Guidelines to manage sage grouse populations and their habitats

John W. Connelly, Michael A. Schroeder, Alan R. Sands, and Clait E. Braun

Abstract The status of sage grouse populations and habitats has been a concern to sportsmen and biologists for >80 years. Despite management and research efforts that date to the 1930s, breeding populations of this species have declined throughout much of its range. In May 1999, the western sage grouse (*C. urophasianus phaios*) in Washington was petitioned for listing under the Endangered Species Act because of population and habitat declines (C. Warren, United States Fish and Wildlife Service, personal communication). Sage grouse populations are allied closely with sagebrush (*Artemisia* spp.). Despite the well-known importance of this habitat to sage grouse and other sagebrush obligates, the quality and quantity of sagebrush habitats have declined for at least the last 50 years. Braun et al. (1977) provided guidelines for maintenance of sage grouse habitats. Since publication of those guidelines, much more information has been obtained on sage grouse. Because of continued concern about sage grouse and their habitats and a significant amount of new information, the Western States Sage and Columbian Sharp-tailed Grouse Technical Committee, under the direction of the Western Association of Fish and Wildlife Agencies, requested a revision and expansion of the guidelines originally published by Braun et al. (1977). This paper summarizes the current knowledge of the ecology of sage grouse and, based on this information, provides guidelines to manage sage grouse populations and their habitats.

Key words *Artemisia, Centrocercus urophasianus,* guidelines, habitat, management, populations, sage grouse, sagebrush

The status of sage grouse populations and habitats has been a concern to sportsmen and biologists for >80 years (Hornaday 1916, Patterson 1952, Autenrieth 1981). Despite management and research efforts that date to the 1930s (Girard 1937), breeding populations of this species have declined by at least 17–47% throughout much of its range (Connelly and Braun 1997). In May 1999, the western sage grouse (*C. urophasianus phaios*) in Washington was petitioned for listing under the Endangered Species Act because of population and habitat declines (C. Warren, United States Fish and Wildlife Service, personal communication).

Sage grouse populations are allied closely with sagebrush (*Artemisia* spp.) habitats (Patterson 1952, Braun et al. 1977, Braun 1987). The dependence of sage grouse on sagebrush for winter habitat has been well documented (Eng and Schladweiler 1972, Beck 1975, Beck 1977, Robertson 1991). Similarly, the relationship between sagebrush

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Sage grouse on a nest with good shrub and herbaceous cover. The nest was successful.

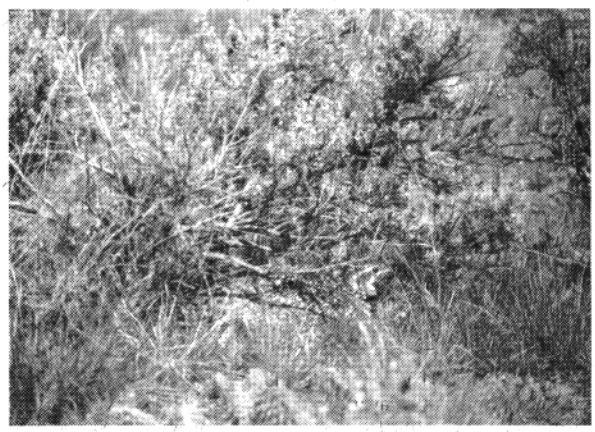
habitats and sage grouse nest success has been described thoroughly (Klebenow 1969, Wallestad and Pyrah 1974, Wakkinen 1990, Connelly et al. 1991, Gregg et al. 1994). Despite the well-known importance of this habitat to sage grouse and other sagebrush obligates (Braun et al. 1976, Saab and Rich 1997), the quality and quantity of sagebrush habitats have declined for at least the last 50 years (Braun et al. 1976, Braun 1987, Swenson et al. 1987, Connelly and Braun 1997).

Braun et al. (1977) provided guidelines for maintenance of sage grouse habitats. Since publication of those guidelines, much more information has been obtained on relative size of sagebrush habitats used by these grouse (Connelly 1982, Connelly et al. 1988, Wakkinen et al. 1992), seasonal use of sagebrush habitats (Benson et al. 1991, Connelly et al. 1991), effects of insecticides on sage grouse (Blus et al. 1989), importance of herbaceous cover in breeding habitat (Wakkinen 1990, Connelly et al. 1991, Gregg 1991, Barnett and Crawford 1994, Drut et al. 1994*a*, Gregg et al. 1994), and effects of fire on their habitat (Hulet 1983, Benson et al. 1991; Robertson 1991; Fischer 1994; Fischer et al. 1996*a*, 1997; Pyle and Crawford 1996; Connelly et al. 2000*b*). Because of continued concern about sage grouse and their habitats and a significant amount of new information, the Western States Sage and Columbian Sharp-tailed Grouse Technical Committee, under the direction of the Western Association of Fish and Wildlife Agencies, requested a revision and expansion of the guidelines originally published by Braun et al. (1977). This paper summarizes the current knowledge of the ecology of sage grouse and, based on this information, provides guidelines to manage sage grouse populations and their habitats.

Population biology

Seasonal movements and home range

Sage grouse display a variety of annual migratory patterns (Beck 1975, Wallestad 1975, Hulet 1983, Berry and Eng 1985, Connelly et al. 1988, Wakkinen 1990, Fischer 1994). Populations may have: 1) distinct winter, breeding, and summer areas; 2) distinct summer areas and integrated winter and breeding areas; 3) distinct winter areas and integrated breeding and summer areas; or 4) well-integrated seasonal habitats (nonmigratory populations). Seasonal movements between distinct seasonal ranges may exceed 75 km (Dalke et al. 1963, Connelly et al. 1988), which complicates attempts to define populations. Thus, Connelly et al. (1988) suggested that sage grouse populations be defined on a temporal and geographic basis. Because of differences in seasonal movements among populations (Dalke et al. 1963, Wallestad 1975, Connelly et al. 1988, Wakkinen 1990), 3 types of sage grouse populations can



Sage grouse on a nest with poor shrub and herbaceous cover. This nest was unsuccessful. Photo by Jena Hickey.

Sage grouse on winter range. Note the relatively sparse cover; without snow, the canopy cover of sagebrush in this area exceeds 20%.

be defined: 1) nonmigratory, grouse do not make long-distance movements (i.e., >10 km one way) between or among seasonal ranges; 2) one-stage migratory, grouse move between 2 distinct seasonal ranges; and 3) 2-stage migratory, grouse move among 3 distinct seasonal ranges. Within a given geographic area, especially summer range, there may be birds that belong to more than one of these types of populations.

