SAGE-GROUSE (*Centrocercus urophasianus*) NESTING AND BROOD-REARING SAGEBRUSH HABITAT CHARACTERISTICS IN MONTANA AND WYOMING

by

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ABSTRACT

Nesting and brood-rearing habitat data for greater sage-grouse (*Centrocercus urophasianus*) near Roundup in central Montana in 2004, Decker in south-central Montana and northern Wyoming in 2003, and Malta in north-central Montana in 2003 was collected. Sage-grouse hens were fitted with radio collars and tracked to nests. Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) canopy cover, density, and height for nest vs. random sites and brood vs. random sites were compared to determine if hens were selecting for these parameters. Forb, grass, total herbaceous, and residual cover, grass height, and residual height were also compared.

Nest sites near Roundup (53 nest sites), Decker (58), and Malta (45) were measured. Most nest sites near Roundup were in sagebrush (91 %). All nest sites near Decker and Malta were in sagebrush. Only nest sites in sagebrush habitats were analyzed. Nest sites had taller (48 vs. 42 cm, $P \leq 0.01$) and more productive (60 vs. 46 g of produced forage, $P \leq 0.01$) nest shrubs than random sites near Roundup. At the Decker study area, nest sites had greater sagebrush cover (22 vs. 14 %, $P \leq 0.01$), density (1.1 vs. 0.6 shrubs per m^2, $P \leq 0.01$), and taller shrubs within 15 m (52 vs. 42 cm, $P \leq 0.01$) than random sites. Nest sites had taller shrubs within 15 m of the nest (30 vs. 26 cm, $P \leq 0.05$) near Malta. Successful and failed nest sites did not differ between the Roundup and Decker study areas. Yearling nest sites had shorter grass than adult sites in Roundup (9 vs. 11 cm, $P \leq 0.05$).

Forty-four brood sites near Roundup and 73 brood sites near Decker were measured. Brood sites were not measured near Malta. Most brood sites near Roundup (71 %) and all near Decker (100 %) were in sagebrush. Only brood sites in sagebrush habitats were analyzed. Vegetation was similar between brood and paired random sites near Roundup. At the Decker study area, brood sites had denser sagebrush (1.1 vs. 0.6 shrubs per m^2, $P \leq 0.01$) than random sites. Adult and yearling hen brood sites did not differ near Roundup. Adult brood sites had greater sagebrush cover (14 vs. 8 %, $P \leq 0.05$), density (1.0 vs. 0.6 shrubs per m^2, $P \leq 0.05$), and taller shrubs within 15 m (44 vs. 37 cm, $P \leq 0.05$) than yearling sites near Decker. Brood sites had less shrub cover at 4 weeks than weeks 1 and 2 (10 vs. 16 and 17 %, $P \leq 0.01$) near Roundup.

Sagebrush habitats comprised 97 % (151 of 156) of the total nest sites and 92 % (108 of 117) of all brood locations. Nest sites had 19–22 % sagebrush cover, 26–52 cm sagebrush heights, and total herbaceous cover of 13–33 %. Brood sites had 12-13 % sagebrush cover, 22–43 sagebrush heights, and 14–33 % total herbaceous cover. This study reinforces the importance of sagebrush habitats for nesting and brood-rearing sage-grouse. Management practices which remove this shrub would probably reduce the nesting and brood-rearing success of sage-grouse in central Montana and northern Wyoming.

CHAPTER 1

INTRODUCTION

Declining numbers of greater sage-grouse (*Centrocercus urophasianus*) have concerned biologists for over 80 years (Connelly et al. 2000b). Sagebrush (*Artemisia* L.) habitat loss, fragmentation, and degradation are the primary factors attributed to sage-grouse declines (Connelly and Braun 1997; Schroeder et al. 2000; Wambolt et al. 2002; Crawford et al. 2004). Sage-grouse require sagebrush habitat for nesting and brood rearing (Klebenow 1969; Rowland 2004; Wallestad 1971; Drut et al. 1994).

