Natural Resources and Environmental Issues

Volume 16 *Shrublands: Wildlands and Wildlife Habitats*

Article 5

1-1-2011

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Beck, Jeffrey L.; Klein, J. Garrett; Wright, Justin; and Wolfley, Kenneth P. (2011) "Potential and Pitfalls of Prescribed Burning Big Sagebrush Habitat to Enhance Nesting and Early Brood-Rearing Habitats for Greater Sage-Grouse," *Natural Resources and Environmental Issues*: Vol. 16, Article 5.
Available at: http://digitalcommons.usu.edu/nrei/vol16/iss1/5

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Potential and Pitfalls of Prescribed Burning Big Sagebrush Habitat to Enhance Nesting and Early Brood-Rearing Habitats for Greater Sage-Grouse

Jeffrey L. Beck[1], J. Garrett Klein[1], Justin Wright[1], and Kenneth P. Wolfley[1]

ABSTRACT

We describe short-term (≤10 yrs) and long-term (>10 yrs) responses of prescribed burning to enhance nesting and early brood-rearing habitat for greater sage-grouse (Centrocercus urophasianus). *Our primary objective was to provide a literature synthesis to identify short- and long-term responses of prescribed burning to important components of sage-grouse nesting and early brood-rearing habitats in mountain* (Artemisia tridentata vaseyana) *and Wyoming* (A. t. wyomingensis) *big sagebrush. In our synthesis, we evaluated ecological status (bare ground and litter), food availability (forbs and insects), and vegetation structure (grass and sagebrush cover). We used six criteria to identify* n *= 12 papers providing meaningful and rigorous results. Of these papers, six reported the effects of burning in mountain big sagebrush; seven in Wyoming big sagebrush; and one provided information for mountain and Wyoming big sagebrush. Our findings point to some potential for short-term enhancement of forbs and grasses in mountain big sagebrush, but no long-term enhancement of herbs in mountain big sagebrush or short- or long-term enhancement of herbs in Wyoming big sagebrush. In particular, prescribed burning leads to a pronounced negative response in sagebrush cover that lasts for at least a few decades. Based on our findings, we cannot recommend burning Wyoming big sagebrush to enhance sage-grouse nesting or early brood-rearing habitat and we suggest prescribed burning has limited short-term value in enhancing forbs and grasses for sage-grouse inhabiting Mountain big sagebrush.*

INTRODUCTION

Three major subspecies of big sagebrush (*Artemisia tridentata*; Beetle 1960; Beetle and Young 1965) dominate the sagebrush biome, a region that historically encompassed >600,000 km^2 of western North America (Küchler 1970; West 1983; Connelly and others 2004). These subspecies of big sagebrush inhabit areas according to climate, soils, and topography (Tisdale and Hironaka 1981; Bunting and others 1987). Mountain big sagebrush (*A. t. vaseyana*) grows on well-developed soils typically at the highest elevations where cooler temperatures and 31–51 cm of annual precipitation prevail; basin big sagebrush (*A. t. tridentata*) occurs at warmer, lower elevations with 25 to 46 cm of annual precipitation on deep, well-drained soils; and, Wyoming big sagebrush (*A. t. wyomingensis*), the most extensive complex in the Intermountain West (Tisdale 1994), inhabits shallower, sometimes slightly saline soils in warmer regions than mountain big sagebrush with 18 to 31 cm of annual precipitation (Tisdale and Hironaka 1981; Bunting and others 1987). Due to greater moisture, forb and grass production is typically higher in mountain big sagebrush than in basin or Wyoming big sagebrush communities (Bunting and others 1987).

Because basin, mountain, and Wyoming big sagebrush are not root-sprouting shrubs, they can be effectively controlled with prescribed burning programs (Pechanec and others 1965). The size of a burn and characteristics of the site are important factors affecting reestablishment of sagebrush. Sagebrush must reestablish through seeds that have been dispersed into burns from unburned stands by wind, water erosion, or animals (Meyer 1994). Based on cover and density values from various studies, Baker (2006) approximated post-burn recovery periods to be from 35 to 100 years for mountain big sagebrush and 50 to 120 years for Wyoming big sagebrush. Slow reestablishment of sagebrush provides opportunities for herbaceous plants to establish due to limited competition for water, sunlight, and nutrients.

