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Title: Use and Selection of Nesting Habitat by Sage Grouse in Oregon

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Sage grouse (Centrocercus urophasianus) populations in Oregon declined during the past 30 years as a result of impaired productivity. The western subspecies (C. u. phaios) was listed as a candidate for threatened and endangered status by the Department of the Interior in 1985 because of declines in Oregon and Washington and extirpation from British Columbia. Little information is available about habitats used for nesting in the range that encompasses the western subspecies. This study was conducted on two areas in southeastern Oregon: Hart Mountain National Antelope Refuge and Jackass Creek. Hart Mountain represented some of the best habitat in the state and Jackass Creek was typical of much of the remaining sage grouse range in Oregon. These areas had long term differences in sage grouse abundance, approximately 2.5 birds/$km^2$ at Hart Mountain and 1.5 bird/$km^2$ at Jackass Creek. The objectives of this study were to determine selection for cover types and habitat components within cover types used for nesting and to compare habitat use and selection between successful and unsuccessful nesting hens. Comparisons were made within and between study areas.

Availability and selection of cover types differed between study areas. Sage grouse selected mountain big sagebrush (Artemisia tridentata vaseyana) stands at Hart Mountain and the mixed sagebrush

cover type at Jackass Creek. Nest success was greater in cover types used selectively by hens.

Habitat components were measured at 47 and 51 nest sites at Hart Mountain and Jackass Creek, respectively. At nests, sage grouse selected medium height shrubs (40-80 cm) with greater canopy cover than was present either adjacent to the nest or random locations. Grass cover was greater at nests than at random sites in cover types used selectively. Amount and type of grass cover were the only habitat components that differed between successful and unsuccessful nests. In mountain big sagebrush stands, 2 grass genera (Elymus sp. and Festuca spp.) represented 81% of grass cover at successful nests and only 1% at unsuccessful nests. These genera were the tallest grasses occurring at either study area. Greater grass cover in association with tall grass at nest sites likely provided increased nest concealment from predators and resulted in greater nest success. The relationship between the grass component of habitat and sage grouse nesting success implies that removal of grass may negatively influence sage grouse productivity.

# Use and Selection of Nesting Habitat by Sage Grouse in Oregon

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I dedicate this thesis to my parents

Wallace and June Gregg

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## INTRODUCTION

Historically, sage grouse (Centrocercus urophasianus) were found wherever sagebrush (Artemisia spp.) occurred in the western United States and southwestern Canada (Klebenow 1985). Conversion of native rangelands associated with settlement, agricultural production, and livestock grazing contributed to reduction and elimination of sage grouse populations from much of their previous range (Klebenow 1985). In Oregon, sage grouse were once common to abundant in non-forested areas east of the Cascade Mountains (Gabrielson and Jewett 1940). Sage grouse declined in abundance and distribution during the early 1900s and occupied approximately one-half of their original range in Oregon by 1940 (Crawford and Lutz 1985). Since 1940, populations declined approximately 60% and percentage of hens with broods and ratio of chicks to adult declined 78% and 83%, respectively (Crawford and Lutz 1985). Survival indices fluctuated but were unrelated to sage grouse declines; reduced productivity fully accounted for decreased sage grouse abundance since 1940 (Crawford and Lutz 1985).

Impaired productivity may result from several factors but is directly related to habitat characteristics available to hens for nesting, particularly vegetative cover (Rasmussen and Griner 1938, Blake 1970). The importance of sagebrush for nesting habitat is well documented (Patterson 1952:114, Gill 1965, Gray 1967, Klebenow 1969, Wallestad and Pyrah 1974, Peterson 1980). In Montana, Wallestad and Pyrah (1974) reported depressed nesting success for hens with nests in sagebrush stands of below average canopy cover and sagebrush cover

surrounding the nest. Litter and grass-forb understory contributed to successful nesting in Idaho (Autenrieth 1981) and Utah (Rasmussen and Griner 1938) by providing additional camouflage at the nest site.

Several studies have provided descriptions of sage grouse nesting habitat, selection of vegetative characteristics by hens, and relation of nest site characteristics to available habitat (Patterson 1950, Gray 1967, Wallestad and Pyrah 1974, Hulet et al 1986). Sage grouse selected nest sites based largely on 2 vegetative components: height and percent cover of sagebrush (Klebenow 1969, Roberson 1986). Further, percent grass cover (Klebenow 1969) and grass height (Wakkinen 1990) also were related to selection of nest sites.

Most research on sage grouse nesting habitat was conducted within the range of the eastern subspecies (C. u. urophasianus). Little information is available about habitat use in the more arid portion of the range that encompasses the western subspecies (C. u. phaios), which was listed as a candidate for threatened and endangered status by the U.S. Department of the Interior (Federal Register, 18 September 1985) because of declines in Oregon and Washington and extirpation from British Columbia. Further, relationships between habitat components, nesting success, and current land management practices are largely unknown. A better understanding of the relationship between habitat use and nesting success of sage grouse is essential for enhancement of populations through sound land management practices.

The objectives of this study were to determine use and selection of cover types and habitat components by nesting sage grouse on 2 study

areas in southeastern Oregon and to compare habitat use and selection between successful and unsuccessful nesting hens.

## STUDY AREAS

The study was conducted on 2 areas (Figure 1): Hart Mountain National Antelope Refuge administered by the U.S. Fish and Wildlife Service (USFWS) and Jackass Creek administered by the Bureau of Land Management (BLM). Historical information about sage grouse populations, dating to the 1950s, was available from surveys conducted by Oregon Department of Fish and Wildlife (ODFW) at Jackass Creek and by the USFWS at Hart Mountain and from 2 research studies. Hart Mountain served as a location for study of habitat use and diet of sage grouse hens (Nelson 1955) and Jackass Creek was used by ODFW for an investigation of habitat selection for nesting and brooding by sage grouse from 1984 to 1986.

These areas had long term differences in sage grouse abundance and productivity. Estimates of sage grouse density since 1980 was approximately 2.5 birds/$km^2$ and 1.5 bird/$km^2$ at Hart Mountain and Jackass Creek, respectively (J. Lemos, Oreg. Dep. Fish and Wildl., unpubl. data; W. H. Pyle U.S. Fish and Wildl. Serv., unpubl. data). Density estimates were based on number of males/lek and a sex ratio of 40 males:60 females (Rogers 1964). Summer productivity counts from 1981 through 1990, the only period for which comparable data were available, were 1.9 and 1.0 chicks/hen for Hart Mountain and Jackass Creek, respectively. Hart Mountain represented some of the best remaining habitat in the state and Jackass Creek was typical of much of the remaining sage grouse range in Oregon.