Connelly et al. (2000b) suggested that nesting sage-grouse need 15–25 % sagebrush cover, sagebrush heights of 30–80 cm, ≥ 15 % herbaceous cover, and grass heights > 18 cm. Although this may be the case in other areas within the range of sage-grouse, few studies were available to support or refute these guidelines in Montana. Nesting and brood-rearing habitat was previously only measured in Petroleum and Beaverhead counties in Montana (Martin 1965; Pyrah 1972; Wallestad and Pyrah 1974; Wallestad 1975). Sagebrush and herbaceous cover for nests in Petroleum County were similar (19 % and 51 %) (Pyrah 1972; Wallestad and Pyrah 1974) to the guidelines proposed by Connelly et al. (2000b). Shrub cover for brood locations in Beaverhead County also matched the shrub cover guideline (19 % vs. 10–25%, respectively) (Martin 1965) for broods proposed by Connelly et al. (2000b). While these habitat values fall within the suggested guidelines, these two areas may not adequately represent sage-grouse habitat across the state. Shrub and herbaceous data were needed from other areas of the Montana to determine if nesting and brood-rearing habitat was similar.

The primary objectives of this study were to compare shrub and herbaceous parameters between 1) nest and random sites near Roundup in central Montana, Decker in south-central Montana and northern Wyoming, and south of Malta in north-central Montana, and 2) brood and random sites near Roundup and Decker to determine if hens selected for specific vegetation characteristics. Sage-grouse nesting and brood-rearing habitat in these 3 areas were previously unstudied.

Secondary objectives of this thesis were to compare shrub and herbaceous parameters between 1) successful and failed nests. 2) yearling and adult hen nests. 3) yearling and adult hen brood sites. 4) broods at different ages. and 5) nest and brood sites. Any differences between the above characteristics would improve our ability to manage sage-grouse habitat.

CHAPTER 2

LITERATURE REVIEW

Sage-grouse (*Centrocercus urophasianus*) is the largest grouse species in North America. Sage-grouse is a sagebrush obligate species and requires large areas of relatively continuous sagebrush cover (Paige and Ritter 1999; Connelly et al. 2000b). Sagebrush is used for nesting (Pyrah 1972; Wallestad and Pyrah 1974), brood-rearing (Klebenow 1969; Martin 1970), winter cover (Eng and Shladweiler 1972; Beck 1977; Wambolt et al. 2002), and is an important staple of sage-grouse diets (Klebenow and Gray 1968; Drut et al. 1994). Declines in sage-grouse populations are largely due to sagebrush removal and habitat alteration (Connelly and Braun 1997; Schroeder et al. 2000; Crawford et al. 2004).

Nesting Habitat

Sage-grouse in central Montana are non-migratory (Wallestad 1975; MSGWG 2002) and nests tend to occur within 3.2 km of the lek of female capture (Martin 1970; Wallestad and Pyrah 1974). However, Aldridge and Brigham (2001) reported only 41% of 27 nests were within that range in Alberta, perhaps because sagebrush cover was limited close to the lek and hens needed to travel farther to find adequate nest sites. Braun et al. (1977) suggested a 3.2 km buffer zone be established around each lek to protect nesting habitat. However, a buffer zone of 5 km may be needed if sagebrush is not distributed uniformly because hens need to travel farther to find adequate nest sites (Connelly et al. 2000b).

Yearling female sage-grouse often (> 50 %) return to their natal-area lek to breed (Dunn and Braun 1985). Female sage-grouse also have high nest-area fidelity between years (Fischer et al. 1993). Even if a nesting attempt fails, unsuccessful females tend to return to the same nesting area (but not the same bush) the following year (Fischer et al. 1993). However, sage-grouse will no longer use a site if sagebrush is completely removed from an area (Klebenow 1969). Nesting habitat treated with herbicides to remove sagebrush may take at least 10 years to support the pre-spray nesting sage-grouse carrying capacity (Klebenow 1969).

Nesting habitat requirements for sage-grouse were summarized by Connelly et al. (2000b) and more recently by Wambolt et al. (2002) and Crawford et al. (2004). Sage-grouse almost always nest under sagebrush (Wallestad and Pyrah 1974; Connelly et al. 1991). Although sage-grouse may nest under plants other than sagebrush, Connelly et al. (1991) found that non-sagebrush nest sites had relatively low nest success (22 %) compared with sagebrush nest sites (53 %). If sagebrush is completely removed sage-grouse will no longer nest in that area (Klebenow 1969).

