AN ABSTRACT OF THE THESIS OF

Michelle K. D. McDowell for the degree of Master of Science in Wildlife Science presented on April 3, 2000. Title: The Effects of Burning in Mountain Big Sagebrush on Key Sage Grouse Habitat Characteristics in Southeastern Oregon.

Abstract approved: Signature redacted for privacy.

John A. Crawford

Sage grouse are a species of concern because their abundance, distribution, and productivity have declined during the past century. Sage grouse productivity has been linked to specific habitat components including particular forbs and native bunchgrasses. Studies on the effects of fire were conducted in Southeastern Oregon in mountain big sagebrush communities to better understand the effects of fire on key sage grouse habitat components. The short-term study was conducted at South Steens Mountain during 1997 and 1998. Habitat components (medium shrub cover; perennial grass cover; hen and chick food forb cover, frequency, and availability; chick food forb nutrition; insect abundance; and sagebrush reproductive branch abundance) were compared between preburn or unburned, 1-year post-burn, and 2-years post-burn areas. The long-term effects of fire on essential sage grouse habitat components were studied during 1997 at Hart Mountain National Antelope Refuge (Lake County), and during 1998 at South Steens Mountain (Harney County). Habitat components (medium height mountain

big sagebrush, tall grass, hen and chick food forb, and other forb cover) were measured at burned and adjacent unburned control sites and compared with recommended cover amounts. Burned sites ranged in age from 5 to 43 years. In the short-term fire effects study, prescribed burning increased the amount of sage grouse hen and chick foods, the quality of some chick foods, and increased the amount of time of these foods were available. Sagebrush cover was essentially eliminated in burned areas. Perennial grass cover was significantly higher in a comparison of the 2-years post burn to the 1-year post burn samples. In the long-term fire effects study, all key vegetative and structural components needed for successful sage grouse reproduction became available in burned areas from 25-35 years old. Sagebrush cover was the only habitat component tested that was substantially affected by burning in the long term. Prescribed burning would be most beneficial to sage grouse habitat if used as a management tool to create a mosaic of needed habitat components.

The Effects of Burning in Mountain Big Sagebrush on Key Sage Grouse Habitat Characteristics in Southeastern Oregon

by

Michelle K. D. McDowell

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APPROVED:

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Dean of Graduate School

I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Michelle K. D. McDowell, Author

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I dedicate this thesis to my mother

Kathie Taus

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INTRODUCTION

Sage grouse (*Centrocercus urophasianus*) were abundant in sagebrush (*Artemesia* spp.)-steppe communities of central and eastern Oregon in the early 20th century but have declined in distribution and abundance since the 1950s (Gabrielson and Jewett 1940, Crawford and Lutz 1985). Dalke *et al.* (1963) stated that the decline in sage grouse abundance resulted in part from expanding agriculture, e.g., conversion of lands to cropland and pasture. Crawford and Lutz (1985) concluded that the 60% decline in sage grouse estimates from the 1950s to the 1980s resulted from a nearly 80% decrease in productivity, measured in chicks per adult. Changes in sagebrush-steppe landscapes may have resulted in this productivity decrease.

Many portions of the western range of sage grouse have more sagebrush cover and less herbaceous understory than in prehistoric times as the result of historic overgrazing and fire suppression (Miller *et al.* 1994 , Kaufmann 1990, Winward 1991). One of the greatest impacts on shrub-steppe habitat by livestock grazing is the reduction of fine fuels, which in turn has reduced fire frequencies (Miller *et al.* 1994, Miller and Rose 1999). Although sage grouse are a sagebrush obligate, Klebenow (1972) found that sage grouse did not nest where shrub cover was > 25%. High densities of sagebrush influence food and cover available for sage grouse (Pyle and Crawford 1996). Suppression of natural fire regimes, which was the primary disturbance factor that influenced secondary plant succession in sagebrush areas, has negatively affected sage grouse habitats throughout the western United States (Wright *et al.* 1979).

Gregg *et al.* (1994) found that certain habitat components (grass cover and height and forb availability) were related to sage grouse reproductive success. Early forbs consumed by prelaying hens improved dietary nutrition (Barnett and Crawford 1994) and early forb availability was positively associated with nest initiation rates (Coggins 1999). Succulent forb availability influences sage grouse distribution during the brood-rearing period (Drut *et al.* 1994b, Gregg *et al.* 1994). In Montana, the diet of chicks 1 to 4 weeks in age consists almost exclusively of forbs and insects (Peterson 1970). Insects are needed in the diet of chicks 3-weeks old and younger for survival (Johnson and Boyce 1990). Within Oregon, habitat changes that reduced forb and residual grass cover adversely affected reproductive success of sage grouse (Barnett and Crawford 1994; Drut *et al.* 1994a, 1994b; Gregg *et al.* 1994).

Fire may benefit sage grouse brood habitat if the burn produces a mosaic of sagebrush cover interspersed with open areas with abundant forbs (Klebenow 1972). Pyle and Crawford (1996) found that spring and fall prescribed burns increased total forb cover and diversity and decreased sagebrush cover. They also found that burning in mountain big sagebrush (*Artemisia tridentata* var. *vaseyana*)-bitterbrush (*Purshia tridentata*) stands enhanced some of the key foods of sage grouse chicks. Use of prescribed fire to improve sage grouse habitat conditions was recommended by Klebenow (1972) and Autenrieth *et al.*(1982).

Because sage grouse need a variety of habitat components to fulfill their life history needs, it is imperative to understand the short and long-term effects of fire on their habitat. Fire typically reduces sagebrush cover substantially while increasing early seral herbaceous cover. Research in Washington and Oregon since 1987 revealed that medium height sagebrush (40-80 cm), residual herbaceous cover >20 cm (typically native bunchgrasses), and many mid-to late seral forbs collectively contribute to sage grouse reproductive success (Gregg 1993, Sveum 1998, Coggins 1999). The rates at which these components are re-established after fire represent essential knowledge for the proper management of habitat for sage grouse and a host of other sagebrush dependent species.

Previous researchers observed sage grouse broods foraging up to 100m into recently burned areas (William Pyle personal communication). Use of burned areas by broods and known habitat associations with forb availability, lead to the question of what happens to key sage grouse foods after burning. The hypotheses I tested included 1) Burning affects primary sage grouse food abundance, 2) Burning affects the duration forbs remain green and available as forage, 3) Burning affects food nutrition and 4) Over the long term, burning affects critical habitat components needed for prelaying, brood-rearing, and nesting.

The goal of this study was to better understand the influence of prescribed fire on sage grouse habitat. The objectives of this study were 1) to determine the short-term response of key sage grouse habitat components (grasses, forbs, sagebrush, and insects) to prescribed burning in mountain big sagebrush stands and 2) to determine the long-term effects of fires on some key sage grouse habitat components (grasses, forbs, and sagebrush) in mountain big sagebrush stands.

STUDY AREAS

SOUTH STEENS MOUNTAIN

The South Steens Mountain (Steen Mountain south loop road south to Skull Creek) was chosen as the study area for the short-term intensive study and for 1 of the long-term study sites because it provided critical breeding, nesting, brood-rearing and wintering habitat for sage grouse. Thirteen leks have been identified on the South Steens Mountain, 8 on public land and 5 on private land. The allotment is located approximately 100 km south of Burns in Harney County, Oregon and it comprises nearly 52,000 ha. (Figure 1). Elevation ranges from 1700 m at the western portion of the study area to 2300 m in the east. Several creeks, lakes, and waterholes provide surface water on the area. Maximum daily temperature averaged 15.0 C, minimum daily temperature averaged 0.2 C; 30 year annual mean precipitation was approximately 31 cm (NOAA). Annual precipitation for 1997 and 1998 was 29 cm and 44 cm respectively.

Most of this area is public land administered by the Bureau of Land Management, but it also includes private lands, owned primarily by the Roaring Springs Ranch. The approved livestock grazing capacity for the South Steens Mountain allotment was placed at 41,150 AUMs, which is greater than the current permitted use of 35,328 AUMs (21,197 public and 14,131 private) (Bureau of Land Management 1995). The current grazing permit allows for approximately 4,000 cows with calves from 1 April through 31 October and 1,885 cattle from 15 November to 15 March (Bureau of Land Management 1995).

As part of a plan to reintroduce fire as a natural process in the sagebrush ecosystem, a site of approximately 24,000 ha has been scheduled for prescribed burning on a rotational basis during the next 10 to 15 years. One unit was burned in October 1996 and three units were burned during 1997.

For the purposes of this study, cover types were defined on the basis of dominant shrub or woody cover, dominant herbaceous cover, and elevation. Mountain big sagebrush, Wyoming big sagebrush (*A. t.* var. *wyomingensis*), low sagebrush (*A. arbuscula*), western juniper (*Juniperus occidentalis*), and quaking aspen (*Populus tremuloides*) constitute the major upland habitats of the area (Table 1).

HART MOUNTAIN NATIONAL ANTELOPE REFUGE

Hart Mountain National Antelope Refuge (HMNAR) was chosen as the other site for a retrospective study of the long-term response to burning because of its documented fire history. The 102,000 ha refuge is administered by the U.S. Fish and Wildlife Service and is located in Lake County Oregon (Figure 2). Annual temperatures range from –22.0 to 36.0 C and annual mean growing season precipitation is 31 cm (Gregg 1992). The refuge historically was used for grazing livestock, however that use was removed in December 1990. Major cover types include mountain big, Wyoming big, and Basin big (*A. t.* var. *tridentata*) sagebrush, low sagebrush, mountain shrub, which consists of mountain big sagebrush and bitterbrush, western juniper, and quaking aspen (Table 1).

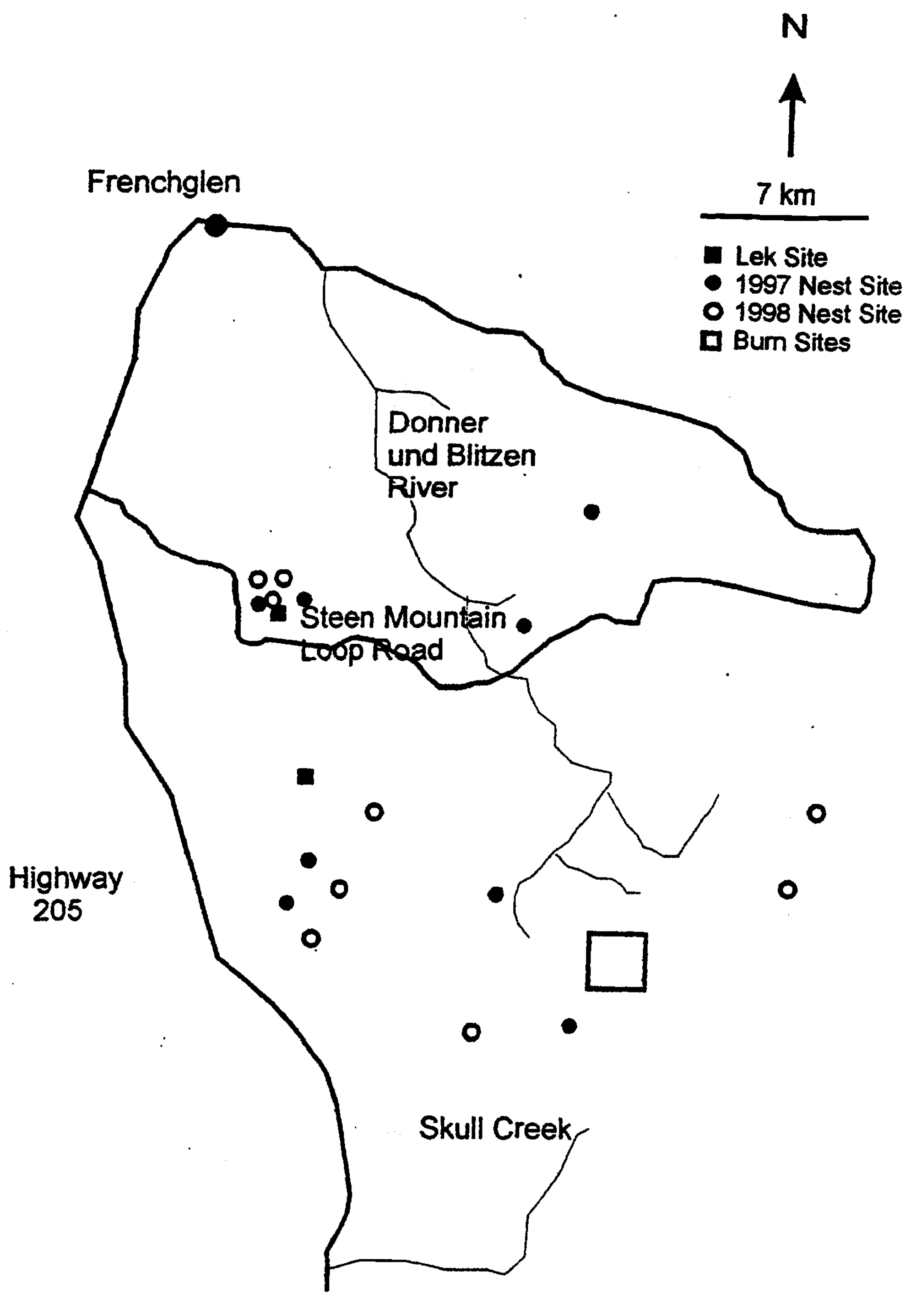

Figure 1. Location of sage grouse lek, 1997 nest, 1998 nest, and short term fire effects burn sites on South Steens Mountain, Oregon.