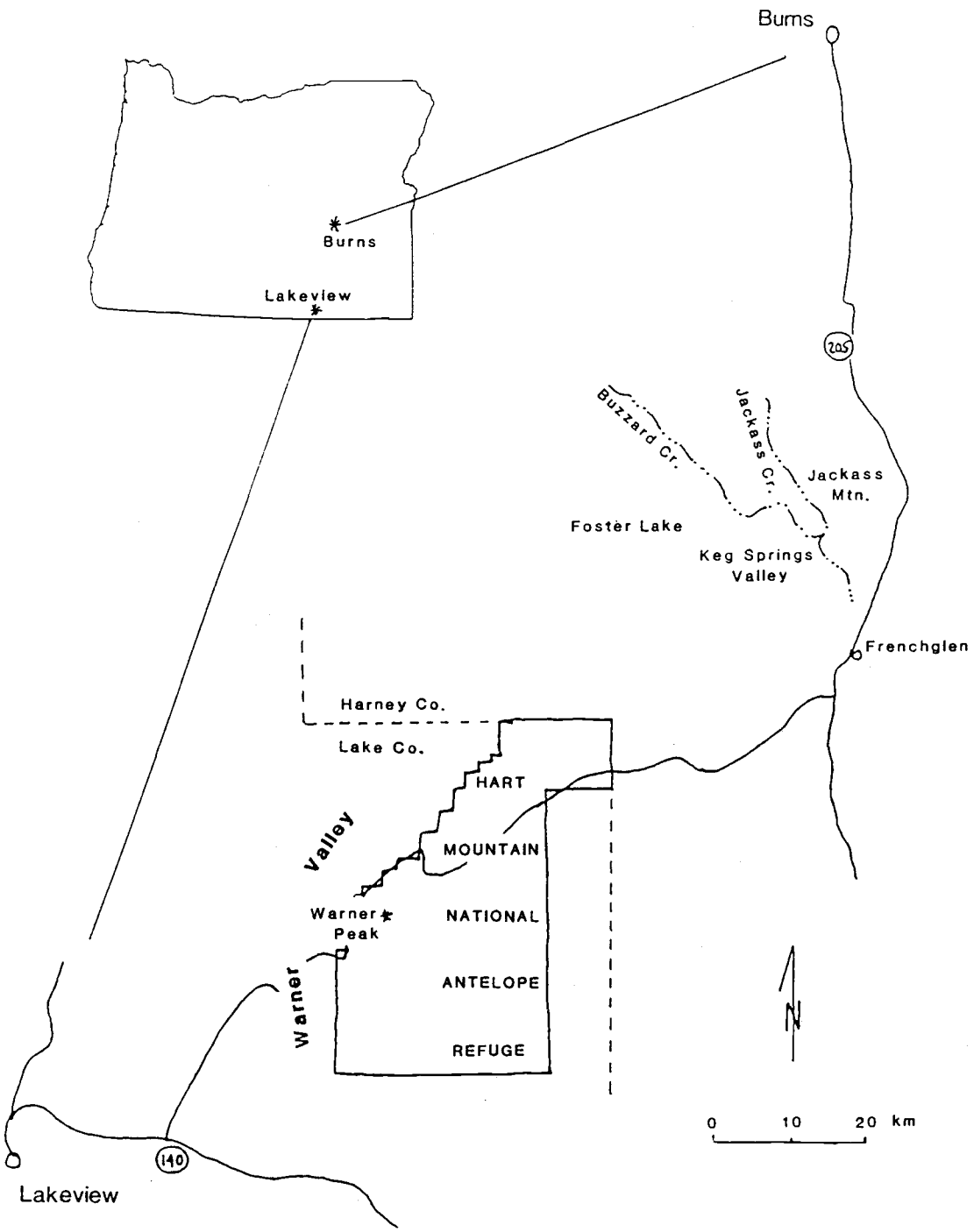


Figure 1. Location of the study areas in Lake and Harney Counties, Oregon.

Hart Mountain National Antelope Refuge

The Hart Mountain National Antelope Refuge study area, located 70 km northeast of Lakeview in Lake County, Oregon, comprised nearly 89,000 ha. Elevation ranged from 1500 m at the eastern portion of the refuge to 2450 m in the west (Warner Peak). Surrounding desert consisted of flat sagebrush plains interrupted by rolling hills, ridges, and draws. Hart Mountain supported several springs, lakes, and creeks and numerous meadow habitats. Seasonally flooded lakebeds, some of which held water throughout summer, were most common in the southern portion of the study area. Climatic conditions on the study area differed with elevation. At refuge headquarters (elevation 1700 m), annual temperature averaged 21 C and mean precipitation was 29 cm.

Dominant cover consisted of low sagebrush (Artemisia arbuscula), big sagebrush (A. tridentata), and bitterbrush (Purshia tridentata). High elevation stands included western juniper (Juniperus occidentalis), mountain mahogany (Cercocarpus ledifolius), and aspen (Populus tremuloides). Common annual and perennial forbs included mountain-dandelion (Agoseris spp.), locoweed (Astragalus spp.), hawksbeard (Crepis spp.), lupine (Lupinus spp.), and phlox (Phlox spp.). Grasses consisted largely of bluegrass (Poa spp.), bluebunch wheatgrass (Agropyron spicatum), needlegrass (Stipa spp.), fescue (Festuca spp.), and giant wildrye (Elymus cinereus). Plant nomenclature was taken from Hitchcock and Cronquist (1987).

Livestock grazing on the refuge averaged approximately 12,000 animal unit months (AUMs) and were allocated from 15 April to 15 December under a rest rotation, deferred grazing system (W. H. Pyle,

U.S. Fish and Wildl. Serv., pers. commun.). Grazing pressure was adjusted annually in relation to range conditions. Wild horses occurred on the area, but numbers were reduced from 225 in fall 1987 to 25 by spring 1988 (W. H. Pyle, U.S. Fish and Wildl. serv., pers. commun.). In 1985, a wildfire burned approximately 4,500 ha in the center of the refuge.

Jackass Creek

The Jackass Creek study area located approximately 100 km northeast of Hart Mountain in Harney County, Oregon, comprised nearly 39,000 ha. It was approximately 300 m lower in elevation and was topographically more uniform than Hart Mountain. The area consisted of flat sagebrush-covered plains in the west and undulating ridges and draws to the east, eventually rising to Jackass Butte (1700 m). The main plateau descended into Keg Springs Valley to the south and Jackass Creek canyon bisected the study area east to west. Main sources of water were Jackass Creek, lakebeds, and water developments. Meadow habitats were small and widely dispersed. Annual temperature averaged 24 C and mean precipitation was 28.5 cm.

Prominent vegetation consisted of early low sagebrush (A. longiloba) and big sagebrush. Western junipers were present but limited to the eastern portion of the study area. Forbs and grasses were similar to those at Hart Mountain.

Livestock grazing on the area averaged 7,000 AUMs and use by wild horses averaged 2,000 AUMs from 1985 through 1990 (F. Taylor., Bur. of Land Manage., pers. commun.). Livestock grazing was permitted from 1 April to 1 September.

# METHODS

Selection for nesting habitat by sage grouse hens was evaluated on a hierarchical order of selection (Johnson 1980). Selection for cover types (third order selection) and for habitat components within cover types (fourth order selection) were evaluated within and between study areas from radio monitored hens.

## Trapping and Radio-marking of Hens

The study was conducted during spring (March-June) 1989 and 1990. One-hundred-eighty-six hens were trapped and equipped with radio transmitters: 96 at Hart Mountain and 90 at Jackass Creek. At the conclusion of the first field season, marked hens were captured and radio transmitters removed. A sample of previously unmarked hens (52 at Hart Mountain and 53 at Jackass Creek) were equipped with radios to maintain an independent sample of nesting habitats among years. Rocket nets, net guns, and spotlights were used to capture grouse (Giesen et al. 1982). Sex and age of grouse were determined by plumage characteristics and wing molt (Beck et. al. 1975). Each hen was fitted with a numbered aluminum leg band and a poncho-mounted solar-powered radio transmitter with a nickel-cadmium battery (Amstrup 1980). Locations of radio-equipped hens were obtained with portable receivers and 2-element hand-held antennae.

## Monitoring Radio-marked Hens

Cover types and habitat components used for nesting were determined from locations of radio-equipped hens. Marked hens were

located at least twice weekly beginning in April of each year to determine nesting chronology. When monitoring revealed that a hen initiated a nest, she was approached until visually observed on the nest. Once nesting was confirmed, hens were monitored remotely to avoid disturbance. Hatch dates were estimated for all nests by projection from the onset of incubation. When monitoring revealed that a hen moved from a nest and incubation had ceased, the fate of the nest was determined. A nest was classified as successful if at least one egg hatched or if incubation exceeded 30 days. Nests were determined unsuccessful by firmly attached shell membranes in broken eggs or missing eggs. Monitoring of unsuccessful hens was continued to assess renesting activities.

Selection of Cover Types (Third Order Selection)

Eleven cover types were described from Soil Conservation Service information (J. Kinzle, U.S. Dep. Agric., Soil Conserv. Serv., unpubl. data) and previous descriptions at Jackass Creek by Trainer et al. (1983) (Appendix A). Nesting cover was classified into 1 of the 11 cover types for each hen. Two of the 11 cover types were not present at Jackass Creek (mountain shrub and low sagebrush/fescue).

Boundaries of the 11 cover types were determined from color infrared aerial photographs (National High Altitude Photography Program) and overlayed on topographic maps of each study area with zoom transfer scopes. Interpretation and ground verification of cover type maps were conducted throughout each field season. Boundaries of the area available for nesting on each study area were determined from

locations of radio-equipped hens with the minimum convex polygon method (Mohr 1947, Odum and Kuenzler 1955). Only locations of hens exhibiting nesting behavior were included. Proportions of cover types within the area available for nesting were determined with a dot grid system (Avery 1977).