On an annual basis, migratory sage grouse populations may occupy areas that exceed 2,700 km^2 (Hulet 1983, Leonard et al. 2000). During winter, Robertson (1991) reported that migratory sage grouse in southeastern Idaho made mean daily movements of 752 m and occupied an area $\geq$140 km^2. For a nonmigratory population in Montana, Wallestad (1975) reported that winter home range size ranged from 11 to 31 km^2. During summer, migratory sage grouse in Idaho occupied home ranges of 3 to 7 km^2 (Connelly and Markham 1983, Gates 1983).

Despite large annual movements, sage grouse have high fidelity to seasonal ranges (Keister and Willis 1986, Fischer et al. 1993). Females return to the same area to nest each year (Fischer et al. 1993) and may nest within 200 m of their previous year's nest (Gates 1983, Lyon 2000).

Survival

Wallestad (1975) reported that annual survival rates for yearling and adult female sage grouse were 35 and 40%, respectively, for poncho-tagged birds. However, Zablan (1993) reported that survival rates for banded yearling and adult females in Colorado were similar and averaged 55%; survival rates for yearling and adult males differed, averaging 52 and 38%, respectively. In Idaho, annual survival of male sage grouse ranged from 46 to 54% and female survival from 68 to 85% (Connelly et al. 1994). Lower survival rates for males may be related to physiological demands because of sexual dimorphism and greater predation rates (Swenson 1986).

Reproduction

Bergerud (1988) suggested that most female tetraonids nest as yearlings. Although essentially all female sage grouse nested in Washington (Schroeder 1997), Connelly et al. (1993) reported that in Idaho up to 45% of yearling and 22% of adult female sage grouse do not nest each year. Gregg (1991) indicated that, of 119 females monitored through the breeding season in eastern Oregon, 26 (22%) did not nest. However, Coggins (1998) reported a 99% nest initiation rate for 3 years for the same population in Oregon. The differences may be related to improved range condition that resulted in better nutritional status of pre-laying hens (Barnett and Crawford 1994).

Estimates of sage grouse nest success throughout the species' range vary from 12 to 86% (Trueblood 1954, Gregg 1991, Schroeder et al. 1999). Nest success also may vary on an annual basis (Schroeder 1997, Sveum et al. 1998*a*). Wallestad and Pyrah (1974) observed greater nest success by adults than yearlings. However, significant differences in nest success between age groups have not been reported in other studies (Connelly et al. 1993, Schroeder 1997).

Clutch size of sage grouse is extremely variable and relatively low compared to other species of gamebirds (Edminster 1954, Schroeder 1997). Average clutch size for first nests varies from 6.0 to

Sage grouse nest. Photo by Jena Hickey.

9.5 throughout the species' range (Sveum 1995, Schroeder 1997). Greatest and least average clutch sizes have been reported in Washington (Sveum 1995, Schroeder 1997).

Renesting by sage grouse varies regionally from <20% (Patterson 1952, Eng 1963, Hulet 1983, Connelly et al. 1993) to >80% (Schroeder 1997). Despite regional variation, differences in renesting rates due to age have not been documented (Connelly et al. 1993, Schroeder 1997). Because of variation in nest initiation, success, and renesting rates, the proportion of females successfully hatching a brood varies between 15 and 70% (Wallestad and Pyrah 1974, Gregg et al. 1994). Despite this variation, sage grouse generally have low reproductive rates and high annual survival compared to most gallinaceous species (Zablan 1993, Connelly et al. 1994, Connelly and Braun 1997, Schroeder 1997, Schroeder et al. 1999).

Little information has been published on mortality of juvenile sage grouse or the level of production necessary to maintain a stable population. Among western states, long-term ratios have varied from 1.40 to 2.96 juveniles/hen in the fall; since 1985 these ratios have ranged from 1.21 to 2.19 (Connelly and Braun 1997). Available data suggest that a ratio ≥2.25 juveniles/hen in the fall should result in stable to increasing sage grouse populations (Connelly and Braun 1997, Edelmann et al. 1998).

Habitat requirements

Breeding habitats

Leks, or breeding display sites, typically occur in open areas surrounded by sagebrush (Patterson 1952, Gill 1965); these sites include, but are not limited to, landing strips, old lakebeds, low sagebrush flats and ridge tops, roads, cropland, and burned areas (Connelly et al. 1981, Gates 1985). Sage grouse males appear to form leks opportunistically at sites within or adjacent to potential nesting habitat. Although the lek may be an approximate center of annual ranges for nonmigratory populations (Eng and Schladweiler 1972, Wallestad and Pyrah 1974, Wallestad and Schladweiler 1974), this may not be the case for migratory populations (Connelly et al. 1988, Wakkinen et al. 1992). Average distances between nests and nearest leks vary from 1.1 to 6.2 km, but distance from lek of female capture to nest may be >20 km (Autenrieth 1981, Wakkinen et al. 1992, Fischer 1994, Hanf et al. 1994, Lyon 2000). Nests are placed independent of lek location (Bradbury et al. 1989, Wakkinen et al. 1992).

Habitats used by pre-laying hens also are part of the breeding habitat. These areas should provide a diversity of forbs high in calcium, phosphorus, and protein; the condition of these areas may greatly affect nest initiation rate, clutch size, and subsequent reproductive success (Barnett and Crawford 1994, Coggins 1998).

Most sage grouse nests occur under sagebrush (Patterson 1952, Gill 1965, Gray 1967, Wallestad and Pyrah 1974), but sage grouse will nest under other plant species (Klebenow 1969, Connelly et al. 1991, Gregg 1991, Sveum et al. 1998*a*). However, grouse nesting under sagebrush experience greater nest success (53%) than those nesting under other plant species (22%, Connelly et al. 1991).

Table 1. Habitat characteristics associated with sage grouse nest sites.

	Sagebrush		Grass		
State	Height[a](cm)	Coverage (%)[b]	Height(cm)	Coverage(%)[c]	Reference
Colo.	52				Petersen 1980
Id.		15		4	Klebenow 1969
Id.	58–79	23–38			Autenrieth 1981
Id.	71	22	18	3–10	Wakkinen 1990
Id.			19–23	7–9	Connelly et al. 1991
Id.	61		22	30	Fischer 1994
Id.		15–32	15–30		Klott et al. 1993
Id.	69	19	34	15	Apa 1998
Mont.	40	27			Wallestad 1975
Oreg.	80	20			Keister and Willis 1986
Oreg.		24	14	9–32	Gregg 1991
Wash.		20		51	Schroeder 1995
Wash.		19		32	Sveum et al. 1998*a*
Wyo.	36				Patterson 1952
Wyo.	29	24	15	9	Heath et al. 1997
Wyo.	31	25	18	5	Holloran 1999
Wyo.	33	26	21	11	Lyon 2000

[a] Mean height of nest bush.
[b] Mean canopy coverage of the sagebrush surrounding the nest.
[c] Some coverage estimates may include both grasses and forbs.

