequences, which are hypothetical portrayals of soil change as a function of time (Fanning and Fanning 1989). General soil groupings that comprise the soils in the Bighorn Basin are aridic, fine textured; aridic, coarse textured/skeletal; udic, cryic; and ustic, frigid. We based these groupings on soil temperature, moisture, and texture, the three main factors that influence sagebrush community establishment and development in the Bighorn Basin (Larry C. Munn, University of Wyoming, personal communication, 2007; Young and others 1999). Much of the breeding and late brood-rearing activity of sage-grouse in the Bighorn Basin is centered on areas overlying aridic, fine textured and ustic, frigid soils, which we retained for consideration.

We randomly selected 3 treated polygons from each treatment combination for field sampling in spring 2008 and repeated sampling at these sites in spring 2009. Treatment combinations included soil type, treatment type, decade of prescribed burn (1990s or since 2000; mowed sites began in 2000), and season of prescribed burn (fall or spring). After conducting two -sample *t*-tests ($P < 0.05$; PROC TTEST, SAS Institute 2003) for each response variable, we found no difference between fall and spring burns, which permitted us to combine prescribed burned sites by soil type and decade of use. We collected data at 4 burned sites in mountain big sagebrush communities and removed them from our analysis to focus on Wyoming big sagebrush communities. We retained 6 treatment combinations across years: 1) mowed sites on aridic soils ($n = 3$), 2) mowed sites on ustic soils ($n = 3$), 3) sites that were prescribed burned during the 1990s on aridic soils ($n = 6$), 4) sites that were prescribed burned during the 1990s on ustic soils ($n = 6$), 5) sites that were prescribed burned since 2000 on aridic soils ($n = 4$), and 6) sites that were prescribed burned since 2000 on ustic soils ($n = 4$). Because we repeated our sampling in 2009, the sample size we used in our analyses is double the number of samples reported.

We selected one untreated reference site near each randomly-selected treated polygon for measurement. To prevent edge effects, we situated reference plots no closer than 100 m from treated plots. The mean distance from treatment to reference sites was408 m (range: 146–1475 m). To ensure sampling sites could be used by sage-grouse, we placed our sampling sites an average of 4.5 km (range: 0.2–11.8 km) from the nearest sage-grouse lek. This area corresponds closely to the area circumscribing a 5-km radius around leks where 64 percent of female sage-grouse nest in Wyoming (Holloran and Anderson 2005). To avoid confounding factors, we excluded from consideration any untreated sites that were visibly degraded, damaged, or destroyed. Although untreated sites that were not degraded, damaged, or destroyed were also affected by past land management practices (for example, livestock and wildlife herbivory), we assumed they represented the potential of the surrounding landscape to provide vegetation structure and ecological function as would be expected given common grazing pressure in the Bighorn Basin.

Our analysis focuses on breeding and late brood-rearing habitats. According to Connelly and others (2000), breeding habitats contain sage-grouse lek sites, nest sites, and early brood-rearing areas. We specifically evaluated habitat characteristics for nesting and early brood-rearing (< 2 weeks post hatching; Thompson and others 2006), which occur during May through June (Connelly and others 2000; Holloran and others 2005). Because we lacked information on seasonal movements of sage-grouse in the Bighorn Basin, we assumed late brood-rearing (> 2 weeks post hatching) occurred at higher elevations where moist conditions promote forb abundance, a pattern typical in many sage-grouse populations (Crawford and others 2004; Schroeder and others 1999). In both years, we initiated data collection in late May at lower elevations and ended field sampling in late July at higher elevation sites to mimic upslope movements of adult females with broods (Schroeder and others 1999).

We measured droop height (cm) of grasses (Connelly and others 2003) and shrubs (tallest leader; Connelly and others 2003) at each 5-meter location along a 100-m surveyor's tape with a meter stick. We measured line intercept along each line to obtain shrub canopy cover (Canfield 1941). At each 5-meter mark along the 100-m tape, we positioned a 20 × 50 cm quadrat to estimate canopy cover of perennial grasses according to the following cover classes: 1= 0–1 percent; 2 = 1–5 percent; 3 = 5–25 percent; 4 = 25–50 percent; 5 = 50–75 percent; 6 = 75–95 percent; and 7 = > 95 percent (Daubenmire 1959).

