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ABSTRACT

Greater sage-grouse (Centrocercus urophasianus) *habitat was studied in central Montana primarily on Wyoming big sagebrush (*Artemisia tridentata *Nutt. ssp.* wyomingensis *Beetle & Young) dominated rangeland. The primary objective was to compare shrub and herbaceous parameters within (use, random or non-use) and between seasonal habitats (nest, brood, winter). Two study sites (Musselshell and Golden Valley counties), and 2 years (2004 and 2005) were compared. Nest, brood, and random sites were compared for herbaceous cover, and grass height. Nest, brood, random, winter use and winter non-use sites were evaluated for shrub cover, density, and height. All differences were considered significant at $P \leq 0.05$. Sage-grouse nested in areas with greater total shrub cover and height, and taller live and residual grass than was randomly available. No differences were found between brood and paired random sites for any of the herbaceous or shrub parameters measured. Shrub cover and density were greater at winter use sites than non-use sites. Winter use sites had less shrub cover than nest sites. The nest and brood habitat had similar shrub cover, density, and height on the study area. Sage-grouse habitats should be managed to include sagebrush, forbs, and grass. Herbaceous vegetation was more important during nesting and brood rearing than during the winter. Therefore, some portions of grouse habitat may benefit from management for greater herbaceous cover, but never at the sake of less sagebrush. Sagebrush cover from 10 to 30 percent was the most consistent component of sage-grouse habitat.*

INTRODUCTION

It is estimated that the overall distribution of sage-grouse (*Centrocercus* spp.) has decreased by 50 percent since European settlement (Braun 1998). The historical distribution of greater sage-grouse (*C. urophasianus*) included 12 states and 3 Canadian provinces; currently sage-grouse have been extirpated from British Columbia and Nebraska (Schroeder and others 2006).

Sage-grouse decline is most often attributed to a loss of habitat. Sage-grouse are sagebrush obligates, dependent on sagebrush for food, thermal cover, and hiding cover (Patterson 1952; Wallestad 1975). Montana currently supports 11 million ha of sage-grouse habitat (Montana Sage-grouse Work Group 2002); although it is estimated 50 percent of the original habitat has been lost (C.L.Wambolt personal communication, March 2005).

Sage-grouse habitat is quite variable due to variations in weather (especially snow depth), sagebrush taxa present, habitat types and patterns available, and topography of habitat (Eng and Schladweiler 1972; Wallestad 1975; Remington and Braun 1985; Connelly and others 2000). Few studies have had the opportunity to concurrently investigate nesting, brood rearing and winter habitats required by sage-grouse. Further information on sage-grouse in Montana would assist land managers in making decisions in favor of sage-grouse.

The primary objective was to compare shrub and herbaceous parameters within (use, random or non-use) and between seasonal habitats (nest, brood, winter) and 2 years (2004 and 2005).

METHODS

Study Area Description

This study was conducted in central Montana with one location in Musselshell county and another in Golden Valley county, 25 km north and 32 km west of Roundup. The majority of the study area is privately owned (75 percent), with some land managed by the Bureau of Land Management (16 percent), and the remaining by the state (5 percent). Eighty-nine percent of the study area is used for range, beef and sheep production. The weather station in Roundup receives a mean annual precipitation of 32 cm (Western Regional Climate Center 2005). During the growing season (April to September) the area receives 75 percent of the annual mean average precipitation. The study area is made up of shale lowlands separated by sandstone ridges containing several undrained basins (USDA 2003). The study sites consisted of the Wyoming big sagebrush (*Artemisia tridentata* Nutt ssp. *wyomingensis* Beetle & Young) habitat type, greasewood (*Sarcobatus vermicultatus* (Hook.)Torr.) bottoms, native and introduced grasslands, and agricultural lands. This study was conducted in conjunction with Sika (2006) whose study focused on breeding ecology, survival rates and mortality causes of sage-grouse on the same study area.

Collection of Bird Locations

Over a 3 year period (2003 to 2005) sage-grouse were captured on or near leks during breeding season and fitted with a radio transmitter. A receiver was used to precisely locate sage-grouse and a geographic position system (GPS)

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was used to record exact location of tracks, fresh sage-grouse droppings, or nest location. Use sites were relocated with GPS in order to conduct habitat measurements. Winter sites were located 3 to 6 months, and nest and brood sites within 7 days after bird location was collected via GPS.