Throughout the sagebrush biome, sagebrush obligate wildlife species such as greater sage-grouse (*Centrocercus urophasianus*) depend on the structural components (for example grass and shrub cover and height) and functional attributes (for example food availability) of sagebrush communities for food and cover. Within sagebrush/bunchgrass landscapes, successful (in other words, ≥1 egg hatched) sage-grouse nests are characterized by cover and height of sagebrush and residual grasses that are greater than randomly available (Sveum and others 1998; Holloran and others 2005). Functional early brood-rearing habitats provide protein-rich insects including ants (Hymenoptera), beetles (Coleoptera), and grasshoppers (Orthoptera) critical for early sage-grouse chick survival (Klebenow and Gray 1968; Peterson 1970; Johnson and Boyce 1990). As summers progress, forbs and then sagebrush leaves form larger proportions of chick and juvenile sage-grouse diets (Klebenow and Gray 1968; Peterson 1970) until the food habits of juveniles parallel that of adult sage-grouse at about 3 months (Rasmussen and Griner 1938). Consequently, the structural and functional characteristics of nesting and early brood-rearing habitats in burned areas are of critical importance to sage-grouse population persistence.

In: Wambolt, C.L. et al. comps. 2011. Proceedings – Shrublands: wildlands and wildlife habitats; 2008 June 17-19; Bozeman, MT. NREI, volume XVI. S.J. and Jessie E. Quinney Natural Resources Research Library, Logan, Utah, USA.

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Burning sagebrush was originally considered an important tool to increase desirable herbaceous forage species limited by dense stands of older sagebrush (for example Mueggler and Blaisdell 1959). Range managers recognized that improper burning and livestock grazing after burning in sagebrush communities leads to degraded soil and vegetation conditions (Harniss and Murray 1973) and that prescribed fire can also increase habitat diversity (Britton and others 1981). Numerous studies have demonstrated that prescribed burning has negative effects (for example Fischer and others 1996; Wambolt and others 2001; Beck and others 2009) on sage-grouse habitats in mountain and Wyoming big sagebrush. However, some still suggest burning sage-grouse habitats is appropriate under certain scenarios (for example Crawford and others 2004), yet, these scenarios present risks to sage-grouse habitats and populations (Schroeder and others 2006).

Our objective was to provide a literature synthesis to identify short-term (≤10 yrs) and long-term (>10 yrs) responses (Nelle and others 2000; Crawford and others 2004) of prescribed burning to important components of sage-grouse nesting and early brood-rearing habitats in mountain and Wyoming big sagebrush. Early brood-rearing habitats have been defined as those areas near the nest of hatch used by sage-grouse hens with chicks up to 3 weeks following hatch (Connelly and others 2000). These differ from late brood-rearing habitats, which are habitats used by sage-grouse following desiccation of herbaceous vegetation in sagebrush uplands (Connelly and others 2004). We focus our review on nesting and early brood-rearing habitats because of their overall importance to sage-grouse population productivity and the fact that they occur in similar sagebrush habitats. We selected mountain and Wyoming big sagebrush because they collectively form the majority of available habitats used by sage-grouse; basin big sagebrush and other sagebrush species are also used by sage-grouse, but are more constrained in distribution (Tisdale and Hironaka 1981; Connelly and others 2004). To accomplish our objective we selected four habitat features required by nesting and brood-rearing sage-grouse (forb availability, insect availability, grass cover, and sagebrush canopy cover) and two features indicative of ecological status following burning (bare ground and litter). We selected this suite of features because they are commonly measured in studies evaluating vegetation and wildlife responses to burned big sagebrush communities and because the four grouse habitat features reflect food and cover necessary for reproduction and survival of sage-grouse (Anderson and Gutzwiller 2005).

METHODS

We reviewed articles published in scientific journals to identify short-term (≤10 yrs) and long-term (>10 yrs) effects of prescribed burning on sage-grouse habitat features in Wyoming big and mountain big sagebrush communities. We did not include theses and dissertations in our review to avoid including literature that had not undergone rigorous peer review. We searched scientific literature data bases using key words including fire, insects, mountain big sagebrush, prescribed burning, and Wyoming big sagebrush to identify potential papers for our review.