Mean height of sagebrush most commonly used by nesting grouse ranges from 29 to 80 cm (Table 1), and nests tend to be under the tallest sagebrush within a stand (Keister and Willis 1986, Wakkinen 1990, Apa 1998). In general, sage grouse nests are placed under shrubs having larger canopies and more ground and lateral cover as well as in stands with more shrub canopy cover than at random sites (Wakkinen 1990, Fischer 1994, Heath et al. 1997, Sveum et al. 1998*a*, Holloran 1999). Sagebrush cover near the nest site was greater around successful nests than unsuccessful nests in Montana (Wallestad and Pyrah 1974) and Oregon (Gregg 1991). Wallestad and Pyrah (1974) also indicated that successful nests were in sagebrush stands with greater average canopy coverage (27%) than those of unsuccessful nests (20%). Gregg (1991) reported that sage grouse nest success varied by cover type. The greatest nest success occurred in a mountain big sagebrush (*A. t. tridentata vaseyana*) cover type where shrubs 40–80 cm in height had greater canopy cover at the site of successful nests than at unsuccessful nests (Gregg 1991). These observations were consistent with the results of an artificial nest study showing greater coverage of medium-height shrubs improved success of artificial nests (DeLong 1993, DeLong et al. 1995).

Grass height and cover also are important components of sage grouse nest sites (Table 1). Grass associated with nest sites and with the stand of vegetation containing the nest was taller and denser than grass at random sites (Wakkinen 1990, Gregg 1991, Sveum et al. 1998*a*). Grass height at nests under non-sagebrush plants was greater ($P<0.01$) than that associated with nests under sagebrush, further suggesting that grass height is an important habitat component for nesting sage grouse (Connelly et al. 1991). Moreover, in Oregon, grass cover was greater at successful nests than at unsuccessful nests (Gregg 1991). Grass >18 cm in height occurring in stands of sagebrush 40–80 cm tall resulted in lesser nest predation rates than in stands with lesser grass heights (Gregg et al. 1994). Herbaceous cover associated with nest sites may provide scent, visual, and physical barriers to potential predators (DeLong et al. 1995).

Early brood-rearing areas occur in upland sagebrush habitats relatively close to nest sites, but movements of individual broods may vary (Connelly 1982, Gates 1983). Within 2 days of hatching, one brood moved 3.1 km (Gates 1983). Early brood-rearing habitats may be relatively open

Radiotelemetry and a pointing dog are used to capture sage grouse chicks for a research project in southeastern Idaho.

(about 14% canopy cover) stands of sagebrush (Martin 1970, Wallestad 1971) with ≥15% canopy cover of grasses and forbs (Sveum et al. 1998*b*, Lyon 2000). Great plant species richness with abundant forbs and insects characterize brood areas (Dunn and Braun 1986, Klott and Lindzey 1990, Drut et al. 1994*a*, Apa 1998). In Oregon, diets of sage grouse chicks included 34 genera of forbs and 41 families of invertebrates (Drut et al. 1994*b*). Insects, especially ants (Hymenoptera) and beetles (Coleoptera), are an important component of early brood-rearing habitat (Drut et al. 1994*b*, Fischer et al. 1996*a*). Ants and beetles occurred more frequently ($P=0.02$) at brood-activity centers compared to nonbrood sites (Fischer et al. 1996*a*).

Summer–late brood-rearing habitats

As sagebrush habitats desiccate, grouse usually move to more mesic sites during June and July (Gill 1965, Klebenow 1969, Savage 1969, Connelly and Markham 1983, Gates 1983, Connelly et al. 1988, Fischer et al. 1996*b*). Sage grouse broods occupy a variety of habitats during summer, including sagebrush (Martin 1970), relatively small burned areas within sagebrush (Pyle and Crawford 1996), wet meadows (Savage 1969), farmland, and other irrigated areas adjacent to sagebrush habitats (Connelly and Markham 1983, Gates 1983, Connelly et al. 1988). Apa (1998) reported that sites used by grouse broods had twice as much forb cover as independent sites.

Fall habitats

Sage grouse use a variety of habitats during fall. Patterson (1952) reported that grouse move from summer to winter range in October, but during

mild weather in late fall, some birds may still use summer range. Similarly, Connelly and Markham (1983) observed that most sage grouse had abandoned summering areas by the first week of October. Fall movements to winter range are slow and meandering and occur from late August to December (Connelly et al. 1988). Wallestad (1975) documented a shift in feeding habits from September, when grouse were consuming a large amount of forbs, to December, when birds were feeding only on sagebrush.

Winter habitats

Characteristics of sage grouse winter habitats are relatively similar throughout most of the species' range (Table 2). Eng and Schladweiler (1972) and Wallestad (1975) indicated that most observations of radiomarked sage grouse during winter in Montana occurred in sagebrush habitats with >20% canopy cover. However, Robertson (1991) indicated that sage grouse used sagebrush habitats that had average canopy coverage of 15% and average height of 46 cm during 3 winters in southeastern Idaho. In Idaho, sage grouse selected areas with greater canopy cover of Wyoming big sagebrush (*A. t. wyomingensis*) in stands containing taller shrubs when compared to random sites (Robertson 1991).

Table 2. Characteristics of sagebrush at sage grouse winter-use sites.

	Canopy		
State	Coverage[a] (%)	Height[a] (cm)	Reference
Colo.		24–36[bd]	Beck 1977
Colo.		20–30[cd]	Beck 1977
Colo.	43[b]	34[b]	Schoenberg 1982
Colo.	37[c]	26[c]	Schoenberg 1982
Colo.	30–38[de]	41–54[de]	Hupp 1987
Id.	38[e]	56[e]	Autenrieth 1981
Id.	26[b]	29[b]	Connelly 1982
Id.	25[c]	26[c]	Connelly 1982
Id.	15	46	Robertson 1991
Mont.	27	25	Eng and Schladweiler 1972
Mont.	>20		Wallestad 1975
Oreg.	12–17[d]		Hanf et al. 1994

[a] Mean canopy coverage or height of sagebrush above snow.
[b] Males
[c] Females
[d] Ranges are given when data were provided for more than one year or area.
[e] No snow present when measurements were made or total height of plant was measured.

In Colorado, sage grouse may be restricted to <10% of the sagebrush habitat because of variation in topography and snow depth (Beck 1977, Hupp and Braun 1989). Such restricted areas of use may not occur throughout the species' range because in southeastern Idaho, severe winter weather did not result in the grouse population greatly reducing its seasonal range (Robertson 1991).

