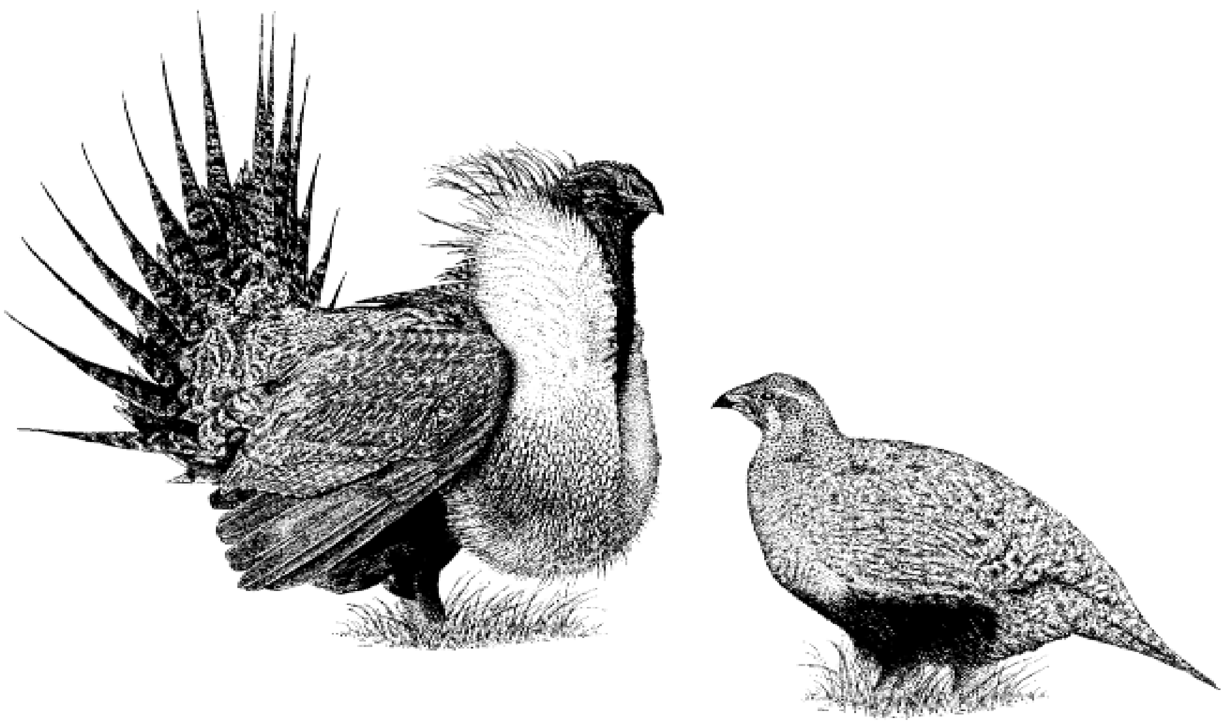
EFFECTS OF MANAGEMENT PRACTICES ON GRASSLAND BIRDS:

GREATER SAGE-GROUSE



Grasslands Ecosystem Initiative
Northern Prairie Wildlife Research Center
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This report is one in a series of literature syntheses on North American grassland birds. The need for these reports was identified by the Prairie Pothole Joint Venture (PPJV), a part of the North American Waterfowl Management Plan. The PPJV adopted a goal to stabilize or increase populations of declining grassland- and wetland-associated wildlife species in the Prairie Pothole Region. To further that objective, it is essential to understand the habitat needs of birds other than waterfowl, and how management practices affect their habitats. The focus of these reports is on management of breeding habitat, particularly in the northern Great Plains.

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Species for which syntheses are available:

American Bittern
Mountain Plover
Marbled Godwit
Long-billed Curlew
Willet
Wilson's Phalarope
Upland Sandpiper
Greater Prairie-Chicken
Lesser Prairie-Chicken
Greater Sage-Grouse
Northern Harrier
Swainson's Hawk
Ferruginous Hawk
Golden Eagle
Prairie Falcon
Merlin
Short-eared Owl
Burrowing Owl
Horned Lark
Sedge Wren
Loggerhead Shrike
Sprague's Pipit
Grasshopper Sparrow
Baird's Sparrow
Henslow's Sparrow
Le Conte's Sparrow
Nelson's Sharp-tailed Sparrow
Vesper Sparrow
Savannah Sparrow
Lark Sparrow
Field Sparrow
Brewer's Sparrow
Clay-colored Sparrow
Chestnut-collared Longspur
McCown's Longspur
Dickcissel
Lark Bunting
Bobolink
Eastern Meadowlark
Western Meadowlark
Brown-headed Cowbird

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GREATER SAGE-GROUSE

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ORGANIZATION AND FEATURES OF THIS SPECIES ACCOUNT

Information on the habitat requirements and effects of habitat management on Greater Sage-Grouse was summarized from information in more than 5,500 published and unpublished papers. A ***range map*** is provided to indicate the current range of Greater Sage-Grouse (adapted from Schroeder et al. 2004). Although birds may be observed outside the breeding range indicated, the maps are intended to show areas where managers might concentrate their attention. It may be ineffectual to manage habitat at a site for a species that rarely occurs in an area. The species account begins with a brief ***capsule statement***, which provides the fundamental components or keys to management for the species. A section on ***breeding range*** outlines the current breeding distribution of the species in North America. The ***suitable habitat*** section describes the breeding habitat and occasionally microhabitat characteristics of the species. Details on habitat and microhabitat requirements often provide clues to how a species will respond to a particular management practice. A ***table*** near the end of the account complements the section on suitable habitat, and lists the specific habitat characteristics for the species by individual studies. A special section on ***prey habitat*** is included for those predatory species that have more specific prey requirements. The ***area requirements*** section provides details on territory and home range sizes, minimum area requirements, and the effects of patch size, edges, and other landscape and habitat features on abundance and productivity. It may be futile to manage a small block of suitable habitat for a species that has minimum area requirements that are larger than the area being managed. The Brown-headed Cowbird (*Molothrus ater*) is an obligate brood parasite of many grassland birds. The section on ***cowbird brood parasitism*** summarizes rates of cowbird parasitism, host responses to parasitism, and factors that influence parasitism, such as nest concealment and host density. The impact of management depends, in part, upon a species' nesting phenology and biology. The section on ***breeding-season phenology and site fidelity*** includes details on spring arrival and fall departure for migratory populations, peak breeding periods, the tendency to renest after nest failure or success, and the propensity to return to a previous breeding site. The duration and timing of breeding varies among regions and years. ***Species' response to management*** summarizes the current knowledge and major findings in the literature on the effects of different management practices on the species. The section on ***management recommendations*** complements the previous section and summarizes specific recommendations for habitat management provided in the literature. If management recommendations differ in different portions of the species' breeding range, recommendations are given separately by region. The ***literature cited*** contains references to published and unpublished literature on the management effects and habitat requirements of the species. This section is not meant to be a complete bibliography; a searchable, annotated bibliography of published and unpublished papers dealing with habitat needs of shrub-steppe birds and their responses to habitat management is posted at the Web site mentioned below.

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GREATER SAGE-GROUSE
(*Centrocercus urophasianus*)

Figure. Shaded area represents the current distribution of Greater Sage-Grouse (adapted from Schroeder et al. 2004).

Keys to management are maintaining expansive stands of sagebrush (*Artemisia* spp.), especially varieties of big sagebrush (*A. tridentata*), with abundant forbs in the understory, particularly during spring; undisturbed and relatively open sites for leks; and healthy perennial grass and forb stands intermixed with sagebrush for brood rearing. Within suitable habitats, areas should have 15 to 25% canopy cover of sagebrush 30 to 80 cm tall for nesting, and 10 to 25% canopy cover from 40 to 80 cm tall for brood rearing (Connelly et al. 2000*b*). In winter habitats, shrubs should be exposed 25 to 35 cm above snow level and have 10 to 30% canopy cover exposed above snow. In nesting and brood-rearing habitats, understory habitats with adequate cover of grasses (≥15%) and forbs (≥10%) at least 18 cm tall are needed (Connelly et al. 2000*b*).

Unless otherwise noted, this account refers to habitat requirements and environmental factors affecting Greater Sage-Grouse and not Gunnison Sage-Grouse (*C. minimus*). Habitats used by Gunnison Sage-Grouse are generally similar to those used by Greater Sage-Grouse, but some differences have been reported (Young et al. 2000). The Greater Sage-Grouse is a game bird and is hunted throughout most of its current range. This account does not address harvest and its effects on populations; rather, the report focuses on effects of habitat management.

Breeding range:

The range of Greater Sage-Grouse has been substantially reduced since historical times (Connelly and Braun 1997; Braun 1998; Schroeder et al. 1999, 2004). Currently, Greater Sage-Grouse occur in somewhat disjunct ranges within suitable sagebrush habitats in central Washington through southern Idaho, much of Montana, extreme southeastern Alberta and southwestern Saskatchewan, south to the southwestern corner of North Dakota, northwestern and southwestern South Dakota, most of Wyoming, western Colorado, and portions of Utah, and west to Nevada, extreme eastern California, and southeastern Oregon (Schroeder et al. 1999, 2004; see figure). The species has been extirpated from Arizona, British Columbia, Kansas, Nebraska, and Oklahoma (Schroeder et al. 1999, 2004).

Suitable habitat:

Greater Sage-Grouse are widely distributed in sagebrush habitats throughout the western United States, and are considered a sagebrush obligate species because of their year-round dependence on sagebrush communities (Patterson 1952, Braun et al. 1976, Braun and Beck 1996, Paige and Ritter 1999, Schroeder et al. 1999). Although most closely allied with larger forms of sagebrush (big sagebrush, threetip sagebrush [*A. tripartita*], and silver sagebrush [*A. cana*]), sage-grouse also use a variety of other native habitats, especially outside the breeding season, including low sagebrush types (e.g., little sagebrush [*A. arbuscula*] and black sagebrush [*A. nova*]), antelope bitterbrush (*Purshia tridentata*), rabbitbrush (*Chrysothamnus* spp.), riparian and upland meadows, and sagebrush grasslands (Patterson 1952, Dalke et al. 1963, Wallestad 1971, Nisbet et al. 1983, Klebenow 1985, Connelly et al. 1991, Gregg et al. 1993, Musil et al. 1994, Braun 1995, Apa 1998, Sveum et al. 1998, Schroeder et al. 1999, Aldridge and Brigham 2002, Crawford and Davis 2002, Danvir 2002).

Despite their reliance on sagebrush habitats, Greater Sage-Grouse also use human-modified habitats, such as croplands, when such habitats are adjacent to sagebrush sites (Schroeder et al. 1999). Sage-grouse have been reported in crested wheatgrass (*Agropyron cristatum*) seedings, alfalfa fields, and irrigated and dry cropland (e.g., wheat and barley fields) (Batterson and Morse 1948, Patterson 1952, Leach and Browning 1958, Gill 1965, Wallestad 1971, Beck 1977, Gates 1981, Hulet et al. 1986, Willis 1991, Leonard et al. 2000).

Specific characteristics of habitats used by sage-grouse vary through the year. During the breeding season, males display on leks that are characterized by low, sparse vegetation or bare ground (Patterson 1952, Gill 1965, Klebenow 1985). Nesting habitats include moderate sagebrush cover, typically ranging from 15 to 25% (Connelly et al. 2000*b*); nests are most commonly placed beneath a sagebrush shrub (Patterson 1952, Petersen 1980, Drut et al. 1994*a*, Gregg et al. 1994). Herbaceous understories composed of native grasses and forbs are an important component of nesting and brood-rearing habitats (Wallestad 1970, Klott and Lindzey 1990, Connelly et al. 1991, Drut et al. 1994*a*, Delong et al. 1995). During winter, sage-grouse rely for forage on sagebrush exposed above snow (Batterson and Morse 1948, Patterson 1952, Schroeder et al. 1999).

Formal guidelines for managing habitat for sage-grouse were first published in the 1970's (Braun et al. 1977) and subsequently updated (Connelly et al. 2000*b*). The more recent guidelines recommend maintaining a diversity of habitats for sage-grouse during different seasonal-use periods (e.g., breeding, brood rearing, and wintering). Specifically, Connelly et al.

(2000*b*) recommended that canopy cover of sagebrush in both arid and mesic sites should be maintained as follows: 15 to 25% in breeding habitat; 10 to 25% in brood-rearing habitat; and 10 to 30% in wintering habitat (canopy cover in winter refers to the portion of sagebrush exposed above snow). The recommended percentages of grass-forb cover during breeding are ≥15% in arid sites, but ≥25% in mesic sites. During brood rearing, grass-forb cover should exceed 15% in both mesic and arid sites. (Cover of grasses and forbs for wintering habitats is irrelevant, because of the nearly complete reliance of sage-grouse upon sagebrush during this period.) Recommendations for sagebrush height also are provided in the guidelines: breeding and brood rearing – 40 to 80 cm (mesic sites) or 30 to 80 cm (arid); and winter – 25 to 35 cm (exposed above snow level). The recommended height of grasses and forbs in both mesic and arid sites is >18 cm for breeding habitats; in brood-rearing habitat, height can be variable, and in winter is not applicable (Connelly et al. 2000*b*). At least 80% of breeding and winter habitats, and 40% of brood-rearing habitats, should be maintained within these prescribed conditions (Connelly et al. 2000*b*). Sagebrush cover within the range of sage-grouse in Canada is generally less than that in the southern portions of the species' range (Aldridge and Brigham 2002), suggesting that the guidelines may require adjustment when used in northern fringe habitats.

