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**Spatial and Temporal Changes
of Sage Grouse Habitat
in the Sagebrush Biome**



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Cover Photo

Male sage grouse at lek near Jack Mountain in Harney County, Oregon
(Photo by Larry G. Hammond).

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This paper was written as a book chapter on the ecology and biology of sage grouse. Because the book was never fully developed, we chose to publish the information with the OSU Agricultural Experiment Station.

Contents

Introduction.....	1
Spatial Changes.....	2
Climate.....	2
Ecosystem Types and Subdivisions Within the Sagebrush Biome..	3
Figure 1.....	4
Figure 2.....	5
Sagebrush Steppe.....	6
Great Basin Sagebrush Ecosystem Type.....	6
Potential Natural Flora.....	7
Herb Layer.....	7
Table 1.....	8
Table 2.....	9
Shrub Layer.....	9
Sagebrush Community Types.....	10
Other Vegetation Zones.....	14
Temporal Change.....	15
A Prehistoric Perspective.....	15
Long-Term Climate Cycles.....	15
Short-Term Climate Cycles.....	15
Table 3.....	16
Fire.....	16
A Historic Perspective.....	17
Pre-Settlement Communities.....	17
Table 4.....	18
New Post-Settlement Disturbance Factors.....	19
Table 5.....	20
Twentieth Century Plant Communities.....	20
Management: Influencing Temporal Changes.....	23
Fire.....	23
Grazing Management.....	24
Other Considerations.....	26
Conclusions.....	26
Literature Cited.....	27

Spatial and Temporal Changes of Sage Grouse Habitat in the Sagebrush Biome

Abstract

Sage grouse (*Centrocercus urophasianus*) occur in regions that are spatially diverse and temporally dynamic in western North America. During the past 130 years, significant changes in disturbance regimes have affected their habitat. Plant communities in existence today are unique from any other time period because of altered disturbance regimes, confounded by a continual change in climate. In some portions of their range, sage grouse populations have been reduced or eliminated from loss of habitat through land conversion to agriculture or shifts from perennial shrub grasslands to introduced exotic annual grasslands or pinyon-juniper woodlands. However, in other sections of their range, changes in plant community composition and structure have been minimal. Causes for decline in sage grouse populations in these areas are less clear and often debated. Spatial and temporal diversity significantly affect the quality of sage grouse habitat. Because of the diversity of biotic and abiotic factors and land use history across the range of sage grouse, plant community structure and composition have responded differently throughout this region. When considering a sagebrush steppe restoration plan or sage grouse habitat management plan, one must take into account landscape heterogeneity, site potential, site condition, and habitat needs of sage grouse during different segments of their life cycle: breeding, nesting, brood rearing, wintering, etc. This paper describes the spatial diversity of sage grouse range, short- and long-term dynamics and disturbance regimes across this ecosystem, and potential management implications related to sage grouse habitat.

Introduction

There is rising concern over decreasing sage grouse (*Centrocercus urophasianus*) populations throughout the West. Causes are frequently attributed to habitat fragmentation, land conversion, overgrazing, introduction of exotic weeds, pesticides, altered fire regimes, predation, recreation, and urban development. Sage grouse range is spatially diverse and temporally dynamic. Their range crosses several climatic zones, two sagebrush ecosystem types, several sagebrush geographic subdivisions, and includes multiple plant associations¹. Temporal change is also spatially diverse throughout this region. In some areas, large expanses of sagebrush steppe have been converted to croplands whereas little cultivation has occurred in other areas. In other

¹ Nomenclature follows physiognomic-floristic hierarchy from Grossman et al. 1998; a plant association is defined by the dominant/diagnostic species of the upper most stratum and an additional dominant/diagnostic species from any strata.

parts of their range, large areas of Wyoming big sagebrush have been converted to alien annual grasslands with increasing mean fire intervals. In contrast, large sections of mountain big sagebrush are succeeding from shrub steppe to woodlands with decreasing fire return intervals. The interactions between spatial and temporal dynamics are complex often making it difficult to fully explain the recent sage grouse population declines (Connelly and Braun 1997). To begin to identify potential problems limiting sage grouse populations and to develop effective management strategies that enhance this species, biologists and land resource managers must consider the high degree of spatial and temporal heterogeneity both at regional and local levels of sage grouse range.

The purpose of this publication is to document the spatial heterogeneity, which characterizes the historic range of sage grouse in the West. We also discuss long- and short-term temporal changes, which influence both community structure and food availability for sage grouse. Factors affecting these changes are also explored as are potential management considerations.

Spatial Changes

Soils, topography, and climate, which influence spatial changes in plant communities vary greatly throughout the range of sage grouse. These variable landscapes provide opportunities for sage grouse to move from valley floors to high elevation communities or from semi-arid uplands to wet meadows, following the phenology of succulent forbs through the growing season. They also provide food and cover during winter. The matrix of plant communities that characterize these landscapes and their composition and structure determine how well food and cover needs of sage grouse are met throughout the year.

Sage grouse, a sagebrush obligate, are found throughout the sagebrush (*Artemisia* spp.) biome (Fig. 1). The sagebrush biome is the largest semi-arid ecosystem in the western United States, comprised of 62.7×10^6 ha (West 1983) and two ecosystem types: sagebrush steppe and Great Basin sagebrush. Most of this biome lies between the Sierra Nevada and Cascade Mountain ranges and the Rocky Mountains. However, the sagebrush biome extends east into the northern Great Plains of Wyoming and south-central Montana (Kuchler 1985) with its eastern limit at the western edge of South Dakota (Johnson 1979). Sagebrush extends as far north as Kamloops on the Southern Interior Plateau in British Columbia and south into northern Arizona and New Mexico.

Climate

The sagebrush biome crosses several climatic boundaries distinguished by temperature gradients, air mass movements, and timing and variability of precipitation (Mitchell 1976) (Fig. 1). However, meteorological parameters such as precipitation and temperature are severely modified by the numerous

mountain ranges in the West. Climate across a large portion of this region is semiarid, temperate, and continental, characterized by cold wet winters and hot dry summers (West 1983). The primary source of moisture for this area is the Pacific Ocean, with low pressure centers moving inland during the fall, winter, and spring. However, the southeastern portion of this region is influenced by both moisture from the Pacific Ocean and an influx of air from the Gulf of Mexico and California. This causes an increase in the frequency of summer precipitation from west to east and north to south across the sagebrush biome. Temperatures, evaporation potentials, and the variability of precipitation increase from north to south across the biome (West 1983).

Ecosystem Types and Subdivisions Within the Sagebrush Biome

Sagebrush is usually the dominant shrub in the Intermountain Region where precipitation is greater than 178 mm and soils are salt free (Cronquist et al. 1972). In the Great Basin, shadscale often replaces sagebrush where precipitation is not adequate (Billings 1949). Elevation of sagebrush communities range from 150 m in the Columbia Basin (Rickard and Vaughn 1988) to 3,300 m in the Great Basin (Cronquist et al. 1994). Kuchler (1985) separated the sagebrush biome into two major ecosystem types. In the northern region, the sagebrush steppe ecosystem type, extends over an area of 44.4×10^6 ha, and to the south, the more arid Great Basin sagebrush ecosystem type occupies 17.9×10^6 ha (Fig. 1). The sagebrush steppe is characterized by an overstory of *Artemisia* and an understory of perennial grasses and forbs. In the Great Basin sagebrush ecosystem type the herbaceous component contributes only a small portion of the total plant cover (West 1983). The majority of the Great Basin sagebrush ecosystem type lies south of the polar front gradient (Fig. 1) where temperatures are warmer, summer precipitation increases, and winter precipitation decreases (Neilson 1987). The sagebrush steppe lies primarily north of the winter (also called polar front) gradient.

Within the two ecosystem types, several geographic subdivisions can be defined (West 1983), which we have slightly modified. The sagebrush steppe is subdivided into the Columbia Basin, northern Great Basin, Snake River Plain, and Wyoming Basin, (Fig. 2). The Great Basin sagebrush ecosystem type is subdivided into the southern Great Basin and Colorado Plateau. These subdivisions differ in climate, elevation, topography, geology, and soils. However, similarities and dissimilarities of vegetation between these subdivisions are often not clear. This in part is due to the modifying effects of highly variable elevation and topography. Generally a much greater separation in vegetation is seen along elevation gradients, which involves changes in soils and climate (West 1983).