Selection of Habitat Components (Fourth Order Selection)

Habitat sampling was conducted at nest sites after hatching for successful nests or on predicted hatch dates for unsuccessful nests. Percent cover of forbs, grasses, and shrubs; height classes of shrubs; frequency of herbaceous vegetation; and vertical cover were measured at all nest sites. Two 10-m perpendicular transects intersecting at the nest site were arranged. The position of the first transect was determined from a randomly selected compass bearing. The intercept distance (cm) of all species of shrubs along each transect was recorded to determine canopy coverage (Canfield 1941). Height of each shrub intercepted was measured from the ground to the top of the shrub canopy and placed into 1 of 3 classes: low (<40 cm), medium (40-80 cm), or tall (>80 cm). Shrubs were classified to species and forbs and grasses were classified to genus. Dominant forb and grass genera were defined as those with percent cover $\geq 1$ or frequency $\geq 25$.

Percent cover of forbs and grasses was estimated in 5 equidistantly spaced 20 x 50-cm rectangular plots on each transect (Daubenmire 1959). Sampling intensity was determined by constructing a species area curve with data collected from initial vegetation sampling (Pieper 1978:12). Vertical cover at the center of the transect was

determined with a 1 x 1-m cover board. Measurements were taken from a distance of 1.5 m at 45° and 5 m at a height of 50 cm (Jones 1968, Dunn and Braun 1986). Heights of dominant grass genera were measured at random locations throughout each study area.

Within each cover type, the same vegetative measurements taken at nest sites were collected at random sites during the nesting period (March-June) to characterize available nesting habitat (Appendices B and C). Random sites were located with a random numbers table, which was used to determine starting point, compass bearing, and distance traveled. The number of random locations sampled in each cover type was based on canopy cover of sagebrush and was determined with the "n-test" (Snedecor and Cochran 1980).

## Data Analysis

Within study areas, cover types used for nesting were compared with cover type availability. Between study areas, cover type availability and use were compared. Data were arranged in contingency tables and analyzed with Chi-square analysis. If differences were detected, confidence intervals were calculated to identify cover types contributing to the difference (Neu et al. 1974, Byers et al. 1984). Nest success in cover types used greater than was available were compared with success in all other cover types used for nesting with chi-square analysis.

Nest sites were apportioned into 2 parts: a 3-$m^2$ area at the nest (nest) and a 75-$m^2$ area immediately adjacent to the nest (nest area). To determine selection of habitat components (percent cover of forbs,

grasses, and shrubs and vertical cover) for nesting, comparisons were made between the nest, nest area, and random sites within each cover type used for nesting. The same analysis was conducted for dominant forb and grass genera found at nest and random sites. Similar comparisons were made between successful and unsuccessful nests. Percent cover of forbs, grasses, and shrubs and vertical cover of all nests at Hart Mountain were compared with all nests at Jackass Creek. Multivariate analysis of variance (MANOVA) was used for all tests. If a significant MANOVA was found a factorial analysis of variance was used to determine habitat components contributing to the difference (Snedecor and Cochran 1980). Assumption of normality was meet and no transformations of the data was required. Results were considered significant at the 95% confidence level.

# RESULTS

Of 96 radio-equipped hens at Hart Mountain during 1989 and 1990, 44 (46%) nested. Five hens unsuccessfully renested after an unsuccessful first attempt. Nest success was 24% (12/49). Complete information (nest site characteristics) was not available for 2 nests. Of 90 radio-equipped hens at Jackass Creek, 49 (54%) nested and 2 hens unsuccessfully renested after an unsuccessful initial attempt. Nest success was 12% (6/51). If hens that did not nest or reach incubation were included, nest success fell to 18% and 10% at Hart Mountain and Jackass Creek, respectively. Remaining hens from Hart Mountain (n=36) and Jackass Creek (n=31) died, were missing, or status was unknown (Table 1).

## Selection of Cover Types

Sage grouse nested in 7 of 11 cover types at Hart Mountain. Mountain big sagebrush was used more frequently and low sagebrush/bunchgrass and Wyoming big sagebrush were used less frequently than available on the study area (Table 2). At Jackass Creek, sage grouse nested in 4 of 9 cover types. Mixed sagebrush was used more frequently than expected (Table 2). Sage grouse used Wyoming big sagebrush and mixed sagebrush more frequently and mountain big sagebrush less frequently at Jackass Creek than at Hart Mountain (Table 2). Availability of all cover types differed between study areas.

Table 1. Status of sage grouse hens captured and equipped with radio transmitters at Hart Mountain National Antelope Refuge and Jackass Creek study areas, Lake and Harney Counties, Oregon, 1989-1990.

| | Hart Mountain | | Jackass Creek | |
|---|---|---|---|---|
| Status | n | % | n | % |
| Nested | 44 | 46 | 49 | 54 |
| Renested | 5 | 16 | 2 | 5 |
| Successful | 12 | 24 | 6 | 12 |
| Unsuccessful | 37 | 76 | 45 | 88 |
| Did not nest | 16 | 17 | 10 | 11 |
| Mortality | 20 | 21 | 13 | 14 |
| Missing | 6 | 6 | 18 | 20 |
| Unknown[a] | 10 | 10 | 0 | 0 |

[a]birds located off study area (n=7) or captured with brood patch (n=3)

Table 2. Cover types available (%) and used (%) for nesting by radio-equipped sage grouse hens at Hart Mountain National Antelope Refuge (n=49) and Jackass Creek (n=51) study areas, Lake and Harney counties, Oregon, 1989-1990.

| | Hart Mountain | | Jackass Creek | |
|---|---|---|---|---|
| Cover type | Available | Used | Available | Used |
| Low sagebrush bunchgrass | 41 | 20[a] | 30 | 37 |
| Wyoming big sagebrush[b] | 26 | 6[a] | 53 | 37 |
| Mountain big sagebrush[b] | 12 | 55[c] | 2 | 0 |
| Grassland | 6 | 2 | <1 | 0 |
| Juniper/aspen/mahogany | 5 | 0 | 1 | 0 |
| Mountain shrub | 3 | 10 | - | - |
| Low sagebrush fescue | 2 | 4 | - | - |
| Lakebed | 2 | 0 | 5 | 0 |
| Meadow | 2 | 0 | <1 | 0 |
| Basin big sagebrush | 1 | 2 | 2 | 2 |
| Mixed sagebrush[b] | <1 | 0 | 7 | 24[c] |

[a]use of cover type less than expected ($P < 0.05$)
[b]use of cover type different between study areas ($P < 0.05$)
[c]use of cover type greater than expected ($P < 0.05$)

Cover Type Use in Relation to Nest Success

Nest success was greater in cover types used selectively by hens ($x^2$=5.71, df=1, P=0.02). Mountain big sagebrush contained 55% (27/49) of all nests located and 37% (10/27) were successful. Only 9% (2/22) of the remaining nests in 6 other cover types were successful. Although nest success was lower at Jackass Creek, a similar trend was evident. Mixed sagebrush contained 24% (12/51) of all nests located and 17% (2/12) were successful. Success for the remaining 39 nests, located in 3 other cover types, was 10% (4/39).

Selection of Habitat Components

Ninety-three of 99 nests (94%) from radio-equipped hens were located under sagebrush. Other vegetation used for nesting included rabbitbrush (Crysothamnus spp.) (n=4), bitterbrush (n=1), and giant wildrye (n=1). Sagebrush collectively represented 86% of the shrub component at nest and random sites. Other shrubs included bitterbrush (7%), rabbitbrush (4%), horsebrush (Tetradymia spp.) (1%), snowberry (Symphoricarpos oreophilus) (1%), and spiny hopsage (Atriplex spinosa) (1%).