Traditionally, managers have monitored status of sage-grouse populations through counts of males on leks and, to a lesser extent, numbers of birds seen along routes driven during summer ("brood counts") and hunter harvest data (e.g., Batterson and Morse 1948, Patterson 1952, Beck et al. 1975, Jenni and Hartzler 1978, Emmons and Braun 1984, Willis et al. 1993, Braun and Beck 1996, Schroeder et al. 1999). Leonard et al. (2000) found a negative relationship between mean numbers of males/lek and area in agriculture during a 17-yr period for sage-grouse populations in the Upper Snake River Plain in Idaho; nearly 30,000 ha of sagebrush in the study area were converted to cropland during 1975-1992. In North Park, Colorado, Braun and Beck (1996) examined lek counts in relation to habitat loss from both plowing and spraying with 2,4-D of >28% of the study area, a site known as "one of the best sage-grouse habitats in Colorado." Initial spraying of >1600 ha occurred in 1965, with an additional 500 ha sprayed and 1460 ha plowed and seeded during the following 5 yr. The 5-yr mean of males on active leks declined from 765 (1961 to 1965) to 575 (1971 to 1975). Numbers rebounded by 1976 to 1980, however, and even exceeded the pre-treatment levels (5-yr mean = 1,109 males/lek). The authors stated that spraying of large (>200 ha) blocks of sagebrush clearly was detrimental, leading to lek abandonment and shifts in distribution of sage-grouse (Braun and Beck 1996).

Specific information on habitats used during various seasons, e.g., courtship activities (lekking), nesting, brood rearing, and foraging, appears in the following sections.

Lek sites.—Displaying male sage-grouse require relatively open areas during the breeding season (Scott 1942; Patterson 1952; Dalke et al. 1963; Klebenow 1973, 1985; Autenrieth 1981; Schroeder et al. 1999). Such sites are typically adjacent to sagebrush with adequate cover for nesting hens as well as protection from avian predators, and support low, sparse vegetation, if any at all (Scott 1942, Petersen 1980, Autenrieth 1981, Klebenow 1985). Flat or gently sloping terrain is a common characteristic of leks (Rogers 1964), as is their location in valley bottoms or draws (Patterson 1952, Rogers 1964). There is no evidence that suitable habitat for leks is limiting for sage-grouse (Schroeder et al. 1999).

Of 10 leks surveyed in Mono County, California, six were in meadows, although meadows composed only 9% of the available sagebrush/meadow habitat (Gibson 1996). Habitat type did not appear to be the primary factor in lek location, however; instead, female dispersal traffic (patterns of travel between wintering and nesting areas) appeared to most strongly influence lek location (Bradbury et al. 1989*a*, Gibson 1996). In addition to open areas for display by males and traffic by hens, protection from raptors is a factor in lek location (Bradbury et al. 1989*b*).

Forty-one leks in Nevada and Utah were preferentially located in black sagebrush habitats (based on use versus availability) (Nisbet et al. 1983). Environmental variables beyond vegetation type that were included in a lek preference model were slope (<10%), precipitation (>25 cm), distance to nearest water source ($\leq$2,000 m), and predicted encroachment by pinyon (*Pinus* spp.)/juniper (*Juniperus* spp.) woodlands (Nisbet et al. 1983). In North Park, Colorado, mating areas (arenas) within leks had an average canopy cover of only 7.3% and a mean vegetation height of 5.3 cm; sagebrush species present included big sagebrush, alkali sagebrush (*A. arbuscula longiloba*), and black sagebrush (Petersen 1980). Rogers (1964) reviewed characteristics of 120 leks throughout Colorado during 1953-1961 and found that, on average, half were in sagebrush; 54% were on gentle slopes; 55% were in bottoms; only 5% were within 200 m of a building; and that although 42% were >1.6 km from an improved road, 26% were within 100 m of a county or state highway. During daytime, male sage-grouse in northeastern Utah used areas near leks that had comparatively greater canopy cover (mean = 31%) and taller shrubs (mean = 53 cm) than did nearby non-use areas (Ellis et al. 1989). Minimum core day-use areas of males were 0.25 km^2 in size, and the birds often walked to such sites for feeding and loafing (Ellis et al. 1989).

Sage-grouse establish leks not only in native habitats but also in altered or recently disturbed environments (Schroeder et al. 1999). Leks have been found on airstrips, firing ranges, gravel pits, sheep bedding grounds, cultivated fields, recently burned sagebrush, plowed fields, cleared roadsides or roadbeds, and actively occupied ant mounds (Batterson and Morse 1948, Patterson 1952, Dalke et al. 1963, Rogers 1964, Klebenow 1973, Giezentanner and Clark 1974, Autenrieth 1981, Connelly et al. 1981, Gates 1985, Hofmann 1991). This flexibility suggests that man-made leks are a potential management tool when traditional leks are destroyed, such as by wildfire or human activities (Connelly et al. 1981).

Leks vary in size; Klebenow (1973) reported a typical range from 0.04 to 4.0 ha. Scott (1942) reported a range of 0.4 to 16 ha, based on his work on the Laramie Plains in Wyoming; one lek, however, was about 20 ha in size and supported 400 strutting males. Hofmann (1991) reported a mean size of 36 ha for the four largest leks in a study in central Washington.

Leks often occur in complexes, with satellite leks on the periphery that may not be used in all years, depending on population size or weather (Dalke et al. 1963, Rogers 1964, Wiley 1978). In a study of 31 leks in Idaho, mean interlek distance (i.e., distance between nearest-neighbor leks) was about 1.6 km (Wakkinen et al. 1992). Of 13 leks examined in the Upper Snake River Plains in Idaho, 10 were in threetip sagebrush (Klebenow 1969). For two of these leks, interlek distance was 0.8 km, and for eight others, 2.4 km. In Wyoming, lek density of 29 leks within a water-reclamation project area averaged 6.8 leks per 100 km^2, compared with 8.4 leks per 100 km^2 for 18 leks in nearby, undeveloped sagebrush habitats (Patterson 1950). Similar lek densities were reported in Oregon; there were 4.3 leks per 100 km^2 at Hart Mountain National Antelope Refuge and 4.7 leks per 100 km^2 at Jackass Creek (Willis et al. 1993).

A recent study compared the percentage of tilled versus non-tilled land within 4 km surrounding sage-grouse leks in North and South Dakota (Smith 2003). This analysis revealed that abandoned leks (n = 10) had a higher percentage of tilled lands within 4 km than did active leks (n = 12; P = 0.0105). In addition, percentage of tilled land was greater around random points (n = 18) than around active leks (P = 0.0204). However, similar comparisons for leks in

South Dakota revealed no significant relationships. There was no increase in the percentage of tilled land surrounding leks (both active and currently inactive) from the 1970s to the late 1990s, suggesting that if the amount of tilled land was a factor in lek abandonment, this effect had occurred prior to the 1970s (Smith 2003). Smith (2003) also found no relationship between lek size (counts of males on active leks) and percent tilled land surrounding leks.

Nesting habitat. **—**Greater Sage-Grouse nest in a variety of cover types, but most nests are under big sagebrush (Patterson 1952, Gill 1965, Wallestad and Pyrah 1974, Petersen 1980, Wakkinen 1990, Connelly et al. 1991, Drut et al. 1994*a*, Gregg et al. 1994, Sveum et al. 1998, Schroeder et al. 1999). Other shrubs used for nesting cover include bitterbrush, greasewood (*Sarcobatus vermiculatus*), horsebrush (*Tetradymia* spp.), low sagebrush, mountain mahogany (*Cercocarpus* spp.), rabbitbrush, shadscale saltbush (*Atriplex confertifolia*), snowberry (*Symphoricarpos* spp.), and western juniper (*Juniperus occidentalis*) (Patterson 1952, Klebenow 1969, Wakkinen 1990, Connelly et al. 1991, Crawford and Davis 2002). Nests also have been found on bare ground devoid of cover (Patterson 1952) and under basin wildrye (*Leymus cinereus*) (Wakkinen 1990, Crawford and Davis 2002). Young (1994) reported a Gunnison Sage-Grouse nest beneath a Douglas-fir (*Pseudotsuga menziesii*) tree.

The most suitable nesting habitat includes a mosaic of sagebrush with horizontal and vertical structural diversity. A healthy understory of native grasses and forbs provides 1) cover for concealment of the nest and hen from predators, 2) herbaceous forage for pre-laying and nesting hens, and 3) insects as prey for chicks and hens. Mean sagebrush canopy cover at nest sites ranges from 15 to 38%, and mean sagebrush height ranges from 36 to 79 cm (Schroeder et al. 1999). Mean distance between nests and nearest leks varies from 1.1 to 6.2 km; however, nests have been found >20 km from the nearest lek (Connelly et al. 2000*b*).

In central Oregon, nests were most common in mountain big sagebrush (*A. t. vaseyana*); however, the percentage of nests in this type was similar to the availability of the type (Hanf et al. 1994). Although mountain shrub types (mountain big sagebrush/antelope bitterbrush) and native grasslands were less commonly used, sage-grouse appeared to select these types for nesting; that is, use exceeded availability (Hanf et al. 1994). In southeastern Oregon, Drut et al. (1994*a*) found that 13 of 18 nests were in big sagebrush. In another study in southeastern Oregon, Gregg et al. (1994) found that 94% of all nests of radio-marked hens were under sagebrush in an area where sagebrush composed 87% of the shrubs.

Sveum et al. (1998) evaluated nesting habitat selection at the Yakima Training Center in Washington, which contains some of the most intact sage-grouse habitat remaining in the state. Most first nest attempts (64% of 72) were in the big sagebrush/bunchgrass cover type. This type was preferred (use exceeded availability) in 1 of 2 yr of study. Sage-grouse nested in stiff sagebrush (*A. rigida*)/bluegrass (*Poa* spp.) and grassland cover types less than expected in both years. They showed no preference (i.e., use was proportional to availability) for nesting in big sagebrush/bunchgrass that had reduced shrub cover and increased bare ground resulting from military training activities, or in riparian cover types (ephemeral streams and wet areas). Shrub cover at nest sites averaged 51% (1992) and 59% (1993), compared with 6 to 7% at random sites. Shrub height was greater (59 and 63 cm) at nest sites than at random sites (15 and 13 cm) (1992 and 1993, respectively). Nest sites also had less cover of short (<18 cm) grasses, greater vertical cover height, less bare ground, and more litter than random sites.

In an Idaho study, 216 nest bushes were taller and larger than big sagebrush shrubs in 40-m^2 plots surrounding the nests (Autenrieth 1981). Mean height of nest bushes ranged from 58.2 cm to 79.3 cm, compared with 30.2 to 54.9 cm in the plots. Mean diameter of nest bushes ranged from 93.9 to 109.7 cm, compared with 42.7 to 61.0 cm for other sagebrush shrubs in the plots (Autenrieth 1981). Canopy cover in the surrounding plots ranged from 23.4 to 38.1%. Distance from nests to water varied from 530 to 2,257 m.

Patterson (1952) recorded >200 sage-grouse nests during 1949-50 in the Eden Valley-Pacific Creek area in Wyoming. Height of cover at nest sites ranged from 0 to 102 cm, with a mean of 36 cm; nests were most commonly placed beneath "short sagebrush of medium density, such as is found on drier sites, in preference to the dense, tall sagebrush found along watercourses…." (Patterson 1952:114). Although the specific taxa of sagebrush were not mentioned, this area is an arid Wyoming big sagebrush (*A. tridentata wyomingensis*) site, thus accounting for the relatively shorter stature of nesting shrubs compared to those reported for Washington and Idaho.

In the Green River Valley in Wyoming, Lyon (2000) compared a suite of variables at 50 nests with random vegetation plots. Compared with independent, random sites, nest-use plots had taller average live sagebrush (32.7 vs. 27.6 cm), more grass cover (10.6 vs. 5.4%), more forb cover (8.2 vs. 4.3%), and taller nest bushes (44.4 vs. 21.4 cm).

Of 61 sage-grouse nests at the Sheldon National Wildlife Refuge (NWR) in Nevada, 41% were in mountain big sagebrush, 31% were in mountain shrub (including mountain big sagebrush, antelope bitterbrush, bluegrass, and needlegrass [*Achnatherum* spp.]), and 13% were in low sagebrush cover types (Crawford and Davis 2002). Neither cover type, medium-height (40 to 80 cm) shrub cover, nor total forb cover were related to nest success, and no relationship was found between age of hen and type of cover used for nesting (Crawford and Davis 2002). Compared to random sites, nest sites had greater tall (>18 cm) residual grass cover and greater cover of medium-height shrubs.