MEASUREMENTS

Nesting Habitat

Sagebrush canopy cover, density, and height, forb, grass, and herbaceous cover, and live and residual grass height were measured at each nest site. The height and average diameter of the shrub the hen nested under was determined. Nest shrub productivity was calculated by measuring the nest shrub's major axis, followed by a perpendicular minor axis, and 2–45° crown width measurements, and is reported in grams of available winter forage (Wambolt and others 1994). All measurements were conducted on 2 perpendicular 30 m N-S and E-W transects, with the nest located at the center (15 m point) of each line.

Line intercept sampling was used to estimate shrub canopy cover, and height along transects (Canfield 1941, Connelly 2003). Gaps in shrubs >3 cm (0.1 ft) were excluded. Shrub height was measured every 2 m on the nearest shrub with an average crown >15 cm in diameter (n = 15/transect). Belt transects were used to estimate shrub density (Connelly and others 2003). All shrubs >15 cm in diameter and rooted within 1 m of either side of the 3 to 30 m transect lines were recorded. Total herbaceous forb and grass cover were measured using 20 x 50 cm quadrats (Daubenmire 1959). A total of 20 quadrats were measured along each of the two transects. Vegetative droop height of living grass and residual grass was also recorded at each quadrat.

Random sites were paired with nest sites within the same habitat to test if hens were randomly selecting shrub or herbaceous characteristics for nesting. Shrub and herbaceous measurements were completed using the same methods as nest sites. Random sites were measured on the same or next day as their paired nest sites. At each nest site a random compass direction and distance (between 30 m and 1000 m) were chosen using random number tables. The tallest sagebrush, nearest the end of the random distance was selected as the random nest shrub. If the habitat encountered at the random site was not sagebrush, such as an agricultural field, the closest sagebrush stand in the same direction was selected.

Brood Rearing Habitat

Hens with broods were tracked throughout the brood-rearing season. Shrub and herbaceous parameters at brood sites were measured using the same methods as nest sites. Paired random locations were selected in the same way as nest sites. Brood locations were located and measured at 1 and 4 weeks after hatch.

Winter Habitat

Winter habitat measurements were collected along 3 to 30 m transects. The sampling layout differed from nest and brood sites because typically during the winter birds are in flocks that are spread out across the landscape. The first transect was centered over droppings found at the GPS location of the use site. The second and third transects were 30 m to each side and parallel to the first transect. Shrub measurements including cover, density and height were completed precisely the same as for nest sites. Residual grass height (including inflorescence) and cover were measured at 2005 to 2006 winter use and non-use sites.

Sage-grouse winter non-use sites were established during the summer of 2005 and the winter of 2005 to 2006. Random points were placed on ArcGIS 9® within areas that were not known to be used heavily during winter. Random points were only placed in soil types that grouse had used during our study. No random points were placed within 300 m of the actual winter bird location.

A GPS unit was used to locate sampling sites. An area of $1200m^2$ was delineated around each GPS location for sampling. This area was searched thoroughly for droppings; if droppings were found the site was dropped from our analysis. Droppings were persistent for at least 6 months. At locations with no indication of use, 3 30 m transects, duplicating those in use sites were sampled. Sites with < 2 percent sagebrush were discarded and not sampled as non-use sites.

ANALYSES

An analysis of variance (ANOVA) was conducted using the GLM version of SAS® 9.0 to determine if sage-grouse habitat differed by season (nest, brood, random, winter, or winter non-use), or year (2004 and 2005). Nest, brood, and random sites were compared for total herbaceous, grass, and forb cover, and live and residual grass height. Nest and paired random sites were evaluated for nest shrub height, nest shrub productivity and crown diameter of nest shrub. Nest, brood, random, winter use and winter non-use sites were compared for total shrub canopy cover, total shrub density, and shrub height. The experimental unit was each bird location, or one sampled site, all transects from each site were averaged together. Effects in the model were compared with least squares means. Because data were unbalanced a Tukey-Kramer test was used to separate least squares means (Kramer 1959). The linear model included all main effects (season, year, county) and all possible interactions. When interaction terms were not significant reduced models were fitted to the data. Least squares means are presented where no interactions were determined. Least

squares means for the interactive terms are reported when interactions were significant. Residual grass height and cover from the 2005 to 2006 winter were analyzed with either 2-independent sample t-tests or Wilcoxon-Mann-Whitney tests depending on normality. These data could not be added to the ANOVA because of differences in sampling methodology. All differences were considered significant at $P \leq 0.05$.