Five cover types (low sagebrush/bunchgrass, mixed sagebrush, Wyoming big sagebrush, mountain big sagebrush, and mountain shrub) contained enough nests for analysis of structural characteristics. Shrub cover of medium height was greater at nests than nest areas and random sites in all cover types except low sagebrush/bunchgrass and mountain shrub at Hart Mountain (Table 3 and 4). Shrub cover of low height was less at nests than at random sites in all cover types except

Table 3. Structural characteristics at nests (1-m area around nest), nest areas (4-m area adjacent to nest), and random sites in cover types used for nesting by radio-equipped sage grouse hens at Hart Mountain National Antelope Refuge, Lake County, Oregon, 1989-1990. Means with same letter or no letter within cover type are not different (P > 0.05).

| | Cover type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low sagebrush bunchgrass[a] | | | Mountain big sagebrush | | | Mountain shrub | | |
| Characteristic (%) | Nest (n=7) $\bar{x}$(SD) | Nest area (n=7) $\bar{x}$(SD) | Random (n=10) $\bar{x}$(SD) | Nest (n=27) $\bar{x}$(SD) | Nest area (n=27) $\bar{x}$(SD) | Random (n=62) $\bar{x}$(SD) | Nest (n=5) $\bar{x}$(SD) | Nest area (n=5) $\bar{x}$(SD) | Random (n=31) $\bar{x}$(SD) |
| Forb cover | 5(4) | 7(5) | 6(3) | 7(6)A | 11(6)B | 14(6)B | 6(4) | 10(7) | 6(3) |
| Grass cover | 24(22) | 17(8) | 11(4) | 17(19)A | 12(8)AB | 11(6)B | 13(14) | 19(12) | 18(8) |
| Shrub cover | | | | | | | | | |
| Low (0-40 cm) | 31(15) | 16(6) | 20(10) | 11(12)A | 13(8)A | 16(10)B | 17(19) | 12(6) | 10(6) |
| Medium (40-80 cm) | 6(11) | 5(9) | 0.5(1) | 44(19)A | 18(12)B | 18(11)B | 35(17) | 12(6) | 24(12) |
| Tall (> 80 cm) | 0 | 0 | 0 | 1(3) | 1(2) | 1(3) | 2(4) | 0.3(1) | 7(1) |
| Vertical cover | | | | | | | | | |
| from 1.5 m at 45° | 29(9)A | | 12(6)B | 49(14)A | | 28(14)B | 50(20)A | | 34(17)B |
| from 5 m at 50 cm | 50(22)A | | 29(8)B | 81(15) | | 73(20) | 73(17)A | | 91(12)B |

[a]data from 1990 only

Table 4. Structural characteristics at nests (1-m area around nest), nest areas (4-m area adjacent to nest), and random sites in cover types used for nesting by radio-equipped sage grouse hens at Jackass Creek, Harney County, Oregon, 1989-1990. Means with same letter or no letter within cover type are not different ($P > 0.05$).

| | Cover type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low sagebrush bunchgrass | | | Mixed sagebrush | | | Wyoming big sagebrush | | |
| Characteristic (%) | Nest (n=19) $\bar{x}$(SD) | Nest area (n=19) $\bar{x}$(SD) | Random (n=59) $\bar{x}$(SD) | Nest (n=12) $\bar{x}$(SD) | Nest area (n=12) $\bar{x}$(SD) | Random (n=36) $\bar{x}$(SD) | Nest (n=19) $\bar{x}$(SD) | Nest area (n=19) $\bar{x}$(SD) | Random (n=36) $\bar{x}$(SD) |
| Forb cover | 12(11) | 10(4) | 11(5) | 9(8) | 6(4) | 7(4) | 16(11)$^{a}$ | 11(7)$^{ab}$ | 11(7)$^{b}$ |
| Grass cover | 8(5) | 9(4) | 7(4) | 16(17)$^{a}$ | 11(5)$^{ab}$ | 9(5)$^{b}$ | 11(8) | 14(9) | 12(6) |
| Shrub cover | | | | | | | | | |
| Low (0-40 cm) | 41(19)$^{a}$ | 29(8)$^{b}$ | 26(7)$^{b}$ | 12(15) | 19(10) | 20(10) | 2(4)$^{a}$ | 7(5)$^{b}$ | 6(4)$^{b}$ |
| Medium (40-80 cm) | 14(18)$^{a}$ | 2(3)$^{b}$ | 0.2(1)$^{c}$ | 39(23)$^{a}$ | 7(10)$^{b}$ | 6(5)$^{b}$ | 38(20)$^{a}$ | 13(8)$^{b}$ | 12(6)$^{b}$ |
| Tall (> 80 cm) | 0 | 0 | 0 | 6(17) | 0.4(1) | 4(8) | 14(22) | 4(4) | 6(6) |
| Vertical cover | | | | | | | | | |
| from 1.5 m at 45$^{o}$ | 23(6)$^{a}$ | | 9(4)$^{b}$ | 39(14)$^{a}$ | | 11(11)$^{b}$ | 52(19)$^{a}$ | | 33(23)$^{b}$ |
| from 5 m at 50 cm | 41(6)$^{a}$ | | 27(6)$^{b}$ | 63(19) | | 56(23) | 82(16) | | 81(16) |

low sagebrush/bunchgrass and mountain shrub. All vertical cover measurements from 1.5 m at 45° were greater at nests than random sites. Vertical cover from 5 m at 50 cm was greater in low sagebrush/bunchgrass and lower in mountain shrub at nest sites than random sites. Grass cover was greater at nests than at random sites in mixed sagebrush and mountain big sagebrush. Forb cover was greater in Wyoming big sagebrush at Jackass Creek. No pattern was evident for dominant forb and grass genera in any cover type (Appendices D and E).

Nests at Hart Mountain had less forb cover and shrub cover of tall height, greater grass cover, and more vertical cover from 5 m at 50 cm than nests at Jackass Creek (Table 5). In addition, nest areas at Hart Mountain had less shrub cover of low and tall height and greater shrub cover of medium height than those of Jackass Creek (Table 5). Collectively, successful nests had greater grass and shrub cover of medium height than unsuccessful nests (Table 6). Nest sites of successful and unsuccessful hens had greater shrub cover of medium height at nests than at nest areas (Table 6). In mountain big sagebrush, grass cover was greater at successful nests than unsuccessful nests and no differences in shrub cover was detected (Table 7). Similar comparisons were made for successful and unsuccessful nests in the other cover types (Appendices F through H). Although sample sizes of successful nests were low, similar trends were apparent in mixed sagebrush at Jackass Creek (Appendix H).

Mountain big sagebrush was the only cover type with a sufficiently large sample of successful and unsuccessful nests to compare cover of dominant taxa. No consistent trend was evident for

Table 5. Structural characteristics of sage grouse nests and nest areas from radio-equipped hens at Hart Mountain National Antelope Refuge (n=47) and Jackass Creek (n=51), Lake and Harney Counties, Oregon, 1989-1990.

| | Nest (1m area at nest) | | Nest area (4m area adjacent nest) | |
|---|---|---|---|---|
| | Hart Mountain | Jackass Creek | Hart Mountain | Jackass Creek |
| Characteristic (%) | $\bar{x}$(SD) | $\bar{x}$(SD) | $\bar{x}$(SD) | $\bar{x}$(SD) |
| Forb cover | 6(5)[a] | 12(11) | 10(6) | 10(5) |
| Grass cover | 18(20)[a] | 11(10) | 14(9) | 11(7) |
| Shrub cover | | | | |
| Low (0-40 cm) | 15(15) | 19(22) | 14(8)[a] | 18(12) |
| Medium (40-80 cm) | 35(22) | 30(23) | 14(12)[a] | 7(9) |
| Tall (> 80 cm) | 1(3)[a] | 7(17) | 0.4(2)[a] | 2(3) |
| Vertical cover | | | | |
| from 1.5 m at 45° | 44(17) | 38(18) | | |
| from 5 m at 50 cm | 72(20)[a] | 62(22) | | |

[a]mean different from nests at Jackass Creek ($P < 0.05$)

Table 6. Structural characteristics of nests (1-m area at nest) and nest areas (4-m area adjacent to nest) of successful (n=17) and unsuccessful (n=80) radio-equipped sage grouse hens at Hart Mountain National Antelope Refuge and Jackass Creek study areas, Lake and Harney Counties, Oregon, 1989-1990.