In North Park, Colorado, Petersen (1980) studied breeding biology of sage-grouse hens; mean sagebrush canopy cover at 35 nest sites was 24% (range from 9.4 to 52.6%), and mean sagebrush height was 32 cm (range 11.1 to 59.8 cm), with no differences between nest sites used by adult versus yearling hens. Slope at nest sites was gentle, with 85% of nests on slopes of <12% (Petersen 1980). Gill (1965), also working in North Park, located 92% of 117 nests under sagebrush; mean height of cover at the nest was 43 cm. Nests were typically on flat ground, with mean slope of 2% (Gill 1965). In southcentral Idaho, Klott et al. (1993) found four sage-grouse nests in Wyoming big sagebrush, two in low sagebrush, and one each in mountain big sagebrush and crested wheatgrass. No nests were found in quaking aspen (*Populus tremuloides*), mountain mahogany, mountain shrub, or meadow habitat types.

In the Upper Snake River Plains of southeastern Idaho, sage-grouse nested primarily in threetip sagebrush (Klebenow 1969). Mean height of shrubs under which sage-grouse nested was 43 cm, whereas mean height of threetip sagebrush in the study area was only 20 cm. Mean total shrub cover in the vicinity of nest sites was 18.4%, compared with 14.4% in the threetip sagebrush community overall. Although big sagebrush density and crown cover were greater near nests than in the general area, sage-grouse nests were not found in big sagebrush stands with cover exceeding 25%. Bitterbrush provided all or part of the nesting shrub cover for 29% of the nests. The author used stepwise discriminant function analysis in an attempt to distinguish between nest sites and the surrounding habitat in the threetip sagebrush community; however, a satisfactory model could not be developed with the data collected (Klebenow 1969).

For sage-grouse in a xeric Wyoming big sagebrush community in southeastern Idaho, Wakkinen (1990) also attempted to build a logistic-regression model to discriminate between nest and non-nest sites. The resulting model, however, had poor classification accuracy. Two variables, grass height and nest bush area, were significant; sage-grouse nested in sites with taller grasses (mean = 18.2 vs. 15.3 cm) and larger shrubs (mean area = 11,108 vs. 9,384 cm^2) compared with random plots. Of the 42 nests used in developing the model, 23 (55%) were under Wyoming big sagebrush and 12 (29%) were beneath threetip sagebrush (Wakkinen 1990). The area within a 20-m radius of each nest was characterized as follows: mean canopy cover of sagebrush = 21.5%, and mean height of sagebrush = 43.9 (1988) and 46.9 cm (1987). Mean height of nest bushes was 70.6 cm (n = 49). In central Idaho, translocated sage-grouse nested in sites with greater horizontal cover (86%) compared to random sites (67%); mean shrub height at nests was 51 cm (Musil et al. 1994).

Several studies have investigated sage-grouse nest location in relation to leks to address the hypothesis that hens nest midway between leks to avoid relatively high predation rates often associated with leks (Bergerud 1988). In addition, current guidelines for sage-grouse recommend protecting breeding habitat within 3.2 km of the lek for nonmigratory populations, and within 18 km of the lek for migratory populations (Connelly et al. 2000*b*). In Idaho, Wakkinen (1990) found that 37 nests were farther from leks compared to distances midway between nearest-neighbor leks (i.e., one-half the interlek distance, n = 31 leks; P = 0.004, using a Kolmogorov-Smirnov test to compare distributions of distances). In addition, distances from nests to the nearest lek were no different than distances from random points to the nearest lek (Wakkinen 1990). In another Idaho study, distance from nests to the nearest lek was highly variable; in two sites, >95% of nests were within 3.2 km of the nearest lek, whereas in one site, only 52% were within 6.4 km (Autenrieth 1981). In southeastern Alberta, mean distance from nest to lek of capture was 4.7 km for hens, but 59% of 27 nests were >3.2 km from the lek (Aldridge and Brigham 2001). Autenrieth (1981) suggested that nests were placed closer to leks when nesting cover around leks was good.

Conflicting results have been reported regarding nest success in relation to vegetation characteristics at nest sites and in the surrounding vegetation community. At the Yakima Training Center in Washington, nest success did not appear to vary among cover types (for example, big sagebrush/bunchgrass vs. grassland), and nests placed under big sagebrush shrubs were not more successful than nests placed under other shrub species (Sveum et al. 1998). Wakkinen (1990) also found no differences in vegetation characteristics between 24 successful and 16 unsuccessful nests in southeastern Idaho. Autenrieth (1981) reported that, based on 165 nests in Idaho, neither height nor canopy cover of nest bushes differed between successful and unsuccessful nests. By contrast, nest success in Montana was significantly related to vegetation characteristics (Wallestad and Pyrah 1974). The 31 successful nests were in areas of higher sagebrush density than the 10 unsuccessful nests, and canopy cover of sagebrush was greater (27%) in stands with successful nests versus unsuccessful nests (20%). Neither mean height of sagebrush plants covering nests nor mean height of the tallest sagebrush plants covering nests differed between successful and unsuccessful nests, however (Wallestad and Pyrah 1974). Nest success of both yearling and adult sage-grouse in southeastern Idaho (n = 84) was significantly greater under sagebrush shrubs (53%) than under other vegetation (e.g., bitterbrush, rabbitbrush; 22%) (Connelly et al. 1991).

In Oregon, Gregg et al. (1994) investigated habitat at 124 sage-grouse nests and found that 18 non-depredated nests were in areas of greater medium-height (40 to 80 cm) shrub cover (41%) than depredated nests (29%) or random sites (8%). Cover of tall (>18 cm) grasses also was greater at non-depredated nest sites (18%) than at depredated nests (5%) or random sites (3%). A study of predation rates of 330 artificial nests within mountain big sagebrush and low sagebrush communities in Oregon revealed that nests in sites with relatively less cover of tall grasses and medium-height (40-80 cm) shrubs (mean cover = 5 and 29%, respectively) were more likely to be depredated than were nests in sites of greater cover (mean cover = 18 and 41%, respectively, for nests not depredated) (DeLong et al. 1995). By contrast, Ritchie et al. (1994) found higher predation rates in Utah on artificial nests in untreated sagebrush sites with greater cover compared to sites that had been treated (i.e., disced or sprayed and planted with crested wheatgrass) 25 yr prior to the study (mean shrub cover = 27% in untreated sites vs. 17% in treated; mean herbaceous cover = 21% in untreated vs. 18% in treated). Predation rates were not significantly correlated with shrub cover but were positively correlated with increasing horizontal cover, herbaceous cover, and maximum shrub height (Ritchie et al. 1994).

In Alberta, where sagebrush cover is generally less than in more southern portions of the species' range, sage-grouse nested in sites that had nearly twice the canopy cover of silver sagebrush than random sites (Aldridge and Brigham 2002). Vegetation characteristics at 14 successful nests differed from 15 unsuccessful nests; for example, successful nests were in areas with less grass cover (33.8 vs. 48.9%) but taller grasses (31.6 vs. 24.4 cm) than unsuccessful nests (Aldridge and Brigham 2002).

Using 238 artificial nests placed around eight sage-grouse leks in southeastern Alberta, Watters et al. (2002) studied predation rates in relation to predator type and vegetation characteristics. In the best-fit model, with a correct classification of 65.4%, successful nests were associated with greater forb cover (mean = 11.1% at successful nests vs. 8.2% at depredated nests), greater sagebrush cover (26.5% vs. 24.9%), and fewer sagebrush plants (3.1 vs. 3.4 sagebrush plants around the nest) (Watters et al. 2002).

Density of sage-grouse nests varies across the range of the species, with densities of 3.8 to 55.6 per km^2 reported by Schroeder et al. (1999). Nest densities averaged 16.2 per km^2 over two breeding seasons within big sagebrush habitats in Wyoming (Patterson 1952). In southeastern Idaho, there were 3.8 nests per km^2 in a big sagebrush/threetip sagebrush site; however, nests were not evenly distributed across the study area, and in some areas nest density reached 24.7 nests per km^2 (Klebenow 1969). Across North Park, Colorado, nest density was estimated at 12.4 per km^2 (Gill 1965). In the most productive nesting habitat in the Strawberry Valley in Utah, Rasmussen and Griner (1938) found 36 nests per km^2. This habitat was composed of recently disturbed (e.g., from burning or flooding) sites in which big sagebrush or black sagebrush had recovered so that >50% of total cover was in sagebrush, and shrubs were >45 cm tall.

***Brood-rearing habitat*. —**Brood-rearing habitats for sage-grouse are typically mosaics of upland sagebrush and other habitats (e.g., wet meadows, riparian areas) that together provide abundant insects and forbs for hens and chicks (Schroeder et al. 1999, Connelly et al. 2000*b*). In two study sites in southeastern Oregon, Hart Mountain National Antelope Refuge and Jackass Creek, sage-grouse broods were most common in low sagebrush during early brood rearing (first 6 weeks post-hatch), but then moved to sites dominated by big sagebrush (7-12 weeks after hatching) (Drut et al. 1994*a*). Following brood breakup in August, sage-grouse used meadows and lake beds more frequently than earlier during the brood-rearing period (Drut et al. 1994*a*). During early brood rearing at Jackass Creek, forb cover at sites used by broods was 10 to 14% and exceeded forb cover at random sites (Drut et al. 1994*a*); however, no pattern was evident during late brood rearing. Broods at Hart Mountain used forb cover in relation to its availability during early brood rearing, but selected sites with greater forb cover (19 to 27%) during the late brood-rearing period (Drut et al. 1994*a*).

Sage-grouse broods at the Sheldon NWR used primarily sagebrush uplands (low sagebrush and mountain and Wyoming big sagebrush) during 1978 and 1980; however, during the drought year of 1979, use was greater in wet meadows, and upland sites were abandoned by broods by late summer (Klebenow 1985). Brood habitat in uplands differed from that in wet meadows. Upland brood sites had greater canopy cover of sagebrush (mean = 25 vs. 0%), less grass cover (15 vs. 57%), and less forb cover (10 vs. 38%). Meadows into which tall sagebrush has encroached were seldom used by sage-grouse during brood rearing, with no grouse found in areas with a mean shrub height of 140 cm and >40% canopy cover (Klebenow 1985). In these meadows, most broods occurred in sites with relatively shorter shrubs (60 cm) and greater dominance of grass and forb cover (Klebenow 1985).

In a subsequent study during 1998-2000 at Sheldon NWR, broods (*n* = 392 locations) used primarily low sagebrush for the first few weeks after hatching, moving to big sagebrush (mountain or Wyoming) or mountain shrub communities by 3 weeks post-hatch (Crawford and Davis 2002). Important brood habitats were low sagebrush (40% of all brood locations), a 10-yr old burn in a mountain big sagebrush site (19%), mountain shrub (16%), and mountain big sagebrush (13%). Differences in vegetation characteristics (e.g., tall grass cover and forbs consumed by hens) were found between brood locations and random sites; these differences, however, varied among cover types. For example, in the low sagebrush cover type, cover of forbs eaten by hens and chicks was less at brood locations (about 5.5%) than at random sites (10.2 and 8.2% for hens and chicks, respectively), but tall grass cover was greater (4.4% at brood locations vs. 1.4% at random sites). By contrast, cover of forbs used by hens and chicks in the burn was greater at brood locations (6.7 and 5.2%) versus random sites (2.3 and 3.4%, respectively), but tall grass cover was less (18.3% at brood locations vs. 26.2% at random sites). Of the five cover types in which there were significant differences, cover of forbs used by hens and chicks was greater at brood locations than at random sites in four types (all but low sagebrush). No differences were found in vegetation characteristics between early and late brood-rearing habitats.

Summer habitat use by hens with and without broods was studied at Cold Spring Mountain, Colorado (Dunn and Braun 1986). Sites use by grouse differed from random sites; horizontal cover and habitat interspersion (as measured by distance to a different cover type or edge) were two important variables in discriminating summer habitats. Habitat use did not differ between juvenile and adult females (Dunn and Braun 1986). Mean canopy cover of sagebrush at juvenile grouse locations (*n* = 84) was 24%, versus 16% at random locations. Mean sagebrush height at grouse locations was 28 cm, and forb ground cover was 5%. The authors recommended managing for homogeneous sagebrush stands with regard to shrub size and density, which are in turn juxtaposed with other cover types (e.g., meadows, aspen stands).