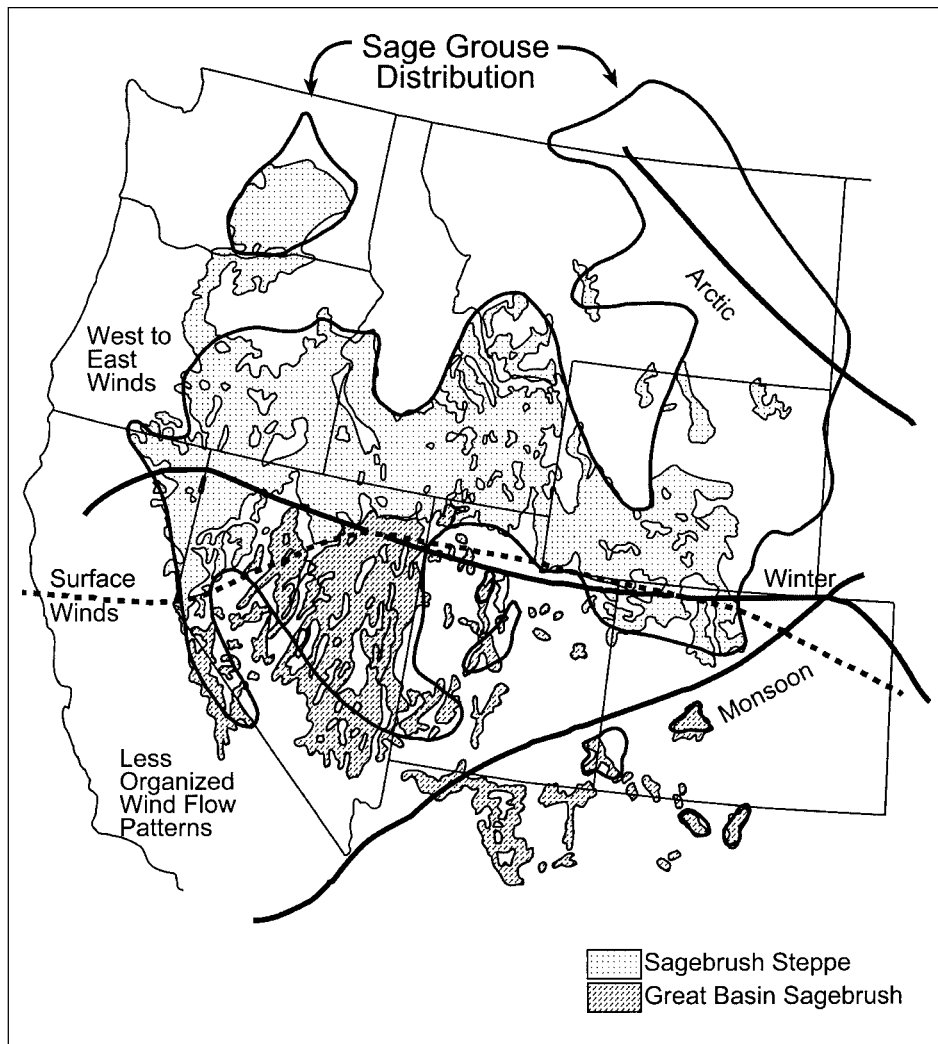


Figure 1. Sage grouse distribution (derived from Wallestad 1975) overlays the majority of the sagebrush biome, composed of the Great Basin sagebrush and sagebrush steppe ecosystem types (derived from Kuchler 1985). Climate boundaries are the Arctic, Winter (or Polar Front), and Monsoon (Mitchell 1976). The winter boundary forms a line between essential east-west oriented surface winds to the north and much less organized pattern to the south. It also is the zone of maximum change in equivalent potential temperature. The monsoon boundary is the zone where the influence of Gulf air masses greatly decline moving north of the line.

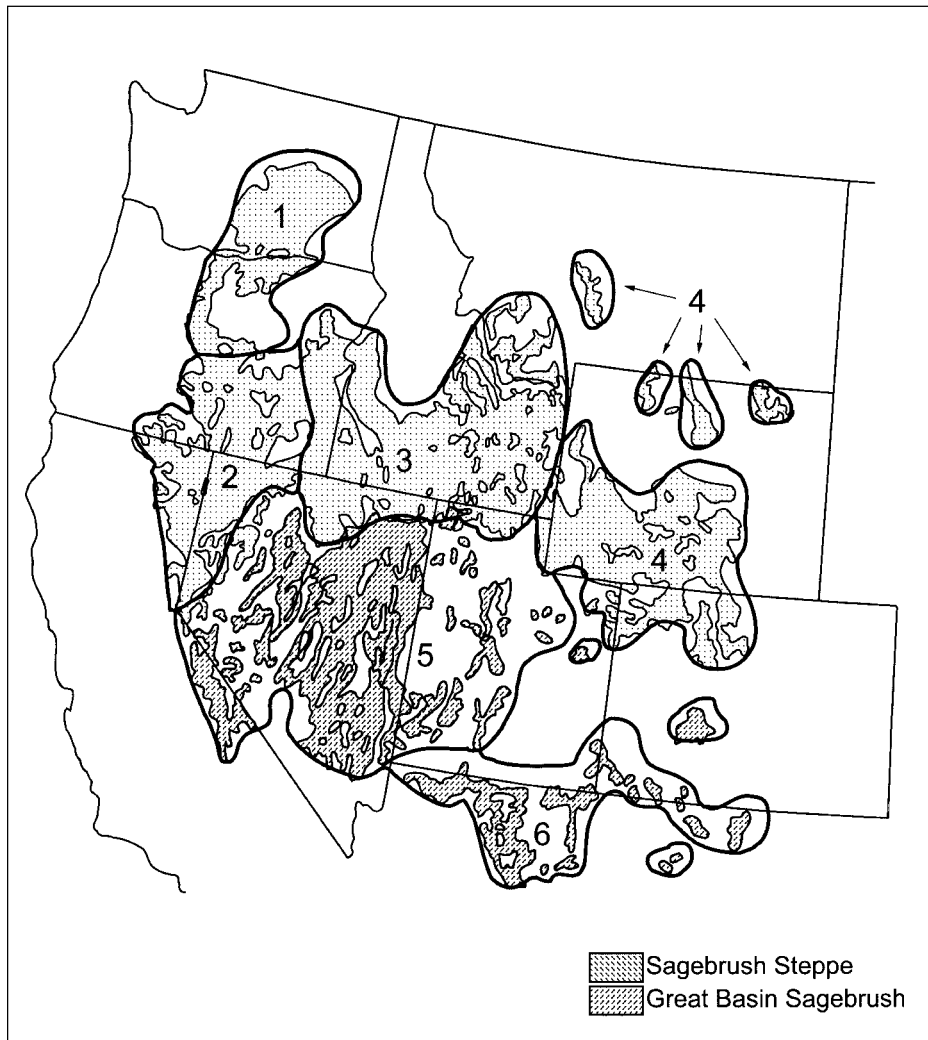


Figure 2. Geographic subdivisions of the sagebrush biome for the sagebrush steppe are, (1) Columbia Basin, (2) northern Great Basin, (3) Snake River Plain, (4) Wyoming Basin; and for the Great Basin sagebrush are, (5) southern Great Basin, and (6) Colorado Plateau (derived from West 1983 and Kuchler 1985).

Sagebrush Steppe

The Columbia Basin (area 1, Fig 2) contains the lowest elevation sagebrush communities in the sagebrush biome. Predominant sagebrush in this region are Wyoming big sagebrush (*Artemisia tridentata* var. *wyomingensis*) and basin big sagebrush (*A. tridentata* var. *tridentata*). The Columbia Basin sagebrush steppe is bordered by the Palouse Prairie and coniferous forests. Precipitation primarily occurs in the winter and spring. The basin is underlain by vast lava flows however, soils have been greatly influenced by glacial loess and Pleistocene outwash (Rickard and Vaughn 1988). Soils commonly range from sandy loams to silt loams.

The northern Great Basin sagebrush steppe (area 2, Fig. 2) occurs between salt deserts occupying valley floors and woodlands, conifer forests, and alpine meadows. Predominant sagebrush are Wyoming big sagebrush, mountain big sagebrush (*Artemisia tridentata* var. *vaseyana*), and low sagebrush (*A. arbuscula*). Precipitation primarily occurs in the winter and spring. Soils are typically derived from volcanic materials (West 1983), with some outcropping of sedimentary materials (Walker and MacLeod 1991).

Sagebrush communities in the Snake River Plain (area 3, Fig. 2) lie between the salt deserts occupying the low valleys and the coniferous forests at the upper elevation. The sagebrush component is dominated by Wyoming big sagebrush and basin big sagebrush. Mountain big sagebrush primarily occurs at the higher elevations in the mountains. Summer precipitation events increase from west to east. The Snake River Plain is built on numerous lava flows overlapped by alluvial fans from the massive granite Idaho batholith to the north and the largely sedimentary mountains to the east and south (Hironaka 1979, West 1983).