Sagebrush cover is important to nesting sage-grouse. Aldridge and Brigham (2002) found that silver sagebrush cover (*Artemisia cana* A.Nels.) was the only variable that discriminated nest and random sites in Alberta. Sagebrush cover around nest sites can exceed 30 % (Klott et al. 1993) and is almost always greater than 15 % (Connelly et al. 2000b). In Montana, Wallestad (1975) reported sagebrush cover of 27 % at nest sites. Wallestad and Pyrah (1974) observed that successful nests had more cover (27 %) than failed nests (20 %). Connelly et al. (2000b) suggested that nesting sage-grouse require 15

to 25 % sagebrush cover and 30–80 cm sagebrush height. In general, sage-grouse do well in habitats with 15–30 % of sagebrush canopy cover (Wambolt et al. 2002).

Grass height and grass cover are also important to nesting sage-grouse. Grasses provide important lateral cover to nesting sage-grouse and hide nests from predators (Wallestad and Pyrah 1974; Wakkinen 1990; Crawford et al. 2004). Grass cover and height can reach 51 % and 34 cm at nest sites (Connelly et al. 2000b). Grass cover tends to be greater at successful nests than failed nests (Gregg et al. 1994; Sveum et al. 1998). Gregg (1991) reported that grass cover within 1 m of a nest was greater at successful (8 cm) than unsuccessful nests (10 cm) in Oregon, although he found no differences 4 m from a nest. Connelly et al. (2000b) suggested that nesting sage-grouse need grass cover ≥ 15 % and height ≥ 18 cm.

Brood-Rearing Habitat

Sage-grouse eggs in Canada hatch, on average, around May 28th for first nests and June 30th for renesting attempts, with a mean hatch date of June 5th (Aldridge and Brigham 2001). In Montana, peak of hatch usually occurs during the second week of June (Wallestad 1975). Individual broods can be followed until about the third week of July, when brood organization tends to break down and juveniles begin to flock together (Dalke et al. 1963).

Brood sites in southwestern Montana had 19 % sagebrush cover and 1.2 shrubs per m^2 (Martin 1970). Wallestad (1971) observed that broods in central Montana most often used areas in low (1–10 %) to moderate (10–25 %) sagebrush cover. Connelly et al. (2000b) suggested that broods need 10–25 % sagebrush cover and 40–80 cm

sagebrush height. Klebenow (1969) stated that the most important variable distinguishing brood and non-brood habitat was sagebrush density. Broods occupied sites with fewer sagebrush plants (1.7 shrubs per m^2) than the overall big sagebrush vegetation type (2.8 shrubs per m^2).

Martin (1970) observed that broods 6 weeks old used areas with 0.9 shrubs per m^2 and 14 % cover. By August and September broods were located in areas comparable to adult-use sites (1.5 shrubs per m^2 and 25 % cover). However, Aldridge and Brigham (2002) found no differences between younger and older broods.

Sage-grouse broods prefer areas of sagebrush that are less dense and have a lower percent crown cover than nesting habitat in Idaho (Klebenow 1969). Klebenow (1969) found that broods used areas with 9 % sagebrush cover versus 17 and 18 % cover for nesting habitat in two years, and used areas with significantly less crown cover than the overall average (9 versus 14 %) (Klebenow 1969).

Although brood sites tend to have lower sagebrush cover and density than nest sites, they do not prefer to use areas thinned by herbicides (Martin 1970). This may be in response to forb availability rather than sagebrush cover and density. In Klebenow's (1970) study, broods only used the sprayed plot that had the same amount of forb and shrub cover as the unsprayed control. Two other sprayed areas where forbs had not recovered were devoid of broods. Martin (1965) noted that although the area sprayed by herbicide was approximately 9 times greater in size than the unsprayed strips, it provided only 4 percent of the grouse observed.