During winter, sage grouse feed almost exclusively on leaves of sagebrush (Patterson 1952, Wallestad et al. 1975). Although big sagebrush dominates the diet in most portions of the range (Patterson 1952; Wallested et al. 1975; Remington and Braun 1985; Welch et al. 1988, 1991), low sagebrush (*A. arbuscula*), black sagebrush (*A. nova*, Dalke et al. 1963, Beck 1977), fringed sagebrush (*A. frigida*, Wallestad et al. 1975), and silver sagebrush (*A. cana*, Aldridge 1998) are consumed in many areas depending on availability. Sage grouse in some areas apparently prefer Wyoming big sagebrush (Remington and Braun 1985, Myers 1992) and in other areas mountain big sagebrush (Welch et al. 1988, 1991). Some of the differences in selection may be due to preferences for greater levels of protein and the amount of volatile oils (Remington and Braun 1985, Welch et al. 1988).

Effects of habitat alteration

Range management treatments

Breeding habitat. Until the early 1980s, herbicide treatment (primarily with 2,4-D) was the most common method to reduce sagebrush on large tracts of rangeland (Braun 1987). Klebenow (1970) reported cessation of nesting in newly sprayed areas with < 5% live sagebrush canopy cover. Nesting also was nearly nonexistent in older sprayed areas containing about 5% live sagebrush cover (Klebenow 1970). In virtually all documented cases, herbicide application to blocks of sagebrush rangeland resulted in major declines in sage grouse breeding populations (Enyeart 1956, Higby 1969, Peterson 1970, Wallestad 1975). Effects of this treatment on sage grouse populations seemed more severe if the treated area was subsequently seeded to crested wheatgrass (*Agropyron cristatum*, Enyeart 1956).

Using fire to reduce sagebrush has become more common since most uses of 2,4-D on public lands were prohibited (Braun 1987). Klebenow (1972) and Sime (1991) suggested that fire may benefit sage grouse populations. Neither Gates (1983),

Martin (1990), nor Bensen et al. (1991) reported adverse effects of fire on breeding populations of sage grouse. In contrast, following a 9-year study, Connelly et al. (1994, 2000*b*) indicated that prescribed burning of Wyoming big sagebrush during a drought period resulted in a large decline (>80%) of a sage grouse breeding population in southeastern Idaho. Additionally, Hulet (1983) documented loss of leks from fire and Nelle et al. (2000) reported that burning mountain big sagebrush stands had long-term negative impacts on sage grouse nesting and brood-rearing habitats. Canopy cover in mountain big sagebrush did not provide appropriate nesting habitat 14 years after burning (Nelle et al. 2000). The impact of fire on sage grouse populations using habitats dominated by silver sagebrush (which may resprout following fire) is unknown.

Cheatgrass (*Bromus tectrorum*) will often occupy sites following disturbance, especially burning (Valentine 1989). Repeated burning or burning in late summer favors cheatgrass invasion and may be a major cause of the expansion of this species (Vallentine 1989). The ultimate result may be a loss of the sage grouse population because of long-term conversion of sagebrush habitat to rangeland dominated by an annual exotic grass. However, this situation largely appears confined to the western portion of the species' range and does not commonly occur in Wyoming (J. Lawson, Wyoming Department of Game and Fish, personal communication).

Mechanical methods of sagebrush control have often been applied to smaller areas than those treated by herbicides or fire, especially to convert rangeland to cropland. However, adverse effects of this type of treatment on sage grouse breeding populations also have been documented. In Montana, Swenson et al. (1987) indicated that the number of breeding males declined by 73% after 16% of their study area was plowed.

Brood-rearing habitats. Martin (1970) reported that sage grouse seldom used areas treated with herbicides to remove sagebrush in southwestern Montana. In Colorado, Rogers (1964) indicated that an entire population of sage grouse appeared to emigrate from an area that was subjected to several years of herbicide application to remove sagebrush. Similarly, Klebenow (1970) reported that herbicide spraying reduced the brood-carrying capacity of an area in southeastern Idaho. However, application of herbicides in early spring to reduce sagebrush cover may enhance some brood-rearing habitats by increasing the amount of herbaceous plants used for food (Autenrieth 1981).

Fire may improve sage grouse brood-rearing habitat (Klebenow 1972, Gates 1983, Sime 1991), but until recently, experimental evidence was not available to support or refute these contentions (Braun 1987). Pyle and Crawford (1996) suggested that fire may enhance brood-rearing habitat in montane settings but cautioned that its usefulness requires further investigation. A 9-year study of the effects of fire on sage grouse did not support that prescribed fire, conducted during late summer in a Wyoming big sagebrush habitat, improved brood-rearing habitat for sage grouse (Connelly et al. 1994, Fischer et al. 1996*a*). Prescribed burning of sage grouse habitat did not increase amount of forbs in burned areas compared to unburned areas (Fischer et al. 1996*a*, Nelle et al. 2000) and resulted in decreased insect populations in the treated area compared to the unburned area. Thus, fire may negatively affect sage grouse brood-rearing habitat rather than improve it in Wyoming big sagebrush habitats (Connelly and Braun 1997), but its effect on grouse habitats in mountain big sagebrush communities requires further investigation (Pyle and Crawford 1996, Nelle et al. 2000).

Sage grouse often use agricultural areas for brood-rearing habitat (Patterson 1952, Wallestad 1975, Gates 1983, Connelly et al. 1988, Blus et al. 1989). Grouse use of these areas may result in mortality because of exposure to insecticides. Blus et al. (1989) reported die-offs of sage grouse that were exposed to methamidiphos used in potato fields and dimethoate used in alfalfa fields. Dimethoate is used commonly for alfalfa, and 20 of 31 radiomarked grouse (65%) died following direct exposure to this insecticide (Blus et al. 1989).

Winter habitat. Reduction in sage grouse use of an area treated by herbicide was proportional to the severity (i.e., amount of damage to sagebrush) of the treatment (Pyrah 1972). In sage grouse winter range, strip partial kill, block partial kill, and total kill of sagebrush were increasingly detrimental to sage grouse in Montana (Pyrah 1972) and Wyoming (Higby 1969).

In Idaho, Robertson (1991) reported that a 2,000-ha prescribed burn that removed 57% of the sagebrush cover in sage grouse winter habitat minimally impacted the sage grouse population. Although sage grouse use of the burned area declined following the fire, grouse adapted to this disturbance by moving 1 to 10 km outside of the burn to areas

with greater sagebrush cover (Robertson 1991) than was available in the burned area.