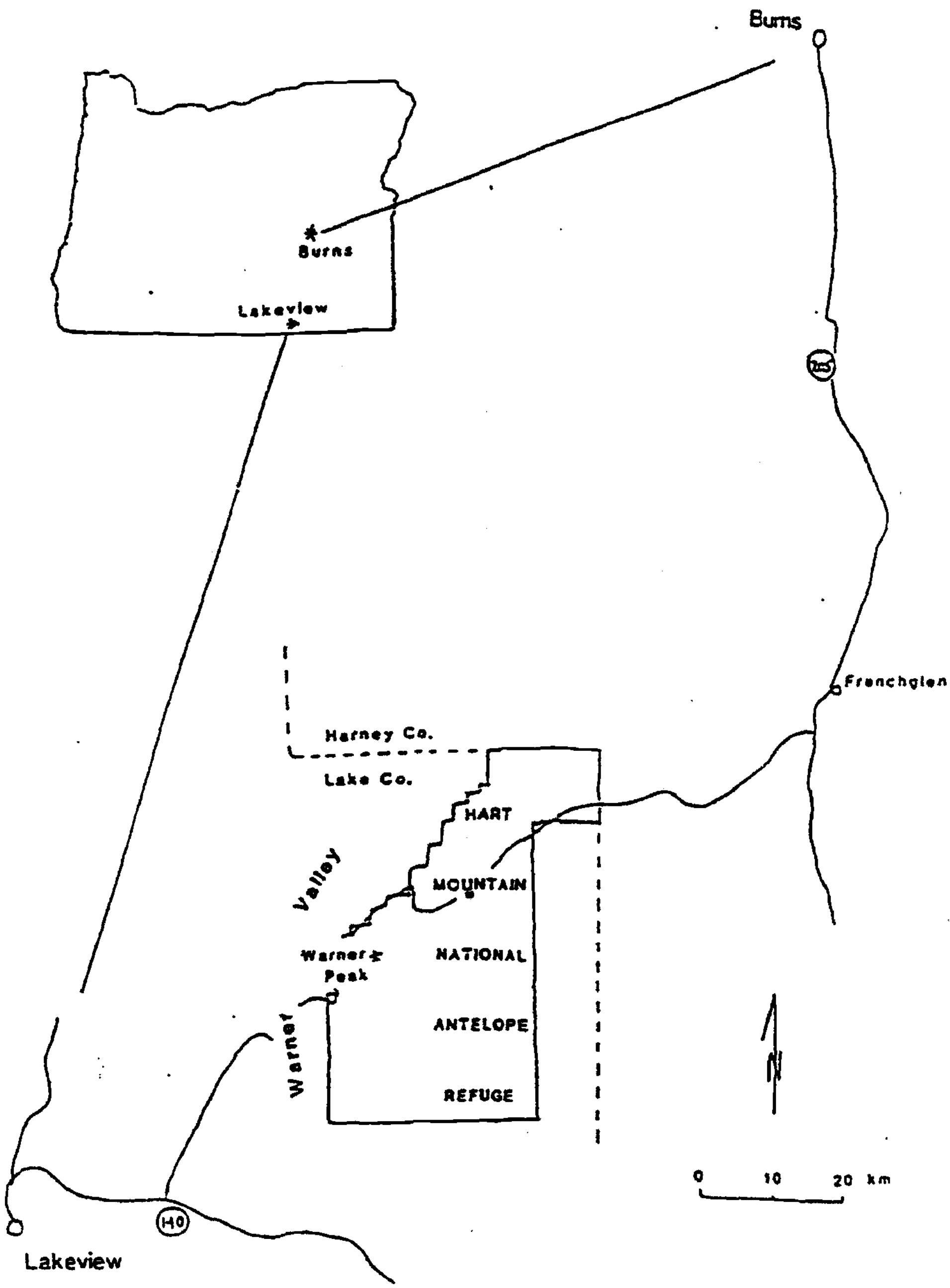

Figure 2. Location of Hart Mountain National Antelope Refuge Study Area, 1997.

Table 1. Description of cover types present at South Steens Allotment and HMNAR Study Sites and vicinity, Harney and Lake Counties, Oregon (adapted from Crawford *et al.* 1992).

Cover type	Cover type description
Wyoming big sagebrush	Occurs on rolling uplands and lake basin terraces with slopes <30%. Primary plant species include Wyoming big sagebrush (*A.tridentata* var. *wyomingensis*) and bottlebrush squirreltail (*Elymus elymoides*). Also may be associated with spiny hopsage (*Atriplex spinosa*).
Low sagebrush	Found on alluvial fans and tablelands with <30% slope, and on exposed ridges and side slopes at higher elevations (>2000 m).. Principal plant species are low sagebrush (*Artemisia arbuscula*), bluebunch wheatgrass (*Pseudoroegneria spicata*), bluegrass (*Poa* spp.) and Idaho fescue (*Festuca idahoensis*).
Mountain big sagebrush	Occurs at higher elevations (1800 to 2300m) on ridges and mountain shoulders. Primary plant species are mountain big sagebrush (*A. t.* var. *vaseyana*) and Idaho fescue (*F. idahoensis*) or rough fescue (*F. scabrella*).
Juniper/Aspen	Associated with low ridges or footslopes. Primary plant species are western juniper (*Juniper occidentalis*), and/or aspen (*Populus tremuloides*) interspersed with big sagebrush.
Mixed sagebrush	Characteristic of scabrock areas (15 to 75% rock fragments) associated with ridge tops, sloping tablelands, and alluvial plains. Primary plant species are low sagebrush, big sagebrush (*A. t.* spp.), and Sandberg's bluegrass (*P. sandbergii*).

Table 1. (continued)

Cover type	Cover type description
Mountain Shrub	Common at elevations between 1800 and 2300 m. Primary plant species are mountain big sagebrush, bitterbrush (*Purshia tridentata*), bluegrass, and needle grass (*Stipa* spp.).
Basin big sagebrush	Occurs on low terraces associated with drainages and lake basins. Primary plant species are basin big sagebrush (*A. t.* var. *tridentata*) and basin wild rye (*Leymus cinereus*).
Grassland	Natural grasslands or areas disturbed by fire. Primary plant species are cheat grass (*Bromus tectorum*), bluegrass, and bottle brush squirreltail.
Meadow	Associated with stream valleys that have poorly drained soils and subsurface water in summer. Primary plant species are bluegrass, sedge (*Carex* spp.), and baltic rush (*Juncus balticus*).
Playa	Found on depressions covered with water in spring. Primary plant species are silver sage (*A. cana*) and bluegrass.

METHODS

The short-term effects of fire on essential sage grouse habitat components were studied during the field seasons (March-August) of 1997 and 1998 at Steens Mountain, OR. Habitat components studied to compare preburn vs. 1-year post burn effects included: 1) medium shrub cover; 2) perennial grass cover; 3) cover, frequency, and availability of key forbs in sage grouse hen and chick diets; 4) other forb cover and frequency; and 5) insect abundance. One-year post burn to 2-years post burn effects were also studied for the habitat components mentioned above. Nutritional content of key chick forbs was studied in 1998 with comparisons between unburned, 1-year post burn, and 2-year post burn treatments. Sagebrush reproductive branch abundance was studied in 1998 to compare the interior of an unburned site and its edge adjacent to a 1-year post burn site. The long-term effects of fire on major sage grouse habitat components were studied during 1997 at Hart Mountain NAR, OR and during 1998 at Steens Mountain, OR. Habitat components studied for the long-term effects included medium height mountain big sagebrush, perennial grass, key hen and chick forb, and other forb cover.

SHORT-TERM FIRE EFFECTS

Site Selection

Four sites were chosen, 3 in 1997, 1 in 1998, in or adjacent to the area that had been burned in 1996 (within 1996 Ankle Creek Prescribed Burn Unit), in mountain big sagebrush cover type. Of these sites, the1997-1 burn site (within

1997 Home Creek Prescribed Burn Unit) burned as planned in the fall of 1997. Another, the 1997-2 burn site was planned to remain unburned and used as a control site; however, it burned in the fall of 1997. The 1998 control site was selected after the original control burned and consisted of a portion of 1997 control site that did not burn and unburned area adjacent to 1997-1 burn site. Soils were similar in all sites and had been grazed historically and in the recent past, however burn sites were not grazed during the years 1997 and 1998, and the 1998 control site was not grazed in 1998. Vegetation homogeneity and size and shape of area within the selected cover type also were factors in site selection. The location of the sites is T35S, R32.75E, S16 and 21.

For preburn vs. 1-year post burn comparisons two sites were used, the1997-1 burn site and the1997-2 burn site. For 1-year vs. 2-years post burn comparisons the 1996 burn site was used.

Preburn vs. 1-Year Post Burn Effects

Prescribed Burning

The 1997 Home Creek Prescribed Burn Unit was 1352 ha. Percentage of area burned was determined from aerial photographs of the 1996 and 1997 prescribed burn sites. The 1997 prescribed fire was initiated with drip-torches. This site was burned on 22 September 1997 between 1500 and 1600 hrs. Areas were considered "treated" if at least 30% of the total area burned. Prescribed fires are highly variable, therefore, the following factors were measured for the 1997-1 burn (Young and Miller 1985, Sapsis and Kauffman 1991, Pyle 1992):

a. weather conditions (ambient temperature, humidity, and wind speed),
b. fire behavior (rate of spread, flame length, flame depth, residence time), and
c. fuel moisture content (10 hr. fuel moisture sticks).

Samples were clipped before and after burning and separated into shrubs (overstory biomass), and grasses and forbs (combined into understory biomass) (Pyle 1992) and dried at 50-60 °C until samples reached constant weight. Fuel consumption was estimated with total fuel biomass (combined understory and overstory biomass) from which postfire biomass (calculated in the same manner) was subtracted to yield total consumed biomass, which was then divided by total fuel biomass to yield percent biomass consumed.

The 1997 control site (1997-2) was burned unintentionally on 23 and 24 September 1997; consequently, a new control site was located for 1998 vegetation sampling.

Experimental Design

In the 1997-1 and 1997-2 burn sites, vegetation cover and frequency (1 sample/15 subsamples at each site/season/year), and forb availability (1 sample/15 subsamples/site/season/year) were collected in early and late growing season sampling periods of 1997 and 1998. Insect abundance (1 sample/50 subsamples/site/year) data were collected at these sites in the early growing season period of 1997 and 1998. These data were used to determine preburn vs. 1 year post burn effects. Data were collected for the early growing season from 11 June to 18 July; late growing season data were collected 16 July to 4 August.

Cover and Frequency of Occurrence of Key Sage Grouse Habitat Components

Aerial cover and frequency in the 1997-1 burn, 1997-2 burn (in 1997 and 1998) were sampled twice each growing season, early and late. The early sample was conducted mid June-early July (early brood-rearing, which corresponds to peak forb abundance). The late sample was conducted late July-early August (late brood-rearing).