Wallestad (1971) measured vegetation at 511 brood locations in a big sagebrush/grassland-dominated site in central Montana. Some, but not all, broods moved from big sagebrush to greasewood bottoms and alfalfa fields in August, returning to sagebrush by early September. Mean sagebrush cover at brood locations varied during the summer, reflecting these shifts; average cover was 14% in June, decreasing to 10% in August, and increasing to 21% in September. Shifts in distribution appeared tied to changes in food availability. Forb canopy cover averaged 27% and 17% in the two summers of the study; a dominant forb was yellow sweet clover (*Melilotus officinalis*). Mean canopy cover of grasses at brood locations was 47 to 51%. Mean height of shrubs, primarily big sagebrush, at brood locations was 18 cm in June, but increased to 25 cm by August

In southeastern Idaho, sage-grouse broods were most often found in big sagebrush (83% of broods), whereas sage-grouse in this area nested primarily in threetip sagebrush (Klebenow 1969). Mean big sagebrush crown cover at brood locations was 8.5%, significantly less than in the surrounding area (14.3%). Broods appeared to avoid sites with dense (e.g., 40%) big sagebrush cover and few forbs. In the development of a predictive model for brood habitat with discriminant function analysis, several variables were useful in distinguishing brood habitat. Compared to the available big sagebrush habitat, broods used areas with lower density of big sagebrush plants and greater frequency of three forbs: western yarrow (*Achillea millefolium*; 23.5%), tailcup lupine (*Lupinus caudatus*; 18.3%), and common dandelion (*Taraxacum officinale*; 12.0%) (Klebenow 1969).

Autenrieth (1981) summarized brood-rearing studies in Idaho and noted that, when broods do not migrate to upland habitats during summer, they rely on springs and wet meadows for succulent forbs. Livestock often graze these sites, so that when precipitation is scarce, adequate access to succulent forbs for sage-grouse can be difficult (Autenrieth 1981). Important forbs for sage-grouse in Idaho include common dandelion, prickly lettuce (*Lactuca serriola*), common salsify (*Tragopogon* spp.), western yarrow, alfalfa, and sweet clover (*Melilotus* spp.) (Autenrieth 1981).

Lyon (2000) examined sage-grouse ecology in a natural-gas field development in western Wyoming. Early brood-rearing use sites had greater total herbaceous cover than did available habitats, whereas density of live sagebrush, total shrub canopy cover, live sagebrush canopy cover, litter, and bare ground cover were less at used versus available sites. Near Savery, Wyoming, sage-grouse broods used primarily sagebrush-grass (n = 26) and sagebrush-bitterbrush (n = 21) habitats (Klott and Lindzey 1990). Sage-grouse broods used sagebrush-bitterbrush habitats more, and mountain shrub less, than expected based on availability. Overall, broods were in sites with shorter shrubs and lower shrub canopy cover than the surrounding habitat. Total shrub cover for all brood locations during the 2-yr study averaged 29.6%, whereas shrub cover at random sites averaged 45.8%. Mean sagebrush cover at brood sites was 16.9%, mean grass cover was 22.2%, and mean forb cover was 16.6% (Klott and Lindzey 1990). Discriminant function analysis suggested that two variables were significant in classifying sage-grouse brood habitat: perennial herbaceous species, and snowberry cover/presence of desert madwort (*Alyssum desertorum*), an introduced plant. Functions based on these two variables correctly classified 68% (1985) and 73% (1986) of the sites. Holloran (1999) also examined sage-grouse habitat use in Wyoming, and found that early brood-rearing habitat was characterized by lower shrub cover and greater total herbaceous and forb cover than in available habitats. Late brood-rearing habitat, and that used by broodless hens and males, was associated with greater forb cover and less residual grass cover than in available habitats.

During summer, shifts of broods to more mesic habitats with substantial forb production are common, but may depend on seasonal moisture patterns. Increased use of meadows and riparian areas in mid- to late summer is common as herbaceous vegetation in upland habitats becomes desiccated (Schroeder et al. 1999, Connelly et al. 2000*b*). In Idaho, Fisher (1994) found that when moisture in forbs was below about 60%, summer migration ensued; he suggested there might be a threshold for moisture content that triggers movement to areas with more succulent forage. At Sheldon NWR in Nevada, sage-grouse broods generally remained in upland habitats (primarily low sagebrush), with 92% of all brood locations in upland sites during two summers (1978 and 1980) (Klebenow 1985). During the intervening summer (1979), however, rainfall was scarce and sage-grouse used meadows more than upland sites (64% of locations in meadows vs. 36% in upland sites). Danvir (2002) found a similar relation, with increased use of meadows during dry summers. In central Montana, sage-grouse broods shifted from sagebrush grasslands to alfalfa fields and greasewood bottoms as forbs at higher elevations became desiccated (Wallestad 1971). Sage-grouse in Idaho formed large flocks near water and green meadows as plants senesced during summer (Dalke et al. 1963). In southeastern Idaho, broods moved to higher elevations during both summers of study, presumably in response to food availability (Klebenow 1969). A shift to sites with bitterbrush, associated with more mesic conditions, also was noted as the summer progressed; in June, 38% of broods were in this type, increasing to 53% in July (Klebenow 1969).

Seasonal shifts in brood-rearing habitat may not occur. Within silver sagebrush habitats in Alberta, Aldridge and Brigham (2002) found no difference between early (<7 wk) and late (7- to 12-wk-old) brood habitats. Overall, brood-rearing sites were characterized by sagebrush canopy cover nearly twice that of random sites (8.7 vs. 4.5%). These differences were also seen at brood sites (1-m^2 plot at the brood location) and at 7.5-m and 15-m scales. In addition, height of both sagebrush and palatable forbs was significantly greater at brood-use locations than at random sites (Aldridge and Brigham 2002).

Broodless hens may exhibit different seasonal habitat use patterns than hens with broods. In Oregon, Gregg et al. (1993) found that broodless hens moved to meadows earlier in the summer (early July) than did hens with broods (early August). Broodless hens selected for mountain big sagebrush, low sagebrush/fescue, and meadow cover types during summer, whereas they avoided low sagebrush/bunchgrass cover types (Gregg et al. 1993). Compared to hens with broods, broodless hens used more low sagebrush/bunchgrass, grassland, and meadow types and less low sagebrush/fescue (Gregg et al. 1993).

***Winter habitat.* —**During winter, sage-grouse rely almost exclusively on sagebrush for forage (Connelly et al. 2000*b*). The spatial distribution of sage-grouse in winter often is related to snow depth (Patterson 1952; Dalke et al. 1963; Gill 1965; Klebenow 1973, 1985; Beck 1975, 1977; Danvir 2002). At the onset of winter, sage-grouse gradually move to lower elevations with greater exposure of sagebrush above the snow; in migratory populations, this movement may extend up to 160 km (Patterson 1952). During more severe winters, a large proportion of the sagebrush may be beneath snow and thus unavailable for roosting or foraging.

In northern Utah, wintering sage-grouse flocks were found among increasingly taller sagebrush shrubs as snow depth increased (R^2 = 0.47; Danvir 2002). With deep (>30 cm) snows, sage-grouse selected for tall (>56 cm) sagebrush (Danvir 2002). Regardless of snow depth, the average height of sagebrush extending above the snow was about 25 cm at winter use sites (Danvir 2002). In central Montana, sage-grouse selected dense (>20% canopy cover) stands of big sagebrush during winter (Eng and Schladweiler 1972), whereas in central Idaho they preferred black sagebrush when these shrubs were available above the snow (Dalke et al. 1963). Sage-grouse in Oregon typically winter in low sagebrush habitats or in a mosaic of low and big sagebrush types, often on windswept ridges with less snow (Willis et al. 1993). In a study in central Oregon, 98% of winter observations were in mountain big sagebrush (Hanf et al. 1994), and sagebrush canopy cover was typically >20% at winter-use sites. Within these sites, however, grouse tended to use patches with lower (12-16%) canopy cover.

In Utah, Homer et al. (1993) used satellite imagery to classify winter habitat of sage-grouse into seven shrub categories. Wintering grouse preferred shrub habitats with medium to tall (40-60 cm) shrubs and moderate shrub canopy cover (20-30%; Homer et al. 1993). Sage-grouse most strongly avoided winter habitats characterized by medium (40-49 cm) shrub height with sparse (<14%) sagebrush canopy cover.

In Colorado, female sage-grouse were more likely than males to use dense stands of sagebrush (primarily *A. t. vaseyana*) during winter (Beck 1977). Flocks were typically on south- or southwest-facing aspects of gentle slope (generally <5%; Beck 1977). In northern Utah, wintering sage-grouse flocks also selected flat areas, with 87% of the winter locations on slopes of <5% (Danvir 2002). With deep (>30 cm) snows, however, sage-grouse were most common in draws dominated by tall basin big sagebrush (*A. t. tridentata*; Danvir 2002).

Sage-grouse in North Park, Colorado, concentrated during winter in seven small areas that totaled only 85 km^2; these areas, however, composed only 7% of the sagebrush in the entire study area (Beck 1977). Eng and Schladweiler (1972) suggested that sagebrush removal in winter habitats, which may compose a small portion of the year-round habitat of sage-grouse, may be especially detrimental because of the relatively long periods that winter habitat may be occupied by sage-grouse. Swenson et al. (1987) found marked declines in sage-grouse abundance in Montana when a large (30%) percentage of the winter habitat was plowed, primarily for grain production. Maintaining winter habitat for sage-grouse may be of critical importance in areas of energy development (e.g., natural gas fields, coal-bed methane), especially if several populations converge in a common wintering area (Lyon 2000).

***Roosting, foraging, and loafing habitat.* —**In Montana, roost sites were in sagebrush with a mean canopy cover of 26% and usually on flat terrain (Eng and Schladweiler 1972). During winter, sage-grouse may roost in snow burrows or snow forms, apparently for energy conservation (Back et al. 1987). In central Montana, sage-grouse foraged in big sagebrush with a mean canopy cover of 28%, and observations in more dense (>20%) cover were more common than those in less dense sagebrush (Eng and Schladweiler 1972). During the breeding season in Montana, feeding and loafing sites used by males averaged 32% sagebrush canopy cover; no males were observed in areas with <10% sagebrush canopy cover (Wallestad and Schladweiler 1974).

In Colorado, winter feeding-loafing sites did not differ from roosting sites in physical characteristics or vegetation (Beck 1977). Relatively short shrubs characterized roosting sites used by hens during the breeding season in North Park, Colorado, where 80% of 40 roosting sites were in areas with sagebrush ≤10 cm tall (Petersen 1980). Feeding and loafing sites used by hens during this study were most commonly in sagebrush ranging from 15 to 30 cm in height.

***Water use.* —**Sage-grouse do not appear to be dependent on free-flowing water, although their reliance on water or vegetation associated with water is variable (Schroeder et al. 1999). In Nevada, few leks were far from water; thus, in developing a model for lek preference Nisbet et al. (1983) excluded all areas >2 km from a water source. During a seven-yr study in eastern Idaho, sage-grouse gathered in large flocks near water during the fall migration, watering from 10 to 30 minutes (Dalke et al. 1963). Sage-grouse may remain in irrigated fields during much of the summer (Connelly and Markham 1983, Gates 1983, Wakkinen 1990). At the Idaho National Engineering Laboratory, sage-grouse often remained near lawns and ponds during summer, watering at these sources and feeding on succulent vegetation (Connelly and Ball 1978, Connelly 1982, Connelly and Markham 1983). Any consistent benefits of developed water sources to Greater Sage-Grouse are not apparent. In Oregon, sage-grouse were more abundant in areas where springs had not been developed (e.g., by fencing and planting vegetation; Batterson and Morse 1948). The authors hypothesized that "rank growth" at developed springs, where livestock were excluded by fencing, was unattractive to sage-grouse (Batterson and Morse 1948). A table near the end of the account lists the specific habitat characteristics for Greater Sage-

Grouse by study.

Area requirements:

Sage-Grouse populations typically inhabit large, unbroken expanses of sagebrush and are characterized as a landscape-scale species (Patterson 1952, Wakkinen 1990); however, conclusive data are unavailable on minimum patch sizes of sagebrush necessary to support viable populations of sage-grouse. In Colorado, the only population of Gunnison Sage-Grouse not "severely reduced" from historical times (Oyler-McCance et al. 2001:329) was in an area with a relatively low rate of habitat loss (11% over 35 yr) and >340,000 ha of habitat remaining. In Wyoming, Patterson (1952) found that sage-grouse "packs" could range as widely as several thousand square kilometers. Migratory populations of sage-grouse may use areas exceeding 2,700 km^2 (Connelly et al. 2000*b*, Leonard et al. 2000), and travel of 35 km from a lek to a winter area has been recorded (Berry and Eng 1985).

Wiley (1978:116) suggested that the "basic unit of sage grouse social organization is a lek covering about two hectares … and has a single mating center some 50 square meters in extent." Schroeder et al. (1999), in summarizing several studies, reported that the average area defended by males on leks ranged from 5 to 100 m^2.

Differences in techniques used to measure movements of sage-grouse render comparisons among studies, or reporting of average seasonal ranges, problematic (Schroeder et al. 1999). In North Park, Colorado, adult sage-grouse hens moved on average 5.4 km from leks to nest sites, whereas yearling females traveled only 2.3 km (Petersen 1980). Distances moved by female sage-grouse from leks to nests in central Montana were similar between age classes, with adults moving 2.5 km, and yearlings 2.8 km (Wallestad and Pyrah 1974). Danvir (2002) reported comparable data for sage-grouse in Utah, with 77% of hens nesting no farther than 3.3 km from the lek where they were captured. Females generally stayed within 5 km of the nest site the remainder of the summer (Danvir 2002). Sage-grouse may move much longer distances between seasonal ranges. In eastern Idaho, the mean distance moved between summer and winter ranges was 48.2 km for 28 hens; this movement involved a decrease in mean elevation of 446 m (Hulet et al. 1986).