Land use

Mining-energy development. Effects of mining, oil, and gas developments on sage grouse populations are not well known (Braun 1998). These activities negatively impact grouse habitat and populations over the short term (Braun 1998), but research suggests some recovery of populations following initial development and subsequent reclamation of the affected sites (Eng et al. 1979, Tate et al. 1979, Braun 1986). In Colorado, sage grouse were displaced by oil development and coal-mining activities, but numbers returned to pre-disturbance levels once the activities ceased (Braun 1987, Remington and Braun 1991). At least 6 leks in Alberta were disturbed by energy development and 4 were abandoned (Aldridge 1998). In Wyoming, female sage grouse captured on leks disturbed by natural gas development had lower nest-initiation rates, longer movements to nest sites, and different nesting habitats than hens captured on undisturbed leks (Lyon 2000). Sage grouse may repopulate an area following energy development but may not attain population levels that occurred prior to development (Braun 1998). Thus, short-term and long-term habitat loss appears to result from energy development and mining (Braun 1998).

Grazing. Domestic livestock have grazed over most areas used by sage grouse and this use is generally repetitive with annual or biennial grazing periods of varying timing and length (Braun 1998). Grazing patterns and use of habitats are often dependent on weather conditions (Valentine 1990). Historic and scientific evidence indicates that livestock grazing did not increase the distribution of sagebrush (Peterson 1995) but markedly reduced the herbaceous understory over relatively large areas and increased sagebrush density in some areas (Vale 1975, Tisdale and Hironaka 1981). Within the intermountain region, some vegetation changes from livestock grazing likely occurred because sagebrush steppe in this area did not evolve with intensive grazing by wild herbivores, as did the grassland prairies of central North America (Mack and Thompson 1982). Grazing by wild ungulates may reduce sagebrush cover (McArthur et al. 1988, Peterson 1995), and livestock grazing may result in high trampling mortality of sagebrush seedlings (Owens and Norton 1992). In Wyoming big sagebrush habitats, resting areas from livestock grazing may improve understory production as well as decrease sagebrush cover (Wambolt and Payne 1986).

There is little direct experimental evidence linking grazing practices to sage grouse population levels (Braun 1987, Connelly and Braun 1997). However, grass height and cover affect sage grouse nest site selection and success (Wakkinen 1990, Gregg 1991, Gregg et al. 1994, Delong et al. 1995, Sveum et al. 1998*a*). Thus, indirect evidence suggests grazing by livestock or wild herbivores that significantly reduces the herbaceous understory in breeding habitat may have negative impacts on sage grouse populations (Braun 1987, Dobkin 1995).

Miscellaneous activities. Construction of roads, powerlines, fences, reservoirs, ranches, farms, and housing developments has resulted in sage grouse habitat loss and fragmentation (Braun 1998). Between 1962 and 1997, >51,000 km of fence were constructed on land administered by the Bureau of Land Management in states supporting sage grouse populations (T. D. Rich, United States Bureau of Land Management, personal communication). Structures such as powerlines and fences pose hazards to sage grouse because they provide additional perch sites for raptors and because sage grouse may be injured or killed when they fly into these structures (Call and Maser 1985).

Weather

Prolonged drought during the 1930s and mid-1980s to early 1990s coincided with declining sage grouse populations throughout much of the species' range (Patterson 1952, Fischer 1994, Hanf et al. 1994). Drought may affect sage grouse populations by reducing herbaceous cover at nests and the quantity and quality of food available for hens and chicks during spring (Hanf et al. 1994, Fischer et al. 1996*a*).

Spring weather may influence sage grouse production. Relatively wet springs may result in increased production (Wallestad 1975, Autenrieth 1981). However, heavy rainfall during egg-laying or unseasonably cold temperatures with precipitation during hatching may decrease production (Wallestad 1975).

There is no evidence that severe winter weather affects sage grouse populations unless sagebrush cover has been greatly reduced or eliminated (Wallestad 1975, Beck 1977, Robertson 1991).

Predation

Over the last 25 years, numerous studies have used radiotelemetry to address sage grouse survival and nest success (Wallestad 1975; Hulet 1983; Gregg 1991; Robertson 1991; Connelly et al. 1993, 1994; Gregg et al. 1994; Schroeder 1997). Only Gregg (1991) and Gregg et al. (1994) indicated that predation was limiting sage grouse numbers, and their research suggested that low nest success from predation was related to poor nesting habitat. Most reported nest-success rates are >40%, suggesting that nest predation is not a widespread problem. Similarly, high survival rates of adult (Connelly et al. 1993, Zablan 1993) and older (>10 weeks of age) juvenile sage grouse indicate that population declines are not generally related to high levels of predation. Thus, except for an early study in Oregon (Batterson and Morse 1948), predation has not been identified as a major limiting factor for sage grouse (Connelly and Braun 1997).

Constructing ranches, farms, and housing developments has resulted in the addition of nonnative predators to sage grouse habitats, including dogs, cats, and red foxes (*Vulpes vulpes*; J. W. Connelly, Idaho Department of Fish and Game, unpublished data; B. L. Welch, United States Forest Service, personal communication) and may be responsible for increases in abundance of the common raven (*Corvus corax*, Sauer et al. 1997). Relatively high raven populations may decrease sage grouse nest success (Batterson and Morse 1948, Autenrieth 1981), but rigorous field studies using radiotelemetry do not support this hypothesis. Current work in Strawberry Valley, Utah, suggests that red foxes are taking a relatively high proportion of the population (Flinders 1999). This may become a greater problem if red foxes become well established throughout sage grouse breeding habitat.

Recommended guidelines

Sage grouse populations occupy relatively large areas on a year-round basis (Berry and Eng 1985, Connelly et al. 1988, Wakkinen 1990, Leonard et al. 2000), invariably involving a mix of ownership and jurisdictions. Thus, state and federal natural resource agencies and private landowners must coordinate efforts over at least an entire seasonal range to successfully implement these guidelines. Based on current knowledge of sage grouse population and habitat trends, these guidelines have been developed to help agencies and landowners effectively assess and manage populations, protect and manage remaining habitats, and restore damaged habitat. Because of gaps in our knowledge and regional variation in habitat characteristics (Tisdale and Hironaka 1981), the judgment of local biologists and quantitative data from population and habitat monitoring are necessary to implement the guidelines correctly. Further, we urge agencies to use an adaptive management approach (Macnab 1983, Gratson et al. 1993), using monitoring and evaluation to assess the success of implementing these guidelines to manage sage grouse populations.