Fifteen randomly placed 20-m permanent transects were sampled twice (early and late growing season) in each site. Aerial cover and frequency of forbs and grasses, and shrub cover were measured. Shrubs were identified to species or subspecies and grasses and forbs were identified to genus or species. Canopy cover of shrubs was measured by the line-intercept method (Canfield 1941). Height of each intercepted shrub was measured to the top of the canopy and placed in 1 of 3 height classes: short (<40 cm), medium (40-80 cm), and tall (>80 cm) (see Gregg et al. 1994 and Delong et al. 1995). Shrub canopy cover was measured separately for each height class. Grass and forb cover and frequency of occurrence were estimated in 10, 20-x 50-cm rectangular plots, spaced equidistantly on each transect (Daubenmire 1959).

Forb cover was analyzed by functional group: hen/chick foods, and other forbs. These variables were the culmination of the aerial cover for each genius that made up the functional group. Hen/chick forbs included the genera: *Antennaria, Astragalus, Agoseris, Crepis, Erigeron, Eriogonum, Lomatium, Microseris, Phlox, Taraxacum*, and *Trifolium*, all composed $\geq$ 1% of the relative dry weight of prelaying hen and/or chick diets in this area of southeastern Oregon (Barnett and Crawford 1994, Drut et al. 1994b). Other forbs included all other genera.

Type II statistical errors were a concern because of small sample sizes; therefore, an alpha level of 0.1 was chosen a priori. Cover and frequency of occurrence of perennial grass, hen/chick forbs, and other forbs were tested with 2-way ANOVA procedures to determine if the differences between preburned and 1-year post burn samples were significant ($\alpha = 0.10$) (Zar 1984, Ramsey and Schaffer 1997). Normality was assessed at the subsample level. Residual plots for the cover data showed a horn shape; an arcsine squareroot transformation was used to improve normality (Snedecor and Cochran 1980, Ramsey and Schaffer 1997). After the transformation, residual plots appeared normal. Cover measurements were analyzed on the arcsine squareroot scale. Residual plots for the frequency data appeared normal. Common transformations (logarithm, square root, and reciprocal) were evaluated, but did not improve skewness or kurtosis. Frequency was analyzed on the original scale.

Climatic differences between years may have been a confounding variable. Precipitation was higher in 1998. In general, the forb component in mountain big sagebrush systems has more variation between years than the grass and shrub components; and may be affected by precipitation. To assess this effect, forb cover of the 2 transects that remained unburned in the 1997 control site were compared between the 2 years of this study. For these transects, mean ($\pm$90% confidence intervals) hen/chick forb cover and mean other forb cover were calculated for 1997 and 1998 and were compared. Cover measurements were analyzed on the arcsine squareroot scale.

Forb Availability

Since sage grouse broods eat green, succulent forbs it was necessary to quantify how much forb cover was green (not senescent) and available as forage. Forb availability was defined for each genus as green forb cover /total forb cover. Fifteen randomly placed transects were sampled twice (early and late growing season) in each site with 10, 20-x 50-cm rectangular plots, spaced equidistantly on each transect. Forb availability was recorded at the same time as forb cover. Forbs were characterized as green if $\geq$ 50 percent of the plants in each plot were green. Availability data were tested with 2-way ANOVA procedures to determine if differences between preburn and 1-year post burn samples were significant (α = 0.10) (Zar 1984, Ramsey and Schaffer 1997). Data were analyzed without transformation because residual plots appeared normal and standard transformations did not improve skewness and kurtosis.

Insect Response

Because insects are a major portion of the diet of chicks < 3 weeks old, insect abundance was sampled with pitfall traps, in the early growing season, in the 1997-1 burn, and 1997-2 burn site (Morrill 1975). One 200-m transect was randomly placed in each of the burn sites. Fifty, 227-ml pitfall traps were spaced equidistantly along each transect (every 4 m). Traps were filled with a saline or ethylene glycol solutions and buried flush with ground (Fischer 1994). The traps were collected after 7 days. Key insects in sage grouse diets, i.e. Coleoptera, Orthoptera, and Formicidae (Perterson 1970, Drut et al.1994b) were collected and identified.

Normality was assessed at the subsample level (normality could not be assessed at the experimental unit level, n=2); the residual plots showed a horn shape for Coleoptera, Orthoptera, and Formicidae, and the box plots were skewed. Insect variables were transformed to the log scale to reduce skewness and kurtosis. A 2-way ANOVA was used to statistically test for differences in abundance between preburn and 1-year post burn samples ($\alpha = 0.10$) (Zar 1984, Ramsey and Schaffer 1997).

1-Year Post Burn vs. 2-Years Post Burn Effects

Prescribed Burning

The size of the 1996 Ankle Creek Prescribed Burn Unit was 619 ha. Percentage of area burned was determined from aerial photographs. The 1996 prescribed burn was initiated on 10 October 1996 with drip-torches and a Ping-Pong machine. Fire behavior measurements were not taken during the 1996 burn; because it occurred before the start of this study.

Experimental Design

Vegetation cover and frequency (15 subsamples/season/year), forb availability (15 subsamples/season/year) were collected early and late growing season of 1997 and 1998. Insect abundance (50 subsamples/year) was collected in the early growing season of 1997 and 1998. These 1996 burn site data were used for the 1-year post burn vs. 2-years post-burn effects. Data were collected for the early growing season from 11 June to 18 July; late growing season data were collected 16 July to 4 August.

Cover and Frequency of Occurrence of Key Sage Grouse Habitat Components

Methods for collecting cover and frequency of occurrence data for the 1-year post burn vs. 2-years post burn comparison are the same as those mentioned for the preburn vs. 1-year post burn comparison. Aerial cover and frequency in the 1996 burn site was sampled twice each season: mid June-early July (early brood-rearing, which corresponded to peak forb abundance), and late July-early August (late brood-rearing).

Cover and frequency of occurrence of perennial grass, hen/chick forbs, and other forbs were tested with 2-way ANOVA procedures to determine if the differences between 1-year post burn and 2-years post burn samples were significant ($\alpha = 0.10$) (Zar 1984, Ramsey and Schaffer 1997). Normality was assessed at the subsample level. Residual plots for the cover data showed a horn shape; an arcsine squareroot transformation was used to improve normality (Snedecor and Cochran 1980, Ramsey and Schaffer 1997). After the transformation residual plots appeared normal. Cover measurements were analyzed on the arcsine squareroot scale. Residual plots for the frequency data appeared normal. Common transformations (logarithm, square root, and reciprocal) were evaluated, but did not improve skewness or kurtosis. Frequency was analyzed on the original scale.

Forb Availability

Methods for collecting forb availability data for the 1-year post burn vs. 2-years post burn comparison are the same as those mentioned for the preburn vs. 1-year post burn comparison. Forb availability was recorded at the same time as forb cover. Availability data were tested with 2-way ANOVA procedures to determine if the differences between 1-year post burn and 2-years post burn samples were significant ($\alpha = 0.10$) (Zar 1984, Ramsey and Schaffer 1997). Data were analyzed without transformation because residual plots appeared normal and standard transformations did not improve skewness and kurtosis.

Insect Response

Methods for collecting insect response data for the 1-year post burn vs. 2-years post burn comparison are the same as those mentioned for the preburn vs. 1-year post burn comparison.

Data were analyzed on the subsample level (n=50) due to the lack of a replicate site. Normality was assessed at the subsample level. The residual plots showed a horn shape for Coleoptera, Orthoptera, and Formicidae, and the box plots were skewed. Insect variables were transformed to the log scale to reduce skewness and kurtosis. A 2-way ANOVA was used to statistically test for differences in abundance between 1-year post burn vs. 2-years post burn samples ($\alpha = 0.10$) (Zar 1984, Ramsey and Schaffer 1997).

Nutritional Analysis of Key Forbs

Plant collection for nutritional analysis was conducted in July and August 1998. Several chick foods (*Agoseris glauca, Microsteris gracilis*, and *Crepis acuminata*) were collected in unburned (1998 control), 1-year post burn (1997-1 and 1997-2 burn), and 2-year post burn (1996 burn) sites during the flowering stage. *Agoseris glauca* was not collected in the 2-year post burn site because of low abundance of flowering specimens during the collection time. The samples were dried at 50-60 $^{\circ}$C until samples reached constant weight. Samples were ground in a Wiley mill with a 1 mm screen. Energy content was determined with a bomb calorimeter. Crude protein was determined from analysis of ammonium nitrogen with the Kjeldahl method. To determine calcium and phosphorus levels, samples were first ashed and then dissolved in ethanol. Calcium levels were determined with an atomic absorption spectrophotometer; phosphorus levels were determined with a UV-visible spectrophotometer. For calcium and phosphorus content, samples were blind tested (sample identity unknown to recorder at time of the test).

Differences between duplicate samples within the aggregate samples were used for variance for statistical analysis. Two-way ANOVA, with Fisher's Protected LSD Multiple Comparison Test, were used to test for differences of nutritional content between samples collected in burned and control sites ($\alpha = 0.10$) (Ramsey and Schaffer 1997). Data were analyzed without transformation because residual plots appeared normal and standard transformations did not improve skewness and kurtosis.

Reproductive Output of Edge Sagebrush

To assess one component of mountain big sagebrush re-establishment in burned areas, reproductive branches were counted on the interior of an unburned site and along its edge. Sampling was done in late July, 1998. Two 150-m transects were selected. The first transect was along (within 2 m) a 1-year post burn edge (1997-1 burn site). The second was placed parallel to the first and was located 50 m to the interior of the 1998 control site. The two transects were on similar slopes and soil types. Reproductive branches were counted in 30 randomly placed 20-x 20-cm plots placed in the sagebrush canopy along each transect. Data were converted to number of reproductive branches/m^2 of canopy (Miller *et al.*

1991). Data were transformed to the squareroot scale to diminish skewness and kurtosis. A Student's t-test was used to determine if the mean number of reproductive branches was significantly different ($\alpha = 0.10$) along a 1-year post burn edge compared with the interior (Ramsey and Schaffer 1997).

LONG-TERM FIRE EFFECTS

Site Selection

Fourteen sites were chosen (7 in burns and 7 in adjacent unburned control areas) in 1997, in the mountain big sagebrush cover type at Hart Mountain NAR. Ages of the 7 burns in 1997 were 5, 7, 12, 25, 35, 38, and 43 years after burning. Six sites were chosen (3 in burns and 3 in adjacent unburned control areas) in 1998, in the mountain big sagebrush cover type at South Steens Allotment. Ages of the 3 burns in 1998 were 11, 14, and 17 years after burning. Paired sites had visually similar soils, slopes, vegetation homogeneity, and historic landuse.

Cover of Key Sage Grouse Habitat Components

Vegetation was sampled along 20-m transects in the burned and control sites. In 1997, at Hart Mountain NAR, 10 randomly placed transects were sampled in each burn site and 2 randomly placed transects were sampled in adjacent control sites. In 1997, at South Steens Mountain, 8 randomly placed transects were sample in each burn site and 4 randomly placed transects were sampled in adjacent control sites. Cover and frequency of forbs and grasses, and shrub cover were measured. Shrubs were identified to species or subspecies and grasses and forbs were identified to genus or species. Canopy cover of shrubs was measured by the line-intercept method (Canfield 1941). Height of each intercepted shrub was measured to the top of the canopy and placed in 1 of 3 height classes: short (<40 cm), medium (40-80 cm), and tall (>80 cm). Shrub canopy cover was measured separately for each height class. Grass and forb cover were estimated in 10, 20-x 50-cm rectangular plots, spaced equidistantly on each transect (Daubenmire, 1959). Grasses were measured from the ground to the maximum droop height (excluding flower stalks) and classified as short (<20 cm) or tall (>20 cm).

For the long-term data, medium height mountain big sagebrush, tall grass, hen/chick forb, and other forb cover were transformed to the arcsine square root scale to diminish skewness and kurtosis. Mean cover measurements ($\pm$90% confidence intervals) were calculated for each burn and control site. These mean values were compared to the recommended cover levels for sage grouse reproductive habitat in mountain big sagebrush. Based on previous studies in southeastern Oregon, amounts recommended of critical components in mountain big sagebrush areas are: 1) 15-20% mountain big sagebrush cover; 2) 10% tall ($\geq$20cm) residual grass cover in the spring, 20% at the 1m diameter nest site; 3) 15-30% spring and summer forb cover with $\geq$ 5% key sage grouse food forbs and the insects associated with them (Coggins 1999, Drut *et al.* 1994a, Gregg 1993).

