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ABSTRACT

*Small (<40.5-ha) patch fires or mechanical manipulations to reduce big sagebrush (*Artemisia tridentata*) cover has been suggested as a management option to improve sage-grouse pre-nesting and brood rearing habitat and provide a diverse habitat mosaic. We evaluated the effects of prescribed fire and wildfire on sage-grouse habitat in three Wyoming big sagebrush associations (Bluebunch, Thurber's needlegrass, Thurber's needlegrass-Idaho fescue). Response variables included vegetation cover, herbaceous productivity, yield and nutritional quality of forbs preferred by greater sage-grouse, and abundance of common arthropod orders. Wildfire eliminated all sagebrush and >90 percent of the perennial grasses on the Thurber's association. On the Bluebunch association wildfire eliminated sagebrush, but most perennial grasses survived. The prescribed fire on the Thurber's needlegrass-Idaho fescue association removed 95 percent of the sagebrush with most perennial grasses surviving. Habitat cover (shrubs and tall herbaceous cover (> 18cm height)) was 33-90 percent lower after burning compared to unburned controls. The removal of big sagebrush decreased structural cover and reduced or eliminated forage provided by big sagebrush for sage-grouse. This would be potentially damaging in sage-grouse year-round and wintering habitat. Burning reduced Wyoming big sagebrush forage production by about 450 kg/ha on the Thurber's needlegrass-Idaho fescue association. Yields or cover of perennial forbs used by sage-grouse in their diets did not differ between burned sites and not burned sites in the Bluebunch and Thurber's needlegrass-Idaho fescue associations. In the Thurber's needlegrass association long leaf phlox was the only perennial forb to increase after fire. Pale alyssum, a non-native forb, was the dominant annual after fire in the Thurber's needlegrass and Thurber's needlegrass-Idaho fescue associations. Yields or cover of annual forbs used by sage-grouse in their diets increased temporarily after fire in the Bluebunch association. Although cheatgrass increased in the Thurber's association it has remained a minor component of the post-fire community. The abundance of ants (Hymenoptera) decreased after fire while the abundance of other arthropods remained unaffected in the Thurber's needlegrass-Idaho fescue association. The results indicate that prescribed fire will not improve habitat characteristics for sage-grouse in Wyoming big sagebrush steppe where the community already consists of shrubs, native grasses, and native forbs. Burning of Wyoming big sagebrush communities to enhance other species habitat requirements should minimize mortality of native perennial grasses and forb species, result in a mosaic pattern of burned and unburned patches, and avoid areas of critical habitat.*

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INTRODUCTION

Big sagebrush (*Artemisia tridentata*) steppe is one of the major vegetation types of the western United States and estimates of its historic coverage exceed 600,000 km^2 (Anderson and others 1998, West 1983; West and Young 2000). Big sagebrush steppe has been fragmented and reduced in area the past 150 years as a result of altered fire regimes, invasive weed dominance, agricultural land conversion, non-native grass seeding, sagebrush removal programs, piñon-juniper (*Pinus-Juniperus*) woodland expansion, and urban and industrial development (Knick and others 2003; Miller and others 2005; Rowland and Wisdom 2005; West 1983; West and Young 2000).

Big sagebrush steppe is delineated into three complexes: Wyoming big sagebrush (*Artemisia tridentata* spp. *wyomingensis*); basin big sagebrush (*Artemisia tridentata* spp. *tridentata* Nutt.); and mountain big sagebrush (*Artemisia tridentata* spp. *vaseyana*). The Wyoming big sagebrush alliance is considered the most vulnerable as it is susceptible to replacement by invasive annual grasses, particularly after fire disturbance (Miller and Eddleman 2001; Suring and others 2005). Large areas of the alliance are in low seral condition or have converted to cheatgrass (*Bromus tectorum*) grasslands. The dominance of cheatgrass has resulted in dramatic increases in both size and frequency of wildfires in the

Great Basin, Snake River Basin, and Columbia Plateau. It is estimated that mean fire return intervals (MFRI) in many Wyoming big sagebrush plants communities have been reduced from 50-100 years to less than 10 years as a result of cheatgrass (*Bromus tectorum*) invasion (Baker 2006; Whisenant 1990; Wright and others 1979). The conversion from native to annual grass-dominated communities has resulted in the loss of habitat and reduced populations of sagebrush obligate and facultative wildlife species (Connelly and Braun 1997; Connelly and others 2000a; Crawford and others 2004; Welch 2002).

Southeastern Oregon, northern Nevada, and southwestern Idaho retain extensive Wyoming big sagebrush communities in mid to late seral ecological stages. These areas are co-dominated by big sagebrush and perennial bunchgrasses with little cheatgrass present (Davies and others 2006). While large scale application of fire is not recommended for this alliance, the use of small (<40.5-ha) patch fires and mechanical manipulations to reduce big sagebrush cover has been recommended as a management option to improve sage-grouse pre-nesting and brood-rearing habitat and provide a diverse habitat mosaic for other species (Connelly and others 2000b; Dahlgren and others 2006; Hagen 2005; Helmstrom et al. 2002; Petersen and Best 1987). Thinning dense stands of sagebrush or creating open patches of herbaceous vegetation has been suggested as methods to increase herbaceous cover and forb production (Dahlgren and others 2006; Wirth and Pyke 2003). Forbs amount to 50-80 percent of the diet of sage-grouse during pre-nesting and brood-rearing periods in the spring (Barnett and Crawford 1994; Drut and others 1994).

The effect of prescribed fire on habitat characteristics of big sagebrush steppe, specific to sage-grouse, has produced both variable and consistent results. Whether fires are large, small, or mosaic in pattern, the loss of big sagebrush reduces structural cover for successful nesting and concealment, as well as decreasing forage provided by sagebrush (Crawford and others 2004; Davies and others 2007). In Wyoming big sagebrush communities, burning has not been effective at increasing total forb diversity or abundance, although productivity of individual forb species has increased (Bates and others 2009; Beck and others 2009; Fischer and others 1996; Nelle and others 2000; Wrobleski and Kauffman 2003). Insects are an important dietary component of young sage-grouse and may comprise 75-100 percent of the diet the first several weeks after hatching (Gregg 2006; Johnson and Boyce 1990; Patterson 1952). Fire in a Wyoming big sagebrush community in Idaho reduced the abundance of ants while beetles, crickets, and grasshoppers were unaffected (Fischer and others 1996; Rickard 1970).

We evaluated the effects of wildfire and prescribed fire on sage-grouse habitat characteristics in three Wyoming big sagebrush plant associations by measuring impacts to; 1) vegetation cover requirements developed by (Connelly and others 2000b) for sage-grouse habitat, 2) the productivity of forb species utilized by sage-grouse in their diets, and 3) the abundance of arthropods.

STUDY AREAS

We conducted post-fire studies on the Northern Great Basin Experimental Range (NGBER), 56 km west of Burns, Oregon, and the Sheepshead Mountains, 110 km southeast of Burns. Three Wyoming big sagebrush associations were evaluated. The sites were representative of mid to high seral Wyoming big sagebrush plant communities with a mix of big sagebrush, native grasses, and native forbs. Big sagebrush and total herbaceous cover values were representative of Wyoming big sagebrush associations in eastern Oregon (Davies and others 2006). Sites were located in year-round sage-grouse habitat and were within 1-5 km of active leks. Vegetation cover values met sage-grouse nesting and brood-rearing habitat requirements for arid big sagebrush sites as suggested by Connelly and others (2000b). Climate is typical of the northern Great Basin with most precipitation arriving in winter and early spring, whereas summers are warm and dry. Annual precipitation at Burns, Oregon, has averaged about 280 mm since the 1930s. Drought occurred in 2000-2002 and 2007 and precipitation was below average in 2003, 2004, and 2008. Precipitation was above average in 2005, 2006, and 2009. General references used for plant identification were Hitchcock and Cronquist (1987) and the Natural Resource Conservation Service (2009).