Vegetative parameters were analyzed for 648 sites measured in 2004 and 2005. Sites with 0 percent shrub cover were omitted from the analyses. Included in the analysis were 22 sites where greasewood contributed >50 percent of total canopy cover, and 4 sites where silver sage contributed >50 percent total canopy cover. The remaining 626 sites (97 percent) sampled had >50 percent shrub cover of Wyoming big sagebrush. Wyoming big sagebrush, silver sagebrush, and greasewood sites were analyzed together as one shrub cover type in the ANOVA. Over 90 percent of shrub cover was from Wyoming big sagebrush.

RESULTS AND DISCUSSION

Nesting Habitat

The importance of herbaceous and shrub cover for nest concealment has been demonstrated in previous studies (Connelly and others 2000, Sveum and others 1998). Sage-grouse nested in areas with greater total shrub cover (15 percent vs. 13 percent; $P<0.03$) and height (28 cm vs. 26 cm; $P<0.05$), and taller live (12 cm vs. 11cm) and residual grass (9 cm vs. 8 cm) than was randomly available in our study. When total shrub cover, residual grass height, or residual grass cover increased by 10 percent, the probability of a nest increased by 31.3 percent (Holloran et. al. 2005). The shrub under which the hen nested was taller (50 cm vs. 44 cm; $P<0.001$) and had greater productivity (61 g vs. 51 g; $P<0.001$) than random shrubs in both years.

Due to increased precipitation in 2005, total herbaceous (18 percent vs. 13 percent), grass (15 percent vs. 12 percent), and forb cover (7 percent vs. 3 percent), and live grass height (13 cm vs. 10 cm) were greater ($P<0.001$) in 2005 than 2004. Average crown diameter was greater at nest sites than random sites in 2004 but similar in 2005 (figure 1). Sika (2006) found weak support for increased nest success in 2005 on the same study area. Coggins (1998) found nest success for sage-grouse increased in years with greater residual tall grass cover. Haustliner (2003) considered grass height to be a limiting factor for nest success during drought years. Herbaceous cover associated with nest sites may have provided scent, visual, and physical barriers to predators (DeLong and others 1995).

There was a greater number of re-nests (ie. 2nd and 3rd nest attempts) in 2005 than 2004. Re-nests were more successful (56 percent) than first nests (32 percent) (Sika 2006). This was likely because of the increase in herbaceous cover. Although there was a higher proportion of successful nests in 2004, there was greater hen success in 2005 (success in raising a brood out of all of the females beginning the study) (Sika 2006). Moynahan (2004) found that nesting probability increased when range condition was improved.

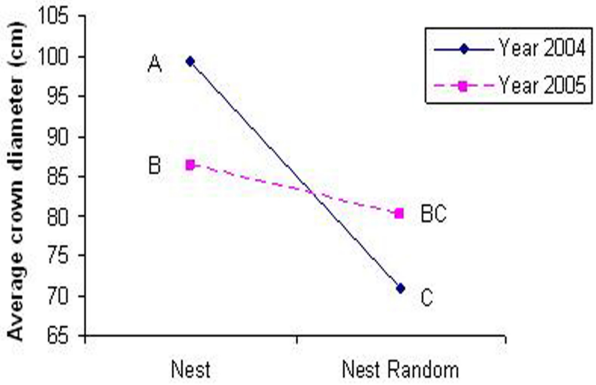

Figure 1—Interaction between year and seasonal habitat for average crown diameter of the nest shrub for nest and paired random sites in 2004 and 2005 in Golden Valley and Musselshell counties. Means differ ($P \leq 0.05$) between sites when followed by a different letter.

Brood Rearing Habitat

No differences were found between brood and paired random sites for any of the herbaceous or shrub parameters measured on our study. Klebenow (1969) did not find a statistical difference between brood and random sites in Idaho. A meta-analysis of 7 sage-grouse studies throughout the west found areas used by broods < 6 weeks of age had greater forb and grass cover, taller grass, and less sagebrush cover than random sites (Hagen and others 2007).