RESULTS

SHORT-TERM FIRE EFFECTS

Preburn vs. 1-Year Post Burn Effects

Prescribed Burning

The 1997 Home Creek Prescribed Burn Unit included 1352 ha; 60% was burned, which represented a management-sized treatment area. Ambient temperature was 27° C, relative humidity ranged from 16-17%, and wind speed ranged from 4.8-6.5 km/h from the N. The fuel moisture content was estimated to be 6.0% heavy fuels (10 hr. fuel moisture stick) and 3.8% for fine fuels (1 hr. fuel moisture stick). Flame heights ranged from 1-8 m. averaging 4 m. Flame depths ranged from 1.5-7.6 m. averaging 4.6 m. Flame angles ranged from 40-90° averaging 60°. Rate of spread ranged from 4.6 m/min to 91 m/min, averaging 45 m/min. Residence time was approximately 1 hr. This prescribed fire created its own weather conditions including several fire whorls in excess of 6 m in height. Fuel consumption was 79%.

For the 1997 control site burn, ambient temperature was 26° C, relative humidity ranged from 15-26%, and wind speed ranged from 11.3-30.6 km/h from the S. The fuel moisture content was estimated to be 8.5% heavy fuels (10 hr. fuel moisture stick) and 4.3% for fine fuels (1 hr. fuel moisture stick). Other fire measurements were not taken since efforts were aimed at fire suppression to save the control site. We were not successful in suppressing the fire. It became the 1997-2 burn site.

Cover of Key Sage Grouse Habitat Components

Sagebrush was virtually eliminated from the 1997 burn sites. There was no sagebrush of the height and cover needed for sage grouse nesting habitat 1-year post burn. Perennial grass cover did not differ for either the early or late growing season samples (Table 2) between preburn and 1-year post burn. Hen/chick forb cover was significantly greater, in both the early and late growing season periods, in the 1-year post burn sample than in the preburn sample ($p=0.04$, $n=2$ sites, and $p=0.08$, $n=2$ sites). Other forb cover did not differ for the early samples, but was significantly greater in the late sample in the 1-year post burn sample than in the preburn sample ($p=0.08$, $n=2$ sites).

Hen/chick forb cover and other forb cover did not differ between 1997 and 1998 for the remaining unburned control transects, suggesting that the higher precipitation in 1998 did not have a confounding effect (Figure 3).

Table 2. Median cover (%), SD, and P-values of key herbaceous sage grouse habitat components in preburn (1997) and 1-year post burn (1998) comparisons, during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, OR.

			Treatment				
			Preburn		1-year postburn		
Component[a]	Sampling Period	N	Median	SD	Median	SD	P-value
Perennial Grass	Early	2	21.3	0.8	7.8	0.2	0.11
	Late	2	11.7	0.3	8.2	0.2	0.36
Hen and Chick Forb	Early	2	6.0	<0.1	8.9	<0.1	0.04
	Late	2	2.6	<0.1	7.9	0.2	0.08
Other Forb	Early	2	29.6	0.1	24.1	0.1	0.14
	Late	2	14.0	0.1	33.2	1.0	0.08

[a]Analyzed on arcsine squareroot scale

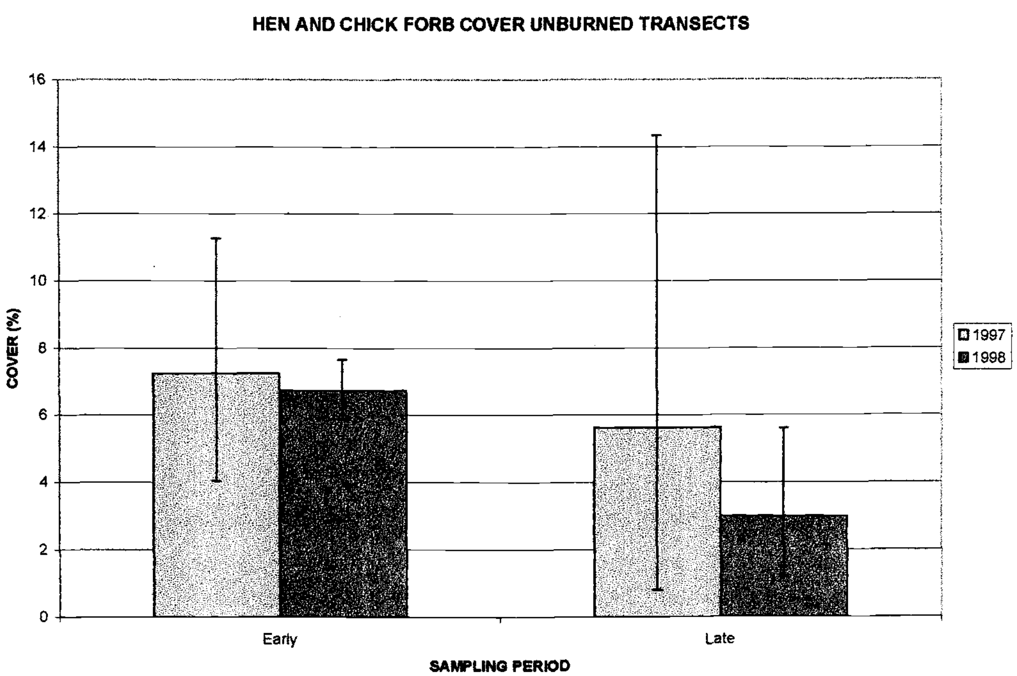

Figure 3. Median (90% CI) key sage grouse hen and chick forb cover in control transect sampling (1997 and 1998), during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, Oregon, (n=2 transects).

Frequency of Occurrence of Key Sage Grouse Habitat Components

Agoseris frequency was significantly greater, in both the early and late seasons, in the 1-year post burn sample than the preburn sample on the 1997 burn sites (p=0.03, n=2 sites, and p=0.06, n=2 sites) (Table 3). *Crepis* and *Microseris* frequencies did not differ in the early and late seasons, between the 1-year post burn sample and the preburn sample on the 1997 burn sites. These results may have been the effect of frame size. *Microsteris* frequency was significantly greater in the early sample (p=0.08, n=2 sites) but did not differ in the late sample in the comparison of the 1-year post burn sample and the preburn sample on the 1997 burn sites.

Table 3. Mean frequency of occurrence (%), SD, and P-values of key sage grouse chick and hen foods in preburn (1997) and 1-year post burn (1998) comparisons, during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, OR.

			Treatment				
			Preburn		1-year post burn		
Component	Sampling Period	N	Mean	SD	Mean	SD	P-value
Agoseris	Early	2	18.3	5.2	56.7	7.5	0.03
	Late	2	8.7	0.9	37.0	9.9	0.06
Crepis	Early	2	2.7	0.9	4.7	4.7	0.62
	Late	2	2.3	0.5	3.7	3.3	0.63
Microseris	Early	2	28.7	5.7	25.3	0.9	0.50
	Late	2	20.7	8.5	23.3	13.2	0.83
Microsteris	Early	2	2.7	0.9	22.7	8.5	0.08
	Late	2	5.7	3.3	17.0	8.0	0.21

Forb Availability

Agoseris availability (green cover/total cover) was greater in the late season in the 1-year post burn sample compared with the preburn sample ($p=0.07$, $n=2$ sites) (Table 4). *Lomatium* availability was significantly higher in the early sample of the 1-post burn when compared to preburn ($p=0.01$, $n=2$ sites).

No other significant differences were found with comparisons of preburn to 1-year post burn with the early and late samples of *Agoseris*, *Astragalus*, *Crepis*, *Erigeron*, *Lomatium*, *Microseris*, *Microsteris*, *Taraxacum*, and *Trifolium* availability. Not all of the tests could be performed for *Astragalus*, *Erigeron*, *Lomatium*, *Taraxacum*, and *Trifolium* availability because of their absence from one or more sites (Table 4).

Table 4. Mean availability (green cover/total cover), SD, and P-values of key sage grouse chick and hen foods in preburn (1997) and 1-year post burn (1998) comparisons, during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, OR.

			Treatment				
			Preburn		1-year postburn		
Component	Sampling Period	N	Mean	SD	Mean	SD	P-value
Agoseris	Early	2	0.88	0.17	1.00	0	0.41
	Late	2	0.22	0.23	0.80	0.05	0.07
Astragalus	Early	2	1.00	-	1.00	0	-
	Late	2	1.00	0	1.00	-	-
Crepis	Early	2	1.00	0	1.00	0	-
	Late	2	0.96	0.06	1.00	0	0.42
Erigeron	Early	2	1.00	0	-	-	-
	Late	2	0.98	0.04	1.00	0	0.42
Lomatium	Early	2	0.10	0.14	1.00	0	0.01
	Late	2	0	-	0.33	0.47	0.67
Microseris	Early	2	0.72	0.18	1.00	0	0.17
	Late	2	0.02	0.03	0.22	0.12	0.15
Microsteris	Early	2	1.00	0	1.00	0	-
	Late	2	0.05	0.07	0.06	0.04	0.88
Taraxacum	Early	2	-	-	-	-	-
	Late	2	1.00	-	-	-	-
Trifolium	Early	2	1.00	-	-	-	-
	Late	2	-	-	-	-	-

Insect Response

Coleoptera abundance in the 1-year post burn treatment was significantly lower than in the preburn treatment ($p<0.01$, n=2) (Table 5). Orthoptera abundance in the 1-year post burn treatment was not different than the preburn treatment

(Table 5). Abundance of Formicidae in the 1-year post burn treatment was not different than in the preburn treatment (Table 5).

Table 5. Median, SD, and P-values of insect abundance (number of individuals/transect) in three taxonomic groups in preburn (1997) and 1-year post burn (1998) comparisons, in a mountain big sagebrush community, South Steens Mountain, OR.

		Treatment				
		Preburn		1-year post burn		
Component[a]	N	Median	SD	Median	SD	P-value
Coleoptera	2	1099.0	117.4	264.5	19.1	<0.01
Orthoptera	2	257.5	26.2	223.0	9.9	0.21
Formicidae	2	6112	4061.6	7467.5	7934.4	0.94

[a]Analyzed on log scale

1-Year Post Burn vs. 2-Years Post Burn Effects

Prescribed Burning

The size of the 1996 Ankle Creek Prescribed Burn Unit was 619 ha; 60% was burned, which represents a management-sized treatment area. Ambient temperature ranged from 23-24° C, relative humidity ranged from 25-26%, wind speed averaged 11.3 km/h from the SW, cloud cover was 50%. The heavy fuel moisture content was estimated at 12% (10 hr. fuel moisture stick).

Cover of Key Sage Grouse Habitat Components

Perennial grass cover was significantly greater in the 2-years post-burn early sample than in the 1-year post-burn early sample (p=0.01, n=15 transects) (Table 6). The 2-years post-burn late perennial grass cover sample also was significantly greater than the 1-year late sample ($p<0.01$, $n=15$) (Table 6). Hen/chick forb cover was significantly greater in both the early and late samples, in the 2-years post burn than the 1-year post burn within the 1996 burn site ($p<0.01$, $n=15$ transects, and $p<0.01$, $n=15$ transects respectively) (Table 6). Other forb cover was significantly greater in both the early and late samples, in the 2-years post burn than the 1-year post burn within the 1996 burn site ($p<0.01$, $n=15$ transects, and $p<0.01$, $n=15$ transects respectively) (Table 6).

Table 6. Median cover (%), SD, and P-values of key herbaceous sage grouse habitat components comparisons in 1-year post burn (1997) and 2-years post burn (1998) comparisons, during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, OR.

			Treatment				
			1-year post burn		2-years post burn		
Component[a]	Sampling Period	N	Median	SD	Median	SD	P-value
Perennial Grass	Early	15	5.5	0.6	10.9	1.5	0.01
	Late	15	3.3	0.6	9.9	0.9	<0.01
Hen and Chick Forb	Early	15	10.0	0.5	17.0	1.1	<0.01
	Late	15	4.8	0.6	16.3	2.7	<0.01
Other Forb	Early	15	21.8	1.2	48.7	1.0	<0.01
	Late	15	20.7	1.0	63.2	2.2	<0.01

[a]Analyzed on arcsine squareroot scale

Frequency of Occurrence of Key Sage Grouse Habitat Components

Agoseris frequency did not differ in the early and late samples, between the 2-years post burn and the 1-year post burn treatments (Table 7). *Crepis* frequency did not differ in the early and late samples, between the 2-years post burn and the

1-year post burn treatments (Table 7). *Microseris* frequency was significantly greater in the early samples ($p=0.02$, $n=15$ transects), but did not differ in the late samples, between the 2-years post burn and the 1-year post burn treatments (Table 7). *Microsteris* frequency was significantly greater, in the early and late samples, in the 2-year post burn than the 1-year post burn treatments ($p<0.01$, $n=15$ transects, and $p<0.01$, $n=15$ transects respectively) (Table 7).