The site at the NGBER was a Wyoming big sagebrush/Thurber's needlegrass (*Achnatherum thurberianum*)-Idaho fescue (*Festuca idahoensis*) association (Thurber's-Idaho fescue Association). Elevation is 1400 m and topography is flat (0-2

percent slope). Soils are a complex of four series sharing several attributes; all are Durixerolls, soil surface texture is sandy loam to loamy sand, and are well drained with a duripan beginning between 40-75 cm deep (Lentz and Simonson 1986). Wyoming big sagebrush was the dominant shrub and basin big sagebrush and green rabbitbrush (*Chrysothamnus viscidiflorus*) were subdominant shrubs. Idaho fescue and Thurber's needlegrass were the main perennial bunchgrasses. Sandberg's bluegrass (*Poa secunda*), bluebunch wheatgrass (*Pseudoroegneria spicata*), prairie Junegrass (*Koeleria macrantha*), and bottlebrush squirreltail (*Elymus elymoides*) were subdominant perennial grasses. Common perennial forbs were of taper-tip hawksbeard (*Crepis acuminata*), milkvetch (*Astragalus* spp.), fleabanes, (*Erigeron* spp.), western groundsel (Senecio intergerrimus), common yarrow (*Achillea millefolium*), and long-leafed phlox (*Phlox longifolia*). Common annual forbs were little blue-eyed Mary (*Collinsia parviflora*), slender phlox (M*icrosteris gracilis*), and non-native pale alyssum (*Alyssum alyssoides*). Wyoming big sagebrush cover averaged 10 percent (range 6-17 percent) and grass-forb cover exceeded 15 percent (Davies and others 2007). Cheatgrass was present in trace amounts (<1 percent cover). Prior to livestock removal in 1999, grazing by cattle was of moderate use (40-50 percent utilization), using a rest rotation system.

Sites on the Sheepshead Mountains included two plant associations: Wyoming big sagebrush/ bluebunch wheatgrass (Bluebunch) and Wyoming big sagebrush/Thurber's needlegrass (Thurber's). Light cattle grazing occurred in the winter and early spring. The Thurber's association sites were in mid seral and high seral condition. Elevation was about 1280 m and sites were located on lake terraces (0-5 percent slope) created during the Pleistocene epoch. Soils were a complex of Durixerolls, Haplocambids, and Haploargids. Wyoming big sagebrush was the dominant shrub and green rabbitbrush, spiny hopsage (*Atriplex spinosa*) and gray horsebrush (*Tetradymia canescens*) were present in low densities. Thurber's needlegrass was the main perennial bunchgrasses. Sandberg's bluegrass and bottlebrush squirreltail were subdominant grasses. Common perennial forbs were taper-tip hawksbeard, Nevada lomatium (*Lomatium nevadense*), lava aster (*Aster scopulorum*), fleabane species, and long-leafed phlox. Annual forbs were represented by little blue-eyed Mary and pale alyssum. Cheatgrass was present in trace amounts (<1 percent cover).

Bluebunch association sites were rated in high seral condition. Sites were located on hillslopes and ridges with slopes between 5-40 percent at elevations between 1300-1480 m. Soils included Argixerolls, Paleargids, and Haploargids. Wyoming big sagebrush was the dominant shrub and green rabbitbrush was present in low densities. Bluebunch wheatgrass was the main perennial bunchgrasses with Sandberg's bluegrass and Cusick's bluegrass (*Poa cusickii*) as subdominant perennial grasses. Common perennial forbs consisted of western hawksbeard (*Crepis occidentalis*), prairie lupine (*Lupinus lepidus*), milkvetch, low pussytoes (*Antennaria dimorpha*), taper-tip onion (*Allium acuminata*), Lomatium spp. (*Lomatium* spp.), lava aster, fleabanes, and Hoods phlox (*Phlox hoodii*). Annual forbs were represented by little blue-eyed Mary, narrow-leaf collomia (*Collomia linearus*), slender phlox, willow-weed (*Eppilobium paniculatum*), and rocketstar (*Lithophragma bulbifera*). Cheatgrass was present in trace amounts.

METHODS

NGBER

We used a randomized complete block design to compare vegetation response variables and arthropod abundance between burned (burn) and not burned (control) for the Thurber's-Idaho fescue association. We established five 4-ha blocks in 2001 and within each block were two 2-ha plots, with one plot randomly assigned to be burned. Prescribed burning was done in late September and early October 2002. The burn application was a strip head fire, ignited using a gel-fuel terra torch (Firecon, Inc., Ontario, Oregon). Wind speeds were between 5–20 km/hr, air temperatures were 20°–25° C, and relative humidity varied from 10–35 percent during prescribed burns. Moisture content of fine fuels (herbaceous vegetation) was 8–12 percent and fine fuel loads were 350–420 kg/ha. Burns were complete across treatment plots and killed 92 percent of Wyoming big sagebrush. We randomly placed six 50-m transects within each treatment plot in 2001. Transects were permanently marked using 40 cm rebar stakes. We measured plant species cover in June 2001-2006, 2008, and 2009. Shrub canopy cover was measured by species using the line intercept technique and excluded canopy gaps >15 cm from measurements (Canfield 1941; Boyd and others 2007).

Herbaceous canopy cover (by species), bare ground and rock, litter, and biological crust (moss, lichen,, algae) was estimated inside 40 × 50-cm frames (0.2 m²) located at 3-m intervals on each transect line. Herbaceous yield was gathered by clipping at the functional group level (Sandberg's bluegrass, perennial bunchgrasses, perennial forbs, annual forbs, and cheatgrass) in mid-June 2002-2008. From 2004-2009, we measured forb yield by species in mid-April, mid-May, and mid-June. We collected data at these periods to determine availability of dietary forbs used by sage-grouse from late breeding through brood rearing periods. Forb species that are consumed by sage-grouse were determined from review of the literature (Barnett and Crawford 1994; Drut and others 1994; Klebenow and Gray 1968; Nelle and others 2000; Peterson 1970; Wallestad and others 1975). Perennial grasses were clipped to a 2-cm stubble height. Cheatgrass and forbs (perennial and annual) were clipped to ground level. Perennial grasses and forbs were clipped in 15, 1-m² randomly located frames per 2-ha plot each sampling period. Annual forbs and cheatgrass were clipped in 0.20-m^{-2} nested plots inside 1-m² frames. Clipped samples were oven dried at 56° C for 48 hours. Perennial and annual forbs were weighed by species or tribes. Arthropods were collected using pitfall traps containing a 1: 4 mixture of antifreeze and water. In each plot we randomly placed 10 traps each collection period. Traps were sampled once a week during 2-week periods in early May and early June of 2004-2005. Captured arthropods were identified to Order and counted.

We used a repeated measures analysis of variance (ANOVA) PROC MIXED procedure for a randomized complete block design to compare time, treatment, and time by treatment interactions for plant species cover, forb and grass yield, and arthropod counts (SAS Institute, Cary, North Carolina). We evaluated vegetation canopy cover by grouping species according to sage-grouse habitat guidelines: big sagebrush, green rabbitbrush, total herbaceous, tall herbaceous (>18 cm ht), perennial grasses (>18 cm ht), perennial forbs, and annual forbs (Connelly et al. 2000b). We categorized yield by life form: perennial grass, Sandberg's bluegrass, perennial forb, annual forb, sage-grouse dietary perennial and annual forbs, pale alyssum, and total herbaceous biomass. We tested data for normality using the univariate procedure and arcsine-square root transformed data when normality failed to stabilize variance. We report back transformed means and set statistical significance of all tests at $P < 0.05$.