The Wyoming Basin, the eastern extension of the sagebrush steppe and sage grouse distribution, extends into the northern Great Plains (Johnson 1979) (area 4, Fig. 2). This eastern extension of the sagebrush steppe is primarily the result of climate. A low area of the continental divide allows air masses to flow into this area from the Great Basin during the fall and winter increasing the influence of winter precipitation. The vegetation includes many Great Basin plants with a strong component of Wyoming big sagebrush often associated with silver sagebrush (*Artemisia cana*). The sagebrush steppe lies between the mixed grass prairie to the east and north, salt desert communities in the lower basins, and coniferous forests at the higher elevations. Soils are primarily loosely consolidated rock composed of shales and marlstones from ancient Eocene lakes, and alluvium from the high mountains (West 1983).

Great Basin Sagebrush Ecosystem Type

The southern Great Basin (area 5, Fig. 2) and Colorado Plateau (area 6, Fig. 2) subdivisions lie south of the sagebrush steppe and north of the creosote (*Larrea tridentata*) and blackbrush (*Coleogyne ramosissima*) deserts. Predominant sagebrush species in these two subdivisions are Wyoming big

sagebrush, mountain big sagebrush, low sagebrush, and black sagebrush (*Artemisia nova*). Plant communities in this region are often more arid than sagebrush communities located to the north. Recovery from fire, grazing, or other disturbances is usually slower and attempts at land restoration less successful than in the sagebrush steppe (West 1983).

Season of precipitation varies from minimal summer rainfall in the north-west corner of the southern Great Basin to near 40% summer rainfall in southern Utah, northern Arizona, and northern New Mexico. The majority of the Colorado Plateau receives more moisture than the southern Great Basin; however, sagebrush distribution is greatly limited by marine shale outcroppings which forms halomorphic (saline) soils. In the southern Great Basin, sagebrush communities are typically on uplands between the salt deserts occupying the lower elevation Great Basin valley floors and the semi-arid woodlands and forests occupying the mid to upper mountain slopes. However, sagebrush communities extend to nearly 3,300 m on many mountain ranges (Cronquist et al. 1994).

Potential Natural Flora

Sagebrush communities are generally characterized by an overstory dominated by a low or tall form of sagebrush with an understory of forbs and grasses. These communities generally contain three to four vegetation layers: (1) the shrub layer 3-10 dm tall, (2) forbs and caespitose grasses 2-6 dm, (3) low growing grasses and forbs <1-2 dm, and (4) the cryptogamic soil crust. Vegetal cover is usually not continuous with considerable bare ground exposed (Blaisdell et al. 1982), but can reach near 100% in very wet sagebrush communities. Sagebrush community structure and species composition are as variable as the terrain that characterizes this biome. Potential composition of the shrub, grass, and forb groups is largely a function of amount and season of precipitation (Cronquist et al. 1972) and soil characteristics which influence availability and distribution of soil water through the profile.

Herb Layer

The herb layer, composed of grasses and forbs, is an important component of sage grouse habitat, providing both food and cover. The primary function of caespitose perennial grasses is hiding and nesting cover. Tall residual grass cover, greater than 15cm tall, has been found to positively correlate with nesting success (Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998, Coggins 1998). Forbs provide high quality foods for birds prior to nesting, through chick rearing late in summer (Table 1). Forbs contributed 20 to 50% of prelaying hens diet in Oregon and are higher in crude protein, phosphorus, and calcium than sagebrush (Barnett and Crawford 1994). Coggins (1998) reported nest initiation by hens increased 34% in a year when forbs were twice as plentiful prior to nesting as compared to a previously dry year. The availability of succulent forbs is also an important factor during brood rearing,

determining brood movements (Patterson 1952, Pyrah 1954, Klebenow and Gray 1968, Savage 1969, Peterson 1970, Drut et al. 1994a), and relating to chick survival (Coggins 1998). As the availability of succulent forbs decreases, sagebrush increases in the diet (Patterson 1952, Gill 1965, Wallestad 1975, Autenrieth 1981). Within the sage grouse home range, forb availability is determined by climate, particularly amount and timing of precipitation, site potential, and the matrix of associated plant communities.

Table 1. Common perennial forbs in the sagebrush biome found in the sage grouse diet from prelaying through chick rearing (Klebenow and Gray 1968, Crawford 1991, Barnett and Crawford 1994, Drut et al. 1994a).

<i>Achillea millefolium</i>	<i>Liananthus harknessii</i>
<i>Agoseris</i> spp.	<i>Lomatium</i> spp.
<i>Astragalus</i> spp.	<i>Microsteris gracilis</i>
<i>Calochortus macrocarpus</i>	<i>Phlox longifolia</i> ¹
<i>Castilleja</i> spp.	<i>Taraxacum officinale</i> ²
<i>Crepis</i> spp.	<i>Tragopogon dubius</i> ²
<i>Eriogonum</i> spp.	<i>Trifolium macrocephalum</i>
<i>Lactuca serriola</i> ²	

¹ Calcium rich forb important in the diet of pre-laying hens

² Introduced species

A large number of herbaceous species are present throughout the sagebrush biome but relatively few form the bulk of the biomass (Blaisdell et al. 1982). There are a greater number of forb than grass species, but forbs constitute a smaller percentage of the biomass and ground cover. Across 372 range sites in Nevada, 218 species were encountered, of which 39 were shrubs, 35 were grasses, and 140 were forbs (Jensen 1989a). Across 112 mountain big sagebrush communities in the northern Great Basin, forbs accounted for 247 of the total 337 plant species encountered (Miller et al. 2000). However, forbs generally account for less than 10% of the total plant cover or biomass in shrub steppe communities (Daubenmire 1970, Blaisdell et al. 1982, Passey et al. 1982, Miller et al. 2000). Only in the more mesic sagebrush communities characterized by mountain snowberry (*Symphoricarpos oreophilus*), Idaho fescue (*Festuca idahoensis*), and subalpine needlegrass (*Stipa columbiana*) did forb cover exceed 10% cover.

Floristic diversity in sagebrush steppe communities is usually considered as moderate (West 1983). On individual sites with minimal anthropogenic disturbance, species numbers ranged from 20 in the Columbia Basin (Daubenmire 1975), 13-24 in the Snake River Plain (Tisdale et al. 1965), 54 species across several low sagebrush communities in Nevada (Zamora and Tueller 1973), and 24 to 56 species in mountain big sagebrush communities in the northern Great Basin (Miller et al. 2000). In the more arid southern Great

Basin ecosystem type, sagebrush communities are generally floristically simple with an overwhelming dominance of sagebrush (West 1983). In this part of the sagebrush biome, sagebrush can account for 70% of the foliar cover and 90% of the biomass, however, species numbers and biomass greatly vary annually, spatially, and with seral stage.

Herbaceous production and cover are highly variable both across and within different sagebrush cover types. A general trend in yearly production occurs across plant communities containing different sagebrush species and varieties (Table 2). This is primarily attributed to changes in precipitation, temperatures, and soils associated with different sagebrush species. These parameters also influence timing and length of growing season for important sage grouse food plants. In Nevada, Jensen (1989b) reported the average number of days when soil temperature and moisture were not limiting to herbaceous plant growth across 372 range sites ranged from 28 to 32 days on low sagebrush sites, 50 to 56 days on mountain big sagebrush sites, and 130 days on meadows.

Table 2. General ranges of precipitation, elevation, soil depth, and above-ground annual plant production for sagebrush (*Artemisia* spp.) cover types (derived from Passey et al. 1982, Cronquist et al. 1994, and Shiflet 1994).

Species	PPT (mm)	Elev (m)	Soil Depth	Annual Prod (Kg/ha)
<i>A. spiciformis</i>	>400	2,300-3,200	deep	>1,800
<i>A. tridentata</i> var. <i>vaseyana</i>	350-450	1,200-3,200	mod.-deep	700-2,750
<i>A. tridentata</i> var. <i>tridentata</i>	200-400	<2,300	deep	868-2,352
<i>A. tripartita</i>	300-400	1,100-2,300	shallow-mod.	560-1,372
<i>A. tridentata</i> var. <i>wyomingensis</i>	180-300	150-1,200	mod.	440-775
<i>A. arbuscula</i>	200-400	1,000-3,300	shallow	370-1,008
<i>A. nova</i>	200-300 (400)	1,400-2,550	shallow	437-616
<i>A. rigida</i>	200-400	230-1,300	shallow	123-246

Shrub Layer

Composition, height, and density of the shrub layer is a function of climate, soils, topography, and disturbance. Species of sagebrush are numerous and occur in different sizes and degrees of palatability. Cronquist et al. (1994) recognized 27 species and four varieties of *Artemisia* growing in the western

United States. Those most abundant in the sage grouse range are listed in Table 2. Other shrub species commonly associated with sagebrush are rabbitbrush (*Chrysothamnus* spp.), horsebrush (*Tetradymia* spp.), granite gilia (*Leptodactylon pungens*), spiny hopsage (*Grayia spinosa*), winterfat (*Ceratoides lanata*), Mormon tea (*Ephedra* spp.), bitterbrush (*Purshia tridentata*), mahogany (*Cercocarpus* spp.), cliff rose (*Cowania mexicana*) currant (*Ribes* spp.), and snowberry (*Symphoricarpos* spp.). Sagebrush and associated shrubs provide cover from predators and sage grouse food during late summer and winter when succulent forbs are not available. Sagebrush typically makes up 100% of the winter diet (Wallested 1975) declining to 50 and 70% for prelaying hens as availability of forbs increases early in the spring (Barnett and Crawford 1994).