Table 7. Mean frequency of occurrence (%), SD, and P-values of key sage grouse chick and hen foods in 1-year post burn (1997) and 2-years post burn (1998) comparisons, during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, OR.

			Treatment				
			1-year post burn		2-years post burn		
Component	Sampling Period	N	Mean	SD	Mean	SD	P-value
Agoseris	Early	15	60.0	19.3	59.3	18.3	0.92
	Late	15	38.7	26.7	35.3	24.2	0.72
Crepis	Early	15	4.0	5.1	2.7	5.9	0.51
	Late	15	1.3	3.5	0.7	2.6	0.56
Microseris	Early	15	18.7	14.1	34.7	19.6	0.02
	Late	15	28.0	18.6	19.3	16.2	0.18
Microsteris	Early	15	10.7	11.6	64.0	22.0	<0.01
	Late	15	6.7	9.8	73.3	23.2	<0.01

Forb Availability

Agoseris availability was significantly higher in the late sample in the 2-years post burn when compared to the 1-year post burn (p=0.06, n=15 transects) (Table 8).

No other significant differences were found with comparisons 1-year post-burn to 2-years post-burn with the early and late samples of *Agoseris*, *Astragalus*, *Crepis*, *Erigeron*, *Lomatium*, *Microseris*, *Microsteris*, *Taraxacum*, and *Trifolium* availibility. Not all of the tests could be performed for *Astragalus*, *Erigeron*, *Lomatium*, *Taraxacum*, and *Trifolium* availability because of their absence from one or more sites (Table 8).

Table 8. Mean availability (green cover/total cover), SD, and P-values of key sage grouse chick and hen foods in 1-year post burn (1997) and 2-years post burn (1998) comparisons, during early and late growing season periods, in a mountain big sagebrush community, South Steens Mountain, OR.

			Treatment				
			1-year post burn		2-years post burn		
Component	Sampling Period	N	Mean	SD	Mean	SD	P-value
Agoseris	Early	15	1.00	0	1.00	0	-
	Late	15	0.70	0.35	0.91	0.20	0.06
Astragalus	Early	15	1.00	-	1.00	0	-
	Late	15	-	-	-	.	-
Crepis	Early	15	1.00	0	1.00	0	-
	Late	15	1.00	0	1.00	-	-
Erigeron	Early	15	-	-	-	-	-
	Late	15	1.00	0	1.00	0	-
Lomatium	Early	15	1.00	0	1.00	0	-
	Late	15	-	-	0	0	-
Microseris	Early	15	1.00	0	1.00	0	-
	Late	15	0.13	0.26	0.05	0.18	0.43
Microsteris	Early	15	1.00	0	1.00	0	-
	Late	15	0	0	0	0	-
Taraxacum	Early	15	1.00	-	1.00	-	-
	Late	15	1.00	0	1.00	-	-
Trifolium	Early	15	-	-	-	-	-
	Late	15	-	-	-	-	-

Insect Response

Coleoptera abundance in the 2-years post burn treatment was significantly greater than the 1-year post burn treatment on the 1996 site ($p<0.01$, $n=50$) (Table 9). Orthoptera abundance in the 2-year post burn treatment was significantly greater than the 1-year post burn treatment on the 1996 site ($p<0.01$, $n=50$) (Table 9). Formicidae abundance in the 2-year post burn treatment was significantly lower than the 1-year post burn treatment on the 1996 site ($p<0.01$, $n=50$) (Table 9).

Table 9. Median, SD, and P-values of insect abundance (number of individuals/trap) in three taxonomic groups in 1-year post burn (1997) and 2-years post burn (1998) comparisons, in a mountain big sagebrush community, South Steens Mountain, OR.

		Treatment				
		1-year post burn		2-years post burn		
Component[a]	N	Median	SD	Median	SD	P-value
Coleoptera	50	14.1	7.9	26.7	19.0	<0.01
Orthoptera	50	7.5	5.5	24.4	10.4	<0.01
Formicidae	50	83.4	263.0	24.5	44.0	<0.01

[a]Analyzed on log scale

Nutritional Analysis of Key Forbs

Percentage of calcium in forbs was greater or not different in burned sites than the control site except for the flowers of *Crepis acuminata* (Table 10). Percentage of phosphorus was either higher or not different in the burn treatments than in the control except for *Agoseris glauca* (Table 11). Crude protein was greater in the burn samples than in the control except for the flowers of *Agoseris glauca* (Table 12). There were few differences in amounts of gross energy (Table 13). *Crepis acuminata* leaves were higher in gross energy in burn samples compared with control. *Agoseris glauca* flowers were lower in gross energy in the burn sample compared with the control, and gross energy of *Microsteris gracilis* was lower 1-year post-burn than the 2-years post-burn and control samples

Table 10. Mean and SD of calcium (%) in key sage grouse chick foods collected in prescribed burn treatment and control sites during the late brood-rearing period, South Steens Mountain, OR, 1998.

	Calcium (%)[a]					
	Control		1-year post burn		2-years post burn	
Plant Species and Parts	Mean	SD	Mean	SD	Mean	SD
Microseris nutans						
Flowers	0.69^{B}	0.01	1.13^{A}	0.13	0.86^{B}	0.09
Crepis acuminata						
Flowers	0.85^{C}	0.03	0.65^{A}	0.03	0.73^{B}	0.01
Leaves	2.09^{A}	0.09	2.24^{A}	0.06	2.07^{A}	0.11
Agoseris glauca						
Flowers	0.37^{B}	0.01	0.51^{A}	0.03		
Leaves	1.41^{B}	0.06	1.71^{A}	0.11		
Microsteris gracilis						
Whole plant	1.33^{B}	0.06	1.67^{A}	0.04	1.37^{B}	0.08

[a] different letter indicates significant difference at $\alpha = 0.1$

Table 11. Mean and SD of phosphorus (%) in key sage grouse chick foods collected in prescribed burn treatment and control sites during the late brood-rearing period, South Steens Mountain, OR, 1998.

	Phosphorus (%)[a]					
	Control		1-year post burn		2-years post burn	
Plant Species and Parts	Mean	SD	Mean	SD	Mean	SD
Microseris nutans						
Flowers	0.62^{A}	0.02	0.65^{A}	0.00	0.70^{B}	0.02
Crepis acuminata						
Flowers	0.40^{B}	0.00	0.46^{A}	0.01	0.46^{A}	0.01
Leaves	0.26^{A}	0.01	0.24^{A}	0.01	0.29^{B}	0.00
Agoseris glauca						
Flowers	0.56^{B}	0.01	0.48^{A}	0.01		
Leaves	0.37^{B}	0.01	0.30^{A}	0.00		
Microsteris gracilis						
Whole plant	0.67^{A}	0.01	0.61^{A}	0.04	0.64^{A}	0.01

[a] different letter indicates significant difference at $\alpha = 0.1$

Table 12. Mean and SD of crude protein (%) in key sage grouse chick foods collected in prescribed burn treatment and control sites during the late brood-rearing period, South Steens Mountain, OR, 1998.

	Crude Protein (%)[a]					
	Control		1-year post burn		2-years post burn	
Plant Species and Parts	Mean	SD	Mean	SD	Mean	SD
Microseris nutans						
Flowers	16.4^{C}	0.0	17.5^{A}	0.0	18.0^{B}	0.0
Crepis acuminata						
Flowers	11.3^{C}	0.0	11.8^{A}	0.1	12.5^{B}	0.1
Leaves	10.4^{C}	0.0	12.8^{A}	0.1	14.3^{B}	0.1
Agoseris glauca						
Flowers	14.9^{B}	0.2	13.9^{A}	0.1		
Leaves	11.5^{B}	0.0	14.6^{A}	0.1		
Microsteris gracilis						
Whole plant	15.8^{B}	0.3	18.3^{A}	0.0	15.7^{B}	0.0

[a] different letter indicates significant difference at $\alpha = 0.1$

Table 13. Mean and SD of gross energy (cal/g) of key sage grouse chick foods collected in prescribed burn treatment and control sites during the late brood-rearing period, South Steens Mountain, OR, 1998.

	Gross Energy (cal/g)[a]					
	Control		1-year post burn		2-years post burn	
Plant Species and Parts	Mean	SD	Mean	SD	Mean	SD
Microseris nutans						
Flowers	4475.4^{A}	148.7	4233.0^{A}	21.7	4337.0^{A}	37.9
Crepis acuminata						
Flowers	4155.4^{A}	32.9	4266.4^{A}	18.4	4145.7^{A}	127.3
Leaves	3847.7^{C}	7.2	3918.8^{A}	4.3	3896.2^{B}	0.2
Agoseris glauca						
Flowers	4266.0^{B}	23.8	4195.2^{A}	1.5		
Leaves	4062.3^{A}	168.4	4154.7^{A}	1.4		
Microsteris gracilis						
Whole plant	3922.2^{B}	6.9	3825.0^{A}	3.7	3917.0^{B}	10.0

[a] different letter indicates significant difference at $\alpha = 0.1$

Reproductive Output of Edge Sagebrush

The median number of reproductive branches of mountain big sagebrush was significantly greater along the edge (median=458.9, sd=30.5) of the 1-year post burn (1997-1 burn) site than in the interior (median=325.5, sd=52.9) of the adjacent 1998 control site (p=0.05).

LONG-TERM FIRE EFFECTS

Mountain big sagebrush was present in the height (40-80cm) and cover (15-20%) needed for sage grouse nesting habitat at burn ages 25 and older (Figure 4). Tall grass was present in the needed coverage level, 10% overall, in the 4 youngest (ages 5-12) and 3 oldest (ages 35, 38, and 43) burn sites (Figure 5). These two data sets combined show that sage grouse nesting and screening cover, was available on burns ages 35, 38, and 43. Hen/chick forb cover met the desired cover level (5%) all ages except 12 and 17 (Figure 8). Other forb cover met the desired cover (10-25%) for all ages (Figure 9). At this level of inquiry, all critical habitat components became available 25-35 years post treatment.