Sheepshead Mountains

Initial vegetation measurements were made in June 2001, as part of a study assessing plant cover potentials in Wyoming big sagebrush, on 15 sites. Twelve of the plots burned in a wildfire in August 2001 that encompassed 16,000 ha. Unburned patches remaining within the fire perimeter and the fires perimeter were used to serve as unburned controls. The Thurber's association had three control sites (1 mid-seral, 2 high seral) and four burned sites (2 mid-seral, 2 high seral). The Bluebunch association had seven high seral control sites and seven high seral burned sites. Control plant association sites were located within 0.1-5 km of burned sites. Vegetation cover values and composition of control sites were not different when compared to preburn values of the burned sites. Five 50-meter transects were permanently established on each site. Shrub canopy cover (by species) was determined using the line-intercept method as described above. Herbaceous species canopy cover and density, bare ground and rock, litter, and biological crust were estimated using 0.2 m² frames. Frames were located every 3 m on transect lines (15 frames per transect/ 75 frames per plot). A completed randomized repeated measures generalized linear model (GLM) PROC MIXED compared year, treatment (burn, control), and year by treatment interaction between burned and control sagebrush steppe for plant vegetation covers and density. Associations were analyzed separately. We evaluated vegetation canopy cover by grouping species according to sage-grouse habitat guidelines as described above. Mean separations, transforms, and significance level were performed as above.

RESULTS

NGBER Prescribed Fire

The prescribed fire significantly altered cover and biomass values in the burn treatment compared to the control. The dynamics of herbaceous cover and biomass were in response to year x treatment interactions resulting from initial fire effects (2003) and post-fire weather. In the first year after fire (2003), cover of tall herbaceous and perennial grasses was 25 percent lower in the burn than the control (2003) (table 1). After 2003, there were no treatment differences for tall herbaceous (P =0.542) and perennial grass cover (P =0.458). Tall herbaceous cover was primarily composed of perennial grasses as tall forb cover did not exceed 1 percent in either

treatment. In both treatments, perennial grass cover increased 20 percent between 2004 and 2006 in response to favorable growing conditions and then declined in 2008 as a result of below average precipitation (P<0.001). Cover of perennial forb species and tall forbs (≥ 18 cm) did not differ between the burn and control (P =0.547) or across years (P =0.804). Annual forb cover was greater in the burn than the control in most years after fire (P =0.012; table 1). Nearly all annual forb cover in the burn consisted of pale alyssum, an introduced old world weed. Cover of other annual forbs did not increase after fire and there were no differences compared to the control (P=0.689). Year x treatment interactions were significant for total herbaceous, perennial grass (≥18cm height), tall herbaceous (≥ 18 cm height), big sagebrush, green rabbitbrush, and annual forb cover. In 2005, 2006, 2008, and 2009 total herbaceous cover was 21-35 percent greater in the burn than the control (P <0.001). Wyoming big sagebrush cover was lower in the burn after fire and in 2009 was about 10 percent of pre-burn cover (P <0.001; table 1). Sagebrush cover in the burn was provided by surviving plants as there was no recruitment of new individuals. Green rabbitbrush cover was reduced the first year (P <0.001) after fire; recovering to pre-burn levels after 2004 (P =0.085; table 1).

Table 1. Prescribed fire effects on herbaceous cover (%) in the Wyoming big sagebrush/Thurber's needlegrass-Idaho fescue association, Northern Great Basin Experimental Range, Oregon. Response variable data are means and standard errors for preburn (2002), first year post-fire (2003), and post-fire average (2004-2009). Data for 2004 -2009 present the range of values for this time period. Italicized values and different lower case letters indicate significant differences between treatments.

	Preburn		**Post burn - 2003**		**Post-burn 2004-2009**	
Response variable	**Burn (%)**	**Control (%)**	**Burn (%)**	**Control (%)**	**Burn (%)**	**Control (%)**
Pere. Grass[1,2] Range[3]	15.2 ± 0.9	14.5 ± 1.1	*9.4 ± 0.6 a*	*13.2 ± 1.2 b*	15.8 ± 1.8 (13 - 22.7)	14.5 ± 1.8 (10.2 - 20.9)
Cheatgrass Range	0.1 ± 0.0	0.1 ± 0.0	0 ± 0	0 ± 0	0.6 ± 0.3 (0 - 1.2)	0.3 ± 0.2 (0 – 0.8)
Perennial Forb[4] Range	0.3 ± 0.1	0.5 ± 0.2	0.2 ± 0.1	0.3 ± 0.1	0.5 ± 0.1 (0.2 - 0.6)	0.7 ± 0.2 (0.4 – 1.0)
Annual Forb Range	0.5 ± 0.2	0.3 ± 0.1	*1.2 ± 0.4 b*	*0.35 ± 0.1 b*	*5.2 ± 1.9 b* (2.0 - 12.5)	*0.7 ± 0.4 a* (0.4 – 1.1)
Dietary Ann. Forb; Range	0.2 ± 0.1	0.2 ± 0.1	*0.6 ± 0.2 b*	*0.2 ± 0.1 a*	0.3 ± 0.1 (0.2 - 0.6)	0.2 ± 0.1 (0.1 – 0.4)
Herbaceous Range	15.9 ± 1.4	15.3 ± 1.7	*10.7 ± .6 a*	*13.8 ± 1.3 b*	*21.3 ± 2.5 b* (15 - 27.6)	*15.9 ± 1.9 a* (11.5 – 22.6)
Sagebrush Range	10.2 ± 1.3	10.8 ± 1.1	*0.3 ± 0.1 a*	*10.6 ± 1.1 b*	*0.7 ± 0.1 a* (0.5 - 0.9)	*10.5 ± 0.4 b* (9.2 – 11.3)
Rabbitbrush Range	2.7 ± 0.9	3.0 ± 0.7	*0.6 ± 0.4 a*	*3.0 ± 0.7 b*	4.1 ± 0.6 (2 – 5.4)	3.1 ± 0.3 (2.4 – 4.0)
Habitat Cover Range	28.9 ± 1.8	29.1 ± 1.8	*10.5 ± 0.8 a*	*27.0 ± 0.5 b*	*21.0 ± 2.2 a* (16.5 – 29.4)	*28.8 ± 2.3 b* (22.7 – 36.5)

[1]Perennial bunchgrasses and Sandberg's bluegrass.
[2]Perennial grass cover represented 95% of tall herbaceous cover which are are plants typically > 18 cm tall.
[3]Cover range across years (2004-2009).
[4]All perennial forbs measured for cover and yield were forbs that are consumed by sage-grouse.

Table 2. Prescribed fire effects (post-burn) to herbaceous cover (%) and yield (kg/ha) in the Wyoming big sagebrush/Thurber's needlegrass-Idaho fescue associations, Northern Great Basin Experimental Range, Oregon. Response variable data are pre-burn, first year post-burn (2003), and 6-year post-fire average (2004-2009). Data for 2004 -2009 also present range of values for this time period. Italicized values and different lower case letters indicate significant differences between treatments for yield within respective time periods.