| Characteristic (%) | Successful | | Unsuccessful | |
|---|---|---|---|---|
| | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) |
| Forb cover | 8(5) | 10(6) | 10(10) | 10(6) |
| Grass cover | 24(22)[a] | 13(9) | 13(14) | 12(7) |
| Shrub cover | | | | |
| Low (0-40 cm) | 13(17) | 15(12) | 18(20) | 16(10) |
| Medium (40-80 cm) | 42(23)[ab] | 15(14) | 30(22)[b] | 9(9) |
| High (> 80 cm) | 1(3) | 1(3) | 5(14)[b] | 1(3) |
| Vertical cover | | | | |
| from 1.5 m at 45° | 44(14) | | 40(19) | |
| from 5 m at 50 cm | 73(20) | | 66(22) | |

[a]mean different from unsuccessful nest ($P < 0.05$)
[b]mean different from nest area ($P < 0.05$)

Table 7. Structural characteristics at nests (1-m area at nest) and nest areas (4-m area adjacent to nest) of successful (n=10) and unsuccessful (n=16) radio-equipped sage grouse hens in mountain big sagebrush cover type at Hart Mountain National Antelope Refuge, Lake County, Oregon, 1989-1990.

| | Successful | | Unsuccessful | |
|---|---|---|---|---|
| Characteristic (%) | Nest x(SD) | Nest area x(SD) | Nest x(SD) | Nest area x(SD) |
| Forb cover | 7(5) | 12(7) | 7(7) | 11(5) |
| Grass cover | 32(23)[a] | 16(10) | 9(10) | 10(6) |
| Shrub cover | | | | |
| Low (0-40 cm) | 11(13) | 15(12) | 11(12) | 12(4) |
| Medium (40-80 cm) | 44(24)[b] | 22(14) | 42(17)[b] | 15(11) |
| Tall (> 80 cm) | 1(4) | 1(4) | 0.4(1) | 0.4(1) |
| Vertical cover | | | | |
| from 1.5 m at 45° | 49(12) | | 50(15) | |
| from 5 m at 50 cm | 80(15) | | 82(15) | |

[a]mean different from unsuccessful nest ($P < 0.05$)
[b]mean different from nest area ($P < 0.05$)

dominant forb genera (Appendix I). Cover of 2 grass genera (Elymus sp. and Festuca spp.) were greater at successful nests than at unsuccessful nests (Appendix I). These grasses were the 2 tallest genera in cover types selected by nesting sage grouse (Table 8).

Table 8. Height (cm) of dominant grass genera at Hart Mountain National Antelope Refuge and Jackass Creek study areas, Lake and Harney Counties, Oregon.

| Genus | $\bar{x}$ | SD | n |
|---|---|---|---|
| Elymus | 53 | 12 | 39 |
| Agropyron | 28 | 6 | 62 |
| Festuca | 20 | 6 | 78 |
| Stipa | 18 | 5 | 122 |
| Sitanion | 15 | 5 | 122 |
| Koleria | 14 | 3 | 62 |
| Bromus | 11 | 4 | 36 |
| Poa | 6 | 4 | 106 |

# DISCUSSION

Results of this study indicated nesting sage grouse selected for cover types (mixed sagebrush and mountain big sagebrush) with a medium height big sagebrush component. Cover types selected by hens for nesting, which also had the highest nest success, had greater grass cover at nests than at random sites. Further, amount and type of grass cover were the only habitat components that differed between successful and unsuccessful nests. These results indicated mountain big sagebrush and mixed sagebrush were the most secure habitats for nesting, which accounted for selective use of these cover types.

In Utah, Rasmussen and Griner (1938) found highest nest densities and nest success in a big sagebrush cover type with sagebrush of medium height (> 50% canopy cover and sagebrush > 46 cm tall). Further, the presence of grasses and forbs interspersed with sagebrush made a more successful nesting type than sagebrush of equal density without the understory (Rasmussen and Griner 1938).

Previous sage grouse studies reported percent herbaceous cover at nest sites (Gray 1967, Hulet 1986, Wakkinen 1990), but only Klebenow (1969) found greater grass cover at nest sites (x=3.7%) than at random sites (x=2.9%, $P < 0.10$). Klebenow (1969) suggested condition of the understory affected the suitability of an area for nesting. In Idaho, herbaceous cover contributed to successful nesting by further camouflaging the nest site (Autenrieth 1981:20).

Two previous studies compared habitat components between successful and unsuccessful sage grouse nests, but only 1 reported

differences in grass cover. Pyrah (1970) noted greater grass cover at successful nests (43%, n=9) than unsuccessful nests (33%, n=4).

In Montana, successful nests were located in sagebrush stands with greater canopy cover than unsuccessful nests and had greater sagebrush cover within 60 cm of nest and within a 9-$m^2$ plot around nest (Wallestad and Pyrah 1974). Results of my study, in relation to shrub cover, were similar only when all nests were considered regardless of cover type. Within cover types, no differences in shrub cover between successful and unsuccessful nests were observed, which indicated nest success was related to cover type and ultimately grass cover and not amount of shrub cover at nest sites.

Grass height also was a possible factor in nest site selection. Although differences were not significant, the tallest grass genera available in each cover type appeared to have greater cover values at nests (both successful and unsuccessful) than at random sites. Only one study reported a measure of grass height at sage grouse nests and results indicated sage grouse selected for areas with taller grass (Wakkinen 1990). Grass height was an important factor in determination of nest fate. In mountain big sagebrush stands, giant wildrye and fescue accounted for 81% of grass cover at successful nests but only 1% at unsuccessful nests. These grasses represented the tallest grasses occurring at either study area. Greater grass cover in association with tall grass at nest sites likely provided increased nest concealment from predators and resulted in greater nest success than in areas with less grass cover. In Idaho, grass height was identified as a possible factor in determining nest fate (Wakkinen 1990).

Results of this study in relation to selection of shrubs paralleled those of previous studies. Past research, conducted in several states, revealed a large variation in canopy coverage and shrub heights used by sage grouse for nesting, but within an area hens selected for nest sites based on height and percent cover of sagebrush (Roberson 1986). In this study, sage grouse selected nest sites based on a small area (3 $m^2$) and for similar structural characteristics regardless of cover type, status, or study area, which was indicated by: 1) consistently greater shrub cover at nests than nest areas, 2) few differences in habitat components between nest areas and random sites, and 3) similarities between nests and differences between nest areas in the shrub component between study areas. Differences in vertical cover measurements were representative of differences in shrub cover and height between nest and random sites.

Previous studies reported stands used for nesting ranged from 20 to 44 percent shrub cover (Klebenow 1969, Wallestad 1975:30, Autenrieth 1981:19, Schoenberg 1982). Further, canopy cover was greater in the immediate area surrounding nests than at random sites (Klebenow 1969, Schoenberg 1982). Braun et al. (1977), in a review of sage grouse literature, noted height of sagebrush used for nesting ranged from 17 to 79 cm, but most nests were located under the tallest bushes available at a particular site. Areas of big sagebrush taller than 90 cm were seldom used in Idaho (Autenrieth 1981:17).

Nest success at Hart Mountain was similar to previous sage grouse studies conducted in Oregon. Nelson (1955) reported 32% nest success at Hart Mountain. Batterson and Morse (1948) reported 24% nest success

in Baker County located in northeastern Oregon. Sage grouse studies in other states reported nesting success ranging from 25% (Patterson 1952:104) to 64% (Wallestad and Pyrah 1974). In 12 studies, with a total of 699 nests, overall success was 35% (Bergerud 1988:593). Most sage grouse studies estimated nest success from nest searches, which were biased because only the most conspicuous nests were found (Bergerud 1988). Studies of radio-equipped sage grouse reported nest success of 40% (Peterson 1980), 61% (Wakkinen 1990), and 64% (Wallestad and Pyrah 1974). The low nesting success observed in this study paralleled recorded declines in productivity measures of sage grouse in Oregon. Brood surveys conducted at both study areas by ODFW and USFWS during each field season indicated low nesting success of radio-equipped hens was not related to the influence of transmitters.