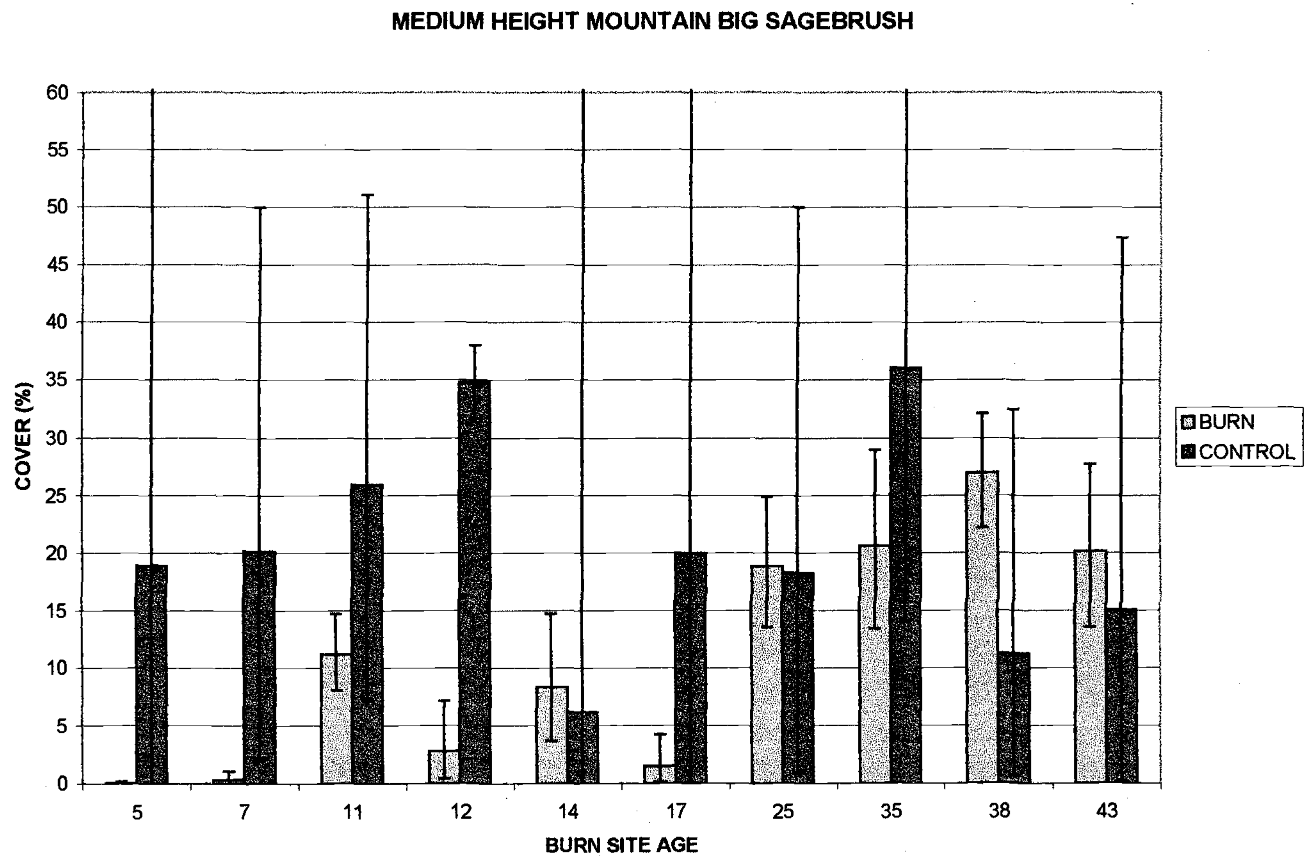

Figure 4. Median (90% CI) medium height sagebrush (40-80 cm) cover at burn sites ranging from 5 to 43 years in age and at adjacent control sites. Burns 11, 14, and 17 in age and adjacent control sites were measured at South Steens Mountain, 1998; all other sites were measured at Hart Mountain NAR, 1997. Recommended cover level for sage grouse mountain big sagebrush nesting habitat in Southeastern Oregon is 15-20%.

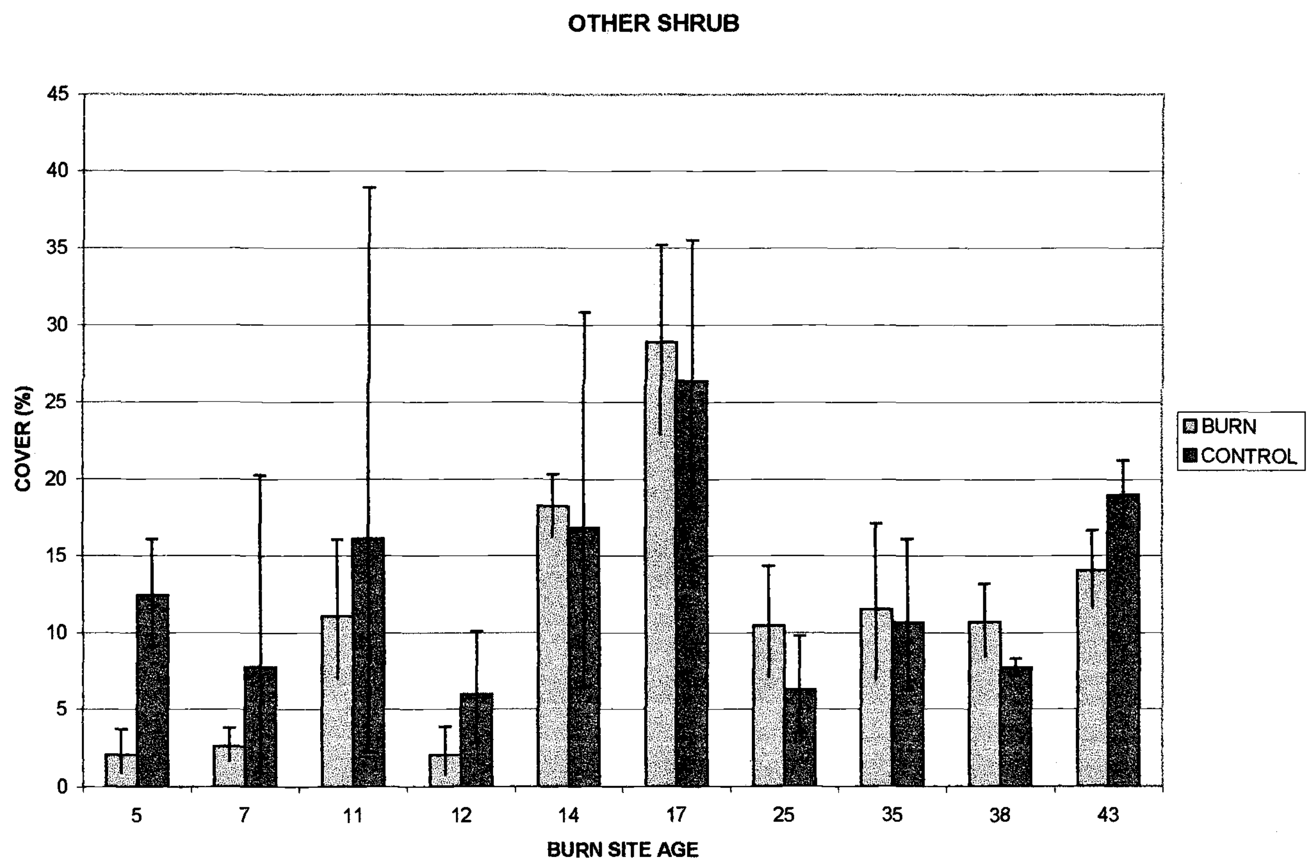

Figure 5. Median (90% CI) other shrub cover (not medium height sagebrush (40-80 cm)) cover at burn sites ranging from 5 to 43 years in age and at adjacent control sites. Burns 11, 14, and 17 in age and adjacent control sites were measured at South Steens Mountain, 1998; all other sites were measured at Hart Mountain NAR, 1997.

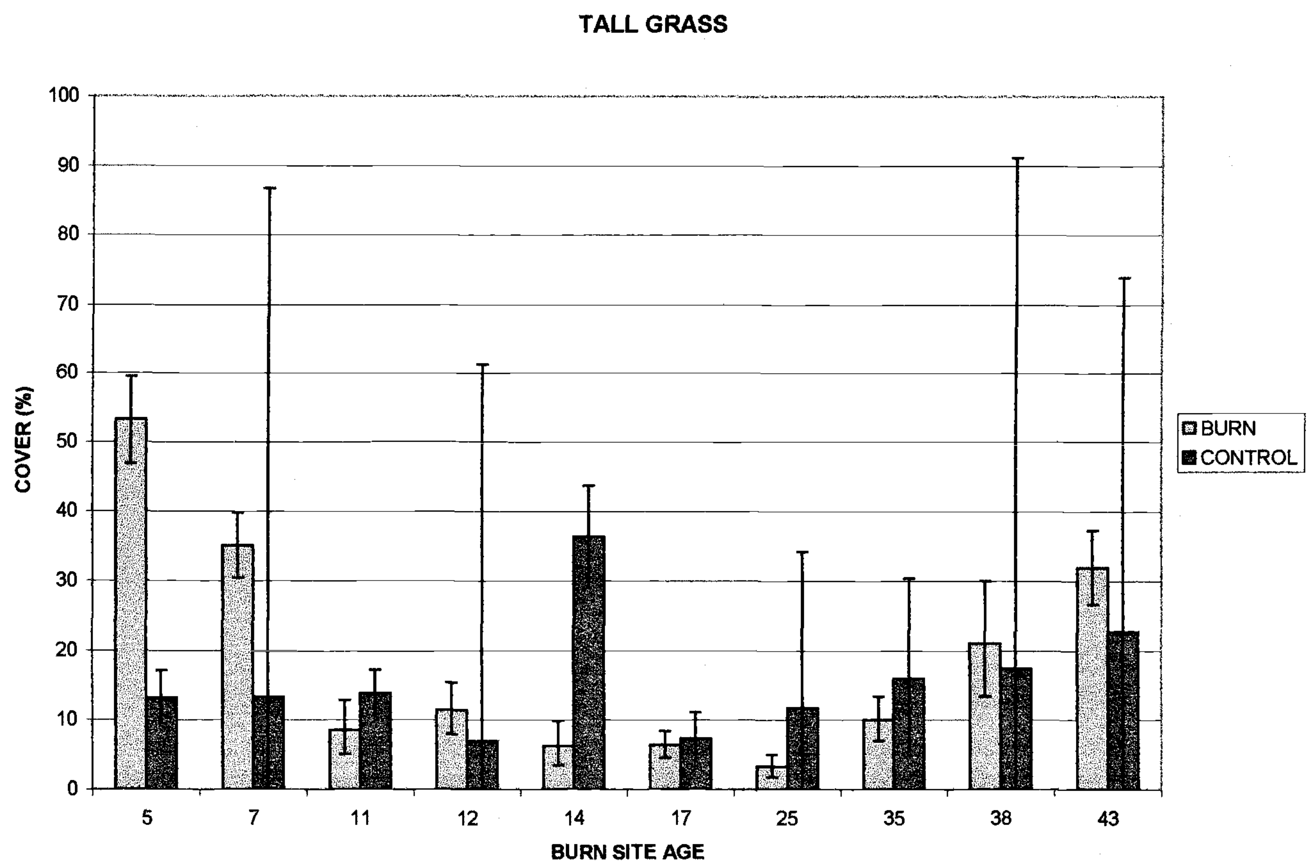

Figure 6. Median (90% CI) tall grass (≥20cm) cover at burn sites ranging from 5 to 43 years in age and at adjacent control sites. Burns 11, 14, and 17 in age and adjacent control sites were measured at South Steens Mountain, 1998; all other sites were measured at Hart Mountain NAR, 1997. Recommended tall grass cover level for sage grouse mountain big sagebrush nesting habitat in Southeastern Oregon is 10%.

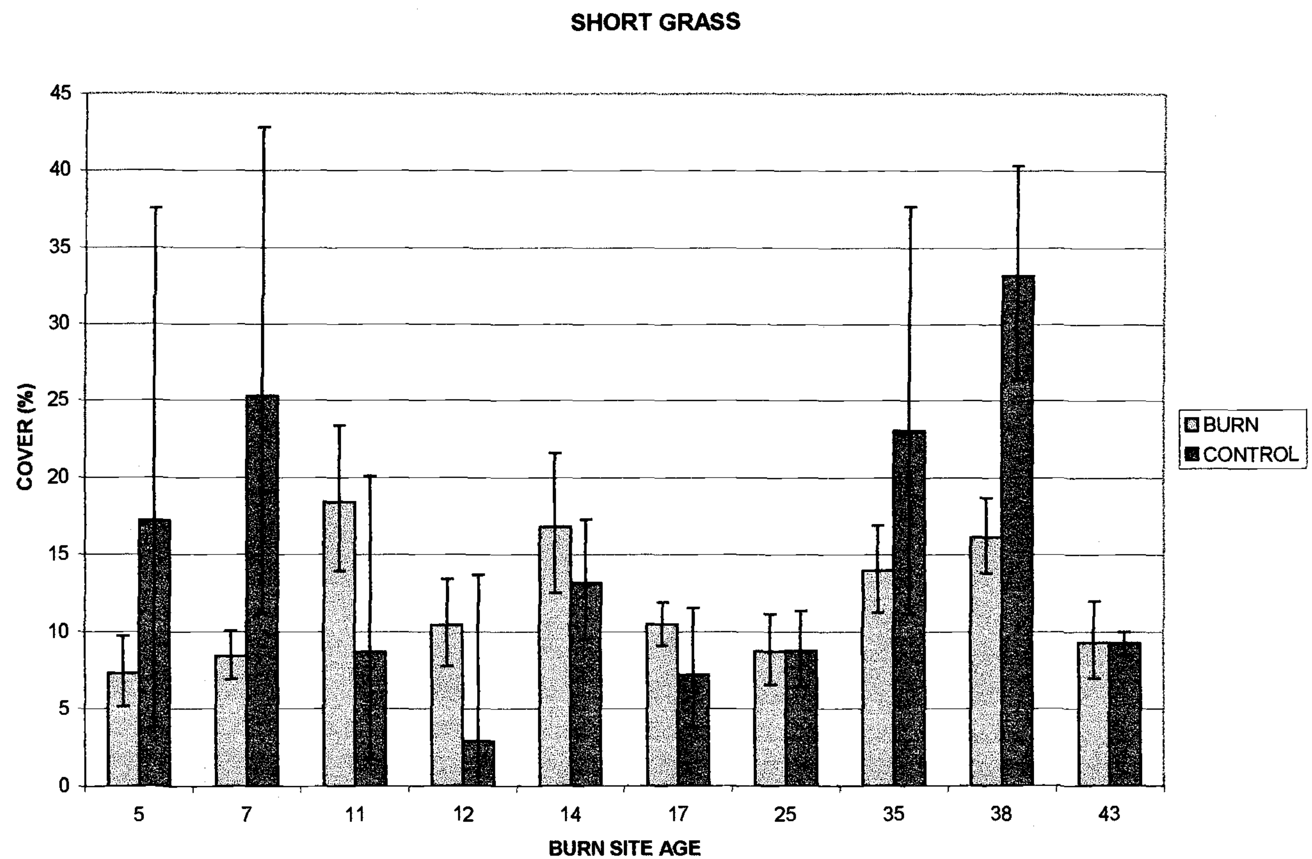

Figure 7. Median (90% CI) short grass (<20cm) cover at burn sites ranging from 5 to 43 years in age and at adjacent control sites. Burns 11, 14, and 17 in age and adjacent control sites were measured at South Steens Mountain, 1998; all other sites were measured at Hart Mountain NAR, 1997.