	Preburn		Post burn - 2003		Post-burn 2004-2009 average	
Response variable	**Burn (kg/ha)**	**Control (kg/ha)**	**Burn (kg/ha)**	**Control (kg/ha)**	**Burn (kg/ha)**	**Control (kg/ha)**
Perennial Grass[1] Range[2]	192 ± 8	207 ± 21	*166 ± 10 a*	*211 ± 28 b*	*449 ± 75 b* (287-910)	*235 ± 48 a* (146-449)
Poa secunda Range	44 ± 5	59 ± 16	*11 ± 1 a*	*27 ± 3 b*	*95 ± 25 b* (45-189)	*52 ± 11 a* (22-79)
Perennial Forb[3] Range	37 ± 4	47 ± 21	*7 ± 1 a*	*30 ± 3 b*	49 ± 6 (33-66)	47 ± 6 (31-65)
Annual Forb Range	13 ± 2	10 ± 2	4 ± 0.4	6 ± 2	*98 ± 14 b* (46-143)	*27 ± 3 a* (16-38)
Dietary Ann. Forb; Range	2 ± 0.2	2.0 ± 0.1	*11 ± 4 b*	*2 ± 1 a*	2 ± 0.4 (0.5-2.5)	1 ± 0.4 (0.2-1.5)
Herbaceous Range	318 ± 14	324 ± 56	*187.2 ± 2.2 a*	*276 ± 32 b*	*692 ± 95 b* (366-1096)	*363 ± 59 a* (217-613)

[1]Large deep-rooted perennial bunchgrasses.
[2]Yield range across years (2004-2009).
[3]All perennial forbs measured for cover and yield were forbs that are consumed by sage-grouse.

Herbaceous yield was greater in the burn than the control treatment by the second year after fire (P <0.001) (table 2). Herbaceous, tall herbaceous, and perennial grass yield was about twice as great in the burn than the control from 2005 to 2009 (P <0.001). Perennial forb yield did not increase after the fire and did not differ from the control. Annual forb yield was greater (P <0.001) in the burn throughout the study. Pale alyssum increased in the burn and comprised 90 percent of forb (annual and perennial) yield after fire (P >0.001).

Yields of dietary forb species demonstrated only a few short-term differences between treatments. Yields of *Astragalus* spp. were greater after fire in June sampling periods (2004 to 2009) (burn, 32.3 ± 1.62 kg/ha; control, 21.9 ± 1.0 kg/ha; P> 0.045). However, *Astragalus* yields did not differ during April (P=0.878) and May (P =0.923) sampling periods. Other species of perennial forbs utilized by sage-grouse did not differ in yield between treatments. These included yields of the Cichorieae tribe (P =0.317) and long-leafed phlox (P =0.76). The yield of annual forbs that sage-grouse utilize in their diet was 8-10 times greater in the burn than the control in 2003 and 2004 (P>0.001). On other sample dates and across the study period dietary annual forbs did not differ in yield between the burn and control (P=0.126). Slender phlox and blue-eyed Mary were the dietary annuals collected. The number of ants captured was 135 percent and 175 percent greater in the control than the burn in 2004 and 2005, respectively. Beetle captures did not differ between treatments (P = 0.504). The number of grasshoppers and crickets captured was 200 percent higher in the burn (P = 0.014) in 2005, while more caterpillars were captured in the control in 2004 (46 percent greater) and 2005 (135 percent greater) (P = 0.036).

Sheepshead Wildfire

The Sheepshead wildfire eliminated Wyoming big sagebrush on all burned sites. Sagebrush seedlings began appearing on several sites in 2004, but at very low densities. Green rabbitbrush re-sprouted the first year after fire but its density remained low across the plots throughout the study period (< 20 plants/ha, < 1

percent cover). Spiny hopsage and gray horsebrush present in the Thurber's needlegrass association were eliminated by the fire. Herbaceous response varied by association. Moss and other biological crust were virtually eliminated by fire and remained well below pre-burn levels on both associations eight years after fire.

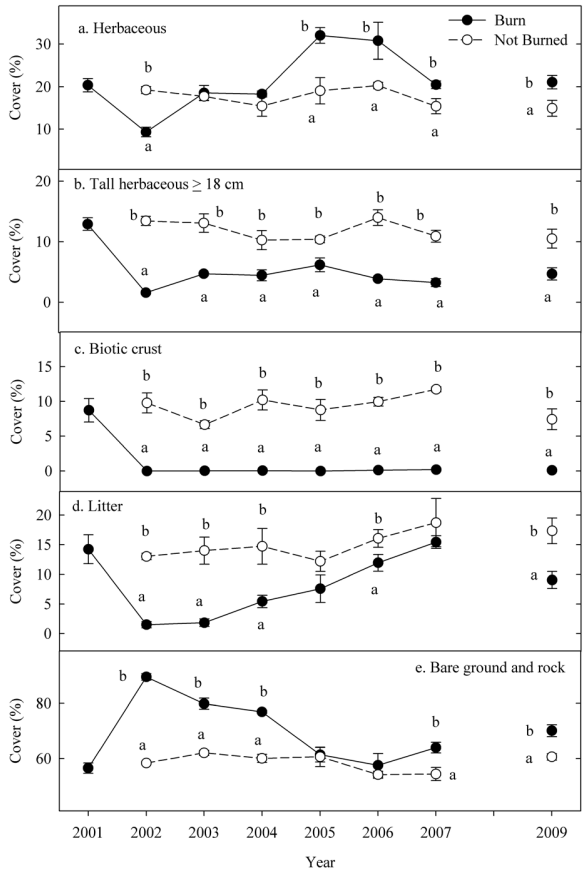

Figure 1. Ground covers (%) for the burned and not burned sites, Wyoming big sagebrush/Thurber's needlegrass association, Sheepshead Mountains, Oregon (2001-2009); (a) herbaceous cover, (b) tall herbaceous cover (>18 cm ht), (c) biotic crust, (d) litter cover, and (e) bare ground and rock. Data are in means ± SE. Means sharing a common lower case letter are not significantly different (P>0.05).

Wyoming Big Sagebrush/Thurber's Needlegrass Association

The Wyoming big sagebrush/Thurber's needlegrass association was severely impacted by the wildfire by altering herbaceous composition and reducing habitat cover (table 3). Sagebrush cover was reduced from an average of 17.3 ± 1.5 percent to zero. Herbaceous cover declined the year after fire but exceeded pre-burn and not burned levels from 2003-2009 (figure 1a; *P*>0.001). However, the fire resulted in an average 64 percent reduction (range 40-88 percent) in tall herbaceous cover (>18 cm) between 2003 and 2009 (figure 1b; *P*>0.001). Micro-biotic crust [primarily twisted moss (*Tortula ruralis*)] and litter were mostly located beneath sagebrush canopies prior to the fire. The fire eliminated the micro-biotic component and reduced litter cover by 17-88 percent depending on year (figure 1c and 1d; *P*>0.001). Litter cover in the burn has increased, however, eight years after the fire it was nearly 50 percent lower than not burned sites (*P*>0.001). Bare ground averaged 21 percent greater in the burn (range 31-53 percent) (figure 1e; *P*>0.001).

Herbaceous compositional changes were reflected by reductions of perennial grass cover and increased cheatgrass and annual forb covers. Perennial bunchgrasses and Sandberg's bluegrass have been slow to respond, as the fire killed the majority of these plants (figure 2a and b). Perennial bunchgrass cover has, on average, been 71 percent lower (range 53-93 percent) than non-burned sites. The reduction in grass cover accounted for most of the loss in tall herbaceous cover. Thurber's needlegrass density was reduced 90 percent to less than 1 plant/m^2 from a pre-burn level of 5.6 ± 0.7 plants/m^2 (*P*>0.001). In 2009, perennial grass density was 1.6 ± 0.6 plants/m^2, 75 percent lower than non burned sites. Cover of perennial forbs did not differ between burned and non-burned sites (figure 2c). However, species responses resulted in altered composition for this life-form group. In the burn sites, longleaf phlox increased by an average of 600 percent while other forb species decreased or were unaffected by the fire. Mat forming perennial forb cover was reduced by >90 percent, including oval-leaved buck-wheat (*Eriogonum ovalfolium*) (*P*=0.024), lava aster (*P*=0.037), Hoods phlox (*P*=0.008), and fleabane species (*P*=0.047). Cover of cheatgrass (*P* = 0.007) and annual forbs (*P*> 0.001) increased after fire (figure 2d and 2e). Cheatgrass cover has averaged about 5 percent cover (20 percent of total herbaceous cover) the past 4 measurement years (2005 to 2009). Annual forb cover was mainly represented by native species the first year after fire, after which annual forbs became increasingly comprised of pale alyssum. Pale alyssum has represented about 50 percent of total herbaceous cover the past 4 measurement years.