We reviewed the study design of each paper to ensure results would provide us with information necessary to rigorously summarize short- and long-term effects of prescribed burning on six features of sage-grouse habitats in Wyoming and mountain big sagebrush. To obtain information on the widespread effects of burning in Wyoming and mountain big sagebrush, we included articles from areas irrespective of whether sage-grouse were known to occur in those areas. The specific criteria we used to identify studies suitable for our review included: (1) reported results were only from prescribed burning programs, excluding results from wildfire studies; (2) prescribed burns must be in vegetation that was not seeded before or after the burn to better understand the influence of prescribed burning on systems that were composed of native perennial species; (3) avoiding the potential bias from studies that provided results on habitat features selected by grouse within burned habitats; (4) when mountain and Wyoming big sagebrush occurred together in the same burn area, results were reported by species; (5) each study had to compare responses in prescribed burned areas to unburned controls; and (6) differences in estimates had to be corroborated with results from statistical hypothesis tests (for example paired *t*-test or ANOVA).

To facilitate efficient reporting of our results, we categorized habitat features into ecological status (bare ground and litter), food availability (forb [canopy cover, frequency, relative abundance, or production] and insect abundance), and vegetation structure (grass cover [basal or canopy] and sagebrush canopy cover) categories. In those cases where variable effects were reported from different sites within the same study, we report the majority response. We considered comparisons in sage-grouse habitat features between burned and unburned control areas to be statistically different when $P \leq 0.05$. Consequently, neutral responses indicate no detectable change in the values of habitat features, whereas negative indicates a statistically detectable decrease in the value of a habitat feature and positive indicates a statistically detectable increase in the value of a feature.

Table 1—Literature reviewed to describe the effects of prescribed burning on short (<10 years) and long-term (≥10 years) response of greater sage-grouse habitat in mountain and Wyoming big sagebrush.

			Mountain Big Sagebrush		Wyoming Big Sagebrush	
Reference[a]	Location[b]	Burn Timing	Short-term	Long-term	Short-term	Long-term
Beck and others (2009)	ID	Autumn				X
Cook and others (1994)	WY	Spring	X			
Fischer and others (1996)	ID	Autumn			X	
Holmes (2007)	OR	Autumn	X			
Peek and others (1979)	ID	Autumn			X	
Perryman and others (2002)	CO, UT	Autumn			X	X
Pyle and Crawford (1996)	OR	Autumn and Spring	X			
Seefeldt and others (2007)	ID	Autumn	X			
Van Dyke and Darragh (2006)	MT	Autumn and Spring	X	X		
Wambolt and others (2001)	MT	Autumn and Spring	X	X	X	X
Wambolt and Payne (1986)	MT	Autumn			X	X
Wrobleski and Kauffman (2003)	OR	Autumn			X	

[a]We suggest consulting these references for other short- or long-term responses that we do not consider in our paper.
[b]Locations are: CO = Colorado, ID = Idaho, MT = Montana, OR = Oregon, UT = Utah

RESULTS

We identified 12 studies that met our selection criteria (table 1). Of these studies, six provided information on the effects of burning in mountain big sagebrush (six short-term and two long-term) and seven in Wyoming big sagebrush (six short-term and four long-term). One study provided information on the short- and long-term effects of prescribed burning in mountain big sagebrush and Wyoming big sagebrush (table 1).

Short-Term Responses

We did not review any studies that reported short-term responses in bare ground in mountain big sagebrush. One study reported a negative short-term response in litter in mountain big sagebrush. We found no short-term response in litter (2 studies) or bare ground (2 studies) in Wyoming big sagebrush (table 2). Reviewed studies indicated a neutral (3 of 6 studies) or positive (3 of 6 studies) response in forb availability in mountain big sagebrush. All reviewed studies (5/5) reported no short-term response in forb availability in Wyoming big sagebrush; however, one study reported a one-year negative response from burning in availability of two of nine sage-grouse food forb species studied in southeastern Oregon (table 2). One paper each provided information on short-term responses in insect availability in mountain and Wyoming big sagebrush. Short-term response of insects was neutral in mountain big sagebrush and neutral (beetles and grasshoppers) or negative (ants) in Wyoming big sagebrush (table 2). Short-term response of grass cover following prescribed burning in mountain big sagebrush was neutral (3 of 6 studies) or positive (3 of 6 studies). Short-term response of grass cover in Wyoming big sagebrush was neutral (3 of 4 studies) or positive (1 of 4 studies; table 2). All studies reported negative short-term responses in sagebrush canopy cover following prescribed burning in mountain and Wyoming big sagebrush (table 2).