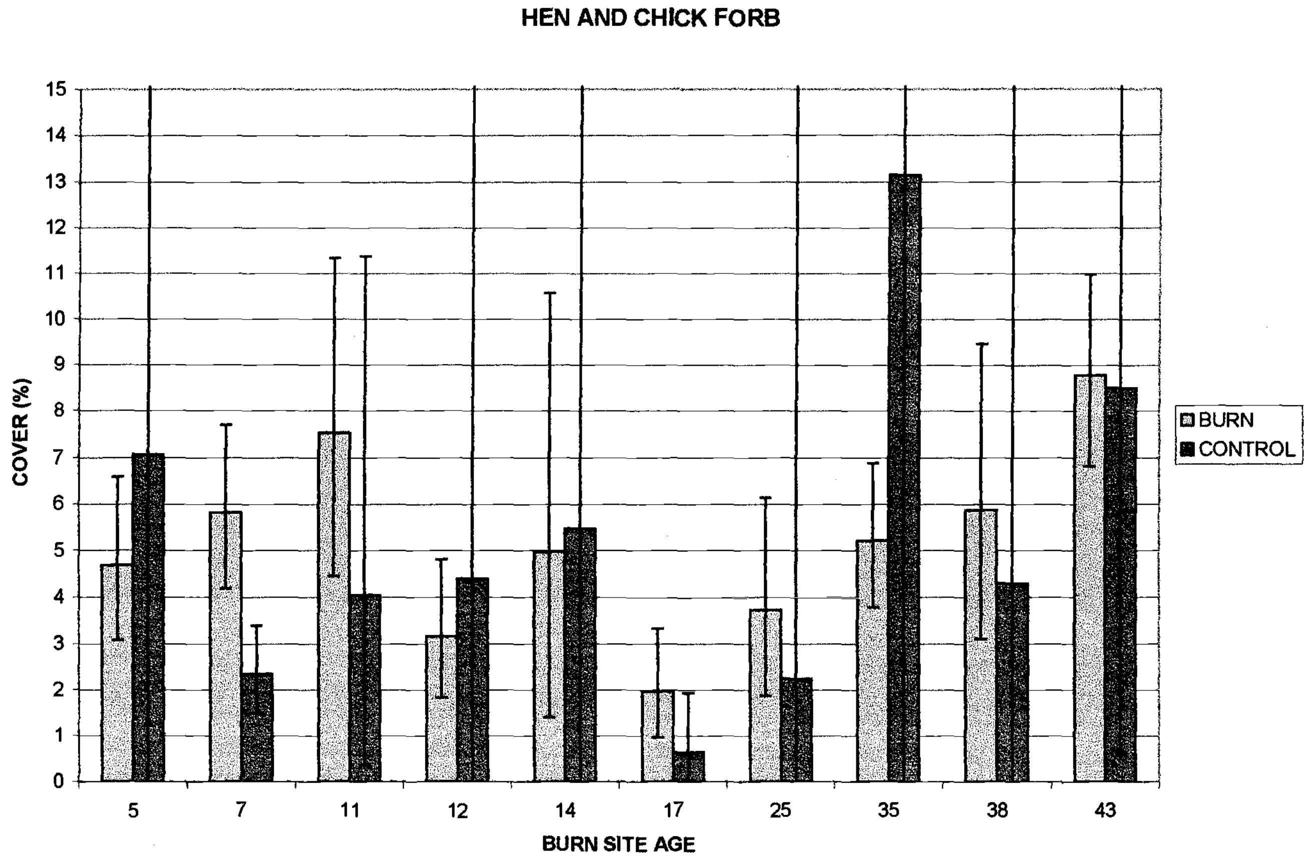

Figure 8. Median (90% CI) key sage grouse hen and chick forb cover at burn sites ranging from 5 to 43 years in age and at adjacent control sites. Burns 11, 14, and 17 in age and adjacent control sites were measured at South Steens Mountain, 1998; all other sites were measured at Hart Mountain NAR, 1997. Recommended key forb cover level for sage grouse mountain big sagebrush habitat in Southeastern Oregon is 5%.

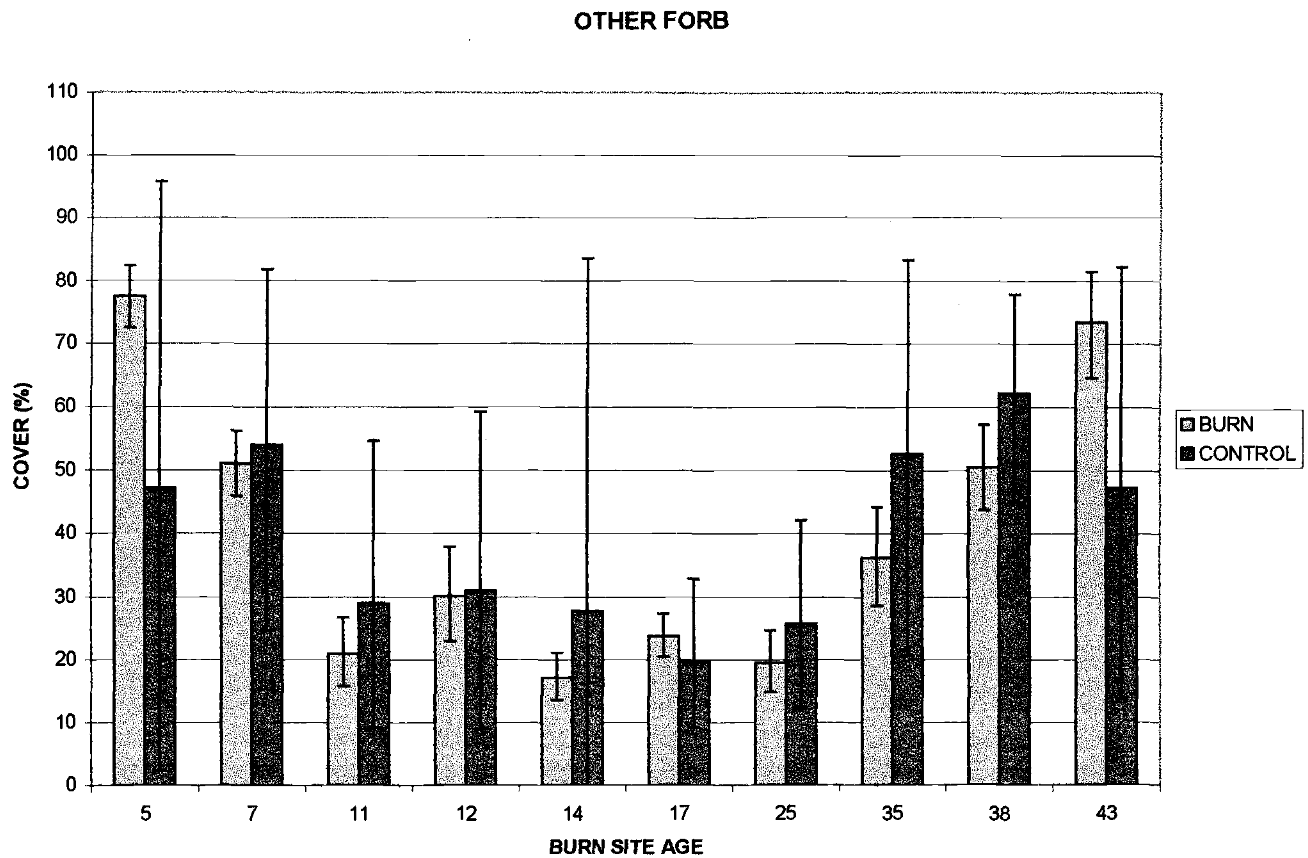

Figure 9. Median (90% CI) other forb (not key sage grouse hen and chick forb) cover at burn sites ranging from 5 to 43 years in age and at adjacent control sites. Burns 11, 14, and 17 in age and adjacent control sites were measured at South Steens Mountain, 1998; all other sites were measured at Hart Mountain NAR, 1997. Recommended other forb cover level for sage grouse mountain big sagebrush habitat in Southeastern Oregon is 10-25%.

DISCUSSION

In Oregon, the reproductive rate of sage grouse seemingly has not been sufficient to sustain populations. This study dealt with how one land management practice affects the quantity (cover and frequency of forbs, and abundance of insects) and quality (forb availability and nutrient content) of chick habitat, which influence chick survival. This study also delved into the question of the long-term effects of burning on key sage grouse habitat components (medium shrub, tall grass, and forb cover).

Burning did affect primary sage grouse food abundance. In the short-term fire effects portion of the study, prescribed burning was associated with higher cover of hen/ chick foods 1 year and 2 years after burning. Prescribed burning also was associated with higher frequency of hen/chick forbs, e.g. higher *Agoseris* frequency 1 year after burning, and higher *Microsteris* frequency 2 years after burning. Hen/chick forbs were more plentiful after burning on these sites, cover and frequency of occurrence were higher after burning. Differences in precipitation did not effect hen/chick and other forb cover on the 2 unburned control transects. Burning did affect the duration forbs remain green and available as forage. Burning was associated with a longer duration of hen/chick forb availability. Burning did affect food nutrition. Some nutrients were higher in burned sites when compared to a control. These effects are probably due to the increase of available nutrients immediately after burning. Although, combustion of plant material volatilizes sulfur and nitrogen, other nutrients are changed to water soluble simple salts, which are readily uptaken by plants (Daubenmire 1968). Total and available nitrogen normally increase after burning from stimulation of nitrogen-fixing bacteria associated with legumes (Young 1983).

Short-term fire effects increased the amount of cover of sage grouse chick foods and increased the frequency of some key chick foods in mountain big sagebrush. Earlier work on fire effects did not separate subspecies of sagebrush. The different subspecies are characteristic of different habitat types, which respond in varying degrees to burning. In general, the drier and less productive a site, the lower the response of the herbaceous community to burning. An example is the study by Fischer *et al.* (1996) in Wyoming big sagebrush where forb cover was not effected by burning during drought conditions. During this same drought period, Pyle and Crawford (1996) found a positive response of forb abundance to burning in a mountain big sagebrush-bitterbrush community. Blaisdell (1953) and Cook *et al.* (1994) also reported increased forb production after burning in mesic sites. Peterson (1970) stated the most important components of brood-rearing habitat are forb abundance and diversity of food and sagebrush cover of 1-20% for cover. An increase in the amount of chick foods was associated with increased brood survival (Drut *et al.* 1994a, 1994b).

My finding that some succulent chick foods were available longer on burned sites supported the study by Blaisdell (1953) where in forb phenology was delayed up to 2 weeks on burned areas. Brood-rearing sites typically had greater forb availability than random locations (Drut et *al.* 1994a, and Sveum et al. 1998).