There was greater shrub height (29 cm vs. 25 cm), total herbaceous cover (19 percent vs. 16 percent), forb cover (15 percent vs. 13 percent), and live grass height (17 cm vs. 11 cm) in 2005 than 2004 ($P<0.001$). Shrub density ($1.5/m^2$ vs. $1.1/m^2$) and residual grass height (9 cm vs. 5 cm) were greater in 2004 than 2005, indicating broods used different areas in years with different precipitation. Broods in southern Oregon and southern Idaho used areas with the greatest forb cover (Klebenow 1969, Drut 1994a). Forbs, insects, and sagebrush are the primary food sources for young chicks (Drut 1994b, Peterson 1970). Forb cover increased 2.5 fold from 2004 to 2005 due to increased precipitation across my study area. As forb cover increased, broods may have been able to forage in a variety of cover types in 2005. The added herbaceous cover may have added a component making chicks less visible in a variety of cover types. Coggins' (1998) brood use was equitably distributed between cover types in wet years more than dry years because of the greater availability of forbs.

Table 1— Maximum, minimum, and average temperature, total precipitation, and total snow depth from January to December in 2004 to 2006 at station 247220 in Roundup, MT (National Oceanic and Atmospheric Administration 2006).

Year	Month	Average Maximum Temp °F	Average Minimum Temp °F	Average Temp °F	Total Precip (in)	Total Snow (in)
2004	Jan	33	12	22.5	0.40	7.5
2004	Feb	43	19	31	0.26	0.5
2004	Mar	60	30	45	0.11	0.5
2004	Dec	46	21	33.5	0.39	4.2
2005	Jan	33	11	22	0.26	6.5
2005	Feb	49	19	34	Trace	Trace
2005	Mar	54	27	40.5	0.63	6.4
2005	Dec	36	18	27	0.33	4.5
2006	Jan	47	28	37.5	0.02	0.0
2006	Feb	42	16	29	0.22	1.4
2006	Mar	47	22	34.5	1.55	8.0

Increased food availability and cover have the potential to increase survival of chicks (Crawford 1998). On our study area there was 71 percent brood survival in 2004, and 84 percent in 2005 (brood survival is the survival of at least one chick to 30 days of age) (Sika 2006). Increased grass height, total herbaceous cover and forb cover, likely increased chick survival.

Due to unfavorable precipitation and a lack of forbs, the food source for chicks could have been comprised more of sagebrush than forbs in 2004. This could be why sagebrush density was higher in 2004 than 2005. Drut (1994a) found chick diets in Oregon to correspond directly to the availability of primary foods. Forbs and invertebrates constituted >75 percent of the diet at Hart Mountain, while sagebrush composed 65 percent of the mass consumed by chicks at Jackass Creek. Peterson (1970) in central Montana and Klebenow (1968) in Idaho found young grouse ate mostly forbs and insects and very little sagebrush until they were ≥10 weeks old.

Winter Habitat

Both winters were relatively mild with no snow accumulations >10 cm on days we collected bird locations and no more than 20 cm of snow fell within a month (table 1). Shrub height was greater at winter non-use sites than use sites in 2005 (36 cm vs. 32 cm; $P<0.01$), but similar in 2004 (27 cm vs. 27 cm). Most winter studies have found height of sagebrush to be an important determinant of sage-grouse habitat because sagebrush availability above the snow pack has been determined to be critical for sage-grouse survival (Wallestad 1975, Beck 1977, Robertson 1991). Snow never completely covered sagebrush during the 2 years of this study. In a study in the Yellow-Water Triangle of Montana, <15 miles north of our Musselshell study site, Wallestad (1975) found sage-grouse restricted to 7 percent of their available range when snow depths exceeded 30 cm. This occurred in 3 of the 7 winters of his study. It is not known where grouse will go under harsh winter conditions on our study area.

Despite our sampling occurring during mild winters, shrub cover (12 percent vs. 10 percent) and density (1.2/m^2 vs. 0.8/m^2) were greater ($P<0.001$) at winter use sites than non-use sites. This is similar to findings in Idaho sage-grouse winter habitats (Robertson 1991). During the winter sage-grouse were almost completely reliant on sagebrush as a food and cover source (Patterson 1952, Wallestad 1975). Sage-grouse were able to maintain or gain weight during the winter (Patterson 1952, Remington and Braun 1988) because of their nutritious diet (Wambolt 2004) of abundant sagebrush.