Shrub canopy cover desirable to sage grouse changes throughout the year with their life cycle. Shrub cover varies from open small areas (0.1 to 5.0 ha) for leks, moderate cover (10-25%) for brood rearing (Klebenow 1985, Connelly et al. 2000), moderately dense ($\geq 17\%$) for nesting (Call and Maser 1985, Hulet et al. 1986, Klebenow 1985, Gregg 1991) relatively dense (27-37%) for male day use areas during the breeding season (Ellis et al. 1989) and, open to moderately dense (10 to 30%) for wintering (Connelly et al. 2000). Klebenow (1969) reported birds did not nest in sagebrush exceeding 37% cover. Shrub heights preferred for nesting vary from 30-60 cm, with 20-80 cm being adequate (Call and Maser 1985, Hulet et al. 1986, Gregg 1991). Shrub cover, density, and height are determined by site factors, species of *Artemisia*, and past history of disturbance.

Sagebrush Community Types

A few species of both low (30-50 cm) and tall forms (40-100+ cm) of *Artemisia* account for the majority of sagebrush across the Intermountain Sagebrush biome. Common low forms of sagebrush, black sage (*A. nova*), alkali sage (a taxonomic variant of low *A. arbuscula*), stiff sage (*A. rigida*), as well as low sage are generally found on shallow or poorly drained soils (Eckert 1957, Fosberg and Hironaka 1964). A strong argillic horizon, duripan or bedrock are generally less than 33 cm from the surface or less than 50 cm in wet areas (Fosberg and Hironaka 1964). When black sage or low sage are found on deeper soils, depth of the wetting horizon is usually limited, and soils are generally very coarse textured (Fosberg and Hironaka 1964, Sabinske and Knight 1978, Tisdale 1994).

Communities characterized by the low sagebrush group are often preferred by sage grouse during the winter when availability is not limited by snow depth (Klebenow 1985). In years when snow depth exceeded 25-30 cm, sage grouse moved from low statured sagebrush sites into Wyoming big sagebrush community types (Barrington and Back 1984). Greater forb abundance in the more mesic low sage communities (e.g. *Artemisia arbuscula*) correlates with preferred use by sage grouse over Wyoming big sagebrush communities. Low

sagebrush can provide excellent habitat for sage grouse when it forms a mosaic with mountain big sagebrush.

Low sage is found throughout most of the northern half of the sagebrush biome south to central Nevada and Utah (Tisdale 1994). As low sage extends south, it is primarily restricted to areas above pinyon-juniper (*Pinus* spp. and *Juniperus* spp.) woodlands. Alkali sage, which is taxonomically not separated from low sage (Cronquist et al. 1994), is typically found in northeastern Nevada (Zamora and Tueller 1973), southeast Oregon, and southern Idaho where it grows on heavy clay soils derived from alkaline shales (Robertson et al. 1966). Shrub canopy cover in low sage types usually varies between 5 and 25%. Shrub height (30-50 cm) and herbaceous production is highly variable across this type. On shallow rocky soils, shrub stature is usually only 30 cm, Sandberg bluegrass (*Poa sandbergii*) is the dominant herbaceous plant, forb species are often diverse, and bare ground is usually >50% (Passey et al. 1982, EOARC data file). However, on deeper (>45 cm) poorly aerated soils, shrub stature is nearer 50 cm, bare ground is usually <50%, and Idaho fescue or bluebunch wheatgrass (*Agropyron spicatum*) usually dominate the understory.

Common forbs in the low sagebrush type are wild onion (*Allium* spp.), low pussytoes (*Antennaria dimorpha*), Pursh locoweed (*Astragalus purshii*), biscutroot (*Lomatium* spp.), Indian paintbrush (*Castilleja* spp.), longleaf phlox (*Phlox longifolia*), hoods phlox (*P. hoodii*), sandwort (*Arenaria* spp.), and big headed clover (*Trifolium macrocephalum*) (Tisdale 1994, EOARC data file). A number of forbs common in low sagebrush communities occur in the sage grouse diet (Table 1). Floristically, these communities can be relatively rich compared to other semi-arid sage communities. Across six low sagebrush/Sandberg bluegrass sites in southeastern Oregon, 26 annual forbs, 33 perennial forbs, 2 annual grasses, 11 perennial grasses and 6 shrubs were present (EOARC data file).

In black sage communities, soil moisture and soil fertility are generally lower and soils less well developed than in alkali sage or low sage communities (Zamora and Tueller 1973, Jensen 1989a, Tisdale 1994). This species grows in the central portion of the sagebrush biome in Nevada and Utah with outlying communities in southeastern Oregon, southwestern Montana, eastern California, and northern Arizona (Tisdale 1994). A large variety of forbs are associated with black sagebrush communities but are usually sparse in the understory. Total plant ground cover is usually less than 30%, providing limited cover for sage grouse.

The deciduous stiff sage or scabland sagebrush (30-40 cm tall) is primarily found in Washington, northeastern Oregon, and west central Idaho (Daubenmire 1970, Hironaka 1979). The least productive sagebrush type, (Table 2), it occurs on thin (<20 cm) stony soils, generally more shallow, and rocky than low sage sites (Hironaka 1979). The herb component in this type is sparse with Sandberg bluegrass, biscutroot, wild onion, pussytoes, Hood s phlox and big headed clover common across these sites (Hall 1973).

Bareground and rock usually account for greater than 60 percent of the ground cover. Hiding cover is typically sparse and the growing season short in this sage type.

The tall forms of sagebrush, commonly called big sagebrush, are basin big sagebrush, Wyoming big sagebrush, and mountain big sagebrush. This big sagebrush group is generally found on moderately deep to deep well drained soils. Big sagebrush does not tolerate poorly aerated or saline soils (Gates et al. 1956, Caldwell 1979). Both soil depth and aeration appear to be the primary factors separating the low and big forms of sagebrush (Fosberg and Hironaka 1964). Within the big sagebrush group, soil fertility and moisture availability usually increase from Wyoming to basin to mountain big sagebrush sites (Jensen 1989b).

Wyoming big sagebrush occupies the more arid sites and accounts for the largest area of the big sagebrush cover types (Tisdale 1994). This subspecies commonly varies between 40 and 55 cm in height (Tisdale 1994) but can approach 80 cm on more productive sites (Trainer et al. 1983). Shrub canopy cover usually varies from 5 and 25%, the latter in communities in poor ecological condition with few perennial herbs in the understory. Shrub cover in Wyoming big sagebrush communities exposed to no or minimal Eurasian impact in southeastern Oregon and composed of an intact native herbaceous understory, varied from 5 to 10% on the dry end of this cover type (20 cm ppt) (Kindschy 1991), to 13 to 18% on the wetter end (30 cm ppt) (EOARC data file). Sites approaching or exceeding 20% shrub canopy cover usually have been overgrazed and contain depleted understories. In areas of high winter concentrations of deer (*Odocoileus hemionus*) and pronghorn antelope (*Antilocarpa americana*) sagebrush cover was <5% (Goodrich et al. 1999).

Communities often contain a high percentage of bare ground and sparse but variable forb cover (Tisdale 1994). Perennial forb cover is usually <10% and highly dependent on amount and timing of precipitation (Kindschy 1991, EOARC data file). Litter is usually sparse but cover of cryptogams can be extensive. Common forbs in Wyoming big sagebrush communities, which have been reported in sage grouse diets are western yarrow (*Achillea millefolium*), locoweed, Indian paintbrush, hawksbeard (*Crepis* spp), biscutroot, microsteris (*Microsteris gracilis*), and longleaf phlox (Klebenow and Gray 1968, Barnett and Crawford 1994, Drut et al. 1994a). These communities, typically occurring at the lower elevations in the sagebrush biome, serve as important wintering areas, particularly when snow depth limits availability of low sagebrush community types (Barrington and Back 1984, Call and Maser 1985, Klebenow 1985).