We computed means (± 1 standard error) by averaging across the three treatment and reference sites sampled each year for each treatment combination, which provided n = 6 samples averaged per treatment combination. We compared these estimates against minimum sage-grouse breeding and late brood-rearing habitat guidelines for canopy cover and height of sagebrush and perennial grass published by Connelly and others (2000) and tested whether estimated responses exceeded the minimum guidelines with one-sample, one-tailed *t*-tests ($P < 0.05$; PROC TTEST, SAS Institute 2003). These structural features are useful to compare as they have been identified as being critical for successful sage-grouse breeding and late brood-rearing (Connelly and others 2000; Crawford and others 2004). Connelly and others (2000) suggested minimum guidelines for sage-grouse breeding habitat of 15 percent sagebrush canopy cover, 15 percent perennial grass canopy cover, 30 cm sagebrush height, and 18 cm perennial grass height. Late brood-rearing minimum guidelines were 10 percent sagebrush canopy cover, 15 percent perennial grass canopy cover, 40 cm sagebrush height, and 18 cm perennial grass height (Connelly and others 2000).

RESULTS

Sagebrush Structural Features

Wyoming big sagebrush canopy cover did not meet breeding or late brood-rearing minimum guidelines at any prescribed burned treatment (figure 1). Mowed sites did not meet the minimum guideline for sagebrush canopy cover for breeding, but did meet the minimum canopy cover guideline for late brood-rearing (aridic soils: mean = 10.0 percent, standard error = 1.9; ustic soils: mean = 10.2 percent, standard error = 2.8; figure 1). Reference sites met the late brood-rearing sagebrush canopy cover guideline, but did not meet the sagebrush canopy cover guideline for breeding on sites paired with mowed sites on ustic soils (mean = 12.0 percent, standard error = 2.2; figure 1).

Wyoming big sagebrush heights did not meet minimum guidelines at mowed or prescribed burned sites (figure 2). Reference sites met the breeding height guideline, but did not meet the late brood-rearing guideline at reference sites paired with mowed sites (aridic soils mean = 27.8 percent, standard error = 5.1; ustic soils mean = 29.2 percent, standard error = 5.1); sites paired with 1990 prescribed burns on aridic soils (mean = 36.3 percent, standard error = 3.0); or sites paired with 2000 prescribed burns on ustic soils (mean= 35.2, standard error=3.1; figure 2).

Perennial Grass Structural Features

The guideline for perennial grass canopy cover for breeding and late brood-rearing was met at mowed, prescribed burned, and reference sites (figure 3). The guideline for perennial grass height at breeding and late brood-rearing sites was met at mowed, prescribed burned, and reference sites (figure 4).

DISCUSSION

According to Connelly and others (2000), treatments should be designed to elicit rapid recovery while disturbing a small amount of sagebrush communities. Our study did not evaluate spatial aspects of recovery of treated sites, but we do provide a temporal perspective of recovery at prescribed burned and mowed Wyoming big sagebrush communities. Overall we found mowing since 2000 maintained adequate sagebrush canopy cover for breeding and late brood-rearing. Prescribed burning largely eliminated canopy cover of sagebrush at our burned study sites; recovering insufficiently to meet guidelines even 19 years following treatment. Neither mowing nor prescribed burning retained adequate sagebrush height for breeding or brood-rearing. Perennial grass heights and canopy cover at prescribed burned and mowed sites surpassed minimum guidelines for breeding and late brood-rearing.