Long-Term Responses

We did not identify any studies that reported long-term responses in bare ground or litter in mountain big sagebrush. Long-term responses in Wyoming big sagebrush for litter and bare ground were neutral (bare ground, two of three studies; litter, one of two studies) or negative (bare ground, one of three studies; litter, one of two studies; table 2). We identified two studies that reported no long-term response of prescribed burning on forb availability in mountain big sagebrush. Three of four long-term studies in Wyoming big sagebrush reported no long-term response, but one of four studies reported a positive response in forb availability in Wyoming big sagebrush (table 2). No papers summarized long-term responses in insect availability in either mountain of Wyoming big sagebrush (table 2). One study each reported a neutral or positive response in grass cover to prescribed burning in mountain big sagebrush, while four studies indicated a neutral long-term response in grass cover following prescribed burning in Wyoming big sagebrush (table 2). Reviewed studies suggest a pronounced negative long-term effect of prescribed burning on sagebrush canopy cover in mountain (2 studies) and Wyoming big sagebrush (3 studies; table 2).

Table 2—Literature describing the short- (<10 years) and long-term (≥10 years) effects (neutral, positive [+], negative [−]) of prescribed burning on sage-grouse habitat features in mountain and Wyoming big sagebrush.

Habitat Features[a]	Mountain Big Sagebrush			Wyoming Big Sagebrush		
	Neutral	+	−	Neutral	+	−
SHORT-TERM						
Ecological Status						
Bare Ground				6,11		
Litter			4	5,6		
Food Availability						
Forbs[b]	2,8,10	4,7,9		3,5,6,10,12		12
Insects	7			3[c]		3[d]
Vegetation Structure						
Grass Cover[e]	7,8,10	2,4,9		5,10,11	6	
Sagebrush Canopy Cover			7,8,9,10			5,10,11
LONG-TERM						
Ecological Status						
Bare Ground				6,11		1
Litter				6		1
Food Availability						
Forbs	9,10			1,6,10	11	
Insects						
Vegetation Structure						
Grass Cover	10	9		1,6,10,11		
Sagebrush Canopy Cover			9,10			1,10,11

[a](1)Beck and others (2009), (2) Cook and others (1994), (3) Fischer and others (1996), (4) Holmes (2007), (5) Peek and others (1979), (6) Perryman and others (2002), (7) Pyle and Crawford (1996), (8) Seefeldt and others (2007), (9) Van Dyke and Darragh (2006), (10) Wambolt and others (2001), (11) Wambolt and Payne (1986), (12) Wrobleski and Kauffman (2003).
[b]Forb availability was reported as canopy cover, frequency, relative abundance, or production.
[c]Coleoptera and Orthoptera.
[d]Hymenoptera.
[e]Basal or canopy cover.

DISCUSSION

Our study provides a synthesis of published literature identifying short- and long-term responses of habitat features used by sage-grouse for nesting and early brood-rearing to prescribed burning in mountain and Wyoming big sagebrush. Our findings point to some potential for short-term enhancement of forbs and grasses in mountain big sagebrush, but no long-term enhancement of forbs or grasses in mountain big sagebrush or short- or long-term enhancement of grasses or forbs in Wyoming big sagebrush. In particular, prescribed burning leads to a pronounced negative response in sagebrush cover that lasts for at least a few decades. Of the studies we reviewed, the study conducted by Wambolt and others (2001) spanned the longest time period. They reported that cover of mountain and Wyoming big sagebrush requires more than 16 and 32 years, respectively, to return to preburn levels following prescribed burning. In comparison, several studies have reported slow recovery rates for big sagebrush particularly Wyoming big sagebrush (Baker 2006; Lesica and others 2007; Beck and others 2009).

There is little available evidence that provides support for positive responses of prescribed burning to sage-grouse habitat. There may be opportunities for limited prescribed burning (0.1 ha burns) in dense stands of mountain big sagebrush summer habitats to increase forbs (Pyle and Crawford 1996). Similarly, Dahlgren and others (2006) reported increased brood use within 40.5 ha mountain big sagebrush plots in south-central Utah that had been partially mechanically or chemically treated; however, greatest brood use for all treatments occurred within 10 m of the edge of treatments where sagebrush cover was available, suggesting the importance of treating small patches of sagebrush to invigorate forbs for brood use. However, systematic and routine burning of sagebrush rangelands will not lead to stabilizing and increasing sage-grouse populations (Wambolt and others 2002). Burning sagebrush should only be undertaken after carefully considering sage-grouse habitat requirements and concomitant habitat conditions (Dahlgren and others 2006). Due to the long recovery period for mountain and Wyoming big sagebrush after a burn (Baker

2006), sage-grouse populations could be lost in an area following frequent, large-scale burning (Pederson and others 2003).