Basin big sagebrush, commonly >1 m tall, is usually found on deep, sandy or loamy textured Mollisols (Beetle 1960, Morris et al 1976, Winward and Tisdale 1977, Tisdale and Hironaka 1981, Shumar and Anderson 1986). Plant cover characterizing this type, like other sagebrush types, is highly variable depending on site characteristics. The shrub overstory can range from fairly open to >30% cover. The understory is usually dominated by perennial grasses

with a moderate forb layer. Structure of the herbaceous layer can vary greatly with basin wildrye (*Elymus cinereus*) dominating the understory to smaller statured, caespitose grasses such as Sandberg bluegrass, squirreltail (*Sitanion hystrix*), and bluebunch wheatgrass. Although this variety of big sagebrush is consumed by sage grouse, it is less palatable than mountain and Wyoming big sagebrush (Welch et al. 1991).

The mountain big sagebrush cover type usually occupies the zone immediately above the other two varieties on cooler and wetter sites providing important nesting and brood rearing habitat. Soils are typically moderately deep to deep Mollisols (Passey et al. 1982, Jensen 1989a). Shrub canopy cover in undisturbed mountain big sagebrush communities typically varies between 15 and 40% but can range up to 50% in mesic communities with deep loamy soils and north aspects. Bitterbrush and, in more mesic areas, mountain snowberry are common shrubs associated with mountain big sagebrush (Tisdale 1994). The shrub layer in mountain big sagebrush communities is typically 80-100 cm tall.

The understory in mountain big sagebrush is characterized by a well-developed perennial grass and forb layer. Idaho fescue, bluebunch wheatgrass, and Thurber needlegrass are the principal grasses on more xeric mountain sagebrush sites or sites with a well-developed argillic soil horizon. On deeper and often more loamy soils, cutting wheatgrass (*Agropyron caninum*), onion grass (*Melica* spp.), western needlegrass (*Stipa occidentalis*), and subalpine needlegrass (*S. columbiana*), are common. The forb component is usually abundant particularly on the more mesic sites. Common genera are *Achillea*, *Agoseris*, *Astragalus*, *Balsamorhiza*, *Castellija*, *Crepis*, *Eriogonum*, *Geum*, *Lomatium*, *Lupinus*, *Phlox*, and *Senecio*. This cover type, often the most preferred sagebrush type by sage grouse during nesting (Gregg 1991), provides excellent nesting cover, and an abundance of succulent forbs. The growing season is usually longer in this cover type than the other two big sagebrush types, providing succulent forbs later into the summer.

Threetip sagebrush (*Artemisia tripartita*), ranges between 45 and 60 cm tall and can resprout from the base (Tisdale 1994). It is most common in southwestern Montana, eastern Idaho, and Wyoming with some scattered stands in Baker County, Oregon. It grows in a similar climate to mountain big sagebrush but usually occupies shallower more gravely soils. Ground cover is highly variable with bluebunch wheatgrass and Idaho fescue most often the dominant grasses. The forb component is usually well-developed and composed of similar species associated with adjacent mountain big sagebrush sites.

Silver sagebrush (*Artemisia cana*) has been separated into three varieties; var. *bolanderi* or Bolander silver sagebrush, var. *cana* or plains silver sagebrush, and var. *viscidula* or mountain silver sagebrush (Beetle and Johnson 1982). Although the three varieties grow on distinctly different sites, Cronquist et al. (1994) report there is little taxonomic distinction between them. All silver sagebrush subspecies resprout from the base following fire or top removal. Bolander silver sagebrush occupies internally drained basins below 1,700 m

in southeastern Oregon and adjacent areas in western Idaho and northern Nevada and California (Winward 1980). Soils are clayey, alkaline, and generally have standing water in the spring. Understory vegetation is sparse with few grasses and forbs.

Plains silver sagebrush is widespread over the northern Great Plains at elevations of 1,200 to 2,100 m and occupies well-drained alluvial flats, terraces valley bottoms, and drainage ways (Hazlett and Hoffman 1975, Morris et al. 1976, and Beetle and Johnson 1982). *Achillea*, *Allium*, *Antennaria*, *Aster*, *Eriogonum*, *Lomatium*, and *Potentilla* are common forb genera associated with plains silver sagebrush stands.

Mountain silver sagebrush is widespread in the western United States at elevations of 1,700 to 3,000 m, along streams and meadow margins where soils are not well drained (Morris et al. 1976, Winward 1980, Beetle and Johnson 1982). Winward (1980) reported that plant communities of mountain silver sagebrush are rich floristically in both grasses and forbs. A wide variety of upland and moist site grasses, rushes (*Juncus* spp.), sedges (*Carex* spp.), and forbs are commonly found. Several species of *Aster*, *Erigeron*, *Lomatium*, *Senecio*, *Taraxacum*, and *Trifolium* are usually associated with this community.

Other Vegetation Zones

Diversity of the sagebrush biome is greatly increased by encompassing other vegetation zones. Salt-desert shrublands, pinyon-juniper woodlands, and riparian communities are major vegetation zones associated with the sagebrush biome. Ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), aspen (*Populus tremuloides*), tall forb, and mountain brush vegetation zones are also located with the sagebrush biome. Salt-desert shrublands including the shadscale zone replace sagebrush where precipitation is not adequate (Billings 1949) and on halomorphic soils (West 1983). This ecosystem type, covering 16.9×10^6 ha, is primarily found in the Great Basin and secondarily on the Colorado Plateau. Incidental reports of sage grouse use have occurred in the salt-desert however, use of this cover type is probably marginal (J.A. Crawford personal communication, 1998). Edges of salt-desert communities may be more frequently used when associated with more desirable plant community types. Total plant cover usually ranges from 0 to 20%.

Pinyon-juniper woodlands are widely scattered throughout the sagebrush biome on areas receiving ≥ 30 cm of precipitation. These woodlands occupy over 29 million ha in the Intermountain Region (West 1984, 1999) and occur on a wide variety of soils. Separation of woodlands from many sagebrush communities, particularly low and big sagebrush, is unclear since it has been actively invading these communities during the past 130 years and tree densities range from open to closed woodlands (West 1988, Miller and Wigand 1994, Miller and Rose 1995). Stage of woodland encroachment probably dictates the level of use by sage grouse.

Riparian areas and meadows are important sage grouse cover types associated with the sagebrush biome. Riparian areas greatly extend the season of available succulent plants for sage grouse well into the summer. Riparian communities are scattered throughout most of the sagebrush biome. Dominant grass-like genera include *Carex*, *Juncus*, *Eleocharis*, and *Scirpus* (Winward 1994). Grass genera include *Calamagrostis*, *Glyceria*, *Poa*, *Phalaris*, and *Distichlis*. Although forbs are normally present, only a few genera are common: *Caltha*, *Mertensia*, *Pedicularis*, *Cammassia* and *Smilacina*. Vegetation structure is highly variable in this type. The potential for woody vegetation to dominate a riparian zone is generally associated with deep soils, drainage, and stream gradient. Klebenow (1985) and Evans (1986) reported sage grouse avoided wet meadows with large amounts of tall shrubs.

Temporal Change

A Prehistoric Perspective

Before Eurasian settlement, the sagebrush biome underwent both long term and short term changes. Changes varied from large spatial shifts in plant distribution, to shifts in community structure and composition, to mass extinction of plants and animals.

Long-Term Climate Cycles

Areas of the western United States, which are now sage grouse habitat have undergone many changes during the past 2,000,000 years (Tausch et al. 1993). During this period there have been numerous glacial advances lasting from 50,000 to 100,000 years, which were separated by interglacial periods of 10,000- to 20,000-years (van Donk 1976). During the last 850,000 years, interglacial cycles have accounted for only 10% of the period (Tausch et al. 1993). From a long-term perspective, the Holocene, which began at the end of the last glacial period 10,000 years ago, can be viewed as a drought.

During the Pleistocene period, the sagebrush steppe was located in the southwest currently dominated by creosote bush. As warming occurred, ending the Pleistocene, plants responded to change in climate through migration, hybridization, or extinction (Tausch et al. 1993). Plant communities, however, did not migrate as intact assemblages. Distribution of individual species changed in different directions and at different rates creating new community patterns (Graham and Grimm 1990). During the Holocene, climate fluctuated with periods of cooler/wetter, cooler/drier, warmer/drier, and warmer/wetter patterns than those of the present (Antevs 1938, Davis 1982).

Short-Term Climate Cycles

Throughout much of the sage grouse range, climate is generally semiarid and highly variable. Prolonged periods of below or above average precipitation are common. Years of subnormal precipitation (<85% of the mean) occur 20 to 30% of the time across much of the sage grouse range, reaching 40% occurrence in the southwest (Stoddart et al. 1976, West 1983).

Short-term climatic cycles greatly affect sage grouse habitat through influencing plant succession, particularly following a disturbance event, abundance of herbaceous cover and food, and duration of forb availability. The forb component is generally the most dynamic plant group compared to grasses and shrubs (Passey et al. 1982). In southeastern Oregon, species numbers fluctuated from a low of 27 during a dry year to a high of 41 in a wet year in three Wyoming big sagebrush/Thurber needlegrass (*Stipa thurberiana*) sites (Table 3) (EOARC data on file). Forb abundance changed up to four fold between dry and wet years.