Much discussion has centered on application of the Connelly and others (2000) guidelines for sage-grouse habitat management (Bates and others 2004). Connelly and others (2000) indicated that structural characteristics of sagebrush communities vary greatly among the western states, and they suggested that local biologists and range ecologists develop height and cover requirements for local areas. However, sage-grouse are known to prefer areas with greater sagebrush canopy cover, taller grasses for nesting, and greater herbaceous canopy cover for brood-rearing throughout their range (Connelly and others 2000; DeLong and others 1995; Gregg and others 1994; Holloran and others 2005, Wallestad and Pyrah 1974). A meta analysis evaluating findings from multiple studies showed that the Connelly and others (2000) guidelines provide a reasonable representation of structural features found at breeding and late brood-rearing locations across the range of sage-grouse (Hagen and others 2007). Therefore, we believe comparing our work to the Connelly and others (2000) guidelines is appropriate. However, some sagebrush communities used by sage-grouse, such as those mowed on ustic soils in our study area, may never meet or exceed published sagebrush or herbaceous canopy cover or height guidelines. Results of our study suggest that sagebrush reduction via mowing or burning is not appropriate in such habitats. If sagebrush characteristics in untreated communities do not meet the minimum Connelly and others (2000) guidelines, managers should investigate whether treatments may negatively affect sage-grouse use of those communities. In these instances, it may be more appropriate to consider changes in land management practices rather than implementing vegetation treatments. Furthermore, insect abundance and diversity, soil quality, and forb abundance and diversity need to be examined to decide which types of treatment (or non-treatment) provide the best breeding and late brood-rearing habitat for sage-grouse (Barnett and Crawford 1994; Coleman and Crossley 1996; Connelly and others 2000; Johnson and Boyce 1990; Killham 1994; Peterson 1970; Wallestad and Eng 1975).

Enhancement of herbaceous attributes is often cited as a principal reason for treatments (Dahlgren and others 2006); however, comparisons between values at reference and treatment sites in our study indicated that perennial grass height and canopy cover were not enhanced through burning or mowing. In fact, perennial grass height and canopy cover at untreated reference sites already met the Connelly and others (2000) guidelines, meaning there was no evidence that treatments were needed to enhance grass attributes used by nesting or brood-rearing sage-grouse. Our findings are supported by other studies showing minimal or no improvement of structural features of sagebrush or perennial grasses following treatment (Baker 2006; Beck and others 2009; Davies and others 2009; Wambolt and others 2001; Wambolt and Payne 1986). Our results suggest two considerations for managers considering burning or mowing to enhance Wyoming big sagebrush for sage-grouse in the Bighorn Basin. First, while mowing retains minimum levels of sagebrush canopy cover for late brood-rearing, neither mowing nor burning results in sagebrush of adequate height for sage-grouse to use it as breeding or late brood-rearing habitat. Second, if sagebrush characteristics in untreated communities do not meet the minimum Connelly and others (2000) guidelines, managers may wish to reconsider treatments in those areas, and instead consider other practices such as replanting sagebrush or no treatment at all. Although our findings are specific to the Bighorn Basin of north-central Wyoming, we believe they have relevance to other ecologically similar Wyoming big sagebrush habitats where prescribed burning and mowing are planned or have been used to manage breeding and late brood-rearing habitat for sage-grouse.