Differences in sage grouse nest success and productivity between study areas were apparently related to differences in grass cover at nests and in availability of cover types selectively used. Grass cover at nests averaged 18% and 11% at Hart Mountain and Jackass Creek, respectively. Mountain big sagebrush represented 12% of available nesting habitat at Hart Mountain and mixed sagebrush represented 7% of available nesting habitat at Jackass Creek.

Cover type selection for nesting differed between study areas because of differences in cover type availability. Mixed sagebrush represented <1% of the Hart Mountain study area. Mountain big sagebrush represented only 2% of the Jackass Creek study area and was dispersed in small units associated with steep slopes and western juniper.

Differences in herbaceous cover at nests between study areas was the result of differences in availability. Hart Mountain received more annual precipitation and was a more productive site than Jackass Creek. Further, grazing intensity was greater at Jackass Creek (0.23 AUM/ha) than at Hart Mountain (0.13 AUM/ha), resulting in less residual grass cover for nest site selection. Jackass Creek, which was approximately 300 m lower in elevation than Hart Mountain, had greater forb availability earlier in the spring.

## MANAGEMENT IMPLICATIONS

Results of this study indicated grass cover and height were the primary habitat components that affected nest fate. Reduced grass cover and height at nests resulted in decreased nest concealment and increased nest predation. The relationship between the grass component of the habitat and sage grouse nesting success suggested reduction of grass cover and height would negatively influence sage grouse productivity. This implies activities that result in reduction of grass cover and height at nest sites (i.e., livestock grazing, shrub increases, disruption of fire cycles, fire suppression, and invasion of exotic plants) would be detrimental to sage grouse populations. Livestock grazing remains one of the most common and widespread uses of rangelands in Oregon and is the principal land management practice and proximate factor that affects grass cover and height (Rickard 1975). Grazing of tall grasses at nest sites will severely decrease their value for nest concealment. Shrub increases (sagebrush and western juniper) and disruption of fire cycles result in loss of grass understory and are cumulative effects of many years of grazing by domestic livestock and programs to prevent and suppress wildfires (Kauffman 1989).

The importance of sagebrush for nesting habitat is well documented. This study revealed that sage grouse selected nest sites in sagebrush stands of medium height. The primary factors that affect sagebrush ecosystems are eradication of sagebrush for agricultural production, increased livestock forage, urban development, and mining activities. All of these practices may negatively impact sage grouse

populations by loss of nesting habitat. The majority of sage grouse habitat in Oregon is public land and maintenance of current land management practices will continue to negatively affect sage grouse populations. Management practices that positively influence grass cover and height (elimination or reduction of cattle grazing and the reintroduction of fire) and maintenance of sagebrush ecosystems are required to regain healthy sage grouse populations in Oregon.

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# APPENDICES

Appendix A. Description of cover types at Hart Mountain National Antelope Refuge and Jackass Creek study areas, Lake and Harney Counties, Oregon.

| Cover type | Cover type description |
|---|---|
| Low sagebrush/bunchgrass | Found on alluvial fans and table lands with <30% slope. Principal plant species are low sagebrush (Artemesia arbuscula), bluebunch wheatgrass (Agropyron spicatum), and bluegrass (Poa spp.). Also may be associated with spiny hopsage (Atriplex spinosa). |
| Low sagebrush/fescue | Found on exposed ridges and side slopes at higher elevations (2000 to 2800m) at Hart Mountain. Primary plant species are low sagebrush and Idaho fescue (Festuca idahoensis). |
| Wyoming big sagebrush | Occurs on rolling uplands and lake basin terraces with slopes <30%. Primary plant species include Wyoming big sagebrush (A. tridentata wyomingensis) and bottlebrush squirrel tail (Sitanion hystrix). Also may be associated with spiny hopsage. |
| Mountain big sagebrush | Occurs at higher elevations (1800 to 2600m) on ridges and mountain shoulders. Primary plant species is Mountain big sagebrush (A. t. vaseyana) and Idaho fescue (F. idahoensis) or rough fescue (F. scabrella). |
| Mixed sagebrush | Characteristic of scabrock areas (15 to 75% rock fragments) associated with ridge tops, sloping tablelands, and alluvial plans. Primary plant species are low sagebrush, big sagebrush (A. t. spp.), and Sandberg's bluegrass (P. sandbergii). |
| Mountain shrub | Common at Hart Mountain at elevations between 1800 and 2300m. Primary plant species are mountain big sagebrush, antelope bitterbrush (Purshia tridentata), blue grass, and needle grass (Stipa spp.) |
| Basin big sagebrush | Occurs on low terraces associated with drainages and lake basins. Primary plant species are basin big sagebrush (A. t. tridentata) and basin wild rye (Elymus cinereus) |

Appendix A. (continued)

| Cover type | Cover type description |
|---|---|
| Grassland | Natural grasslands or areas disturbed by fire. Primary plant species are cheat grass (Bromus tectorum), bluegrass, and bottle brush squirrel tail. |
| Meadow | Associated with stream valleys that have poorly drained soils and subsurface water in summer. Primary plant species are bluegrass, sedge (Carex spp.), and baltic rush (Juncus balticus). |
| Lakebed | Found on depressions covered with water in spring. Primary plant species are silver sagebrush (A. cana) and bluegrass. |
| Juniper/aspen/mahogany | Associated with low ridges or footslopes. Primary plant species are western juniper (Juniperus occidentalis), aspen (Populus tremuloides), and mountain mahogany (Cercocarpus lepifolius). May be found interspersed with big sagebrush. |

Appendix B. Cover (%) and frequency (%) of dominant taxa from randomly sampled locations at Hart Mountain National Antelope Refuge, Lake County, Oregon, 1989-1990.

| Cover type | n | Genus | Cover | Frequency |
|---|---|---|---|---|
| Low sagebrush/bunchgrass | 30 | Collinsia | 0.8 | 50 |
| | | Sitanion | 1.3 | 27 |
| | | Poa | 5.0 | 88 |
| | | Phlox | 2.5 | 43 |
| Low sagebrush/fescue | 30 | Agoseris | 0.5 | 32 |
| | | Arenaria | 0.8 | 25 |
| | | Astragalus | 1.6 | 43 |
| | | Crepis | 0.8 | 30 |
| | | Festuca | 9.6 | 87 |
| | | Phlox | 3.8 | 72 |
| | | Poa | 3.6 | 86 |
| | | Sitanion | 0.9 | 28 |
| Mountain shrub | 31 | Agoseris | 0.5 | 25 |
| | | Agropyron | 1.3 | 18 |
| | | Bromus | 3.2 | 48 |
| | | Collinsia | 1.2 | 65 |
| | | Festuca | 1.5 | 8 |
| | | Poa | 6.2 | 61 |
| | | Sitanion | 3.0 | 36 |
| | | Stipa | 2.6 | 24 |
| Mountain big sagebrush | 62 | Agoseris | 0.7 | 36 |
| | | Agropyron | 1.5 | 33 |
| | | Balsamorhiza | 1.3 | 6 |
| | | Collinsia | 1.0 | 54 |
| | | Eriogonum | 1.2 | 15 |
| | | Festuca | 3.4 | 26 |
| | | Lupinus | 2.4 | 52 |
| | | Poa | 3.0 | 47 |
| | | Sitanion | 1.4 | 30 |
| | | Senecio | 1.0 | 29 |
| Wyoming big sagebrush | 24 | Collinsia | 0.7 | 45 |
| | | Musci | 3.4 | 13 |
| | | Poa | 1.5 | 42 |
| | | Sitanion | 0.9 | 30 |
| Grassland | 20 | Agropyron | 1.8 | 8 |
| | | Bromus | 8.5 | 58 |
| | | Carex | 1.6 | 10 |
| | | Microsteris | 1.1 | 46 |
| | | Poa | 5.1 | 51 |
| | | Sitanion | 3.0 | 34 |
| Lakebed | 10 | Juncus | 1.3 | 52 |