Table 3. The number of plant species with aboveground biomass and % mean precipitation occurring in three Wyoming big sagebrush/Thurber needlegrass livestock exclosures in southeastern Oregon over three consecutive years (EOARC data file).

Year	# of Species	Kg/ha		% of Ave. PPT ¹
		Perennial Forb Biomass	Total Herbaceous Biomass	
1992	30-31	45	200	86
1993	35-41	75	580	185
1994	27-30	19	110	50

¹ Mean precipitation over a 42 year period = 280 mm

Air temperatures and soil moisture also affect seasonal availability of succulent forbs, which can be terminated as early as late spring or extended into mid to late summer. The length of the growing season has an affect on sage grouse movements (Klebenow 1985). In near average moisture years, birds moved from uplands to meadows and riparian areas where succulent forbs were still available during mid to late summer (Wallested 1971, Autenrieth 1981, Dunn and Braun 1986). In dry years as forbs become desiccated, sage grouse moved to wet areas earlier in the season however, in good moisture years birds often remained in uplands sites and forbs remained relatively high in their diet. In drought years, young chicks were found to consume greater amounts of sagebrush and lower amounts of forbs (Drut et al. 1994a).

Fire

Before European settlement, fire had an important role in some sagebrush steppe community types, increasing the dominance of many herbaceous species while reducing the abundance of woody plants (Daubenmire 1968, Burkhardt and Tisdale 1976, Wright et al. 1979, Gruel 1985). Presettlement fires are thought to have occurred every 100 to 200 years in low sagebrush community types (Young and Evans 1981, Miller and Rose 1999) and 50 to 100 years in the more arid sagebrush steppe types (Wright and Bailey 1982). However, on more productive sagebrush sites characterized by mountain big

sagebrush, fire return intervals have been reported to occur between 12 and 25 years (Houston 1973, Burkhardt and Tisdale 1976, Gruell et al. 1994, Miller and Rose 1999). In the Great Basin and Colorado Plateau sagebrush subdivisions, presettlement fire events were less frequent because of limited fuels compared to big sagebrush communities to the north.

Many herbaceous species in the Intermountain sagebrush steppe are well adapted to fire (Table 4), whereas big and low sagebrush and young juniper species less than 50 years old are easily killed by fire (Blaisdell 1953, Wright and Klemmedson 1965, Conrad and Poulton 1966, Burkhardt and Tisdale 1976, Wright and Bailey 1982, Young and Miller 1985). Sagebrush must reestablish from seed from nearby sources or seed reservoirs produced during the previous growing season. Forb species, which resprout belowground from a caudex, corm, bulb, rhizome, or rootstock exhibit rapid recovery following fire. Annual and biennial forbs usually increase following fire through seed dispersal mechanisms. However, forbs that are suffrutescent, low-growing, or mat-forming such as pussytoes or buckwheat can be severely damaged by fire.

A Historic Perspective

Significant changes in plant community structure and composition have occurred across the sagebrush biome and associated vegetation zones during the late 19th and 20th centuries (Miller et al. 1994). Like communities of the past, vegetation assemblages of today are a function of climate, topography, soils, and disturbance. However, the cause of unprecedented changes across the landscape during a relatively short time scale was the result of a shift in the intensity, frequency, and types of disturbance regimes.

Pre-Settlement Communities

Just prior to Eurasian settlement, plant communities in the sagebrush biome had developed under several hundred years of cold wet conditions (the Little Ice Age) (Neilson 1986, Pielou 1991) and wetter and milder conditions during settlement from 1850 to 1916 (Antevs 1948, Graumlich 1985). The Wyoming big sagebrush and low sagebrush cover types, with less frequent disturbance events but slower recovery rates, and the mountain big sagebrush cover type with more frequent disturbance but faster recovery rates created a mosaic of multiple seral stages across the landscape. In addition, fire patterns were patchy, leaving unburned islands, particularly in Wyoming big sagebrush cover types because of limited and discontinuous fuels. Plant composition ranged from dominant stands of sagebrush to grasslands. However, a large portion of the sagebrush steppe ecosystem type was probably composed of open stands of shrubs with a strong component of long-lived perennial grasses and forbs (Hanson and Stoddart 1940, Blaisdell 1953, Christensen and Johnson 1964, Daubenmire 1970, Laycock 1978, Rogers 1982).

Table 4. Relative response of forbs common to the sagebrush biome to fire, herbicide (2,4-D) application, and grazing by cattle and sheep. (S = Severely Damaged, O = Zero to Slight Damage, U = Undamaged, + = increases, - = declines).

Species	Fire ¹	Herbicide ²	Grazing ³	
			Cattle	Sheep
<i>Achillea millifolium</i>	O+	O-U+	U+	U
<i>Agoseris</i> spp.	U	O	O	S
<i>Allium accuminata</i>	U		U	U
<i>Antennaria</i> spp.	O-U	O	U	U
<i>Antennaria</i> (<i>mat</i> spp.)	S	S	U+	U
<i>Astragalus</i> spp.	O-U	S-U	O-U	O-
<i>Arenaria</i> spp.	S	S-U	U	U
<i>Aster</i> spp.	U+	O-U+	U	U
<i>Astragalus purshii</i>	O	O	U	U
<i>Balsamorhiza</i> spp.	U+	S	O-U	O
<i>Castilleja</i> spp.	U	S	O	O
<i>Crepis</i> spp.	O+	U	O	S-
<i>Erigeron</i> spp.	U	O	O-U	O
<i>Eriogonum</i> spp.	S	U	U	O
<i>Eriogonum hieracleoides</i>	S	O	U	O
<i>Geranium</i> spp.	O+	O-U	O	S-
<i>Geum</i> spp.	O-U	S	O	O
<i>Lactuca serriola</i>	O-U	O-U	U+	O
<i>Lomatium</i> spp.	U	O	O	O-
<i>Lupinus</i> spp.	U+	S	U	U+
<i>Mertensia</i> spp.	O-U	S	O	-
<i>Microsteris gracilis</i>	U	O	U+	O
<i>Penstemon</i> spp.	O	S-O	O	S
<i>Phlox longifolia</i>	U+	O	O-U	S
<i>Phlox hoodii</i>	S	O-U+	U+	O
<i>Potentilla</i> spp.	U+	S-O	U+	O
<i>Senecio intergerrimus</i>	O	O	O	O
<i>Solidago</i> spp.	U	U	O	O
<i>Taraxicum</i> spp.	U	O	O	O
<i>Tragopogon dubius</i>	O	U+	U+	O
<i>Trifolium macrocephalum</i>	U	S	S	S
<i>Zigadenus paniculatus</i>		S	U	U

¹ Fire: Blaisdell 1953, Pehanec et al.1954, Lyon and Stickney 1976, Klebenow and Beall 1977, Wright et al. 1979, Volland and Dell 1981, Bradley et al. 1992

² Herbicide (2,4-D): Payne 1973, Blaisdell et al 1982

³ Grazing: from Laycock 1956, Mason 1971, Mueggler and Stewart 1980

New Post-Settlement Disturbance Factors

Settlement introduced new factors into the disturbance equation, which affected the composition and structure of plant communities and landscapes in the sagebrush biome. These included livestock, competitive alien plant species, cultivation, pesticides, water diversion, roads, mining, altered fire frequencies, recreation, urban development, and the increase in atmospheric pollution. In addition, unregulated hunting during this period of settlement in the West caused deer, elk, antelope, and sage grouse populations to decline to low levels (Klebenow 1985, Urness 1989). Predators such as wolves (*Canis lupis*), coyotes (*Canis lantrons*), and grizzly bears (*Urus arctos*) were also hunted aggressively and poisoned (Oliphant 1968) as soon as livestock entered the sagebrush country in the mid to late 1800s. All of these factors, interacting with a gradual change in climate (Easterling 1990, Ghil and Vautgard 1991), had a cumulative effect on the landscape since settlement.

Settlement in much of the Intermountain Region began in the 1840s in Utah and the late 1860s in eastern Oregon and Nevada (Oliphant 1968, West 1983). From 1870 through the early 1900s, numbers of cattle, sheep, and horses rapidly increased peaking at the turn of the century (Oliphant 1968, Young et al. 1976), with an estimated 26 million cattle and 20 million sheep in the West (Wilkenson 1992). Excessive stocking and little to no livestock management during this period caused major changes in plant community composition and structure in less than 10 to 15 years (Hull 1976). By the 1930s, grazing capacity of much of the western ranges had declined 60 to 90 percent (McArdle et al. 1936). Many exotic plant species were introduced during this period, some imported with wheat seed. By the 1940s, animal unit months (1,000 pound mature cow or equivalent) on federal land was estimated to be 14.6 million increasing to 16.5 million in the 1950s and gradually declining to 10.2 million by the 1990s. Domestic sheep numbers have declined at a more rapid rate than cattle.