Sage-grouse chicks eat a wide variety of food items. Chicks in one study ate 122 different foods, but 3 genera of insects, 10 genera of forbs, and sagebrush were primarily

consumed (Drut et al. 1994). Chicks tend to eat mainly insects during the first week. Afterwards, forbs become the most important food item until winter (Klebenow and Gray 1968). Sage-grouse broods tend to use areas that contain significant amounts of these food items (Klebenow 1969; Wallestad 1975). In early summer, broods use upland sagebrush-grassland communities (Wallestad 1970). As the summer progresses and forbs desiccate in feeding areas, broods may shift to more mesic sites to find food and often congregate at permanent water sources (Dalke et al. 1963; Klebenow 1969). These shifts can be to higher elevations, and mountain meadows are important sources of food. Plants mature later in the summer at higher elevations and can be consumed by sage-grouse even as plants at lower elevations senesce (Klebenow 1969).

CHAPTER 3

METHODS

Study Area Descriptions

Roundup Study Area

Hens from 9 leks in Musselshell and Golden Valley counties near Roundup in central Montana were trapped and fitted with radio collars by Jenny Sika of Montana State University in the spring of 2004. The two study sites centered on Emory Road in Golden Valley County and Devil's Basin in Musselshell County. The Golden Valley and Musselshell study sites were located approximately 32 km west and 25 km north of Roundup, Montana, respectively. Sage-grouse in this area were nonmigratory.

Precipitation averages 31 cm annually, with peak rainfall occurring in May and June (NOAA 2004). The year 2004 was 3 cm below average between January and July with only 6 cm of precipitation. Soil taxonomic units which characterize this area include Cabba, Cabbart, and Yamacall (USDA 2003). Elevation range is 826–1495 m.

This area was a mixture of farmland and grazed native prairie, and most land was privately owned. Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle & Young) was the dominant shrub although silver sagebrush (*Artemisia cana* Pursh) and greasewood (*Sarcobatus vermiculatus* (Hook.) Torr.) were also present. Western wheatgrass (*Pascopyron smithii* (Rydb.) A. Löve), Sandberg bluegrass (*Poa secunda* J.Presl), and blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths) were the dominant grasses, while green needlegrass (*Nassella viridula* (Trin.)

Barkworth), needle-and-thread (*Hesperostipa comata* (Trin. & Rupr.) Barkworth), and threadleaf sedge (Carex filifolia Nutt.) were also common. Scarlet globemallow (*Sphaeralcea coccinea* (Nutt.) Rydb.), wild onion (*Allium* sp. L.), Hood's phlox (*Phlox hoodii* Richards), and American vetch (*Vicia americana* Muhl. ex Willd.) were the most abundant forbs. Seeded areas had crested wheatgrass (*Agropyron cristatum* (L.) Gaertn.), alfalfa (*Medicago sativa* L.), and wheat (*Triticum aestivum* L.). Vegetation was similar in Golden Valley and Musselshell (Appendix A), therefore vegetation data for nest and brood sites from these 2 sites were combined to characterize nesting and brood-rearing habitat.

Decker Study Area

Hens were captured, fitted with radio collars, and tracked to nests in Bighorn County in south-central Montana and Campbell County in northwestern Wyoming in the spring and summer of 2003 by Brett Walker of the University of Montana. Three study sites were used: CX, Padlock, and Spotted Horse, and all were within the Powder River basin. The CX and Padlock study sites were in Bighorn County east of Decker, Montana. The Spotted Horse study site was in Campbell County near the town of Spotted Horse in northern Wyoming approximately 70 km southeast of Decker. Study sites were mostly private ranchland with some Bureau of Land Management (BLM) and state land. Sage-grouse in this area are nonmigratory.

Annual precipitation averaged 31 cm with peak precipitation occurring from April to June (NOAA 2003a). June and July were 1 cm below average in 2003, although precipitation from January to May was 1 cm above average. Soil taxonomic units which

characterize this area include Midway, Pierre, and Thedalun (USDA NRCS 2004). Elevation range is 762–1314 m.