Forb availability affects brood habitat use and distribution (Peterson 1970, and Drut et *al.* 1994a, and Sveum et al. 1998). Lower forb availability was associated with larger home range sizes and lower brood survival (Drut et *al.* 1994a).

Succulent forbs in the uplands in July and August may be very important in brood survival by reducing congregations of broods at lakebeds and waterholes by keeping them widely dispersed. Widely dispersed broods reduce the likelihood of density dependent factors having a negative effect on brood survival (e.g. predation, human harvest, parasites and disease).

For most of the forb species studied, crude protein and the percentage of calcium and phosphorus were greater in plants in burned sites than in the control. Few differences were found in gross energy between burned and control sites, and there was not a trend of burned sites having higher or lower gross energy values. Chicks grow at a high rate and require foods high in energy, protein, calcium, and phosphorous to increase their mass and to maintain health and activity levels. Unfortunately, almost no information is available on the dietary requirements of sage grouse chicks. Reports available deal with lower survival without certain foods (Johnson and Boyce 1990; Drut *et al.* 1994a, 1994b,). However, we can gain inferences from pen raised gamebirds. Young (0-4 weeks) pen raised ring-necked pheasants (*Phasianus colchicus*) required 0.90-1.06% calcium and a maximum of 0.80% phosphorous in the diet for normal growth (Hinkson *et al.* 1971). Pheasant chicks 5-14 weeks required 0.50% calcium and 0.48% phosphorus (Scott *et al.* 1958a). The requirements for northern bobwhite (*Colinus virginianus*) chicks, 0-6 weeks, and 6-12 weeks old were 0.60% phosphorus with 1.65% calcium, and 0.48% phosphorous with 1.45% calcium, respectively (Scott *et al.* 1958b). The requirements for turkey (*Meleagris gallopavo*) poults, 0-4 weeks, were: 0.80% phosphorous, 1.2% calcium, and 550-1100 I.C.U. vitamin D/kg of feed for maximum growth (Neagle *et al.* 1968). Sullivan and Kingan (1963) noted in feeding trials of 0-6 week turkey poults, that the lower the vitamin D levels were, the higher the amount of calcium needed to achieve growth. The ratio of calcium to phosphorous is important, if one mineral is deficient, it depletes the other mineral. However, the ratio is of lesser importance if levels of both minerals are above requirements. Also, at optimum calcium to phosphorous levels the required amount of vitamin D is decreased (Harms and Damron 1977). The percentage of calcium and phosphorus in the sage grouse chick foods studied in burn and control sites varied from 0.37% to 2.24%, and 0.24% to 0.70%, respectively. The high ends of these ranges fall within growth parameters for the species mentioned above and probably for sage grouse chicks.

For most of the forb species studied, crude protein was greater in burned sites than in the control. Cook *et al.* (1994) found a higher percentage of crude protein of forbs in burns for 2 years after burning. Insects are also an important source of protein for chicks. Insects made up to 60% of the diet of 1 week old sage grouse chicks (Peterson 1970). Insects are key in the survival of chicks 3 weeks old and younger (Johnson and Boyce 1990). Johnson and Boyce (1990) found that sage grouse chicks (0-10 days) died or had reduced growth without insects in their diet.

Insect response to burning was variable among groups. Coleoptera and Orthoptera abundance was higher 2 years after burning compared to one year after burning. Formicidae abundance did not respond favorably to burning.

In consideration for providing habitat to meet all life history needs, critical considerations include 1) when does sagebrush return to the height and cover for nesting cover and 2) how long do grasses and forbs remain codominant. Over the long term, burning did affect these habitat components needed for prelaying, brood-rearing, and nesting.

The immediate effects of fire were: a virtual elimination of sagebrush cover from the burned sites, an increase in the amount of perennial grass cover 2-years post-burn compared to 1-year post-burn, and an increase in forb cover, frequency, and overall nutrient content. The perennial grass cover seemingly will return to pre-burn levels relatively quickly. In the long-term fire effects study, burned and control areas showed little difference in tall grass cover at 12 years post-burn. The short-term study dealt with perennial grass cover as a functional group, which appears to be positively affected by fire. However, individual species can respond quite differently. The direct effect of fire on herbaceous plants is due to the location of growing points as well as morphological characteristics (Young 1983). Champlin (1983) noted that Idaho fescue was the grass species most negatively effected by burning but production returned to pre-burn levels within 2 years after burning. *Stipa* species are susceptible to direct damage from fire, but bluegrass spp. and bottlebrush squirreltail appeared to be resistant to damage (Wright and Kelmmendson 1965). Bluebunch wheatgrass responds favorable to burning with increased production (Harniss and Murray 1973, Champlin 1983). Because perennial grasses appear to recover from burning fairly rapidly, it is the time of sagebrush reinvasion that limits burns for nesting cover.

Sagebrush seedlings were observed throughout the burned plots during the first and second years after burning. Koniak (1985) also found that big sagebrush reinvasion began within 1 year after burning. Reinvasion is through germination of soil stored seed and from seed that moved in from adjacent unburned areas and germinated (Koniak 1985). Previously, sagebrush seeds were thought to be destroyed by fire; however, Champlin (1982) found that cool (104°C soil surface) and hot (416°C) burning stimulated mountain big sagebrush seed germination. Germination rates were not a limiting factor in a study of sagebrush reinvasion by Harniss and McDonough (1976). I found an increased reproductive effort of sagebrush along a burn edge, which may be due to reduced competition as well as an increase in available nitrogen from drifting ash. Available NO_3 and NH_4 increases after burning, NH_4 from soil pyromitization and both in the deposition of ash (Kauffman *et al.* 1997). Reproductive shoot density of Wyoming big sagebrush increased with the application of NO_3 (Miller *et al.* 1991).

The long-term study determined that sagebrush cover was the only tested habitat component affected long-term by burning. Burning had the longest effect on sagebrush cover of four treatments, spraying with 2,4-D, plowing, and rotocutting, in a Wyoming big sagebrush study (Watts and Wambolt 1996). At 30 years after burning, sagebrush cover had reached, but did not exceed, that of the unburned control site. Sagebrush cover for the other treatments recovered more quickly, within 18 years, and eventually exceeded sagebrush cover in controls. Humphrey (1984) compared 8 burns ranging in age from 2 to 36 on mountain big sagebrush sites. Big sagebrush cover was greatest in the 18 year post-burn site. Pre-settlement fire return intervals for mesic, mountain big sagebrush communities were 12-25 years (Miller and Rose 1999) and 50-100 years for xeric, Wyoming big sagebrush (Wright and Bailey 1982).

The answer to the question when does sagebrush reinvade a site to be of use for nesting cover was 25 years by looking at our range of burn sites. All key vegetative and structural components needed for successful sage grouse reproduction were found in burned areas from 35-43 years old. This is approximately double the historic fire return interval. During this time-frame sagebrush and herbaceous vegetation were codominant. The immediate effect of fire shifting site dominance from sagebrush to grasses and forbs; and as sagebrush gradually reinvades the site the herbaceous cover declines has been a common finding over different sagebrush-steppe sites (Harniss and Murray 1973, Wright *et al.* 1979, Humphrey 1984, Sapsis 1990). However, the herbaceous decline may not be as rapid as previously thought. The 43 year old burn site in this study was still rich in forbs and perennial grasses, suggesting the balance between sagebrush and herbaceous components can stay in place for decades past the fire return interval.

This work was built on the assumption that sage grouse will use these burn sites. Gates (1983) found that sage grouse used a 1-year post burn site more than an unburned control. Future studies will need to be done to further our knowledge of sage grouse use of burn sites.

The reader should be cautioned that the effects revealed in this study are associated with burning. The burn treatments were not applied randomly, therefore the study lacks causal evidence. Future fire effects studies should include pair treatments, before and after comparisons, and more replication and randomization of sites and treatments whenever possible to reduce confounding variables and validly speculate treatment effects on more sites than studied.

MANAGEMENT IMPLICATIONS

Sage grouse life history needs are diverse. They need open spaces for lekking, sagebrush and perennial grass cover for nesting and escape cover, and forbs for hen and chick nutrition. Recommendations for optimum amounts of critical components in mountain big sagebrush areas are: 1) 40% medium height (40-80cm) sagebrush cover within 1-m diameter nest sites, 15-20% cover overall; 2) 20% tall (≥20cm) residual grass cover in the early spring at 1 m diameter nest sites; 5-15% overall, 3) 15-30% early and late forb cover with ≥ 5% key sage grouse food forbs and the insects associated with them (Coggins 1999, Drut *et al.* 1994a, Gregg 1993).

Sage grouse productivity increased at Hart Mountain NAR when nesting and brood-rearing habitat components were at the following levels: 1) 15-20% early forb cover with 2-6% being key sage grouse food forbs, 2) 5-17% early tall grass cover, 3) 8-16% late forb cover with 2-3% key sage grouse food forbs, and 4) 10-20% low (<40cm) and medium (40-80cm) sagebrush canopy cover (Coggins 1999).

Sage grouse are a sagebrush obligate and, therefore, are a useful indicator of sagebrush habitat condition. Sage grouse life history needs make an excellent choice as a goal for a desired landscape in use with ecological restoration. The Great Basin has gone through many changes over the past two centuries. Decisions must now be made about what we want the landscape to look like and at what level of ecological function. Sage grouse needs can be a foundation for this work. With the potential federal listing for this species under the Endangered Species Act, development of specific goals and the changes necessary to meet them are needed. Sage grouse habitat needs can be used in restoration goals. Prescribed fire is one of the management tools to achieve this goal.

This study has determined that prescribed burning benefited sage grouse brood habitat on the sites studied. Fire may benefit sage grouse brood habitat if the burn produces a mosaic of sagebrush cover interspersed with open areas with abundant forbs (Klebenow 1972). Use of prescribed fire to improve sage grouse habitat conditions was recommended by Klebenow (1972) and Autenrieth *et al.* (1982). I concur and recommend prescribed burning as a management tool if the goal is to increase amount of and improve sage grouse brood-rearing habitat. However, the critical component that is limited on site must be considered. Burning will negatively affect nesting and wintering habitat in the short-term. The long-term fire effects study showed that sagebrush cover did not return to the height and cover needed for nesting for well over a decade. On large burns, seeding sagebrush or planting seedlings may be an option to reduce recovery time of sage grouse nesting cover.

Site conditions also need to be considered in prescribed burn plans. More caution must used on more xeric sites where positive results will be limited by precipitation conditions. Consideration of exotic annual grass response is also an issue if they are present. Exotic annual grasses respond to the disturbance and release of nutrients from a burn. Annuals remained site dominants for 5 years following an application of nitrogen; the control was dominated by big sagebrush and perennial grasses (McLendon and Redente 1991). Annual grasses can rapidly dominate a site, creating a more homogeneous stand of fine fuels, which increase the chance of recurring fires and further degradation (Young and Evans 1978).

Based on my study and others in the literature, I recommend applying prescribed fire to mountain big sagebrush sites when tall early grass cover drops below 5-10%, early forb cover drops below 15%, late forb cover drops below 5-10%, or sagebrush cover excedes 20-25%. During the time period sagebrush and herbaceous components are in the desired community structure and composition, the area would meet nesting needs. This recommendation could mean that one site would not be reburned for 40 years or more. Habitat monitoring is essential to determine if fire is needed in the system. For ecological restoration, an input such as burning and/or seeding, will be needed if the site has passed a degradation threshold (Laycock 1991). If the herbaceous cover has decreased below sage grouse nesting requirements, fire may be the necessary input for restoration of the site. Seeding is another tool that could be used in conjunction with burning, to achieve restoration at a faster rate.

A mosaic of different levels of sagebrush and herbaceous cover are needed to sustain sage grouse throughout their different life phases. Because of their diverse needs I recommend burning methods that would result in an interspersion of unburned and burned areas. Prescribed burning may presently be the best tool available to accomplish the goal of restoring the habitat components grouse need on a large-scale basis. With the use of prescribed burning, we can effect, on a landscape level, the abundance of herbaceous and shrub habitat components and ecologically restore their balance.

Prescribed burning is currently used to control juniper invasion, decrease sagebrush densities, increase livestock forage, and ecologically restore the sagebrush-steppe. The effect this management tool has on 1 main indicator species of this ecosystem needs to be understood. This study found some effects on essential habitat components, but there still needs to be research on how prescribed burning ultimately effects sage grouse populations.

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