In the late 1940s, mechanical and chemical control of vegetation were initiated on rangelands. On an annual basis, the area of rangelands treated peaked in the late 1950s and 1960s (Table 5). Many of the areas treated had already lost the majority of the native perennial herbaceous component, particularly those lands plowed and seeded to crested wheatgrass (*Agropyron desertorum*, *A. cristatum*, and *A. sibericum*). However, communities with plant understories still in relatively good condition were often sprayed with phenoxy herbicides (e.g., 2,4-D) to reduce sagebrush and increase native grasses. Documentation on the long term effects of spraying these chemicals on forb composition are limited (Table 4).

Table 5. Total area of sagebrush controlled on Bureau of Land Management land. Treatments include primarily mechanical and chemical control methods, and some prescribed fire. Wildfire, U.S. Forest Service lands, and private lands are not included. Area treated is conservative since not all treatments are reported by districts (Bureau of Land Management Service Center, Denver, CO).

Decade	Hectares Treated
1940s	19,971
1950s	360,234
1960s	1,124,421
1970s	148,374
1980s	109,391
1990-94	53,099

Twentieth Century Plant Communities

The combination of new disturbance factors, introduction of new species combined with continual shifts in climate have created plant communities and landscapes unique from any other time period in the past. One of the greatest factors believed to have caused the decline in sage grouse populations throughout portions of their range has been habitat conversion (Patterson 1952, Braun et al. 1977, Autenrieth 1981). In both the Columbia River Basin and the Snake River Plain, extensive areas of sagebrush steppe have been converted to cropland. Although sage grouse have been reported to use some of these cultivated crops such as fall use of alfalfa (Wallested 1975) these areas, which typically were winter habitat, provide little winter food. Much of the habitat that remains in these areas is fragmented. However, in other portions of the sagebrush biome cultivation has occurred to a lesser extent.

In the nonarable regions of the sagebrush biome, a large portion of sage grouse habitat has primarily been altered through a change in the proportion of trees, shrubs, grasses, and forbs characterizing present day plant communities. Changes in structure and composition in non-cultivated areas is primarily attributed to livestock grazing, introduction of exotic plants, change in fire regimes, and herbicides (Miller et al. 1994). Two common scenarios of plant community change in this region are: (1) an increase in dominance of woody species (shrubs or trees), a decline in fire frequency, and a decrease in perennial forbs and grasses; or (2) an increase in Eurasian weeds, an increase in fire frequencies, and loss of native perennial shrubs, forbs, and grasses.

In the first scenario, over-hanging cover and late summer, fall, and winter sage grouse food are still available from an abundance of shrubs. However, cover provided by herbaceous vegetation and high quality early spring-summer sage grouse food for prelaying hens and brood have been lost. In mountain big sagebrush communities, woodlands can develop, resulting in a near total loss of shrubs and loss of sage grouse habitat (Miller et al. 2000). Where juniper has gained dominance on mountain big sagebrush cover types,

shrub cover declines to <1% and the season of available succulent forms is greatly shortened because of rapid soil moisture depletion.

In the second scenario, herbaceous cover greatly varies from year to year depending on moisture availability; shrub cover is absent; the season of available green plant material is greatly shortened; high quality perennial forbs are scarce; and late summer through winter forage is absent. A third change, which has occurred on moderate to moderately deep soils, is the conversion of large blocks of sagebrush-grasslands seeded to varieties of crested wheatgrass. Understory in these stands prior to conversion was typically in degraded condition with little to no native perennial grasses or forbs and often invaded by introduced species such as cheatgrass (*Bromus tectorum*) and halogeton (*Halogeton glomeratus*). Following conversion, many of these stands lack shrub cover, winter forage, and often are limited in forbs.

In the absence of fire, changes that usually occur with excessive grazing in the different sagebrush types are an increase in density and cover of shrubs, annuals forbs, and annual grasses (especially introduced species), and a decrease in perennial forbs and grasses (Branson 1985, Tisdale 1994). If Sandberg bluegrass is present in the stand, it generally is little affected by fire and typically increases with excessive grazing. Exotic annual grasses such as cheatgrass occur but usually will not dominate in the more mesic and cooler sagebrush types characterized by mountain big sagebrush and low sagebrush above 1500 m in elevation in the northern portion of the sagebrush biome and above 1600m in the southern portion. Cheatgrass usually fares poorly in black sage communities. Medusahead (*Taeniatherum asperum*) can also become abundant on some low sagebrush sites below 1500 m.

Wyoming and basin big sagebrush community types are the most susceptible to invasion by these introduced annuals. The establishment of these highly flammable annuals can eventually convert these sagebrush communities to annual grasslands by increasing the frequency of fire. These Eurasian plant communities dominate more than 40 million ha in the Intermountain West (Mack 1981) of which many can be considered new steady states². These new annual communities will most likely persist even with total removal of livestock (Billings 1990).

The Wyoming big sagebrush community type, the most extensive and more arid of the big sagebrush group, is probably in poorer condition across its range than the more mesic sagebrush types. Many of these communities have been converted to new steady states because of the absence of native perennial forbs and grasses and/or the establishment of aggressive introduced annuals such as cheatgrass, medusahead, halogeton, Russian thistle (*Salsola* spp),

² A plant community that is resistant to change, remaining or returning to its current state following disturbance. However, a major disturbance(s) may change it to a new steady state, in which the community will not return to its former steady state even if the disturbance is removed (Westoby et al. 1989, Laycock 1991) (i.e. new steady states of a sagebrush steppe are annual grassland or closed juniper woodland).

tumble mustard (*Sysimbrium altissimum*), pinnate tansymustard (*Descurania pinnata*), pepperweed (*Lepidium* spp.), and the longer-lived knapweeds (*Centaria* spp.). Even if some native perennial grasses and forbs still remain in Wyoming big sagebrush communities, recovery occurs more slowly than in mountain big sagebrush community types (Tisdale 1994).

Following fire, Wyoming big sagebrush usually reestablishes slowly. Increased continuity and abundance of light fine fuels produced by cheatgrass has shifted fire patterns in these cover types to be more complete, leaving few unburned patches, especially following the second fire event. Unburned patches and edges were probably very important in allowing the reestablishment of sagebrush since seed dissemination is limited to several meters from parent plants. Probably a large majority of annual grasslands dominated by cheatgrass in the Intermountain West were once Wyoming big sagebrush communities.

Mountain and basin big sagebrush generally have a higher capacity for recovery following disturbance than Wyoming big sagebrush. Introduced annuals usually do not dominate mountain big sagebrush communities, and unlike Wyoming big sagebrush, mountain big sagebrush commonly reestablishes rapidly following fire (Tisdale 1994).

Fire was generally not a major factor in community types occupied by the low forms of sagebrush because fuels were limited (Tisdale 1994). Excessive grazing readily depletes palatable understory plants in these types. Sandberg bluegrass is usually little affected by fire and may become the dominant understory species. Recovery is usually slow in the black sage, stiff sage and xeric low sage communities.

Another major change that has occurred primarily in mountain big and low sagebrush community types, and to a lesser extent other associated communities, has been the increase in both pinyon pines (*Pinus monophylla* and *P. edulis*) and juniper (*Juniperus* spp.) throughout the sage grouse range of distribution in the last 130 years (Miller and Wigand 1994). Once a threshold of juniper occupancy on these sites is reached, which varies with site factors, understory species (especially sagebrush and bitterbrush) decline. The density of juniper, at which use by sage grouse decreases or ceases has not been determined. However, in central Oregon, sage grouse avoided western juniper (*J. occidentalis*) communities for nesting and winter use (Bureau of Land Management 1994). Currently many of the mountain big sagebrush and low sagebrush cover types in the early phase of woodland encroachment, which still support populations of sage grouse, will be lost as trees gain dominance on these sites and shrubs are lost. Juniper and pinyon-juniper woodlands also provide minimal herbaceous cover, and the growing season of understory plants is shortened by several weeks (Bates et al. 2000).

Riparian communities have also changed. The severe over-trapping of beaver populations in the early 1800s altered the hydrology in many stream systems, which affected rate of water movement and retention time, stream temperatures, and nutrient cycles (Elmore and Kaufmann 1994). Excessive

livestock numbers and the common practice of year-long or season-long grazing in the late 1800s and into this century resulted in severe degradation of riparian communities throughout the West. Poor livestock distribution, improper season, and/or duration of use has continued to maintain some riparian areas in poor condition. In addition to livestock, roads (often built along drainages), logging, mining, poorly designed engineering projects, and the removal of phreatophytic vegetation further altered these ecosystems (Elmore and Kaufmann 1994).