Although the results indicate that perennial forbs typically consumed by sage-grouse increased after fire, this change was entirely a result of greater long-

leaf phlox cover (figure 3a; P>0.001). Other perennial forbs utilized by sage-grouse either did not increase or declined in cover. The cover of annual forbs consumed by sage-grouse was 5 to 10 times greater the first three years after fire on burn sites (P>0.001). Species included willow weed (*P*>0.001), slender phlox (*P*=0.042), little blue-eyed Mary (P=0.036), and fireweed (*Gayophytum* spp.*; P*>0.001).

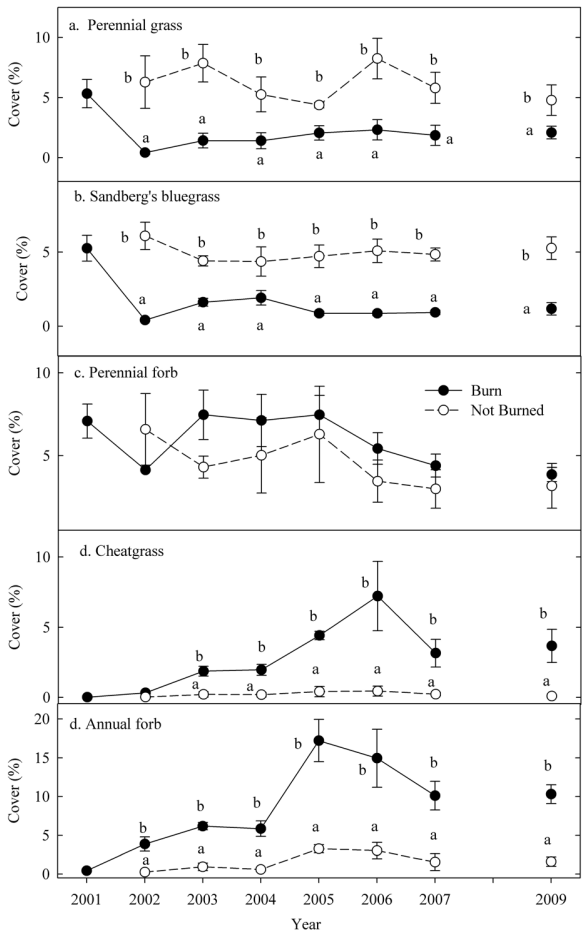

Figure 2. Herbaceous covers (%) for the burned and not burned sites, Wyoming big sagebrush/Thurber's needlegrass association, Sheepshead Mountains, Oregon (2001-2009); (a) perennial grass (e.g. Thurber's needlegrass and other large bunchgrasses), (b) Sandberg's bluegrass, (c) perennial forb, (d) cheatgrass, and (e) annual forb. Data are in means ± SE. Means sharing a common lower case letter are not significantly different (P>0.05).

Wyoming Big Sagebrush/Bluebunch Wheatgrass Association

The wildfire in the Wyoming big sagebrush/bluebunch wheatgrass association moderately impacted herbaceous composition and habitat cover (table 3). Sagebrush cover was reduced from an average of 12.4 ± 1.2 percent to zero. Total herbaceous and tall (≥18 cm) herbaceous cover declined 50 percent the first year after fire, however, since the second year after fire burned sites have not differed from not burned sites (2003-2009) (figure 4a and 4b; *P*=0.459). Micro-biotic crust (primarily twisted moss) was largely eliminated by the fire and has been barely detectable in subsequent years (figure 4c; *P*>0.001). Litter cover decreased 75 percent and remained lower in the burn until 2006, the fifth year after fire (figure 4d). Bare ground averaged 44 percent greater in the burn (range 23-73 percent greater; *P*>0.001) (figure 4e).

Herbaceous compositional changes varied depending on functional group and plant species and have been of short to longer term duration (table 3). Perennial bunchgrass cover was reduced 50 percent the first year after fire; however, after 2003 (second year post-fire) there were no differences between burned and not burned sites (figure 5a). Bluebunch wheatgrass cover was 5-12 percent greater in the burn sites than not burned sites from 2004-2009 (*P*>0.007). Density of bluebunch wheatgrass was unaffected by the fire, averaging 7.8 plants/m^2 (site range 5-11 plants/m^2).

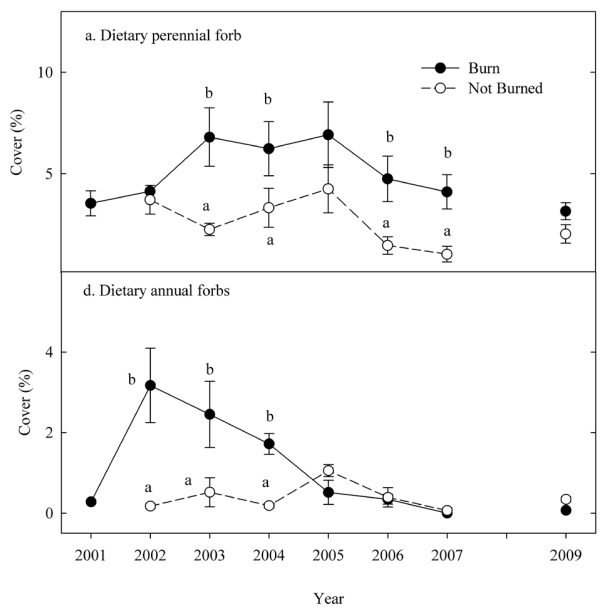

Figure 3. Cover of (a) dietary perennial and (b) dietary annual forbs that are utilized by sage-grouse, burned and not burned sites, Wyoming big sagebrush/Thurber's needlegrass association, Sheepshead Mountains, Oregon (2001-2009). Data are in means ± SE. Means sharing a common lower case letter are not significantly different (P>0.05).

Table 3. Wild and prescribed fire effects to herbaceous species in Wyoming big sagebrush associations, Sheepshead Mountains and NGBER, Oregon, 2001-2010. Italicized species are non-native weeds.

Severely Reduced[1]	Slightly Reduced[2]	No Effect or Increased[3]
Grasses	Grasses	Grasses
Cusick's bluegrass [a]	bottlebrush squirreltail [a]	basin wildrye [a,b]
Indian ricegrass [a]		bluebunch wheatgrass [a,b]
Thurber's needlegrass [a]		bottlebrush squirreltail [b]
Sandberg's bluegrass [a]		Cusick's bluegrass [b]
		Idaho fescue [b]
Perennial Forbs	Perennial Forbs	Indian ricegrass [b]
desert yellow fleabane [a]	daggerpod	junegrass [a,b]
dwarf yellow fleabane [a]	desert yellow fleabane [b]	needle-and-thread [b]
Hood's phlox [a]	dwarf yellow fleabane [b]	Sandberg's bluegrass [b]
Hook's daisy	Hood's phlox [b]	Thurber's needlegrass [b]
lava aster [a]	low pussytoes [b]	*cheatgrass* [a,b]
low pussytoes [a]	lowly penstemon [b]	six weeks fescue [a]
oval-leaf eriogonum [a]	morning milkvetch	
scabland fleabane [a]	obscure milkvetch	
	oval-leaf Eriogonum [b]	Perennial Forbs
	short-lobed penstemon [b]	basalt milkvetch
	wooly-pod milkvetch	big seed lomatium [a]
		Bolander's yampah
		broadsheath lomatium [a]
	Annual forbs	Brunea mariposa lily
	white daisy tidytips [a]	lava aster [b]
		long-leaf phlox
		low hawksbeard [a]
		Nevada lomatium
		Nevada onion
		one-stemmed groundsel
		prairie lupine
		sickle milkvetch
		spurred lupine
		speckle pod milkvetch
		taper-tip hawksbeard
		taper-tip onion [a]
		Tolmie's onion [a]
		western hawksbeard [a]
		Annual forbs
		autumn willow-weed
		blepharipappus [a]
		Cyrptantha spp.
		groundsmoke spp.
		little blue-eyed Mary
		pink microsteris
		pinnate tansy mustard
		sinuate gilia [a]
		thread-stem linanthus [a]
		thread-leaf phacelia [a]
		white-stemmed blazing star
		desert alyssum
		burr buttercup
		Jim Hill tumble mustard [a]
		yellow salsify