Activities responsible for the loss or degradation of sagebrush habitats also may be used to restore these habitats. These activities include prescribed fire, grazing, herbicides, and mechanical treatments. Decisions on land treatments using these tools should be based on quantitative knowledge of vegetative conditions over an entire population's seasonal range. Generally, the treatment selected should be that which is least disruptive to the vegetation community and has the most rapid recovery time. This selection should not be based solely on economic cost.

Definitions

For the purpose of these guidelines, we define an occupied lek as a traditional display area in or adjacent to sagebrush-dominated habitats that has been attended by ≥2 male sage grouse in ≥2 of the previous 5 years. We define a breeding population as a group of birds associated with 1 or more occupied leks in the same geographic area separated from other leks by >20 km. This definition is somewhat arbitrary but generally based on maximum distances females move to nest.

Population management

1) Before making management decisions, agencies should cooperate to first identify lek locations and determine whether a population is migratory or nonmigratory. In the case of migratory populations, migration routes and seasonal habitats must be identified to allow for meaningful and correct management decisions.

2) Breeding populations should be assessed by either lek counts (census number of males attending leks) or lek surveys (classify known leks as active or inactive) each year (Autenrieth et al. 1982). Depending on number of counts each spring (Jenni and Hartzler 1978, Emmons and Braun

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General habitat management

The following guidelines pertain to all seasonal habitats used by sage grouse:

1) Monitor habitat conditions and propose treatments only if warranted by range condition (i.e., the area no longer supports habitat conditions described in the following guidelines under habitat protection). Do not base land treatments on schedules, targets, or quotas.

2) Use appropriate vegetation treatment techniques (e.g., mechanical methods, fire) to remove junipers and other conifers that have invaded sage grouse habitat (Commons et al. 1999). Whenever possible, use vegetation control techniques that are least disruptive to the stand of sagebrush, if this stand meets the needs of sage grouse (Table 3).

Table 3. Characteristics of sagebrush rangeland needed for productive sage grouse habitat.

	Breeding		Brood-rearing		Winter[e]	
	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)	Height (cm)	Canopy (%)
Mesic sites[a]						
Sagebrush	40–80	15–25	40–80	10–25	25–35	10–30
Grass–forb	>18[c]	≥25[d]	variable	>15	N/A	N/A
Arid sites[a]						
Sagebrush	30–80	15–25	40–80	10–25	25–35	10–30
Grass/forb	>18[c]	≥15	variable	>15	N/A	N/A
Area[b]	>80		>40		>80	

[a] Mesic and arid sites should be defined on a local basis; annual precipitation, herbaceous understory, and soils should be considered (Tisdale and Hironaka 1981, Hironaka et al. 1983).

[b] Percentage of seasonal habitat needed with indicated conditions.

[c] Measured as "droop height"; the highest naturally growing portion of the plant.

[d] Coverage should exceed 15% for perennial grasses and 10% for forbs; values should be substantially greater if most sagebrush has a growth form that provides little lateral cover (Schroeder 1995)

[e] Values for height and canopy coverage are for shrubs exposed above snow.1

3) Increase the visibility of fences and other structures occurring within 1 km of seasonal ranges by flagging or similar means if these structures appear hazardous to flying grouse (e.g., birds have been observed hitting or narrowly missing these structures or grouse remains have been found next to these structures).

4) Avoid building powerlines and other tall structures that provide perch sites for raptors within 3 km of seasonal habitats. If these structures must be built, or presently exist, the lines should be buried or poles modified to prevent their use as raptor perch sites.

Breeding habitat management

For migratory and nonmigratory populations, lek attendance, nesting, and early brood rearing occur in breeding habitats. These habitats are sagebrush-dominated rangelands with a healthy herbaceous understory and are critical for survival of sage grouse populations. Mechanical disturbance, prescribed fire, and herbicides can be used to restore sage grouse habitats to those conditions identified as appropriate in the following sections on habitat protection. Local biologists and range ecologists should select the appropriate technique on a case-by-case basis. Generally, fire should not be used in breeding habitats dominated by Wyoming big sagebrush if these areas support sage grouse. Fire can be difficult to control and tends to burn the best remaining nesting and early brood-rearing habitats (i.e., those areas with the best remaining understory), while leaving areas with poor understory. Further, we recommend against using fire in habitats dominated by xeric mountain big sagebrush (*A. t. xericensis*) because annual grasses commonly invade these habitats and much of the original habitat has been altered by fire (Bunting et al. 1987).

Although mining and energy development are common activities throughout the range of sage grouse, quantitative data on the long-term effects of these activities on sage grouse are limited. However, some negative impacts have been documented (Braun 1998, Lyon 2000). Thus, these activities should be discouraged in breeding habitats, but when they are unavoidable, restoration efforts should follow procedures outlined in these guidelines.

Habitat protection

1) Manage breeding habitats to support 15–25% canopy cover of sagebrush, perennial herbaceous cover averaging ≥18 cm in height with ≥15% canopy cover for grasses and ≥10% for forbs and a diversity of forbs (Barnett and Crawford 1994, Drut et al. 1994*a*, Apa 1998) during spring (Table 3). Habitats meeting these conditions should have a high priority for wildfire suppression and should

not be considered for sagebrush control programs. Sagebrush and herbaceous cover should provide overhead and lateral concealment from predators. If average sagebrush height is >75 cm, herbaceous cover may need to be substantially greater than 18 cm to provide this protection. There is much variability among sagebrush-dominated habitats (Tisdale and Hironaka 1981, Hironaka et al. 1983), and some Wyoming sagebrush and low sagebrush breeding habitats may not support 25% herbaceous cover. In these areas, total herbaceous cover should be ≥15 % (Table 3). Further, the herbaceous height requirement may not be possible in habitats dominated by grasses that are relatively short when mature. In all of these cases, local biologists and range ecologists should develop height and cover requirements that are reasonable and ecologically defensible. Leks tend to be relatively open, thus cover on leks should not meet these requirements.

2) For nonmigratory grouse occupying habitats that are distributed uniformly (i.e., habitats have the characteristics described in guideline 1 and are generally distributed around the leks), protect (i.e., do not manipulate) sagebrush and herbaceous understory within 3.2 km of all occupied leks. For nonmigratory populations, consider leks the center of year-round activity and use them as focal points for management efforts (Braun et al. 1977).

3) For nonmigratory populations where sagebrush is not distributed uniformly (i.e., habitats have the characteristics described in guideline 1 but distributed irregularly with respect to leks), protect suitable habitats for ≤5 km from all occupied leks. Use radiotelemetry, repeated surveys for grouse use, or habitat mapping to identify nesting and early brood-rearing habitats.