Wyoming big sagebrush was the dominant shrub, although silver sagebrush, skunkbrush sumac (*Rhus trilobata* Nutt.), common juniper (*Juniperus communis* L.) and rubber rabbitbrush (*Ericameria nauseosus* (Pallas ex Pursh) Nesom & Baird) were also present. Sandberg bluegrass, western wheatgrass, and Japanese brome (*Bromus japonicus* Thunb. ex Murr.) were the dominant grasses, although green needlegrass, prairie junegrass (*Koeleria macrantha* (Ledeb.) J.A. Schultes), and bluebunch wheatgrass (*Psuedoroegneria spicata* (Pursh) A. Löve) were also common. Desert alyssum (*Alyssum desertorum* Stapf), Hood's phlox, scarlet globemallow, American vetch, dandelion (*Taraxacum officinale* G.H. Weber ex Wiggers), and western yarrow (*Achillea millefolium* L.) were the most common forbs. As vegetation was similar between CX, Padlock, and Spotted Horse study sites (Appendix B), vegetation data for nests and brood sites from these three sites were combined to characterize nesting and brood-rearing habitat in this area.

Malta Study Area

Hens were captured and tracked approximately 80 km south of Malta in southern Phillips County in north-central Montana during the spring and summer of 2003 by Brendan Moynahan of the University of Montana. Four study sites were examined including the Charles M. Russell Refuge (CMR), Dry Fork, Little Horse, and Sun Prairie sites.

Annual precipitation averaged 31 cm with peak precipitation between April and July (WRCC 2004). May, June, and July were 0.02, 0.53, and 1.54 cm below average in 2003 which could have reduced forb and grass production (NOAA 2003b). Soil taxonomic units that characterized this area included Absher, Elloam, and Thoeny (USDA 1981). Elevation range is 600–1060 m.

Approximately 60 % of this area was publicly owned by the U.S. Bureau of Land Management (BLM), the U.S. Fish and Wildlife Service (FWS), and the state of Montana (Moynahan 2004). Sage-grouse have relatively large, stable populations in this area (MSGWG 2002).

Wyoming big sagebrush was the dominant shrub although silver sagebrush, greasewood, and rubber rabbitbrush were also present. Western wheatgrass, and blue grama were the dominant grasses, while Sandberg bluegrass, needle-and-thread, and threadleaf sedge were also common. American vetch, scarlet globemallow, and dandelion were the most common forbs. Fringed sagewort (*Artemisia fridida* Willd.), lesser spikemoss (*Selaginella densa* Rydb.), and prickly pear (Opuntia spp. P. Mill) were also common. As vegetation was similar between CMR, Dry Fork, Little Horse, and Sun Prairie (Appendix C), shrub and herbaceous parameters for nest sites and brood sites between these four areas were combined.

Sampling Methods

Nest Sites

Sagebrush canopy cover, density, and height, nest shrub height, nest shrub productivity, forb, grass, herbaceous, and residual cover, grass height, and residual height

were measured. Sagebrush canopy cover was measured using the line-intercept method (Canfield 1941; Klebenow 1969; Gregg 1991; Aldridge et al. 2002), and was considered more precise than other methods (Connelly et al. 2003). Line-intercepts were measured on 2 perpendicular 30 m N-S and E-W transects, with the nest located at the center (15 m) of each line. True north was used to orient the lines at each site. Gaps in the canopy that were greater than 3 cm were recorded, and the amount of live versus dead canopy cover was noted. Dead sagebrush was never more than 3 % cover of the total line intercept, and therefore it was combined with live cover and only total sagebrush cover was reported. The 2 transects were averaged for analysis at each nest site.

Two 30 m by 2 m belt transects were measured along each N-S, E-W line to measure sagebrush density (number of shrubs / m^2) around the nest site. Large plots such as belt transects were useful to measure density on large plants (Gurevitch et al. 2002). The 2 belt transects for each site were averaged to obtain an estimate of sagebrush density per nest site. Belt transects were determined by holding a 1 m measuring stick and walking the length of the tape on both sides. All live and dead sagebrush with a crown diameter $\geq$ 15 cm were counted. Sagebrush with crown diameters < 15 cm were considered immature and were not large enough to provide cover for sage-grouse. Dead sagebrush density never provided more than 0.3 shrubs per m^2, and was combined with live sagebrush density with only total sagebrush density recorded.

Average shrub height around the nest site was estimated by measuring the nearest shrub to the line-intercept at 3 m intervals within 15 m of the nest shrub for a total of 10 shrub height measurements per line. Height of the nest shrub was also measured. Nest shrub productivity was calculated to determine if grouse were selecting nest shrubs based

upon the parameter. 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 et al. 1994). This parameter could not be calculated for Decker due to missing values, although nest shrub height is reported.