Home ranges of sage-grouse hens vary widely among individuals and seasons. Spring home ranges in Idaho for four hens averaged 810 ha (Connelly 1982). In eastern Idaho, home ranges of 28 sage-grouse hens during summer averaged 285 ha but varied widely, from 9 to 710 ha (Hulet et al. 1986). In another Idaho study, average summer home range size for four adult females with broods was 406 ha, whereas three juvenile sage-grouse, including one female, had summer ranges averaging 94 ha (Connelly 1982). At Hart Mountain National Antelope Refuge in Oregon, home ranges of sage-grouse hens during brood-rearing declined from 800 ha during early brood rearing (hatch to 6 weeks) to 100 ha later in the season (7-12 weeks post-hatch) (Drut et al. 1994*a*). At a less productive site (e.g., less forb and tall sagebrush cover), home range size increased from 2,100 ha during the early period to 5,100 ha later in the season (Drut et al. 1994*a*). Drut et al. (1994*a*) suggested these differences were due to differences in forb availability and chick diets between the two sites. Sagebrush patches used by broods averaged 86 ha in June and July in central Montana but diminished to 52 ha later in August and September (Wallestad 1971). Average summer ranges were 297 ha (range = 179 to 821 ha) for 11 radio-marked hens in Idaho that primarily used irrigated cropland (Gates 1983). Winter ranges for four hens in this same study varied from 176 to 1,070 ha (Gates 1983). In Idaho, Connelly (1982) reported a mean fall home range of 2,246 ha for five female sage-grouse (range = 530 to 5,590 ha).

Regarding movements of males, in Montana, the majority (76%) of sage-grouse males were within 1 km of their associated leks during the breeding season; however, movements up to 1.3 km from the lek were common (Wallestad and Schladweiler 1974). Daily movements of males from leks to day-use areas in Utah were 0.5 to 0.8 km on average, and core day-use areas were a minimum of 0.25 km^2 (Ellis et al. 1989). Male sage-grouse in northcentral Utah moved on average 8.3 km from leks to summer use areas (Danvir 2002). Connelly (1982) reported movements of three male sage-grouse from leks to summer habitats with distances ranging from 42 to 50 km. In Washington, 14 males on the Yakima Training Center dispersed an average maximum distance of 15.5 km from the lek (Hofmann 1991). Home range sizes (males and females combined) in this 2-yr study were somewhat large, ranging from 25.9 km^2 in summer to 44.2 km^2 in fall. One male in Idaho used an area of 1,190 ha during winter (Gates 1983).

Brown-headed Cowbird brood parasitism:

Brood parasitism has not been documented for sage-grouse (Schroeder et al. 1999). Grouse species typically are not suitable as hosts for such parasitism because young are precocial and leave the nest immediately after hatching.

Breeding-season phenology and site fidelity:

Sage-grouse males begin to arrive on leks in late winter or early spring, and may display from January through May or even as late as June (Scott 1942, Dalke et al. 1963, Rogers 1964, Wiley 1978, Autenrieth 1981, Schroeder et al. 1999). Occasionally males appear on leks so early that they display on snow-covered ground (Scott 1942, Dalke et al. 1963). The majority of breeding activity occurs shortly after sunrise, with a smaller peak in breeding activity at dusk (Scott 1942, Jenni and Hartzler 1978, Schroeder et al. 1999). Peaks in lek attendance occur earlier in the season for adult males than for subadult males, which arrive at the lek later in the season (Dalke et al. 1963, Eng 1963, Wiley 1978). Overall, yearling males attend leks less frequently than adult males, with yearlings often remaining on the periphery of the lek and seldom breeding (Jenni and Hartzler 1978). Hens occupy leks for a shorter period, typically in March and April, with peak attendance by hens paralleling or preceding that of adult males (Scott 1942, Dalke et al. 1963, Jenni and Hartzler 1978, Wiley 1978, Gibson 1996).

Sage-grouse typically show high fidelity to leks (Scott 1942). Some leks have been occupied for decades (Dalke et al. 1963, Wiley 1978); one lek in Wyoming was used for at least 28 yr (Wiley 1978). In Idaho, Dalke et al. (1963) found that when populations were relatively high, both primary leks and smaller leks were used, but during population lows, smaller, satellite leks were abandoned. Male sage-grouse may move between leks during the breeding season, though dominant males are less likely to do so (Dalke et al. 1963). The percentage of male sage-grouse returning to the leks on which they were banded is also highly variable. In Idaho, this percentage ranged from 5 to 21% over 3 yr (Dalke et al. 1963).

Nesting hens typically exhibit nest area fidelity, often nesting within 1 km of previous nesting areas (Berry and Eng 1985, Schroeder et al. 1999); some hens returned to nest within 70 m of their former nesting sites (Patterson 1952). A similar fidelity was noted for Gunnison Sage-Grouse, with an average distance of 455 m between current and previous years' nests (Young 1994). New nests may be near (i.e., within meters) old nests, but nest bowls themselves apparently are not reused (Patterson 1952, Schroeder et al. 1999). Fidelity to winter areas has not been well studied. Some evidence of fidelity to winter areas among years has been demonstrated, however, in Washington (Schroeder et al. 1999) and Wyoming (Berry and Eng 1985).

Breeding dates vary by site, ranging from early to late March in Washington to mid- to late April in Montana and Wyoming, and annual variation in weather can cause delays in nest initiation (Schroeder et al. 1999). Incubation of eggs begins about 3 weeks after copulation, with young hatching from early April to late July (Schroeder et al. 1999). Yearling hens may initiate nesting later than adults (Schroeder 1997). Renesting is common in some populations but rare in others; the likelihood of renesting after loss of a first clutch ranged from 5 to 87% in 16 studies reviewed by Schroeder et al. (1999). Adults are more likely to renest than are yearlings (Patterson 1952, Petersen 1980, Schroeder et al. 1999). Renesting by sage-grouse in Washington was an important contributor to overall nest success, with 87% of 69 females laying a second clutch (Schroeder 1997). At the Yakima Training Center in Washington, Sveum et al. (1998) found that 28 and 23% of hens renested during the 2 yr of their study. On the Sheldon NWR in Nevada, nine of 36 of hens renested, with five of nine successful (Crawford and Davis 2002). A renesting rate of 36% was reported for sage-grouse in Alberta (Aldridge and Brigham 2001). By contrast, renesting by Gunnison Sage-Grouse in Colorado was low, with only 1 of 30 renesting (Young 1994). Young (1994) postulated that relatively later hatching dates for Gunnison Sage-Grouse and more severe winter weather could leave inadequate time or resources for hens to renest.

<u>Species' response to management</u>:

Habitats used by Greater Sage-Grouse have been widely altered by land management practices during the last 150 yr (Patterson 1950; Kufeld 1968; Braun 1987; Drut 1994; Connelly and Braun 1997; Schroeder et al. 1999, 2004; Miller and Eddleman 2000; Wisdom et al. 2000, 2002*a*). By 1974, about 10 to 12% of the 40 million ha of sagebrush rangelands in North America had been treated to provide forage for livestock (Vale 1974). Overall, >80% of sagebrush rangelands have been altered in some way by human activities (West 1999). In Washington, Dobler (1994) estimated that >60% of the native sagebrush steppe had been converted for human use by 1994. In Colorado, Kufeld (1968) reported that >1,000 km^2 of sagebrush on federal lands had been treated by 1966, primarily to increase livestock forage; the majority of this area had been sprayed, although 21% had been plowed.

Historically, brush control was used widely to eliminate sagebrush, especially from 1960 to 1970 (USDI Bureau of Land Management et al. 2000). Sagebrush control efforts diminished in the 1970's, primarily due to reduced federal funding combined with increasing environmental concern (Donoho and Roberson 1985). Whereas vast areas of former sagebrush have been converted to non-native grasses such as crested wheatgrass, some lands also have been planted to agricultural crops such as alfalfa, potatoes, or wheat. Although sage-grouse will use alfalfa fields and other croplands when such lands are adjacent to large patches of native sagebrush, especially during brood rearing (Patterson 1952, Leach and Browning 1958, Wallestad 1971, Gates 1981, Connelly et al. 1988), application of chemicals to agricultural lands poses a hazard to sage-grouse populations (Patterson 1952, Blus et al. 1989). Patterson (1952) also reported substantial losses of sage-grouse, particularly juveniles, from mowing operations in alfalfa fields. Large-scale reclamation projects involving dam construction, plowing, and irrigation impacted rangelands across the west; for example, the 400-km^2 Riverton Project in Wyoming resulted in extirpation of sage-grouse from the area (Patterson 1950).

Mechanical removal of sagebrush, while as effective as herbicides or fire in eliminating sagebrush, tends to be applied to smaller patches of habitat (Connelly et al. 2000*b*). Swenson et al. (1987) found that removal by plowing of 16% of the sagebrush in their Montana study area, from 1954 to 1984, corresponded to a decline in the population index (number of males on leks in spring) from 241 to 65. No comparable trend was discernable in nearby control areas. The authors concluded that plowing was a more serious threat to sage-grouse than was herbicide application, primarily because plowed lands tend to be planted to crops, whereas recovery of sagebrush is more likely in sprayed habitats. In addition to land management practices that directly remove sagebrush, other practices such as livestock grazing, pesticide application, and prescribed fire may degrade habitats and thus affect populations of Greater Sage-Grouse. These influences are described below. Nearly all studies of effects of land management practices on sage-grouse rely on indices of abundance (e.g., lek counts), rather than measures of survival or reproductive success. In addition, the dearth of manipulative studies to elucidate cause-effect relations of land management practices on sage-grouse has been noted (Braun and Beck 1996, Rowland and Wisdom 2002).

Fire.— Prescribed fire has been used not only to remove sagebrush, primarily to enhance livestock forage, but also with the expressed goal of improving habitat conditions for sage-grouse and other wildlife (Klebenow 1973). Although some studies have demonstrated neutral or even positive effects on sage-grouse habitats from fire (e.g., Martin 1990, Fischer 1994, Pyle and Crawford 1996, Crawford and Davis 2002), others have documented population declines and long-term habitat degradation (Connelly et al. 2000*a*, Nelle et al. 2000). While some short-term benefits, such as increases in annual forbs, may accrue from prescribed burning, nesting cover in particular may be reduced and thus become less suitable (Wrobleski 1999, Nelle et al. 2000). A 9-yr study in southeastern Idaho examined lek attendance in relation to prescribed burning and suggested that declines in breeding populations of sage-grouse were more severe following fire (Connelly et al. 2000*a*). The study area was a Wyoming big sagebrush/bluebunch wheatgrass (*Pseudoroegneria spicata*) site, with 23 cm average annual precipitation. Four yr of pre-treatment data were obtained before a 5,000-ha portion was burned; nearly 60% of the sagebrush was eliminated, leaving a mosaic of sagebrush and grassland types. Although declines in lek attendance occurred throughout the study in both treatment and control sites, declines were greater in the burned area. Following the burn, the number of active leks declined 58%, from 12 to 5, in the treatment versus 35%, from 17 to 11, in the control. Furthermore, mean number of males/lek postburn was 6 in the treatment versus 17 in the control, whereas these variable values had been similar at both sites prior to treatment. Attendance at the major leks following the fire declined 90% at the treatment site versus 63% at the control.

In southeastern Idaho, Nelle et al. (2000) examined characteristics of 20 burns of differing ages and sizes in mountain big sagebrush-dominated communities in relation to sage-grouse habitat. Mean size of four wildfires in the study area was 390 ha, whereas the mean size of 12 prescribed burns was 975 ha. Canopy cover of forbs, grasses, and shrubs was measured, along with invertebrate abundance. The authors concluded that burning conferred no benefits to sage-grouse nesting or brood-rearing habitat, and that long-term negative impacts resulted from fires in nesting habitat, due to the lengthy time (>20 yr) for the sagebrush canopy to recover to suitable levels for nesting.

Retrospective studies of burns (5- to 43-yr old) at Hart Mountain and Steens Mountain in southeastern Oregon revealed that key components of sage-grouse habitat used during the breeding period were available in burned areas ranging from 25- to 35-yr old (Crawford and

McDowell 1999, McDowell 2000). Sagebrush cover was the only habitat component "substantially affected" in the long term by burning (McDowell 2000). During the first 2 yr after prescribed burning in mountain big sagebrush at Steens Mountain, forage quality (e.g., percentages of calcium and crude protein) was generally superior in burned sites compared to control sites (McDowell 2000). The fires in this study covered 619 and 1,352 ha.