4) For migratory populations, identify and protect breeding habitats within 18 km of leks in a manner similar to that described for nonmigratory sage grouse. For migratory sage grouse, leks generally are associated with nesting habitats but migratory birds may move >18 km from leks to nest sites. Thus, protection of habitat within 3.2 km of leks may not protect most of the important nesting areas (Wakkinen et al. 1992, Lyon 2000).

5) In areas of large-scale habitat loss (≥40% of original breeding habitat), protect all remaining habitats from additional loss or degradation. If remaining habitats are degraded, follow guidelines for habitat restoration listed below.

6) During drought periods (≥2 consecutive years), reduce stocking rates or change management practices for livestock, wild horses, and wild ungulates if cover requirements during the nesting and brood-rearing periods are not met. Grazing pressure from domestic livestock and wild ungulates should be managed in a manner that at all times addresses the possibility of drought.

Sage grouse just leaving a nest in good-condition breeding habitat in southwestern Idaho. Note the height of grass and herbaceous cover.

7) Suppress wildfires in all breeding habitats. In the event of multiple fires, land management agencies should have all breeding habitats identified and prioritized for suppression, giving the greatest priority to those that have become fragmented or reduced by >40% in the last 30 years.

8) Adjust timing of energy exploration, development, and construction activity to minimize disturbance of sage grouse breeding activities. Energy-related facilities should be located >3.2 km from active leks whenever possible. Human activities within view of or <0.5 km from leks should be minimized during the early morning and late evening when birds are near or on leks.

Habitat restoration

1) Before initiating vegetation treatments, quantitatively evaluate the area proposed for treatment to ensure that it does not have sagebrush and herbaceous cover suitable for breeding habitat (Table 3). Treatments should not be undertaken within sage grouse habitats until the limiting vegetation factor(s) has been identified, the proposed treatment is known to provide the desired vegetation response, and land-use activities can be managed after treatment to ensure that vegetation objectives are met.

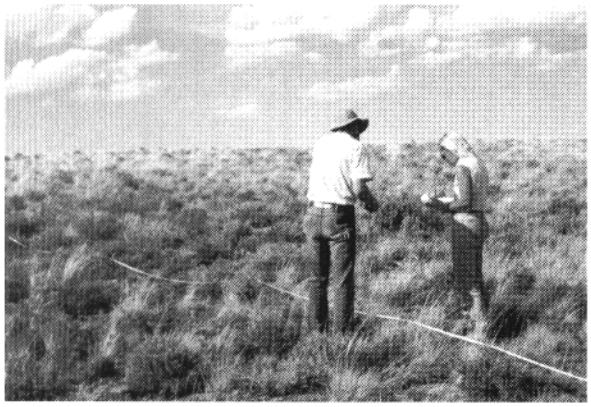
2) Restore degraded rangelands to a condition that again provides suitable breeding habitat for sage grouse by including sagebrush, native forbs

(especially legumes), and native grasses in reseeding efforts (Apa 1998). If native forbs and grasses are unavailable, use species that are functional equivalents and provide habitat characteristics similar to those of native species.

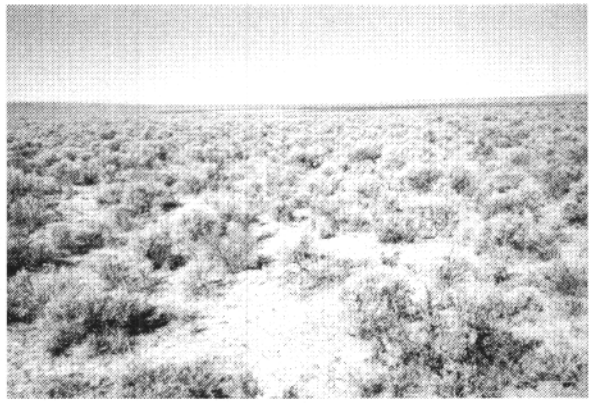
3) Where the sagebrush overstory is intact but the understory has been degraded severely and quality of nesting habitat has declined (Table 3), use appropriate techniques (e.g., brush beating in strips or patches and interseed with native grasses and forbs) that retain some sagebrush but open shrub canopy to encourage forb and grass growth.

4) Do not use fire in sage grouse habitats prone to invasion by cheatgrass and other invasive weed species unless adequate measures are included in restoration plans to replace the cheatgrass understory with perennial species using approved reseeding strategies. These strategies could include, but are not limited to, use of pre-emergent herbicides (e.g., Oust®, Plateau®) to retard cheatgrass germination until perennial herbaceous species become established.

5) When restoring habitats dominated by Wyoming big sagebrush, regardless of the techniques used (e.g., prescribed fire, herbicides), do not treat >20% of the breeding habitat (including areas burned by wildfire) within a 30-year period (Bunting et al. 1987). The 30-year period represents the approximate recovery time for a stand of Wyoming big sagebrush. Additional treatments should be deferred until the previously treated area again provides suitable breeding habitat (Table 3). In some cases, this may take <30 years and in other cases >30 years. If 2,4-D or similar herbicides are used, they should be applied in strips such that their effect on forbs is minimized. Because fire generally burns the best remaining sage grouse habitats (i.e., those with the best understory) and leaves areas with sparse understory, use fire for habitat restoration only when it can be convincingly demonstrated to be in the best interest of sage grouse.



Nest habitat is measured in Owyhee County, southwestern Idaho.



This breeding habitat is in poor condition because of a lack of understory.

6) When restoring habitats dominated by mountain big sagebrush, regardless of the techniques used (e.g., fire, herbicides), treat ≤20% of the breeding habitat (including areas burned by wildfire) within a 20-year period (Bunting et al. 1987). The 20-year period represents the approximate recovery time for a stand of mountain big sagebrush. Additional treatments should be deferred until the previously treated area again provides suitable breeding habitat (Table 3). In some cases, this may take <20 years and in other cases >20 years. If 2,4-D or similar herbicides are used, they should be applied in strips such that their effect on forbs is minimized.

7) All wildfires and prescribed burns should be evaluated as soon as possible to determine whether reseeding is necessary to achieve habitat management objectives. If needed, reseed with sagebrush, native bunchgrasses, and forbs whenever possible.

8) Until research unequivocally demonstrates that using tebuthiuron and similar-acting herbicides to control sagebrush has no long-lasting negative impacts on sage grouse habitat, use these herbicides only on an experimental basis and over a sufficiently small area that any long-term negative impacts are negligible. Because these herbicides have the potential of reducing but not eliminating sagebrush cover within grouse breeding habitats, thus stimulating herbaceous development, their use as sage grouse habitat management tools should be examined closely.

John Crawford explains Oregon's sage grouse research program to field-trip attendees during a meeting of the Western States Sage and Columbian sharp-tailed Grouse Technical Committee.