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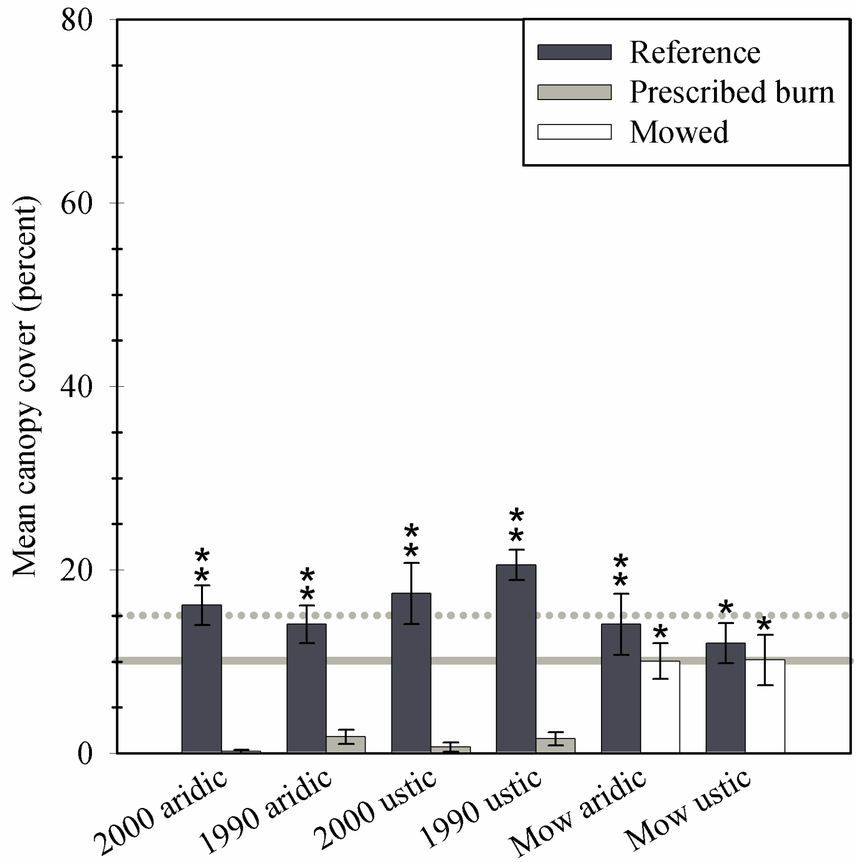
Figure 1— Mean (± 1 standard error) Wyoming big sagebrush canopy cover (percent) for 10 combinations of treatments in the Bighorn Basin, Wyoming, USA, 2008 and 2009. Horizontal lines represent the Connelly and others (2000) recommended guidelines for sagebrush canopy cover for sage-grouse breeding (15 percent; dashed line) and late brood-rearing (10 percent; solid line). One asterisk denotes the late brood-rearing guideline was met, while two asterisks denote both breeding and late brood-rearing guidelines were met. Aridic and ustic refer to different general soil groupings where aridic are fine-textured soils in more arid climates and ustic are soils with intermediate soil moisture in cool temperature regimes.

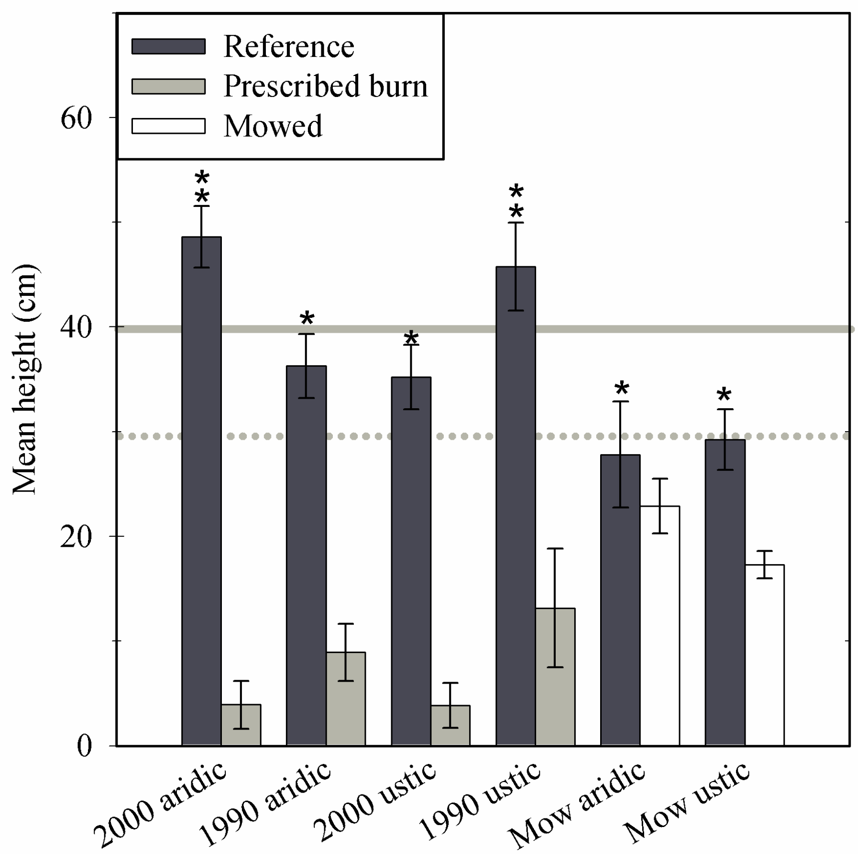
Figure 2—Mean (± 1 standard error) Wyoming big sagebrush heights (cm) for 10 combinations of treatments in the Bighorn Basin, Wyoming, USA, 2008 and 2009. Horizontal lines represent the Connelly and others (2000) recommended guidelines for sagebrush height for sage-grouse breeding (30 cm; dashed line) and late brood-rearing (40 cm; solid line). One asterisk indicates the breeding guideline was met at that site, while two asterisks indicate both breeding and late brood-rearing guidelines were met. Aridic and ustic refer to different general soil groupings where aridic are fine-textured soils in more arid climates and ustic are soils with intermediate soil moisture in cool temperature regimes.