Wrobleski (1999) evaluated the response of vegetation to prescribed fire in a Wyoming big sagebrush site at Hart Mountain National Antelope Refuge in eastern Oregon. Vegetation was sampled in eight 400-ha plots, of which four were subsequently burned, creating 27 km of burned/unburned edge. Measurements were obtained for 1 yr postfire; annual forb cover increased in burned versus control plots, but perennial grass cover decreased. Most pronounced differences were large increases in sagebrush vigor (number of reproductive and vegetative shoots) along the edge of the burned areas. Fischer (1994) investigated effects of a 5,800-ha prescribed fire on sage-grouse habitat in southeastern Idaho. The study area was primarily Wyoming big sagebrush/bluebunch wheatgrass, but threetip sagebrush also was common. During the 3 yr after the fire, 655 grouse were captured and 127 followed with radiotelemetry. Data had been collected on sage-grouse for 3 yr prior to the burn. Nest success and habitat characteristics did not differ between burned and unburned areas, and no positive response by sage-grouse to the burned habitat was noted. Abundance of Hymenoptera, an important grouse food item, declined significantly following the fire (Fischer 1994). At Sheldon NWR in Nevada, however, arthropod abundance did not decline following wildfire (Crawford and Davis 2002).

The relationship between fires and leks is inconsistent. At the U.S. Sheep Experiment Station near Dubois, Idaho, fires (both wild and prescribed) apparently caused the abandonment of two active leks, enhanced the creation of one, and had no apparent effect on the fourth (Hulet et al. 1986). Also in Idaho, Fischer (1994) found that, although the number of active leks declined during the 3 yr after a prescribed burn, this decline was similar in burned and control areas.

Coupled with the outright loss of sage-grouse habitat from fire, altered fire regimes have resulted in severe habitat degradation in sagebrush steppe from invasion of cheatgrass (*Bromus tectorum*) and other exotic vegetation following wildfires (Pellant 1990, Billings 1994, Knick 1999, West 1999). This problem is most severe in Wyoming big sagebrush communities at lower elevations (Miller and Eddleman 2000, Hemstrom et al. 2002) and is uncommon in cooler, more mesic areas such as Montana and Wyoming. It is estimated that >50% of the sagebrush ecosystem in western North America has been invaded to some extent by cheatgrass (West 1999), with losses projected to accelerate in the future (Hemstrom et al. 2002).

Livestock grazing.— Grazing by livestock has occurred over virtually the entire range of sage-grouse (Braun 1998); thus its influence on sage-grouse habitat is perhaps the most pervasive of any land management practice. Effects of livestock grazing on vegetation species composition and structure in the sagebrush community have been well documented (Vale 1974, Owens and Norton 1992, Fleischner 1994, West 1999, Belsky and Gelbard 2000, Jones 2000, Anderson and Inouye 2001). However, few empirical studies report the responses of sage-grouse to grazing, and experimental research on effects of livestock on sage-grouse is lacking (noted by Braun 1987, Guthrey 1996, Beck and Mitchell 2000, Connelly et al. 2000*b*, Rowland and Wisdom 2002). No published studies on the effects of livestock grazing on sage-grouse were manipulative experiments in which cause-effect relationships could be measured. Instead, many studies imply negative effects of livestock grazing on sage-grouse by noting that grazing systems must be designed such that adequate herbaceous and shrub cover for nesting or brood rearing are maintained (e.g., Gregg et al. 1994, DeLong et al. 1995, Sveum et al. 1998). For example, DeLong et al. (1995) found that predation rates on sage-grouse nests in Oregon were negatively related to percent cover of tall grass and medium-height shrubs, and suggested that practices, such as livestock grazing, that remove grass cover may negatively affect nesting sage-grouse. Interactions of livestock grazing with other factors, such as wildfire, are complex and not widely studied.

Beck and Mitchell (2000) summarized potential effects of livestock grazing on sage-grouse habitats, and cited only four references that provide empirical evidence of direct negative effects of livestock grazing on sage-grouse, as follows. Of 161 nests examined in Utah, two were trampled by livestock (one sheep, one cattle) and five were deserted due to disturbance by livestock (Rasmussen and Griner 1938). In Nevada, sage-grouse habitat in wet meadows was degraded through overgrazing by domestic livestock and altered system hydrology (Oakleaf 1971, Klebenow 1985; as reported by Beck and Mitchell 2000). Klebenow (1982) examined sage-grouse habitat use in relation to grazing at the Sheldon NWR in Nevada, where sheep and cattle had grazed for >130 yr. Dominant sagebrush species at the refuge were low sagebrush, mountain big sagebrush, and Wyoming big sagebrush. Grasses included Sandberg and Cusick's bluegrass (*Poa secunda* and *P. cusickii*, respectively) in wet meadows, and Sandberg bluegrass and mat muhly (*Muhlenbergia richardsonis*) in dry meadows. A rest-rotation system was implemented for cattle grazing in 1980 over the majority of the refuge, where season-long grazing had occurred historically; a smaller portion had previously been managed under deferred rotation. Meadows heavily grazed by livestock (e.g., with few forbs and grasses and dense shrubs present) were avoided by sage-grouse, with the exception of use for free water when available (Klebenow 1982). (No explicit definitions were provided for light versus moderate or heavy grazing.) Some positive effects of livestock grazing were noted. When cattle were introduced into a meadow with residual grass, sage-grouse initially preferred the grazed openings, which had an effective cover height (sensu Robel et al. 1970) of 5 to 15 cm, compared to 30 to 50 cm in the lightly grazed surrounding areas. Grouse avoided dense, ungrazed basin wildrye meadows but were observed in adjacent wildrye that was grazed. One 40-ha meadow that was lightly grazed by cattle (41 yearling heifers, 60 days in June-August) was used throughout the summer by sage-grouse and had more sage-grouse (100) than any other meadow on the refuge. Effective cover height in the meadow did not decrease below 5 cm during the summer.

Danvir (2002) reported two instances of nest abandonment related to livestock grazing in northern Utah during 7 yr of observations; one was caused by cattle, the other by sheep. Sage-grouse behavior on leks did not appear to be altered by the presence of cattle grazing (Danvir 2002). Sheep grazing in Idaho did not appear to disrupt use of leks by sage-grouse (Hulet 1983). Autenrieth (1981), however, cautioned against grazing sheep in sage-grouse winter habitat. He also suggested that livestock use of meadows occupied by sage-grouse, as well as livestock drives in sage-grouse habitat, could be detrimental to sage-grouse. In Wyoming, nesting densities of sage-grouse were considerably lower (10 nests/100 ha) in areas heavily grazed by domestic sheep compared to adjacent sites with moderate grazing (28 nests/100 ha) (Patterson 1952). Nest desertion caused by migrant bands of sheep also was documented (Patterson 1952).

Heath et al. (1998) compared sage-grouse nesting and breeding success at three ranches with different grazing operations and levels of predator control in Wyoming. They found that, despite heavier livestock use (removal of >50% of annual herbaceous production, and grazing by both sheep and cattle) and long-term predator control on one ranch, nesting and breeding success of sage-grouse did not differ substantially among the three sites. Chick survival to 21 days was, however, greater on the ranch with lighter grazing, suggesting that predator control did not fully compensate for the greater reductions in herbaceous production (Heath et al. 1998). Further, hens were documented leaving the more heavily grazed ranch to nest elsewhere but returning to that ranch to rear broods (Heath et al. 1998). In a similar study, Holloran (1999) examined sage-grouse habitat use and productivity in relation to grazing management strategies at four ranches in southeastern Wyoming. He found no differences in nest success, brood survival, or numbers of chicks fledged among the ranches. Some differences in habitat use by sage-grouse were found among the ranches; however, these could not be ascribed to differences in grazing pressure, but were ascribed to differences in soil types and precipitation patterns (Holloran 1999). Above-average precipitation during the study, however, may have obscured any potential differences in habitat suitability for sage-grouse among sites. Neither of these studies employed control sites or replication.

Research on upland meadows in Nevada showed that pastures under a rest-rotation system provided better production of those forb species eaten by sage-grouse than did pastures that were not rested, but sage-grouse also used a pasture not grazed by cattle for 10 yr (Neel 1980). The author concluded that light grazing in meadows might enhance habitat for sage-grouse. Evans (1986, as reported in Beck and Mitchell 2000) also found that grazing by cattle stimulated production of forb species used by sage-grouse in upland meadows in Nevada.

Application of herbicides and pesticides.—Until the 1980's, herbicides such as 2,4-D were the most common method of eliminating large blocks of sagebrush (Connelly et al. 2000*b*). Lands after treatment often were planted with crested wheatgrass or other non-native perennial grasses for livestock forage. Application of herbicides affects all seasonal ranges of sage-grouse (Connelly et al. 2000*b*), and its effects have been widely reported compared to other land management practices (e.g., Gill 1965, Martin 1970, Carr 1967, Klebenow 1970, Pyrah 1970, Braun and Beck 1976, Rowland and Wisdom 2002). Although most of these studies report negative effects of herbicide application within sage-grouse habitats, some report positive effects, such as increased production of forb species eaten by sage-grouse (e.g., Autenrieth 1969).

Spraying of herbicides primarily degrades habitat for sage-grouse by increasing fragmentation and removing shrubs used as nesting cover. Long-term studies in North Park, Colorado, revealed that applying 2,4-D resulted in reduced cover of sagebrush, fewer sagebrush plants and forbs, and lek abandonment (Braun and Beck 1976, 1996). Production of sage-grouse, as measured by percentage young in the harvest and chicks per hen, declined in the 5 yr following treatment but rebounded by 15 yr post-treatment (Braun and Beck 1996). Hens with broods avoided sprayed blocks while moving toward traditional brood-rearing habitats (Carr 1967, Carr and Glover 1971). In another study in North Park, in which >120 flocks (>3,000 birds total) were observed during two winters, only 4 flocks were found in altered (by spraying with 2,4-D, plowing, burning, or seeding) sagebrush habitats, although >30% of the study area had been treated (Beck 1977).

In Montana, 693 ha of big sagebrush in a 777-ha study area were strip-sprayed with 2,4-D in one year; 3 yr of subsequent study revealed nearly complete mortality (97%) of sagebrush in sprayed areas (Martin 1970). Only 4% of 415 observations of sage-grouse were in sprayed strips. Shifts in sage-grouse distribution were attributed to differences in vegetation composition; unsprayed strips had a greater proportion of forbs to grasses (40:60, vs. 20:80 in sprayed strips) and more live sagebrush, as well as more abundant forbs (Martin 1970). In southeastern Idaho, spraying of >1,300 ha of threetip and big sagebrush appeared to effectively eliminate nesting in sprayed areas, at least for 5 yr post-treatment (Klebenow 1970). Sprayed plots also had less basal area of forbs and lower crown cover of big and threetip sagebrush than control plots, in both brood sites and sites with no broods recorded (Klebenow 1970).

Application of pesticides, often for grasshopper (Orthoptera) control, may affect sage-grouse by decreasing available prey (Eng 1952, Patterson 1952, Johnson 1987, Connelly and Blus 1991). Sage-grouse chicks require insects for survival during the first few weeks of life, and the quantity of insects available is related to both survival and growth of chicks (Johnson and Boyce 1990). Pesticides also poison birds through ingestion of contaminated insects or plant materials treated as bait (e.g., for rodent control). Mortality rates directly attributable to organophosphate pesticide application were 16% of 73 sage-grouse in Idaho (Blus et al. 1989, Connelly and Blus 1991). All deaths were of juvenile sage-grouse that died in alfalfa or potato fields. A single die-off of 70 sage-grouse in an alfalfa field was also reported (Connelly and Blus 1991).

In Wyoming, >1.7 million ha were treated with toxaphene and chlordane (applied as baited bran) for grasshopper control during 1949-1950 (Post 1951*a*, Patterson 1952). Forty-five sage-grouse mortalities were recorded on 16 baited 40-ha plots in the following 2 yr (Post 1951*a*). Of these 45, pesticide poisoning was the suspected cause of 11 deaths. Other deaths, however, were indirectly related to toxemia from ingestion of baited grain. Sage-grouse were killed by automobiles and a mowing machine, and all birds showed symptoms of toxemia (Post 1951*a*). Subsequent grasshopper control in Wyoming involved spraying of the more toxic pesticide Aldrin* (1,2,3,4,10,10-hexachloro-1,4,4α,5,8,8α-hexahydro-exo-1,4-endo-5,8-dimethano-napthalene) (Post 1951*b*). No differences were found in bird mortality between unsprayed and sprayed plots, and no sage-grouse mortalities were observed during the single field season (Post 1951*b*).

Effects of energy development, other disturbance, roads, fences, and powerlines.–Resource extraction for energy development has been widespread throughout sagebrush-steppe habitats (Scott and Zimmerman 1984; Braun 1987, 1998; Braun et al. 2002). A survey of 51 surface coal mines in the northwestern United States in the 1980's found that sage-grouse were present on 27 mines; baseline biological data were collected on sage-grouse at most of these sites (Scott and Zimmerman 1984). Impacts of coal mine and oil and gas development on sage-grouse are both short- and long-term (Braun 1987, 1998; Braun et al. 2002). Braun (1987) noted that initial stages of oil field development (e.g., site preparation, drilling, and road construction) led to decreased numbers of grouse in North Park, Colorado. Although populations were sometimes reestablished over time, permanent, negative impacts on sage-grouse populations could occur as a result of the construction of refineries, pumping stations, and other facilities associated with mineral development (Braun 1987).