Summer–late brood-rearing habitat management

Sage grouse may use a variety of habitats, including meadows, farmland, dry lakebeds, sagebrush, and riparian zones from late June to early November (Patterson 1952, Wallestad 1975, Connelly 1982, Hanf et al. 1994). Generally, these habitats are characterized by relatively moist conditions and many succulent forbs in or adjacent to sagebrush cover.

Habitat protection

1) Avoid land-use practices that reduce soil moisture effectiveness, increase erosion, cause invasion of exotic plants, and reduce abundance and diversity of forbs.

2) Avoid removing sagebrush within 300 m of sage grouse foraging areas along riparian zones, meadows, lakebeds, and farmland, unless such removal is necessary to achieve habitat management objectives (e.g., meadow restoration, treatment of conifer encroachment).

3) Discourage use of very toxic organophosphorus and carbamate insecticides in sage grouse brood-rearing habitats. Sage grouse using agricultural areas may be adversely affected by pesticide applications (Blus et al. 1989). Less toxic agrichemicals or biological control may provide suitable alternatives in these areas.

4) Avoid developing springs for livestock water, but if water from a spring will be used in a pipeline or trough, design the project to maintain free water and wet meadows at the spring. Capturing water from springs using pipelines and troughs may adversely affect wet meadows used by grouse for foraging.

Habitat restoration

1) Use brush beating or other mechanical treatments in strips 4–8 m wide in areas with relatively high shrub-canopy cover (≥35% total shrub cover) to improve late brood-rearing habitats. Brush beating can be used to effectively create different age classes of sagebrush in large areas with little age diversity.

2) If brush beating is impractical, use fire or herbicides to create a mosaic of openings in mountain big sagebrush and mixed-shrub communities used as late brood-rearing habitats where total shrub cover is ≥35%. Generally, 10–20% canopy cover of sagebrush and ≤25% total shrub cover will provide adequate habitat for sage grouse during summer.

3) Construct water developments for sage grouse only in or adjacent to known summer-use areas and provide escape ramps suitable for all avian species and other small animals. Water developments and "guzzlers" may improve sage grouse summer habitats (Autenrieth et al. 1982, Hanf et al. 1994). However, sage grouse used these developments infrequently in southeastern Idaho because most were constructed in sage grouse winter and breeding habitat rather than summer range (Connelly and Doughty 1989).

4) Whenever possible, modify developed springs and other water sources to restore natural free-flowing water and wet meadow habitats.

Winter habitat management

Sagebrush is the essential component of winter habitat. Sage grouse select winter-use sites based on snow depth and topography, and snowfall can affect the amount and height of sagebrush available to grouse (Connelly 1982, Hupp and Braun 1989, Robertson 1991). Thus, on a landscape scale, sage grouse winter habitats should allow grouse access to sagebrush under all snow conditions (Table 3).

Habitat protection

1) Maintain sagebrush communities on a landscape scale, allowing sage grouse access to sagebrush stands with canopy cover of 10–30% and heights of at least 25–35 cm regardless of snow cover. These areas should be high priority for wildfire suppression and sagebrush control should be avoided.

2) Protect patches of sagebrush within burned areas from disturbance and manipulation. These areas may provide the only winter habitat for sage grouse and their loss could result in the extirpation of the grouse population. They also are important

seed sources for sagebrush re-establishment in the burned areas. During fire-suppression activities do not remove or burn any remaining patches of sagebrush within the fire perimeter.

3) In areas of large-scale habitat loss (≥40% of original winter habitat), protect all remaining sagebrush habitats.

Habitat restoration

1) Reseed former winter range with the appropriate subspecies of sagebrush and herbaceous species unless the species are recolonizing the area in a density that would allow recovery (Table 3) within 15 years.

2) Discourage prescribed burns >50 ha, and do not burn >20% of an area used by sage grouse during winter within any 20–30-year interval (depending on estimated recovery time for the sagebrush habitat).

Conservation strategies

We recommend that each state and province develop and implement conservation plans for sage grouse. These plans should use local working groups comprised of representatives of all interested agencies, organizations, and individuals to identify and solve regional issues (Anonymous 1997). Within the context of these plans, natural resource agencies should cooperate to document the amount and condition of sagebrush rangeland remaining in the state or province. Local and regional plans should summarize common problems to conserve sage grouse and general conditions (Table 3) needed to maintain healthy sage grouse populations. Local differences in conditions that affect sage grouse populations may occur and should be considered in conservation plans. Natural resource agencies should identify remaining breeding and winter ranges in Wyoming big sagebrush habitats and establish these areas as high priority for wildfire suppression. Prescribed burning in habitats that are in good ecological condition should be avoided. Protection and restoration of sage grouse habitats also will likely benefit many other sagebrush obligate species (Saab and Rich 1997) and enhance efforts to conserve and restore sagebrush steppe.

Although translocating sage grouse to historical range has been done on numerous occasions, few attempts have been successful (Musil et al. 1993, Reese and Connelly 1997). Thus, we agree with Reese and Connelly (1997) that translocation efforts should be viewed as only experimental at this time and not as a viable management strategy.

More information is needed on characteristics of healthy sagebrush ecosystems and the relationship of grazing to sage grouse production. Field experiments should be implemented to evaluate the relationship of grazing pressure (i.e., disturbance and removal of herbaceous cover) to sage grouse nest success and juvenile survival (Connelly and Braun 1997). The overall quality of existing sage grouse habitat will become increasingly important as quantity of these habitats decrease. Sage grouse populations appear relatively secure in some portions of their range and at risk in other portions. However, populations that have thus far survived extensive habitat loss may still face extinction because of a time lag between habitat loss and ultimate population collapse (Cowlishaw 1999).

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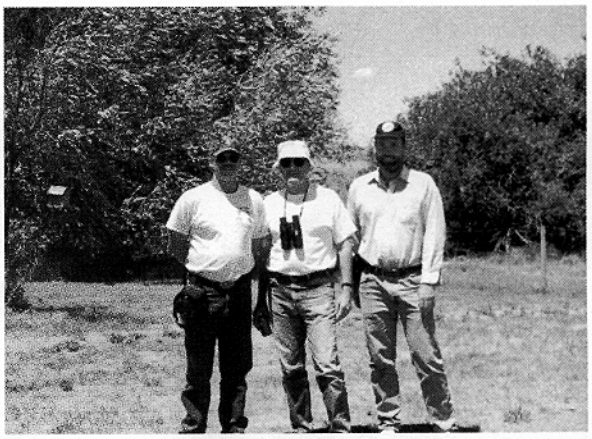

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