Appendix B. (continued)

| Cover type | n | Genus | Cover | Frequency |
|---|---|---|---|---|
| Meadow | 20 | Achillea | 4.1 | 44 |
| | | Agropyron | 2.7 | 35 |
| | | Aster | 1.3 | 18 |
| | | Carex | 5.8 | 41 |
| | | Haplopappus | 2.0 | 19 |
| | | Iris | 1.1 | 14 |
| | | Juncas | 4.5 | 64 |
| | | Koeleria | 1.2 | 14 |
| | | Poa | 10.6 | 81 |
| | | Potentilla | 4.7 | 38 |
| Basin big sagebrush | 20 | Bromus | 1.4 | 17 |
| | | Collinsia | 0.7 | 42 |
| | | Elymus | 1.3 | 6 |
| | | Festuca | 2.4 | 14 |
| | | Microsteris | 1.2 | 49 |
| | | Musci | 2.3 | 9 |
| | | Phlox | 1.7 | 23 |
| | | Poa | 3.7 | 32 |
| | | Sitanion | 2.9 | 29 |
| | | Stipa | 2.5 | 14 |

Appendix C. Cover (%) and frequency (%) of dominant taxa from randomly sampled locations at Jackass Creek study area, Harney County, Oregon, 1989-1990.

| Cover type | n | Genus | Cover | Frequency |
|---|---|---|---|---|
| Low sagebrush/bunchgrass | 59 | Collinsia | 1.5 | 63 |
| | | Lomatium | 1.2 | 29 |
| | | Microsteris | 0.7 | 31 |
| | | Musci | 1.4 | 16 |
| | | Poa | 5.7 | 92 |
| | | Phlox | 0.9 | 25 |
| Wyoming big sagebrush | 36 | Bromus | 1.2 | 21 |
| | | Collinsia | 1.0 | 38 |
| | | Lomatium | 1.4 | 30 |
| | | Microsteris | 1.0 | 37 |
| | | Musci | 1.6 | 8 |
| | | Poa | 7.2 | 70 |
| | | Sitanion | 1.4 | 26 |
| | | Stipa | 2.3 | 16 |
| Mixed sagebrush | 36 | Collinsia | 0.6 | 36 |
| | | Lomatium | 1.3 | 33 |
| | | Microsteris | 0.7 | 36 |
| | | Musci | 1.2 | 10 |
| | | Phlox | 0.7 | 24 |
| | | Poa | 5.6 | 74 |
| | | Sitanion | 1.6 | 31 |
| | | Stipa | 1.2 | 19 |
| Basin big sagebrush | 26 | Bromus | 2.8 | 35 |
| | | Collinsia | 1.4 | 34 |
| | | Microsteris | 1.0 | 28 |
| | | Poa | 11.5 | 72 |
| | | Polemonium | 1.3 | 22 |
| | | Sitanion | 3.1 | 38 |
| Lakebed | 12 | Musci | 1.0 | 5 |

Appendix D. Dominant forb and grass genera at nests (1-m area at nest), nest areas (4-m area adjacent to nest), and random sites in cover types used by radio-equipped sage grouse hens for nesting at Hart Mountain National Antelope Refuge, Lake County, Oregon, 1989-1990. Means with same letter or no letter within cover type are not different (P > 0.05).

| | Cover type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low sagebrush bunchgrass[a] | | | Mountain big sagebrush | | | Mountain shrub | | |
| Genus (%) | Nest (n=7) $\bar{x}$(SD) | Nest area (n=7) $\bar{x}$(SD) | Random (n=10) $\bar{x}$(SD) | Nest (n=27) $\bar{x}$(SD) | Nest area (n=27) $\bar{x}$(SD) | Random (n=62) $\bar{x}$(SD) | Nest (n=5) $\bar{x}$(SD) | Nest area (n=5) $\bar{x}$(SD) | Random (n=31) $\bar{x}$(SD) |
| Forb | | | | | | | | | |
| Agoseris | 0.6(1.0) | 0.2(0.3) | 0.2(0.2) | 0.4(0.6) | 0.7(0.6) | 0.7(0.7) | 0.2(0.3) | 0.5(0.7) | 0.5(0.4) |
| Balsomorhiza | | | | 0 | 0.01(0.1) | 1.3(4.1) | | | |
| Collinsia | | | | 0.4(0.7) | 0.4(0.5) | 1.0(0.9) | 0.3(0.4)A | 0.7(0.8)AB | 1.2(0.8)B |
| Eriogonum | | | | 0.2(1.0) | 0.7(2.4) | 1.2(3.3) | 0.8(1.5)A | 1.9(3.1)A | 0.1(0.2)B |
| Lomatium | 0.1(0.2) | 0.5(0.4) | 0.4(0.3) | 0.4(0.8) | 0.5(0.5) | 0.4(0.7) | | | |
| Lupinus | | | | 1.8(3.7) | 1.4(1.5) | 2.4(2.1) | | | |
| Musci | 0.9(1.9) | 1.6(2.3) | 1.0(1.0) | | | | | | |
| Phlox | 0.4(0.4) | 1.1(0.7) | 1.5(1.2) | 0.8(1.5) | 0.9(1.4) | 0.7(1.1) | | | |
| Senecio | | | | 0.7(1.3) | 1.4(2.7) | 1.0(1.3) | 2.0(2.8)A | 0.8(1.3)AB | 0.3(0.7)B |
| Trifolium | 0.8(1.9) | 1.4(2.4) | 0.8(1.7) | | | | | | |
| Grass | | | | | | | | | |
| Agropyron | 9.8(13.7) | 0.7(5.1) | 0.3(0.8) | 1.5(5.2) | 1.0(2.4) | 1.5(2.0) | 0 | 0.8(1.1) | 1.3(2.2) |
| Bromus | | | | | | | 0 | 0.5(1.0) | 3.2(4.4) |
| Elymus | 7.9(20.8) | 0.5(1.2) | 0 | 4.1(14.6) | 0.2(1.0) | 0.3(1.8) | 7.0(15.7) | 6.0(13.3) | 0.2(1.0) |
| Festuca | | | | 6.1(15.4) | 4.1(7.6) | 3.4(5.5) | 2.2(4.9) | 3.9(4.8) | 1.5(4.6) |
| Poa | 3.7(3.1) | 8.4(5.2) | 7.0(3.4) | 1.9(2.8) | 3.0(2.6) | 3.0(2.8) | 0.5(1.1)A | 3.9(2.0)AB | 6.2(3.5)B |
| Sitanion | 0.4(0.6)A | 2.3(2.4)AB | 2.0(1.9)B | 1.3(2.3) | 1.1(2.2) | 1.4(2.1) | 1.1(1.4) | 1.5(1.1) | 3.0(3.7) |
| Stipa | 2.1(3.7) | 2.3(2.5) | 1.1(2.0) | 0.7(2.5) | 1.3(2.7) | 0.7(1.5) | 2.2(4.9) | 2.4(4.3) | 2.6(3.6) |

[a]data from 1990 only

Appendix E. Dominant forb and grass genera at nests (1-m area at nest), nest areas (4-m area adjacent to nest), and random sites in cover types used by radio-equipped sage grouse hens for nesting at Jackass Creek, Harney County, Oregon, 1989-1990. Means with same letter or no letter within cover type are not different ($P > 0.05$).