A major impact of degraded riparian communities on sage grouse is shortening the period when succulent forbs are available during the summer. As water retention in the flood plain is reduced and ecological condition declines, plant species composition usually shifts from mesic to more xeric adapted plants. The end result is a decline in availability of succulent forbs during the summer when upland plants are desiccated.

Management: Influencing Temporal Changes

The goals of managing sage grouse habitat are often focused on acquiring or maintaining an optimal balance of shrubs, forbs, and grasses at community and landscape levels. These goals are and should be analogous with restoring and or maintaining form, function, and process in sagebrush steppe habitats. When considering a sagebrush steppe restoration plan or sage grouse habitat management plan, one must take into account landscape heterogeneity, site potential, site condition, and habitat needs of sage grouse during different segments of their life cycle: breeding, nesting, brood rearing, wintering, etc.

Tools developed for range management have been primarily used to increase the grass component in sagebrush communities. However, with proper planning and well-defined objectives, these tools can also be used to enhance the other two functional groups, shrubs and forbs. The tools selected and how they are used will depend upon, which plant group and/or successional stages are limiting at the site and landscape levels, as well as the resource objectives for the area.

Site potential and extent of degradation must also be considered since they will determine the rate and amount of recovery and resources required to make these changes. For many areas, accurate resource inventories and assessments need to be made before making management decisions as to when and how each community across the landscape unit should be managed. Treatments need to be evaluated on the basis of the response of both undesirable and desirable plants and on the condition of the landscape unit taking into account the response of soil, water, flora, and fauna.

Fire

There has been debate on the benefits of fire to enhance sage grouse habitat. Four factors determine the negative or positive outcome of fire on sage grouse habitat: (1) site potential, (2) site condition, (3) functional plant group(s) that

is limiting, and (4) pattern and/or size of the burn. Fire is a useful tool to enhance native perennial forbs and grasses, particularly in areas where sagebrush is abundant, a good population of native herbs are present, and exotic species are limited. This most often applies to mountain big sagebrush communities where shrub cover can exceed 35% and perennial forbs can increase 2 to 3 fold following fire (Pyle and Crawford 1996, EOARC data file). Fire can also enhance the nutrient quality of forbs especially protein content (McDowell 2000). Sage grouse have been reported to be attracted to burn areas during summer (Klebenow and Beall 1977, Martin 1990). Small burns with adjacent stands of sagebrush have also been used as leks.

In Wyoming big sagebrush communities, there is little evidence that fire will enhance sage grouse habitat where there is a balance of native shrubs and perennial grasses and forbs. Burning in Wyoming big sagebrush communities did not significantly increase desirable forbs used as sage grouse food (Fischer et al. 1996, EOARC data file). In this same community type Fischer et al. (1996) reported a decrease in beetle populations (Hymenoptera), an important chick food (Pyle and Crawford 1996), following a fire. However, Pyle and Crawford (1996) reported fire did not affect beetle populations. Fire in Wyoming big sagebrush has been reported to increase the length of the growing season for forbs important in the diet of sage grouse (Wroblewski 1999). Fire should not be used where sagebrush cover is the limiting factor for sage grouse or where the understory lacks perennial forbs and grasses and introduced annuals are present. The amount of less palatable shrubs that resprout such as rabbitbrush, horsebrush, and snakeweed (*Gutierrezia sarothrae*) in the stand should also be considered. These species increase following a burn and high amounts often indicate a depleted understory.

In summary, the response of native understory species to fire is usually determined by, which end of the moisture spectrum the sagebrush cover type is located and the condition of the site. On the mesic end, fire is a useful tool for increasing amounts, nutrient quality, and season of succulence of perennial and annual forbs important in the sage grouse diet. However, in the drier sagebrush cover types perennial forbs typically are not increased by fire. Fire can open up dense stands of sagebrush and increase landscape level heterogeneity, or homogenize large landscapes by removing the shrub layer and promoting the dominance of introduced annuals.

Grazing Management

Poor livestock grazing practices can have a large negative impact on sage grouse habitat. Probably the greatest long-term negative impact of excessive livestock grazing on sage grouse is the degradation of sagebrush, meadow, and riparian communities. Poor grazing practices change the proportion of the shrub, grass, and forb functional groups, increase opportunity for invasion and dominance of introduced annuals, shorten the growing season, and can cause an overall decline in site potential through loss of topsoil. A decline in site condition often decreases the ability of soils to capture, store and release water

causing sites to become more arid, which in turn provides less green plant material for shorter periods of time. Excessive grazing also increases the potential of direct competition between livestock and sage grouse.

Grazing management practices, which maintain the integrity of sagebrush communities can have positive, neutral, or negative impacts on sage grouse habitat. Season, duration, distribution, and intensity of use, and class of livestock (e.g. cattle, sheep, etc.) will determine the affects of grazing on sage grouse food and cover. Plant composition and structure at the community and landscape levels will also affect potential interactions between livestock and sage grouse. Spatial and temporal heterogeneity of the landscape will affect length of the growing season, regrowth following herbage removal, herbage abundance, and grazing distribution. Topography, size and shape of pastures, and distribution of salt and water will also influence grazing distribution. All of these factors must be considered when developing gazing management plans sensitive to sage grouse habitat requirements.

Possibly the greatest potential conflict under proper grazing practices is the reduction of herbaceous cover, particularly in nesting areas. Gregg (1991) reported the combination of both aerial and horizontal cover were important in determining nesting success. Nesting success was greater on sites that had higher residual cover of tall grasses (≥ 15 -18 cm tall) (Wakkinen 1990, Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998). Diet overlap between cattle and sage grouse under moderate grazing is minimal since cattle are primarily grass rather than forb consumers. However, the potential for diet overlap with sheep is considerably greater. The spatial distribution of use by livestock and sage grouse will influence the relationship between these animals.

Season of use by livestock also influences use in uplands versus adjacent riparian areas. If availability of succulent forbs is an objective, early use might be considered. Several studies have reported grouse prefer meadows grazed by cattle over ungrazed meadows early in the spring (Neel 1980, Klebenow 1985). Evans (1986) found birds did not select for grazed or ungrazed areas in mid summer, but selected for grazed areas in late summer. Attraction to the grazed meadows during late summer was attributed to delayed phenological development. Evans (1986) also reported grazing increased the abundance of succulent leaves favored by grouse. The season and duration of grazing can influence phenology, leafiness, and regrowth of plants. However, overgrazing of meadows can lead to a shortening of the growing season through an increase in meadow desiccation, and loss of palatable food plants for sage grouse.

In developing grazing plans for specific areas used by sage grouse, it is extremely important to identify potential conflicts between sage grouse and livestock, and spatial and temporal heterogeneity of the management unit. Management solutions will vary if the problem is habitat degradation, season of use, stocking rates, or animal distribution. Most of these problems can be solved with sound creative management.

Other Considerations

Management practices, such as plowing, that significantly reduce shrubs and forbs will eliminate grouse habitat. Past use of phenoxy herbicides not only greatly reduced sagebrush cover but also reduced broadleaf forbs (Miller et al. 1980) (Table 4). However, thinning sagebrush stands that restores the balance of forbs and grasses can enhance sage grouse habitat (Klebenow 1969). In Wyoming, application of tebuthiuron reduced sagebrush cover and increased grass production 2 to 4 fold while forbs remained relatively constant (Olson and Whitson 1999). The greatest herbaceous productivity occurred at 3 to 17% sagebrush cover. However, this will vary across sites and subspecies of sagebrush.

Conclusions

Sage grouse occur in regions that are spatially diverse and dynamic due to natural and anthropogenic influences. Although sage grouse habitats are diverse they must meet essential requirements for populations to be successful. When considering a sagebrush steppe restoration plan or sage grouse habitat management plan, one must take into account landscape heterogeneity, site potential, site condition, and habitat needs of sage grouse during different segments of their life cycle: breeding, nesting, brood rearing, wintering, etc. Communities must provide nutritious forbs for prelaying hens and chicks, insects during early chick rearing, sagebrush for late summer and winter food, and grass and shrub cover for nesting and hiding. The challenge to land managers is in identifying how sage grouse requirements will be met in spatially and temporally diverse regions. Much of the western United States is characterized by a high degree of landscape variability and yearly weather fluctuations. Variable year to year weather patterns can cause dramatic short-term shifts in habitats. Factors limiting sage grouse recruitment may also change from year to year. We have a number of restoration tools available for the manipulation of plant community structure and composition to help meet habitat requirements. Thorough resource inventories will be very important for developing management plans that reduce resource conflict between grouse and other uses such as grazing, recreation, etc. It is important we keep these options open particularly since factors limiting grouse recruitment change both spatially and temporally across their range.

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