Shrub density and cover were greater ($P<0.001$) in 2004 than 2005. Winter weather conditions were similar for both years. In the fall of 2005, 800 ac of important winter habitat in Musselshell County were plowed, making it unavailable for use during the 2005 to 2006 winter. While it appeared that birds had plenty of similar habitats available they were still found in the plowed area and in adjacent habitat that appeared less than ideal. The 10 sites immediately surrounding the newly plowed area during the 2005 winter had a shrub canopy cover of 7.2 percent and a density of 0.86 shrubs/m^2. I found sage-grouse returned to wintering grounds year after year as did Berry and Eng (1985). Swenson (1987) in south-central Montana found that grouse populations declined by 73 percent after 30 percent of a known sage-grouse winter habitat was plowed. On our study area, lek numbers increased the year following the plowing (MTFWP unpublished data), possibly due to the wet productive spring before. Declines in population numbers could occur in the future if the study area received harsh winter conditions.

Sika (2006) found monthly winter survival to be lower in the 2005 winter than the 2004 winter on our study area. Because reproductive effort was higher in 2005, Sika (2006) attributed the decline in survival to trade-offs between survival and reproductive effort. The differences in habitat between the 2 years (decreased density and cover in 2005) could have been related to decreased survival in 2005. It is possible that grouse choose habitats that were less suitable causing mortality. It is also possible that grouse choose habitats to mitigate high mortality, for example they may have used habitats with less density and cover in order to be able to visualize and avoid predators.

Residual grass height (19 cm vs. 18 cm) and cover (13 percent vs. 14 percent) were similar at winter use and non-use sites. Because grass heights measured for residual grass height in the winter of 2005 to 2006 included inflorescences the heights are not comparable with nest and brood residual grass heights were vegetative droop heights were measured. Sage-grouse did not appear to be selecting areas with vegetative cover in the winter. To our knowledge, no other study has addressed the importance of herbaceous cover in the winter. Selection for areas with greater herbaceous cover seems to be restricted to nesting and brood rearing activities when predator avoidance requires hiding.

Our winter use sites had less shrub cover ($P<0.001$) than nest sites (12 percent vs. 15 percent), seemingly in conflict with Wallestad (1975) who found nest and winter habitats to be synonymous in central Montana. We believe our winter sites were low in cover, height, and density compared to other studies because snow depth was not great enough during this study to influence grouse distribution. Wallestad's (1975) study included 3 of 7 winters which were above average in snow accumulation. If our study had occurred in similar winters it is likely that the winter habitat could have been similar to nesting habitat.

Other studies have found brood sites to have less shrub cover than random sites and nest sites to have greater shrub cover than random sites (Hagen and others 2007); however we found the 2 habitats (nest and brood) to be similar in our study area. We removed all non-shrub habitats from our analysis in order to compare shrub habitats; if this had not been done the average cover of shrubs at brood sites would have been lower. As forbs desiccate, grouse often moved to more mesic sites in other studies (Connelly and others 2000). Birds in our study were non-migratory with movements typically less than 10 km between seasonal habitats, therefore, nesting and brood rearing routinely took place within close proximity.

Logically, because of difference in season, brood sites had greater grass height than nest sites and nest sites had greater residual grass height than brood sites ($P<0.02$). Total herbaceous cover and forb cover were greater ($P<0.04$) at brood sites, but grass cover was similar at nest and brood sites. Residual grass height was lower at brood sites because live grass was providing greater cover than residual grass and because residual grass was continually degrading as the season progressed.

Wallestad (1975) analyzed sage-grouse production over 10 years and found that rain during the laying season resulted in poor production due to a late hatch, but spring rainfall increased production overall. The spring of 2005 was rainy during the laying period in early May and until the end of June. More nests failed in 2005 than 2004, but the hens were able to re-nest, and re-nests were more successful (Sika 2006). The continuing rain may have enabled the green up period to last long enough to promote chick survival. Due to increased precipitation, total herbaceous, grass and forb cover were greater in 2005 than 2004 ($P<0.05$). The proportion of hens that successfully raised a brood to 30 days of age increased from 28 percent in 2004 to 43 percent in 2005 (Sika 2006). Lek counts increased between 30 to 50 percent from 2005 to 2006 (MTFWP unpublished data) verifying high recruitment from the 2005 breeding season. Moynahan (2004) also observed greater re-nesting in a year when 1st nest survival was low to moderate and habitat conditions were favorable.

CONCLUSION

Sage-grouse habitats should be managed to include sagebrush, forbs, and grass. Herbaceous vegetation was more important during nesting and brood rearing than during the winter. Therefore, some portions of grouse habitat may benefit from management for greater herbaceous cover, but never at the expense of sagebrush. Sagebrush cover from 10 to 30 percent was the most consistent component of sage-grouse habitat.

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