[1]Severely reduced – species cover reduced more than 80% with no change in years following fire.
[2]Slightly reduced – species cover between 50% -90% of pre burn levels the first 3 years after fire.
[3]No effect or increased – Cover not affected or increased above pre-burn levels within three years after fire.
[a] Sheepshead wildfire, August 2001.
[b] NGBER prescribed fire, Sept-Oct 2002.

Other perennial bunchgrass species (Idaho fescue, Cusick's bluegrass) were reduced by greater than 95 percent in density (*P*>0.001) and cover (*P*>0.001) and have not recovered. There was a significant reduction in cover of Sandberg bluegrass between 2002 and 2007(figure 5b). Density of Sandberg bluegrass was reduced by 75 percent after fire, to less than 7 plants/m^2 (*P*=0.008). Not until 2009, 8 growing seasons after fire, did Sandberg bluegrass cover equalize between burned and not burned sites, though density was about 25 percent lower in the burned areas. Total perennial forb cover did not differ between burned and unburned sites. Perennial forb cover increased 100 percent in burned and not burned sites in response to higher precipitation in 2005, compared to other years. Mat forming perennial forbs were reduced by >95 percent, however, they represented only a small portion (<10 percent) of total perennial forb cover. Cheatgrass cover was 10 times greater in the burned sites in 2009 (*P*>0.001). However, cheatgrass in the burned sites was a small component of the herbaceous layer, representing less than 5 percent of total herbaceous cover.

Annual forb cover fluctuated by year and was 200-400 percent greater in the burned sites from 2003 to 2006 (*P*>0.001). Annual forb cover has not differed between burned and not burned sites the past two measurement years (2007, 2009; *P*=0.589). Annual forbs were dominated by little blue-eyed Mary, representing between 60 to 90 percent of dietary annual forb cover. Other annuals increasing after the fire were willow weed (P=0.034), *Cyrptantha* spp. (cyrptantha) (*P*=0.011), *Descurainia pinnata* (pinnate-tansy mustard) (*P*=0.004), and a non-native mustard *Sisybrium altissimum* (Jim Hill tumble-mustard) (*P*=0.016). Perennial forbs utilized by sage-grouse did not increase in cover after fire (fig 6a; *P*=0.784). Covers of annual forbs consumed by sage-grouse were 6 to 10 times greater from 2003 to 2006 in the burn sites (figure 3b; *P*>0.001). Species included willow weed, slender phlox, and little blue-eyed Mary.

DISCUSSION

Cover and Composition

The impact of fire on sage-grouse habitat characteristics produced variable effects and responses among the three Wyoming big sagebrush associations. On all associations habitat cover was reduced as result of complete to nearly complete loss of big sagebrush cover. The loss of big sagebrush had a negative effect by not only decreasing structural cover but also reducing or eliminating forage provided by big sagebrush for sage-grouse. On the Thurber's-Idaho fescue association burning reduced Wyoming big sagebrush production by 450 kg ha^{-1} (Davies and others 2007). The loss of big sagebrush cover on burned sites was not compensated by increases in tall herbaceous cover (>18 cm). As a consequence, vegetation cover requirements in the burns did not meet habitat guidelines for sage-grouse as suggested by Connelly and others (2000b).

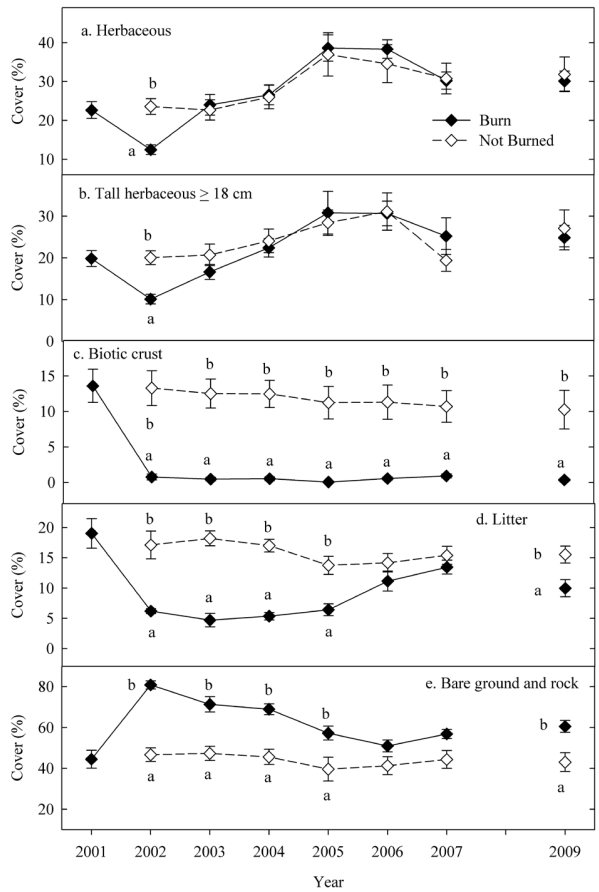

Figure 4. Ground covers (%) for the burned and not burned sites, Wyoming big sagebrush/bluebunch wheatgrass association, Sheepshead Mountains, Oregon (2001-2009); (a) herbaceous cover, (b) tall herbaceous cover (>18 cm ht), (c) biotic crust, (d) litter cover, and (e) bare ground and rock. Data are in means ± SE. Means sharing a common lower case letter are not significantly different (P>0.05).

On two associations (Thurber's-Idaho fescue, Bluebunch) herbaceous composition and cover recovered by the second to third year after fire, and at present they have the appearance of grasslands. Although perennial grass cover did not differ between burned and not burned sites perennial grass yields

about doubled on burned sites. This discrepancy in perennial grass dynamics (yield and canopy cover) likely results from higher tiller density, greater reproductive effort, and taller plants on burned sites and also because canopy cover estimates are less precise than biomass measurements (Bates and others 2009). The 2 to 3 year recovery periods on these two associations are similar to herbaceous response after fire elsewhere in big sagebrush steppe (Blaisdell 1953; Conrad and Poulton 1966; Harniss and Murray 1973; Uresk and others 1976; West and Hassan 1985).