Figure 3— Mean (± 1 standard error) perennial grass canopy cover (percent) for 10 combinations of treatments in the Bighorn Basin, Wyoming, USA, 2008 and 2009. The horizontal line (15 percent) represents the Connelly and others (2000) recommended guidelines for sage-grouse breeding and late brood-rearing perennial grass canopy cover. Asterisks indicate

sites where the minimum guideline was met. Aridic and ustic refer to different general soil groupings where aridic are fine-textured soils in more arid climates and ustic are soils with intermediate soil moisture in cool temperature regimes.

Figure 4— Mean (± 1 standard error) perennial grass height (cm) for 10 combinations of treatments in the Bighorn Basin, Wyoming, USA, 2008 and 2009. The horizontal line (18 cm) represents the Connelly and others (2000) recommended guidelines for sage-grouse breeding and late brood-rearing perennial grass height. Asterisks indicate sites where the minimum guidelines were met. Aridic and ustic refer to different general soil groupings where aridic are fine-textured soils in more arid climates and ustic are soils with intermediate soil moisture in cool temperature regimes.


80
60
40
20
0
Mean canopy cover (percent)
Reference
Prescribed burn
Mowed
2000 aridic
1990 aridic
2000 ustic
1990 ustic
Mow aridic
Mow ustic


Reference
Prescribed burn
Mowed
Mean height (cm)
0
20
40
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2000 aridic
1990 aridic
2000 ustic
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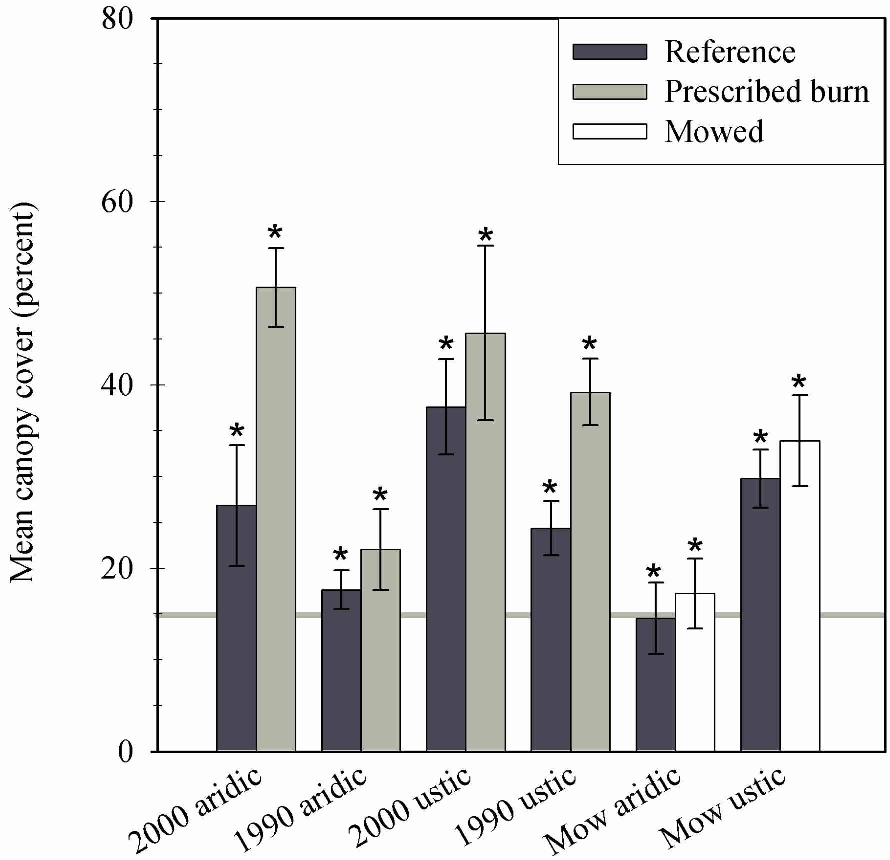
Mow aridic
Mow ustic