CONCLUSIONS

Based on our findings, we cannot recommend burning Wyoming big sagebrush to enhance sage-grouse nesting or early brood-rearing habitat and we suggest small prescribed burns in mountain big sagebrush have limited short-term value in enhancing forbs and grasses for nesting and early brood-rearing sage-grouse. Our recommendation agrees with Schroeder and others' (2006) viewpoint and a recommendation by Beck and others (2009) who argue that loss of sagebrush structural characteristics is so great following prescribed fire that burning may maximize detrimental effects to sagebrush dependent species such as sage-grouse. For instance, burned mountain big sagebrush may not recover sufficiently to support nesting or brood-rearing for more than 20 years (Nelle and others 2000). Available research indicates that burning has some potential to enhance mountain big sagebrush nesting and brood-rearing habitats in small patches, but no potential to enhance habitats used by greater sage-grouse in Wyoming big sagebrush at any scale.

ACKNOWLEDGMENTS

We thank J. W. Connelly for helpful comments that improved our paper.

REFERENCES

Anderson, S.H., Gutzwiller, K.J. 2005. Wildlife habitat evaluation. *In*: Braun, C.E., ed. in Techniques for wildlife investigations and management. 6th ed. Bethesda, Maryland: The Wildlife Society: 489–502.

Baker, W.L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin 34:177–185.

Beck, J.L., Connelly, J.W., Reese, K.P. 2009. Recovery of greater sage-grouse habitat features in Wyoming big sagebrush following prescribed fire. Restoration Ecology. 17:393-403.

Beetle, A.A. 1960. A study of sagebrush—Section Tridentatae of Artemisia. Bull 368. Laramie: University of Wyoming, Agricultural Experiment Station, 83 pp.

Beetle, A.A., Young, A. 1965. A third subspecies in the *Artemisia tridentata* complex. Rhodora 67:405–406.

Britton, C.M., Clark, R.G., Sneva, F.A. 1981. Will your sagebrush range burn? Rangelands 3:207–208.

Bunting, S.C., Kilgore, B.M., Bushey, C.L. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. Gen. Tech. Rep. INT 231. pp. 33.

Cook, J.G., Hershey, T.J., Irwin, L.L. 1994. Vegetative response to burning on Wyoming mountain-shrub big game ranges. Journal of Range Management 47:296–302.

Connelly, J.W., Knick, S.T., Schroeder M.A., Stiver, S.J. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming.

Connelly, J.W., Schroeder, M.A., Sands, A.R., Braun, C.E. 2000. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28:967–985.

Crawford, J.A., et al. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2–19.

Dahlgren, D.K., Chi, R., Messmer, T.A. 2006. Greater sage-grouse response to sagebrush management in Utah. Wildlife Society Bulletin 34:975–985.

Fischer, R.A., Reese, K.P., Connelly, J.W. 1996. An investigation on fire effects within xeric sage grouse habitat. Journal of Range Management 49:194–198.

Harniss, R.O., Murray, R.B. 1973. 30 years of vegetal change following burning of sagebrush-grass range. Journal of Range Management 26: 322–325.

Holloran, M.J. et al. 2005. Greater sage-grouse nesting habitat selection and success in Wyoming. Journal of Wildlife Management 69:638–649.

Holmes, A.L. 2007. Short-term effects of a prescribed burn on songbirds and vegetation in mountain big sagebrush. Western North American Naturalist 67:292–298.

Johnson, G.D., Boyce, M.S. 1990. Feeding trials with insects in the diet of sage-grouse chicks. The Journal of Wildlife Management, 54:89–91.

Lesica, P., Cooper S.V., Kudray, G. 2007. Recovery of big sagebrush following fire in southwest Montana. Rangeland Ecology and Management 60:261–269

Klebenow, D.A., Gray, G.M. 1968. Food habits of juvenile sage grouse. Journal of Range Management 21:80–83.

Küchler, A.W. 1970. Potential natural vegetation. USDI, Geological Survey, the National Atlas of the United States of America. Washington D.C.: U.S. Government Printing Office: 89–92.