In Colorado, numbers of male sage-grouse on two leks within 2 km of surface coal mines declined drastically, to near zero, with some resurgence seen after mining activity was sharply

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*References to chemical trade names does not imply endorsement of commercial products by the Federal Government.

curtailed (Braun 1986, Remington and Braun 1991). Overall population trends, however, were similar between the control area and mining area over a 17-yr period (Remington and Braun 1991). Oil and gas development in Alberta, where sage-grouse have declined 66 to 92% over the last three decades and may number fewer than 320 individuals, has caused abandonment of at least four lek complexes (Aldridge 1998, Braun et al. 2002). Long-term declines in males/lek were correlated with increases in oil-related activities, and >1,500 wells have been drilled in the province (Braun et al. 2002). Sage-grouse in Colorado were not displaced from an active oil field, but eight of 11 active leks that remained were on the field's periphery, and nine were out of sight of active wells or power lines (Braun et al. 2002).

Coal-bed methane development is an emerging concern for sage-grouse. More than 12,000 active wells have been drilled, and 10,000 km of overhead power lines constructed, in an area >11,650 km^2 for extraction of coal-bed methane gas in the Powder River Basin of northeastern Wyoming (Braun et al. 2002). The development area supports about 90 active sage-grouse leks, 40% of all leks in northeastern Wyoming, and is considered year-round habitat for the species. Although development is fairly recent (most activity since 1997), preliminary observations indicate that 1) there are fewer males/lek when leks are <0.4 km of a well than outside this zone; 2) sage-grouse populations associated with leks within 0.4 km of a power line show slower rates of growth than those farther away; and 3) sage-grouse numbers are consistently lower in areas <1.6 km from a coal-bed methane facility. A total of 1,210 km^2 of habitat will be lost outright when the field is fully developed (Braun et al. 2002). Coal-bed methane development is also underway in other portions of the range of sage-grouse, including Utah, Montana, and Colorado.

Creation of artificial leks to replace those destroyed during coal-mining operations has yielded mixed results; such an attempt was somewhat successful in Montana (Eng et al. 1979, Phillips et al. 1986) but not in Wyoming (Tate et al. 1979). Noise associated with oil wells near Walden, Colorado, was believed responsible for the abandonment of a lek that historically had supported 1,000 birds (Rogers 1964). Lyon and Anderson (2003) found that, although sage-grouse nest success was similar on "disturbed" (within 3 km of natural gas development in Wyoming) and control sites, hens captured on disturbed leks had lower nest initiation rates and traveled twice as far to nest as hens on undisturbed leks.

Urbanization, including development of exurban sites, also affects sage-grouse habitat. Braun (1998) estimated that 3 to 5% of the historical sage-grouse habitat in Colorado had been degraded by urbanization. Most nest abandonment by sage-grouse is related in some way to human disturbance (Schroeder et al. 1999). Disturbance from military activity also may cause displacement of sage-grouse, although population-level effects are not known (Hofmann 1991).

Structures associated with energy development and rural expansion, such as fences, roads, and power lines, may fragment habitats for sage-grouse (Braun 1998, Connelly et al. 2000*b*, Braun et al. 2002). Direct mortality also occurs from collisions of sage-grouse with fencing (Call and Maser 1985, Danvir 2002) and vehicles on roads (Post 1951*a*, Patterson 1952). Effects of roads have not been widely studied with regard to sage-grouse populations. In Wyoming, sage-grouse were most susceptible to death from collisions during summer (June-August), when movements of hens with broods increased and grouse were attracted to relatively moist roadside vegetation (Patterson 1952). Vehicle traffic on roads, along with the increased access that roads provide to recreational users of rangelands, may lead to increased disturbance of grouse on leks or during nesting or brood rearing (Braun 1998). In Wyoming, successful hens in a natural gas field nested farther from roads than did unsuccessful hens (Lyon and Anderson

2003). Wisdom et al. (2002*b*) found that current road densities in the interior Columbia Basin were higher in extirpated range of sage-grouse than in currently occupied range. The pattern of higher road density in extirpated range also coincided with lower abundance of habitat, higher human population density, increased agricultural development, and greater likelihood of invasion by exotic plants, suggesting a synergy of effects (Wisdom et al. 2002*b*).

Power lines not only increase habitat fragmentation but also provide perches for avian predators of sage-grouse (Braun 1998; F. Hall, California Department of Fish and Game, Wendel, California, pers. comm.). Although the magnitude of such effects on sage-grouse habitats and populations is unknown, sage-grouse use has been shown to increase as distance from power lines increases (Braun 1998). Disturbance from raptors, particularly Golden Eagles (*Aquila chrysaetos*), may disrupt strutting males on leks (Rogers 1964, Ellis 1984); thus, structures that provide perches for raptors may increase such disturbance. Studies in California identified three factors associated with power lines that could decrease grouse numbers or lek use, either singly or in combination: 1) raptors, especially immature Golden Eagles, hunt more efficiently from perches such as towers and may harass or take adult grouse near or on leks; 2) Common Ravens (*Corvus corax*) may use the towers as perches and nest sites, and prey on eggs and young of sage-grouse near leks; and 3) sage-grouse may respond to towers as potential raptor perch sites and thus abandon, or decrease their use of, a lek from which towers can be seen (F. Hall, pers. comm.).

Translocations.—Translocations of sage-grouse generally have been unsuccessful (Toepfer et al. 1990, Reese and Connelly 1997, Schroeder et al. 1999, Connelly et al. 2000*b*), and further research on their effectiveness is needed (Reese and Connelly 1997, Rowland and Wisdom 2002). During the 1930's, 200 sage-grouse were trapped in Wyoming and reintroduced into New Mexico, where sage-grouse had been extirpated (Allred 1946, Campbell 1953). Presumably, the sage-grouse historically occupying this region were Gunnison and not Greater Sage-Grouse (Young et al. 2000). The transplants eventually failed, and sage-grouse are no longer found in New Mexico. Other efforts to translocate sage-grouse failed in British Columbia, Montana, and Oregon (Toepfer et al. 1990). Patterson (1952) reported that despite massive removals from live-trapping and hunting of >13,000 sage-grouse from the Eden Valley in Wyoming, most transplanted birds, especially adults, returned from release sites to the area of capture. By contrast, Musil et al. (1993) discussed the translocation of nearly 200 sage-grouse over 2 yr in central Idaho and reported that dispersal of birds away from the release site was not a problem. In addition, the translocated birds established five new leks in the release site, nested successfully, and persisted for the first 3 yr following release. Consequently, they concluded that translocation into suitable habitats was a feasible method for supplementing or reestablishing populations of sage-grouse (Musil et al. 1993).

Reese and Connelly (1997) reviewed reports of 56 attempts to translocate sage-grouse, involving >7,200 individuals, and found that only 5% of attempts were successful. They found that successful translocations typically involved 1) reproductively active birds captured on leks during March or April, 2) rapid transportation and release of birds, and 3) release into isolated areas of suitable habitat surrounded by inhospitable habitat. The authors recommended that 1) intensive monitoring of translocated sage-grouse be conducted, 2) the technique be considered experimental only, and that 3) translocations should not be relied upon to re-establish extirpated populations. Reese and Connelly (1997) and Toepfer et al. (1990) provide recommendations and criteria for translocations of sage-grouse. One important benefit of translocations may be maintaining genetic diversity in small populations, particularly when dispersal corridors are lacking (Schroeder et al. 1999).

Management Recommendations:

Native sagebrush habitats have undergone drastic declines in the last century (Hann et al. 1997, West 1999, Miller and Eddleman 2000), with concomitant declines in populations of Greater and Gunnison Sage-Grouse (Connelly and Braun 1997, Braun 1998, Leonard et al. 2000, Oyler-McCance et al. 2001, Beck et al. 2003). Restoration of sage-grouse habitats will require substantial effort to counter the current downward trend in habitat quality (USDI Bureau of Land Management 2001, Bunting et al. 2002, Hemstrom et al. 2002, Wisdom et al. 2002a, Shaw et al. 2004). Several publications provide management recommendations for sage-grouse habitats (e.g., Braun et al. 1977, Paige and Ritter 1999:9-26, Connelly et al. 2000b, Wisdom et al. 2000). The following recommendations draw in part from these publications.

Maintain, conserve, and restore large blocks of intact sagebrush with a healthy understory of native grasses and forbs (Paige and Ritter 1999, Connelly et al. 2000*b*). Where large-scale conversion of sagebrush (e.g., to cropland or non-native grasses) has occurred, sage-grouse populations have declined (Leonard et al. 2000). Sage-grouse are a sagebrush obligate and respond to landscape-scale influences (Patterson 1952, Wakkinen 1990, Paige and Ritter 1999, Schroeder et al. 1999, Connelly et al. 2000*b*). Although total area requirements for the species are unknown (Schroeder et al. 1999), migratory populations of sage-grouse may use areas exceeding 2,700 km^2 (Leonard et al. 2000, Connelly et al. 2000*b*).

Protect lek sites and adjacent habitat (up to 18 km from the lek, depending on migratory status of the population) from alteration, such as burning, spraying, or oil and gas development (Wallestad and Schladweiler 1974, Connelly et al. 2000*b*).

During spring, manage breeding habitats to maintain sagebrush canopy cover of 15 to 25% and perennial herbaceous cover of ≥15% grasses or ≥10% forbs; grasses and forbs should be ≥18 cm tall (Connelly et al. 2000*b*).

In areas where sagebrush density has increased beyond that required for cover, and understory habitat is of poor quality (minimal cover of native, perennial grasses and forbs), judicious management of sagebrush through burning or mechanical means (e.g., chaining, discing) may be appropriate for restoration of healthy sagebrush habitats (Paige and Ritter 1999, Connelly et al. 2000*b*, Danvir 2002).

Control encroachment of pinyon/juniper woodlands into sagebrush habitats, with prescribed fire or mechanical removal such as chaining (Commons et al. 1999, Miller and Rose 1999, USDI Bureau of Land Management et al. 2000). Such encroachment eventually eliminates sagebrush habitat in the understory (West et al. 1979, Miller et al. 1999, Miller and Eddleman 2000). Management practices to control pinyon/juniper must be tailored to local conditions, such as soils, sagebrush taxa present, presence of other species of concern, and available moisture.

Identify and attempt to eliminate or control invasive, non-native plants in sagebrush steppe (Billings 1994, Paige and Ritter 1999, Connelly et al. 2000*b*, Wisdom et al. 2000). The displacement of native sagebrush steppe by cheatgrass is one of the most dramatic changes in western landscapes (Billings 1994), and restoration will require unprecedented resources (Knick 1999, Bunting et al. 2002, Hemstrom et al. 2002, Shaw et al. 2004).

Habitat management should address not only species composition but also topography and other physical characteristics of sites. For example, microsites in drainages may ameliorate effects of wind, especially at low temperatures (Sherfy and Pekins 1995), and contribute to maintaining energy balance.

Use prescribed fire in sagebrush steppe with caution, especially in more arid portions of sage-grouse range (Fischer 1994; Connelly et al. 2000*a*, 2000*b*; Byrne 2002). If prescribed fire is used as a management tool, attempt to maintain a mosaic of habitats following the burn. Prescribed fire in more mesic sagebrush communities, such as mountain big sagebrush, may increase production of some desirable forbs (Pyle and Crawford 1996). If fire occurs in areas susceptible to invasion by cheatgrass or other non-native vegetation, engage in both active (e.g., seeding, planting) and passive (e.g., deferred livestock grazing) restoration until goals for sagebrush restoration are met (Bunting et al. 1987, Beck and Mitchell 2000). Restoration of burned habitats should emphasize re-establishment of native forbs and shrubs, with decreased emphasis on grasses (Beck and Mitchell 2000). Although fire is a natural disturbance agent in all sagebrush ecosystems, fire return intervals vary widely among sagebrush taxa. Intervals for basin big sagebrush communities are intermediate between those for mountain big sagebrush (5-15 yr) and Wyoming big sagebrush (10-70 yr) (Sapsis 1990). In Wyoming big sagebrush communities invaded by cheatgrass, not only are fire intervals shorter, with returns of 5-10 yr common, but complete removal of sagebrush also has occurred, with replacement by annual grasslands (Billings 1994, Monsen 1994).

Manage livestock grazing through stocking rates and season of use on all seasonal ranges of sage-grouse to avoid habitat degradation (Paige and Ritter 1999, Beck and Mitchell 2000, Wisdom et al. 2000), especially on recently disturbed sites, such as those sprayed or burned (Braun et al. 1977). In nesting and brood-rearing habitats, ensure that grazing does not reduce herbaceous understory cover below levels that serve as a deterrent to potential predators of eggs and chicks (Connelly et al. 2000*b*, Hockett 2002). Healthy native understories also support insects and forbs that are important in diets of pre-laying hens and chicks (Johnson and Boyce 1990, Barnett and Crawford 1994, Drut et al. 1994*b*). Riparian areas and wet meadows used for brood rearing are especially sensitive to grazing by livestock; in these habitats, removal of livestock before the nesting season may be prudent (Beck and Mitchell 2000, Hockett 2002).