80
60
40
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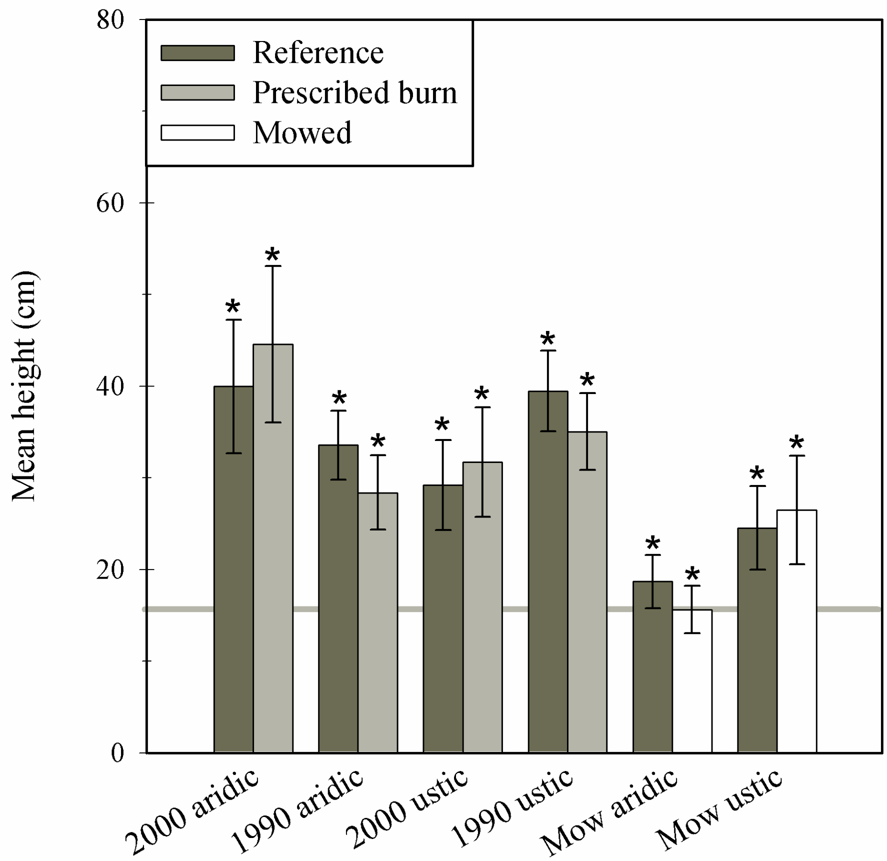
0
Mean canopy cover (percent)
Reference
Prescribed burn
Mowed
*
2000 aridic
1990 aridic
2000 ustic
1990 ustic
Mow aridic
Mow ustic



Reference
Prescribed burn
Mowed
Mean height (cm)
0
20
40
60
80
2000 aridic
1990 aridic
2000 ustic
1990 ustic
Mow aridic
Mow ustic