Meyer, S.E. 1994. Germination and establishment ecology of big sagebrush: implications for community restoration. *In*: Monsen, S.B., Kitchen, S.G., eds. Ecology and management of annual rangelands symposium, proceedings; 1992 May 18–22; Boise, ID. Gen. Tech. Rep. INT-313. Ogden, UT: Intermountain Research Station: 244–251.

Mueggler, W.F., Blaisdell, J.P. 1959. Effects on associated species of burning, rotobeating, spraying, and railing sagebrush. Journal of Range Management 11:61–66.

Nelle, P.J., Reese, K.P., Connelly, J.W. 2000. Long-term effects of fire on sage grouse habitat. Journal of Range Management 53:586–591.

Pechanec, J.F., Plummer, A.P., Robertson, J.H., Hull, A.C., Jr. 1965. Sagebrush control on rangelands. USDA, Handbook Number 277, Washington D.C.

Pederson, E.K., Connelly, J.W., Hendrickson, J.R., Grant, W.E. 2003. Effect of sheep grazing and fire on sage grouse populations in southeastern Idaho. Ecological Modelling 165:23–47.

Peek, J.M., Riggs, R.A., Lauer, J.L. 1979. Evaluation of fall burning on bighorn sheep winter range. Journal of Range Management 32:430–432.

Perryman, B.L., Olson, R.A., Petersburg, S., Naumann, T. 2002. Vegetation response to prescribed fire in Dinosaur National Monument. Western North American Naturalist 62:414–422.

Peterson, J.G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. Journal of Wildlife Management 34: 147–155.

Pyle, W.H., Crawford, J.A. 1996. Availability of foods of sage grouse chicks following prescribed fire in sagebrush-bitterbrush. Journal of Range Management 49:320–324.

Rasmussen, D.I., Griner, L.A. 1938. Life history and management studies of the sage grouse in Utah, with special reference to nesting and feeding habits. Transactions of North American Wildlife Conference 3:852–864.

Schroeder, M.A. et al. 2006. Society for Range Management issue paper: ecology and management of sage-grouse and sage-grouse habitat-a reply. Rangelands 28(3):3–7.

Seefeldt, S.S., Germino, M., DiCristina, K. 2007. Prescribed fires in *Artemisia tridentata* ssp. vaseyana steppe have minor and transient effects on vegetation cover and composition. Applied Vegetation Science 10:249–256.

Sveum, C.M., Edge, W.D., Crawford, J.A. 1998. Nesting habitat selection by sage grouse in south-central Washington. Journal of Range Management 51:265–269.

Tisdale, E.W. 1994. Wyoming big sagebrush SRM 403. *In*: Shiflet, T.N., ed. Rangeland cover types of the United States. Denver, Colorado: Society for Range Management: 42–43.

Tisdale, E.W., Hironaka, M. 1981. The sagebrush-grass ecoregion: a review of the ecological literature. Forest, Wildlife, and Range Experiment Station, Bulletin No. 33 (Contribution No. 209). University of Idaho, Moscow.

Van Dyke, F., Darragh, J.A. 2006. Short- and long-term changes in elk use and forage production in sagebrush communities following prescribed burning. Biodiversity and Conservation 15:4375–4398.

Wambolt, C.L. et al. 2002. Conservation of greater sage-grouse on public lands in the western U.S.: implications of recovery and management policies. Policy Analysis Center for Western Public Lands. Policy Paper SG-02-02, Caldwell, Idaho.

Wambolt, C.L., Payne, G.F. 1986. An 18-year comparison of control methods for Wyoming big sagebrush in southwestern Montana. Journal of Range Management 39:314–319.

Wambolt, C.L., Walhof, K.S., Frisina, M.R. 2001. Recovery of big sagebrush communities after burning in south-western Montana. Journal of Environmental Management 61:243–252.

West, N.E. 1983. Western Intermountain sagebrush steppe. *In*: West, N.E., ed. Temperate deserts and semi-deserts. Ecosystems of the World, Volume 5. Amsterdam, Netherlands: Elsevier Scientific Publishing Company: 351–374.

Wrobleski, D.W., Kauffman, J.B. 2003. Initial effects of prescribed fire on morphology, abundance, and phenology of forbs in big sagebrush communities in southeastern Oregon. Restoration Ecology 11:82–90.