Avoid development of livestock-watering structures in sage-grouse habitat (Connelly et al. 2000*b*). If water developments are constructed for sage-grouse or other wildlife, they should be placed to ensure that water is available during movement of sage-grouse from spring to summer ranges (Wakkinen 1990). Connelly et al. (2000*b*) recommended that pipelines from springs be built so that free water is available to maintain the spring and associated wet meadows.

Avoid application of herbicides or pesticides in sage-grouse habitats, particularly during nesting or brood-rearing periods (Carr 1967, Blus et al. 1989, Beck and Mitchell 2000, Connelly et a. 2000*b*). Sage-grouse feed on insects during spring and summer, and chicks rely heavily on insects during the first few weeks of life (Johnson and Boyce 1990, Drut et al. 1994*b*, Schroeder et al. 1999). Spraying of herbicides not only eliminates large blocks of sagebrush, leading to increased habitat fragmentation, but also may poison insects and other invertebrates eaten by sage-grouse (Carr 1967, Johnson 1987). When spraying cultivated crops, such as alfalfa, adjacent to sagebrush, attempt to intersperse sprayed areas with intact sagebrush habitats that are not sprayed.

Reduce or avoid development of mining and other resource-extraction industries, such as coal-bed methane, within sage-grouse habitats (Braun et al. 2002, Lyon and Anderson 2003). Such developments directly eliminate habitat (e.g., through road-building, construction of settling ponds, and mine excavation), fragment sagebrush communities, and increase disturbance from vehicles and other associated activities (Remington and Braun 1991, Schroeder et al. 1999, Braun et al. 2002, Lyon and Anderson 2003).

Avoid construction of powerlines in sage-grouse habitat, especially within 3 km of seasonal habitats (Braun 1998, Connelly et al. 2000*b*). Increases in predation on sage-grouse may result from increased availability of perches for roosting and nesting by raptors (Ellis 1984, Braun et al. 2002, Rowland and Wisdom 2002).

Minimize human disturbance, such as vehicle traffic and recreation, in sage-grouse habitats, especially around leks and nesting habitat (Paige and Ritter 1999, Connelly et al. 2000*b*, Braun et al. 2002, Lyon and Anderson 2003). Lek abandonment may occur if disturbance activities exceed some threshold (Aldridge 1998, Braun et al. 2002). Most nest abandonment is either directly or indirectly related to human disturbance (Schroeder et al. 1999).

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Table. Greater Sage-Grouse habitat characteristics.

Author(s)	**Location(s)**	**Habitat(s) Studied ***	**Species-specific Habitat Characteristics**
Aldridge and Brigham 2002	Alberta	ARCA	Nested in silver sagebrush with greater canopy cover than in random areas; areas surrounding successful nests had greater sagebrush cover, less grass cover, and taller grasses than areas at unsuccessful nests
Carr 1967	Colorado	ARTRVA, meadow, native grassland	Occurred in sprayed (2,4-D) and unsprayed blocks and strips of big sagebrush (dominated by ARTRVA); spraying did not appear to affect behavior on leks, use of leks, nesting success, use of sagebrush for nests, brood production, or brood survival; movement of broods was affected by spraying, and adult sage-grouse appeared to avoid sprayed blocks outside the lekking season
Commons et al. 1999	Colorado	ARNO, ARTRVA, pinyon (*Pinyon* spp.)-juniper (*Juniper* spp.)woodland	Numbers of male Gunnison Sage-Grouse on treatment leks doubled during the 2nd and 3rd yr after removal of pinyon-juniper trees by cutting and reduction in height of ARTRVA and deciduous shrubs by brushbeating. Sage-grouse avoided pinyon-juniper habitats except during September to November, when they occurred in sagebrush with scattered pinyon-juniper $\geq$2 m tall
Connelly et al. 1981	Idaho	Sagebrush/grass, primarily ARTR/bluebunch wheatgrass (*Pseudoroegneria spicata*) / rabbitbrush (*Chrysothamnus spp.*)	Three leks were found on recently disturbed sites, including a 5-yr old burn and two gravel pits. These leks were in a portion of the study area with relatively fewer natural openings than the remainder of the area.
Connelly et al. 2000*a*	Idaho	ARTRWY-bluebunch wheatgrass, burned, threetip sagebrush	Prescribed burn conducted in site dominated by ARTRWY and threetip sagebrush with low (<26 cm) precipitation to examine effects on sage-grouse lek attendance. Treatment and control sites were 5,000 ha each; collected data 4 yr pre-treatment and 5 yr post-treatment. Control sites had 17

			active leks, and treatment sites 12, prior to burning. Fire removed 57% of the sagebrush in the treated site. Lek counts were similar in treatment and control leks prior to the burn; postburn, lek counts declined 90% on treatment leks and 63% on control leks
Dalke et al. 1963	Idaho	ARNO, ARTR	During brood rearing sage-grouse preferred meadows with dandelion (*Taraxacum* spp.) and clover (*Trifolium* spp.) for foraging; resting cover ranged from sagebrush, willow (*Salix* spp.), and tall grass to uncut fields of hay and grain and patches of quaking aspen (*Populus tremuloides*). Black sagebrush preferred in winter when available
Danvir 2002	Utah	ARTRWY	Thirty nests (83% of 36) were in Wyoming big sagebrush stands, in patches >100 m in diameter. During winter, 87% of observations were in areas of gentle (<5%) slope. Typically selected shrubs with medium height (40 to 60 cm) and canopy cover (20 to 30%) during winter; however, used taller sagebrush in draws when snow >30 cm, and shorter sagebrush on flats and ridge-tops when snow cover was less. Most (80%) grouse flocks in burned and reseeded areas were ≤60 m from sagebrush
Drut et al. 1994*a*	Oregon	ARAR/mixed sagebrush, ARTR, lakebed/meadow	Broods used low sagebrush sites most often during early brood rearing (first 6 weeks after hatching), moving to big sagebrush cover during late brood rearing (7-12 weeks post-hatch); forb cover at brood sites typically 12 to 14%
Eng and Schladweiler 1972	Montana	ARTR	Mean sagebrush canopy cover of habitats used during winter was 26% (range = 9 to 46%) in roosting sites and 28% (range = 6 to 54%) in feeding and loafing sites
Gregg et al. 1994	Oregon	ARAR, ARTR, green rabbitbrush (*Ericameria teretifolia*), western juniper (*J. occidentalis*)	Medium-height (40 to 80 cm) shrub cover was greater at nest sites (mean = 41% for non-depredated nests and 29% at depredated nests) than at areas immediately surrounding nests (10 to 15%) or random sites (mean = 8%). Compared to depredated nests, non-depredated nests had greater cover of medium-height shrubs (41% vs. 29%) and

			tall grasses (18% vs. 5%)
Hofmann 1991	Washington	ARTR	Mean sagebrush cover at nesting areas was 20%; common grasses at nests included Sandberg bluegrass (*Poa secunda*), bluebunch wheatgrass, and cheatgrass (*Bromus tectorum*).
Johnson 1987	Wyoming	ARTR, cropland, riparian	All nests were associated with big sagebrush in draws or along benches; by late June, all broods were near riparian areas; spraying with malathion in June for grasshopper control appeared to reduce brood sizes in one area, but not in another
Kerwin 1971	Saskatchewan	ARCA, grassland	Vegetation at brood sites was as follows: forb cover ranged from 31 to 59%, grass cover from 49 to 75%, and shrub cover from 3 to 10%; sagebrush-grassland habitat type used most by broods in summer, but in proportion to its abundance; meadows used more than expected (23 to 33% vs. 16% of brood-route vegetation); broods moved to more mesic meadow sites after 4 weeks
Klebenow 1982	Nevada	ARAR, ARTRVA, ARTRWY, wet meadow	Meadows heavily grazed by cattle generally were avoided by sage-grouse; dense, grassy meadows that were lightly grazed were not. One 40-ha meadow stocked with 41 yearling heifers was used by 100 sage-grouse throughout summer, and effective cover height remained >5 cm during this time
Klebenow 1985	Nevada	ARAR, ARTRVA, ARTRWY, wet meadow	Mean shrub canopy cover was 25% in brood habitat in upland sagebrush sites, whereas grass and forb cover were lower (15% and 10%); wet meadows used as brood habitat had no shrubs but 57% grass cover and 22% forb cover
Lyon 2000	Wyoming	ARAR, ARNO, ARTRTR, ARTRWY, crested wheatgrass, native grassland	Hens from disturbed leks (near oil and gas development) nested in areas with taller live sagebrush (36 vs. 30 cm) and greater total shrub cover (41 vs. 33%) than did hens from undisturbed leks; comparisons of nest sites with random (available) sites revealed that nest sites had taller live sagebrush; greater grass, total forb, residual grass, and

			total herbaceous cover; less bare ground cover; and taller nest bush height; successful hens raised broods farther from roads than did unsuccessful hens
Martin 1965	Montana	ARAR, ARTR, grasslands, riparian	Used both sprayed (2,4-D) and unsprayed areas, but only 4% of observations (*n* = 415) were in sprayed strips, which comprised 90% of the study area; forb and low shrub cover were reduced in the sprayed strips compared to the control; differences in numbers of sage-grouse between sprayed and unsprayed areas appeared to be due to differences in vegetation composition; broods of ≤6 weeks of age were found in areas with lower densities and crown canopy cover of big sagebrush than were older broods and adults
Patterson 1952	Wyoming	ARTR	82% of >300 nests were in shrub cover ranging from 25 to 51 cm in height (mean = 36 cm)
Petersen 1980	Colorado	ARTR/rabbitbrush	Sagebrush cover on breeding areas within leks averaged 7.3%; mean height was 5.3 cm. Mean shrub canopy height (range = 27 to 76 cm) at nests (*n* = 35) was 52.3 cm, but only 32.3 cm in surrounding areas (range = 11.1 to 59.8 cm). Most (30) nests were on sites with slope <12%. Roost sites were in areas with shorter (mean height = 7.6 cm) sagebrush than were nests
Pyle and Crawford 1996	Oregon	ARTRVA-bitterbrush (*Purshia* spp.), burned	Prescribed fire applied in randomized block design where shrub cover ≥35%; responses of plants and insects important to sage-grouse studied over 2 yr. Increases in frequency of dandelions seen, but no effects of burning seen for other primary forbs used as food or ground-dwelling beetles. Spring and fall burning decreased sagebrush cover, but increased total forb cover and diversity
Rasmussen and Griner 1938	Utah	ARCA, ARNO, ARTR	Of 161 nests, most (32%) were in ARCA with an understory of grasses and forbs, remainder in ARTR and ARNO; no nests found in aspen, meadows, or willow
Rothenmaier 1979	Wyoming	ARTR, crested	Mean height of sagebrush at 10 leks was 28 cm, mean

		wheatgrass, grassland, riparian	cover was 22%; 90% of sample points had sagebrush <43 cm; percentage of sagebrush cover at 6 nest sites ranged from 12 to 29% (mean = 21.6%)
Swenson et al. 1987	Montana	ARTR/bluebunch wheatgrass	Sage-grouse use of control and treatment (plowed) areas was compared over 12 yr by counting males on leks (3 leks in the treatment area and 4 in the control); numbers of males declined 73% in the plowed area, but no discernible trend was seen in the control. The proportion of winter habitat plowed increased during 10 yr (1975 to 1984) from 10 to 30%; however, of the entire treatment area, only 16% had been plowed by 1984 (14% in dryland and 2% in irrigated crops)
Wallestad 1970	Montana	ARTR, cropland, other shrub	Habitat used by sage-grouse broods had average sagebrush canopy cover of 14% in June, decreasing to 10% by August, and increasing to 21% by September; forb cover at brood locations was 17 to 27%, and grass cover averaged 47 to 51%; broods used sagebrush grasslands in June, shifting to greasewood (*Sarcobatus* spp.) bottomlands and alfalfa fields in mid-summer, then returning to sagebrush in late August/early September
Wallestad and Pyrah 1974	Montana	ARTR, greasewood	All nests (*n* = 41) were in sagebrush with canopy cover >15%, and all nests were under sagebrush shrubs; mean height of sagebrush above nests was 40.4 cm, compared to 23.4 cm in surrounding stands
Wallestad and Schladweiler 1974	Montana	ARTR, greasewood	Habitat used by males in a non-migratory population for daytime loafing and feeding during the breeding season had an average sagebrush canopy cover of 32%, with 80% of 100 observations occurring in sites with 20 to 50% canopy cover

* Descriptors were used to standardize terminology among studies and to denote the management or type of habitat. ARAR = little sagebrush (*Artemisia arbuscula*), ARCA = silver sagebrush (*A. cana*), ARNO = black sagebrush (*A. nova*), ARTR = big sagebrush (no subspecies specified; *A. tridentata*), ARTRTR = basin big sagebrush (*A. t. tridentata*), ARTRVA = mountain big sagebrush (*A. t. vaseyana*), and ARTRWY = Wyoming big sagebrush (*A. t. wyomingensis*). "Burned" includes habitats that were burned intentionally, accidentally, or by natural forces (e.g., lightning).

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