| | Cover type | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Low sagebrush bunchgrass | | | Mixed sagebrush | | | Wyoming sagebrush | | |
| Genus (%) | Nest (n=19) $\bar{x}$(SD) | Nest area (n=19) $\bar{x}$(SD) | Random (n=59) $\bar{x}$(SD) | Nest (n=12) $\bar{x}$(SD) | Nest area (n=12) $\bar{x}$(SD) | Random (n=36) $\bar{x}$(SD) | Nest (n=19) $\bar{x}$(SD) | Nest area (n=19) $\bar{x}$(SD) | Random (n=36) $\bar{x}$(SD) |
| Forb | | | | | | | | | |
| Agoseris | | | | 1.4(3.0)[a] | 0.7(0.9)[a] | 0.3(0.6)[b] | | | |
| Astragalus | 0.3(1.2) | 1.0(1.6) | 0.9(1.6) | | | | | | |
| Collinsia | 1.6(2.3) | 1.0(1.5) | 1.5(1.1) | 1.9(4.0)[a] | 0.7(1.0)[a] | 0.6(0.6)[b] | 1.1(1.3) | 1.1(1.4) | 1.0(1.2) |
| Crepis | 2.2(6.6) | 1.2(1.4) | 0.8(1.3) | 0.1(0.2) | 0.8(1.8) | 0.1(0.2) | 1.8(4.5)[a] | 0.7(1.7)[ab] | 0.4(0.7)[b] |
| Lomatium | 0.9(2.0) | 0.7(0.7) | 1.2(1.5) | 1.5(2.5) | 0.4(0.4) | 1.3(1.6) | 0.8(1.6) | 0.9(1.3) | 1.4(2.1) |
| Microsteris | 0.2(0.4) | 0.2(0.3) | 0.7(1.0) | 0.1(0.3)[a] | 0.1(0.2)[a] | 0.7(0.8)[b] | | | |
| Musci | 3.3(8.3) | 1.4(1.8) | 1.4(2.1) | 2.2(5.2) | 0.3(0.8) | 1.2(2.1) | 7.5(12.1)[a] | 3.0(3.6)[ab] | 1.6(3.7)[b] |
| Phlox | 0.8(1.7) | 1.2(1.7) | 0.9(1.2) | 0.1(0.3)[a] | 0.8(0.6)[b] | 0.7(0.7)[b] | 0.3(0.7) | 1.6(3.1) | 0.9(1.1) |
| Polemonium | 1.1(2.6)[a] | 0.3(0.6)[a] | 0.1(0.2)[b] | | | | | | |
| Grass | | | | | | | | | |
| Agropyron | | | | 1.7(5.8) | 0 | 0 | 1.2(5.5) | 0 | 0 |
| Bromus | | | | | | | 0.4(1.2) | 0.2(0.6) | 1.2(2.6) |
| Poa | 3.7(4.8)[a] | 6.4(2.7)[ab] | 5.7(2.6)[b] | 7.6(12.3) | 5.9(2.4) | 5.6(3.8) | 4.4(5.2) | 6.6(5.0) | 7.2(4.9) |
| Sitanion | 2.4(3.0)[a] | 1.4(1.5)[ab] | 0.8(1.0)[b] | 2.8(5.6) | 3.0(4.7) | 1.6(1.7) | 3.6(5.2) | 4.5(6.1) | 1.4(1.3) |
| Stipa | 1.4(3.1) | 0.9(2.1) | 0.5(1.4) | 4.2(12.9) | 2.0(3.4) | 1.2(1.9) | 2.6(5.6) | 2.9(4.9) | 2.2(4.7) |

Appendix F. Structural characteristics at nests (1-m area at nest), nest areas (4-m area adjacent to nest) of successful (n=2) and unsuccessful (n=17) radio-equipped sage grouse hens in low sagebrush bunchgrass cover type at Jackass Creek, Harney County, Oregon, 1989-1990.

| | Successful | | Unsuccessful | |
|---|---|---|---|---|
| Characteristic (%) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) |
| Forb cover | 4(3) | 10(2) | 12(12) | 10(4) |
| Grass cover | 7(7) | 5(6) | 8(5) | 9(3) |
| Shrub cover | | | | |
| Low (0-40 cm) | 40(31) | 33(8) | 41(19)[a] | 28(8) |
| Medium (40-80 cm) | 28(15) | 7(7) | 13(18)[a] | 1(2) |
| Tall (> 80 cm) | 0 | 0 | 0 | 0 |
| Vertical cover | | | | |
| from 1.5 m at 45° | 30(2) | | 23(6) | |
| from 5 m at 50 cm | 47(4) | | 41(6) | |

[a]mean different from nest area ($P < 0.05$)

Appendix G. Structural characteristics at nests (1-m area at nest), nest areas (4-m area adjacent to nest) of successful (n=2) and unsuccessful (n=17) radio-equipped sage grouse hens in Wyoming big sagebrush cover type at Jackass Creek, Harney County, Oregon, 1989-1990.

| | Successful | | Unsuccessful | |
|---|---|---|---|---|
| Characteristic (%) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) |
| Forb cover | 14(6) | 7(4) | 16(12) | 12(7) |
| Grass cover | 8(0.3) | 13(5) | 11(8) | 14(9) |
| Shrub cover | | | | |
| Low (0-40 cm) | 1(2) | 3(1) | 2(4)[a] | 8(5) |
| Medium (40-80 cm) | 50(17) | 12(12) | 37(20)[a] | 13(8) |
| Tall (> 80 cm) | 0 | 0.3(0.4) | 16(23)[a] | 4(4) |
| Vertical cover | | | | |
| from 1.5 m at 45° | 49(18) | | 52(20) | |
| from 5 m at 50 cm | 86(7) | | 81(18) | |

[a]mean different from nest area ($P < 0.05$)

Appendix H. Structural characteristics at nests (1-m area at nest), nest areas (4-m area adjacent to nest) of successful (n=2) and unsuccessful (n=10) from radio-equipped sage grouse hens in mixed sagebrush cover type at Jackass Creek, Harney County, Oregon, 1989-1990.

| | Successful | | Unsuccessful | |
|---|---|---|---|---|
| Characteristic (%) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) |
| Forb cover | 14(5) | 10(1) | 7(8) | 6(4) |
| Grass cover | 30(36) | 13(8) | 14(13) | 10(5) |
| Shrub cover | | | | |
| Low (0-40 cm) | 9(12) | 13(9) | 13(16) | 21(10) |
| Medium (40-80 cm) | 54(9)[a] | 1(1) | 36(25)[a] | 9(10) |
| Tall (> 80 cm) | 0 | 0 | 7(18) | 0.5(1) |
| Vertical cover | | | | |
| from 1.5 m at 45° | 45(1) | | 37(15) | |
| from 5 m at 50 cm | 74(4) | | 60(20) | |

[a]mean different from nest area ($P < 0.05$)

Appendix I. Dominant forb and grass genera at nests (1-m area at nest) and nest areas (4-m area adjacent to nest) of successful (n=10) and unsuccessful (n=16) radio-equipped sage grouse hens in mountain big sagebrush cover type at Hart Mountain National Antelope Refuge, Lake County, Oregon, 1989-1990.

| Genus (%) | Successful | | Unsuccessful | |
|---|---|---|---|---|
| | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) | Nest $\bar{x}$(SD) | Nest area $\bar{x}$(SD) |
| Forb | | | | |
| Agoseris | 0.5(0.6) | 0.6(0.6) | 0.5(0.6) | 0.7(0.7) |
| Antennaria | 0.4(0.8) | 1.3(2.7) | 0 | 0.3(1.0) |
| Collinsia | 0.2(0.3) | 0.2(0.2) | 0.5(0.9) | 0.5(0.6) |
| Eriogonum | 0.1(0.3) | 1.6(4.0) | 0 | 0.1(0.3) |
| Lomatium | 0.2(0.3) | 0.6(0.5) | 0.6(1.0) | 0.4(0.4) |
| Lupinus | 1.0(1.7) | 1.7(1.7) | 2.1(4.5) | 1.0(1.2) |
| Phlox | 1.2(1.9) | 1.1(1.2) | 0.5(0.9) | 0.9(1.6) |
| Senecio | 0.9(1.3) | 1.2(1.3) | 0.6(1.4) | 1.5(3.5) |
| Viola | 0.6(1.4) | 0.4(1.1) | 1.0(3.0) | 1.2(2.9) |
| Grass | | | | |
| Agropyron | 0 | 0.1(0.4) | 2.3(6.7) | 1.3(3.0) |
| Elymus | 11.0(23.0)[ab] | 0.5(1.6) | 0.1(0.3) | 0 |
| Festuca | 15.1(23.1)[a] | 7.8(10.4) | 0.8(2.1) | 2.0(4.0) |
| Koeleria | 0.9(2.3) | 2.1(5.2) | 0.8(2.5) | 0.4(0.8) |
| Poa | 3.0(3.8) | 3.2(2.7) | 1.3(2.1) | 2.9(2.7) |
| Sitanion | 0.4(0.7) | 0.7(1.0) | 1.9(2.8) | 1.4(2.7) |
| Stipa | 1.3(4.0) | 0.9(2.0) | 0.3(0.9) | 1.3(3.0) |

[a]mean different from unsuccessful nest ($P < 0.05$)
[b]mean different from successful nest area ($P < 0.05$)