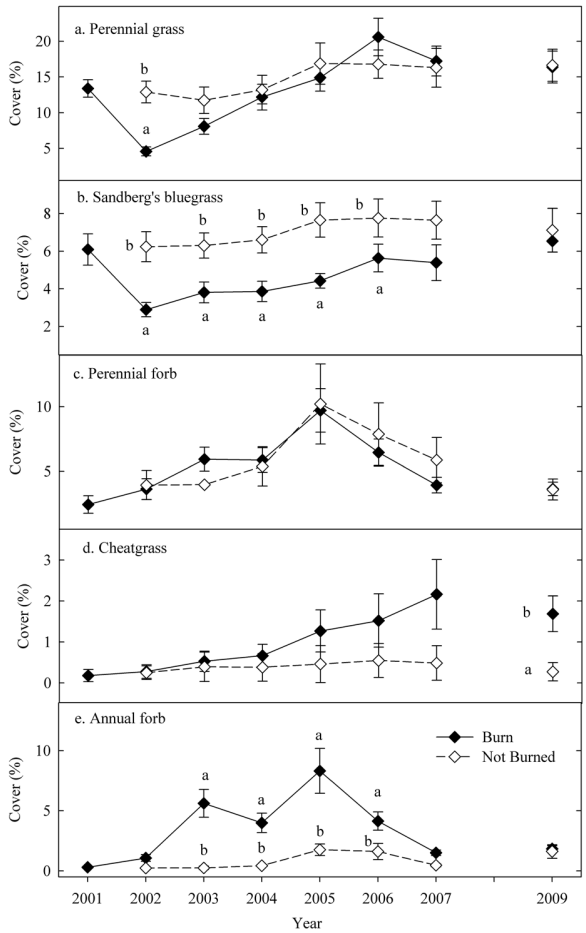

Figure 5. Herbaceous covers (%) for the burned and not burned sites, Wyoming big sagebrush/ bluebunch wheatgrass association, Sheepshead Mountains, Oregon (2001-2009); (a) perennial grass (e.g. Thurber's needlegrass and other large bunchgrasses), (b) Sandberg's bluegrass, (c) perennial forb, (d) cheatgrass, and (e) annual forb. Data are in means ± SE. Means sharing a common lower case letter are not significantly different (P>0.05).

Herbaceous recovery in these associations was mainly a result of low to no mortality among bunchgrass species and increases in cover of pale alyssum (Thurber's needlegrass-Idaho fescue association) or little blue –eyed Mary (Bluebunch association). The lack of major compositional changes in the bluebunch association and the Thurber's-Idaho fescue association indicated that they were resistant to summer wildfire and early fall prescribed fire, respectively. Their rapid recovery of herbaceous composition, cover, and productivity also indicates these associations were resilient following their respective fire disturbances.

The effects of fire on species in the Sheepshead wildfire (table 3) generally agreed with impacts reported in the literature (Britton and others 1990; Conrad and Poulton 1966; Tisdale and 1969; Uresk and others 1976; Wright and Bailey1982; Wright and others 1979). Mat-forming forbs and bunchgrasses with densely packed culms (Thurber's needlegrass, Idaho fescue, and Cusick's bluegrass) were the most severely impacted species. This was evident on the Thurber's needlegrass association where herbaceous composition has not recovered 8 years after wildfire. In the Bluebunch association, Idaho fescue and Cusick's bluegrass were almost eliminated; however, because these species were a minor component of pre-burn herbaceous cover (< 2 percent of total cover; < 1 plant/m^2), there was little impact to overall herbaceous cover or composition.

In the Thurber's association the greater than 95 percent mortality suffered by perennial grasses resulted in little remaining tall herbaceous cover. High mortality of Thurber's needlegrass has been reported for summer wildfires (Uresk and others 1980; Wright and Klemmedson 1965). Herbaceous composition was largely comprised of native and non-native forbs and cheatgrass. Increases in total herbaceous cover were a result of increases in long-leaf phlox, cheatgrass, and annual forbs, particularly pale alyssum. These low growing species provide little value as escape or nesting cover for sage-grouse (Connelly and others 2000b; Crawford and others 2004). The compositional changes suggest that Thurber's needlegrass associations have potentially low resistance and resilience to wildfire. Prescribed fire on similar associations can have comparable effects when high litter accumulation in bunchgrass crowns increases burn residence times and causes

high bunchgrass mortality, resulting in site dominance by cheatgrass and other weedy species (Davies and others 2009).

Sagebrush Recovery

Recovery of Wyoming big sagebrush was limited on all associations after fires. Wyoming big sagebrush is the slowest of the big sagebrush species to recover after fire because of a lack of seed production in most years and because drier conditions make establishment of new plants problematic (Bates et al. 2005; Wright and Bailey 1982). Recovery periods for Wyoming big sagebrush after wildfire are not well quantified and have been variously estimated to take between 50 and 200 years (Baker 2006; Tisdale and Hironaka 1981; Wright and others 1979). Lesica and others (2007) measured a maximum of only 5 percent recovery of Wyoming big sagebrush canopy after a series of wildfires (time since fire, 7–23 yr) in southwestern Montana.

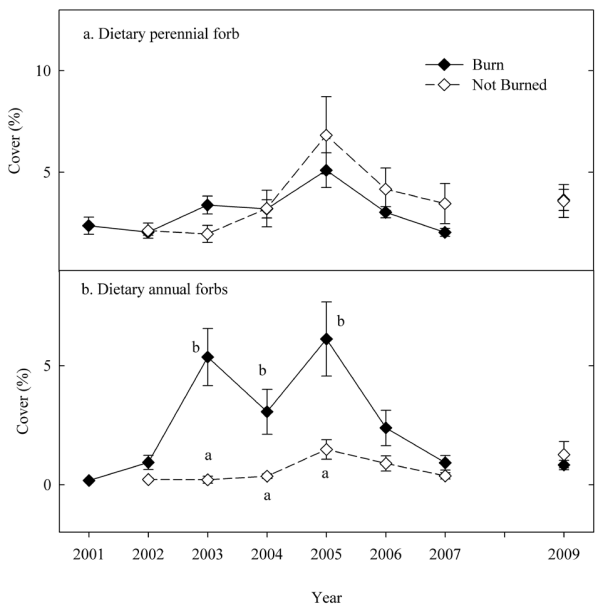

Figure 6. Cover of (a) dietary perennial and (b) dietary annual forbs that are utilized by sage-grouse, burned and not burned sites, Wyoming big sagebrush/ bluebunch wheatgrass association, Sheepshead Mountains, Oregon (2001-2009). Data are in means ± SE. Means sharing a common lower case letter are not significantly different (P>0.05).

Recovery of Wyoming big sagebrush after prescribed fire may occur earlier than after wildfire because fires are often less complete and retain pockets of surviving sagebrush. On the Thurber's-Idaho fescue association surviving sagebrush were scattered throughout the burn and provide a potential seed source. Wyoming big sagebrush cover was about 10 percent of pre-burn levels on the Thurber's-Idaho fescue association seven years after fire. Longer term development on this site will likely result in greater landscape heterogeneity in the form of a grass and shrub mosaic which should benefit a greater variety of wildlife species. On other prescribed burns, Wambolt and Payne (1986) measured a 12 percent recovery of Wyoming big sagebrush cover 18 years after burning in southwest Montana; Beck and others (2009) reported that big sagebrush cover was 20 percent of preburn levels 14 years after prescribed fire; and Wambolt and others (2001) measured a 72 percent recovery 32 years after early fall prescribed fire.

Forb Response

A justification for burning and applying mechanical treatments in big sagebrush habitat has been to enhance forb abundance and productivity from sage-grouse pre-nesting through brood-rearing periods. The evidence indicates that there is limited potential for enhancing perennial forb yield or abundance after fire in Wyoming big sagebrush steppe. On the Thurber's needlegrass-Idaho fescue and bluebunch associations there was no increase in yield or cover of perennial forb species or genera reported to be important in the diet of sage-grouse. The only perennial forb to respond positively to fire was long-leaf phlox on the Thurber's association. Other studies have failed to detect any increase in forb diversity or abundance after burning or mowing in Wyoming big sagebrush communities (Beck and others 2009; Davies and others, in review; Fischer and others 1996; Wrobleski and Kauffman 2003). Crude protein of perennial forbs may be enhanced after fire; however, the effects are of short duration, lasting only the first two years after fire (Rhodes and others 2010).

In mountain big sagebrush communities burning will not necessarily result in substantial increases in perennial forbs. In eastern Oregon, frequency of Cichorieae species increased but abundance of other forbs consumed by sage-grouse did not after prescribed fire (Pyle and Crawford 1996). In southeastern Idaho, forb abundance across different-aged burns did not differ from unburned mountain big sagebrush communities (Nelle and others 2000).

On all associations cover/yields of annual forbs utilized by sage-grouse increased the first 1to3 years post-fire. On the Thurber's needlegrass-Idaho fescue and Thurber's association's annual forbs were mainly

comprised of pale alyssum by the second year after fire. Diet studies do not indicate that pale alyssum is consumed by sage-grouse (Barnett and Crawford 1994; Drut and others 1994; Klebenow and Gray 1968; Peterson 1970; Wallestad and others 1975). Sage-grouse utilize other annual mustards with a similar phenology (Peterson 1970); therefore, there is the potential that grouse may utilize pale alyssum.

Several factors account for the limited native forb response to fire including postfire weather, site potential, interference by perennial grasses and pale alyssum, and lack of forb propagules in the soil seed bank. The amount and timing of precipitation and temperatures can have a major influence on herbaceous productivity in big sagebrush steppe (Bates and others 2005; Sneva 1982). Perennial forbs on the Bluebunch association increased in cover in years with higher precipitation; however, the increase was identical on burned and not-burned sites. Weather did not influence perennial forb production in the Thurber's or Thurber's-Idaho Fescue associations because cover and/or yields did not differ across years despite 4 years of below-average precipitation and 2 years of above-average precipitation.

The potential for increasing perennial forbs may be limited by site characteristics. Perennial forb cover in most Wyoming big sagebrush associations comprises 15-22 percent of total herbaceous cover (Davies and others 2006). Production of perennial forbs and annual forbs in most Wyoming big sagebrush associations of Oregon average about 20 percent (15-30 percent) and 3 percent (0-8.5 percent) of total production, respectively (N=32, EOARC file data). Prior to fire, perennial forb cover and biomass represented 14 percent and 13 percent of total herbaceous cover and biomass, respectively, on the Thurber's needlegrass-Idaho fescue association. After fire the ratio of perennial forbs to total herbaceous production declined below 10 percent because perennial grass and pale alyssum yield increased and forb yield did not change. The response of perennial grasses and other herbaceous plant life forms after the fire may interfere with the ability of native forbs to increase after fire. Increased mortality of perennial grasses could increase the availability of openings for native forbs to establish. However, on the Thurber's needlegrass-Idaho fescue association increased mortality of perennial grasses would probably only have benefited pale alyssum rather than native forbs. In addition, increased mortality of perennial bunchgrasses may also result in cheatgrass invasion or dominance, because this species is present within most Wyoming big sagebrush communities (Davies and others 2006; Davies and others 2008).

Fire in Sage-Grouse Habitat

Evaluating fire or other disturbances in ecosystems is challenging because the impacts can be construed positively, negatively, or without effect depending upon the objectives, scale, and duration of the analysis. In this study we evaluated the short-term impacts of fire on habitat characteristics of Wyoming big sagebrush steppe for sage-grouse, a sagebrush obligate. There is little indication that prescribed burning in Wyoming big sagebrush steppe will provide short-term benefits to sage-grouse. Burning big sagebrush steppe reduces potential nesting areas and roosting cover, as well as diminishing or eliminating forage provided by sagebrush for sage-grouse, which would be especially damaging in year-round and wintering habitat. Population studies indicate that sage-grouse numbers have declined following prescribed burning in Wyoming big sagebrush communities of southeast Idaho, which was likely a result of losses in nesting and wintering habitat (Connelly and Braun 1997; Connelly and others 2000a). In brood-rearing habitat an objective of prescribed fire has been to enhance forb production and availability (Wirth and Pyke 2003). In our studies and others (Beck and others 2009; Fischer and others 1996; Nelle and others 2000; Wrobleski and Kauffman 2003), yields or cover of forbs used by sage-grouse in their diets have been largely unresponsive to fire.

Insects are an important dietary component of young sage-grouse and may comprise 75-100 percent of the diet the first several weeks after hatching (Johnson and Boyce 1990; Patterson 1952). Juvenile sage-grouse survival was positively correlated with high Lepidoptera availability and frequency of slender phlox, and without insects in the diet, mortality rates of 90-100 percent in juvenile sage-grouse have been reported (Gregg 2006; Johnson and Boyce 1990). Fire was detrimental to ant populations in our study (Thurber's needlegrass-Idaho fescue association) and elsewhere in the Wyoming big sagebrush complex (Fisher and others 1996).

Aside from sage-grouse, there are several benefits after burning or mechanically treating big sagebrush for other wildlife species. For large ungulates and granivores, burned areas often result in a doubling of available herbaceous forage and may triple grass seed yield (Bates and others 2009; Cook and others 1994; Davies and others 2007). In mountain big sagebrush communities, creating a mosaic pattern of small treated areas within stands increased sage-grouse brood-rearing and summer use in Utah (Dahlgren and others 2006). A mosaic of different aged burns or greater habitat complexity in sagebrush steppe results in increased invertebrate biomass and avian species diversity and numbers (Petersen and Best 1987; Pons and others 2003; Noson and others 2006; Reinkensmeyer and others 2007; Roth 1976). The advantage of prescribed burning and mechanical brush control is that these treatments can be manipulated to construct a mosaic of sage-brush-steppe and herbaceous dominated areas.

In areas containing Wyoming big sagebrush communities, management of both wild and prescribed fires must be carefully considered. The high mortality of perennial grasses and presence of cheatgrass in the Thurber's needlegrass association suggests there is a substantial risk for annual grass replacement of this association after wildfire and potentially with prescribed burning (Davies and others 2008). Although the Sheepshead wildfire did not severely impact the herbaceous layer in the bluebunch wheatgrass association, this association and Thurber's needlegrass associations are often arranged in a mosaic across the landscape. These associations are the most commonly encountered type in Wyoming big sagebrush steppe of the northern Great Basin (Davies and others 2006). Thus, efforts should be made to limit wildfire disturbance in remaining Wyoming big sagebrush plant associations of the northern Great Basin. The danger of cheatgrass dominance is that wildfire frequencies are likely to increase compared to historic MFRI resulting in further degradation or loss of sagebrush communities (Whisenant 1990). In the Snake River Plains of Idaho, fires typically occur about every 5 years as a result of cheatgrass dominance in former Wyoming big sagebrush communities (Whisenant 1990). These fires are landscape level burns that limit recovery of big sagebrush and associated species (Suring and others 2005). Historically, the Wyoming big sagebrush cover type burned every 50–100 years and fires typically produced a mosaic of burned and unburned patches (Wright and others 1979; West 1983; West and Hassan 1985).

MANAGEMENT IMPLICATIONS

The viability of obligate wildlife species, such as sage-grouse, is best served by maintenance of preferred habitat; thus disturbances, particularly those of large scale, are likely to have deleterious impacts to their populations. Because of the lack of quantifiable short-term benefits of burning in Wyoming big sagebrush communities it appears unnecessary to apply extensive or small-scale brush control treatments for specifically improving habitat for sage-grouse. Burning of Wyoming big sagebrush communities to enhance other species habitat requirements or to increase forage production for livestock should be applied when mortality of native perennial grasses and forb species can be minimized, result in a mosaic pattern of burned and unburned patches, and avoids areas where cheatgrass and other exotics are of concern. Furthermore, when planning prescribed fire in sagebrush steppe, areas of critical habitat should be identified, such as wintering grounds, in order to minimize potential negative impacts to sage-grouse and other sagebrush obligate and facultative wildlife species.

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