Herbaceous understory cover and composition were measured using 20 x 50 cm quadrats (Daubenmire 1959). Connelly et al. (2003) considered these quadrats to be very precise and repeatable. The same N–S, E–W transects used for line-intercepts and belt transects were used for the herbaceous measurements. Quadrats were placed at 3, 6, 9, 12, and 15 m from nest shrub for a total of 20 at each nest site. Total herbaceous, forb, and grass cover were measured by this method. Vegetative droop height of living grass was also recorded at each quadrat. Residual grass cover and height were also measured at the Roundup study area, but not in Decker or Malta. There were no differences between Daubenmire plots at 3, 6, 9, 12, and 15 m from the nest, therefore cover and height data from all quadrats were averaged for statistical analyses.

Nests were considered successful if shell membranes were detached from the shell (Wallestad 1975). This only required one egg to hatch. Hens with worn outermost primaries were considered adults (Wallestad 1975).

Random Sites

In the Roundup study area, random sites were paired with nest sites within the same habitat to test if sage-grouse hens were randomly selecting shrub or herbaceous characteristics for nesting. This paired design addressed the following question. Once a

sage-grouse hen selects a stand of sagebrush in which to nest, are there specific habitat parameters she selects within that stand? The paired random design examines sage-grouse nest selection on a relatively small scale, and is useful to detect within-stand habitat parameter preferences of nesting sage-grouse.

Shrub and herbaceous characteristics of random sites were measured 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 and 1000 m) were chosen using random number tables. The tallest sagebrush ≥ 35 cm 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 (i.e. road, uniform agricultural field, etc.), the closest sagebrush stand in the same direction was selected and, using the milliseconds indicator on a stopwatch, a random distance from 15 to 100 m was determined to locate sampling sites.

At the Decker and Malta study areas, random sites were selected by using Arcview® to select random coordinates within a 5 km radius of each lek, with the restriction that points had to be at least 1 km apart. Random sites were restricted to those in sagebrush-grassland habitat; random sites that fell in other habitats (e.g., riparian, conifer) were not used. Random sites were measured using the same methods as actual nest sites, but they were measured an average of 1 month later than nest sites at Decker. Random nest shrub heights were not measured at Decker.

The systematic random sites addressed a larger scale question than the paired random sites. Instead of examining within-sagebrush stand habitat preferences of nesting grouse, systematic random sites allowed me to determine if nesting sage-grouse were

selecting sagebrush stands with certain attributes on the landscape scale. The differences in random site methodology were the primary reason data from the 3 study areas were not combined.

Brood Sites

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. In Roundup, paired random sites were located for brood sites using the same methods described for paired random sites for nests. Broods were located at 1, 2, and 4 weeks after hatch with 1 site per brood measured at each week. In Decker, the same random sites that were compared to nest sites were also compared to brood sites. Broods in Decker were located 1–10, 11–20, 21–30, and 31–40 days after hatch. Brood sites were not measured in Malta.

Statistical Analysis

To test my primary objectives, measured parameters at nest and brood sites were compared with random sites to determine if nest and brood sites differed in any way from random sites. Individual nest sites were the experimental unit. The parameters tested included shrub cover, density, and height, forb, grass, herbaceous, and residual cover, grass and residual height, nest shrub height, and nest shrub productivity. These variables were first tested for normality using the Shapiro-Wilk test. If $P \leq 0.05$ with this test, the variable was considered to have a non-normal distribution and a nonparametric test was used. At the Roundup study area, paired *t*-tests were used to compare nest and paired

random sites for normally distributed variables, and Wilcoxon signed ranks tests were used for variables with non-normal distributions. Only nests in the sagebrush habitat type had a sufficient sample size to be analyzed in Roundup. Although nests in greasewood, alfalfa, and crested wheatgrass did not have an adequate sample size for individual habitat type analysis, all statistics were recalculated by combining these nests with sagebrush nests to determine if adding these nests changed our results.

At the Decker and Malta study areas, 2-independent sample t-tests or Wilcoxon-Mann-Whitney tests were used to compare nest and random sites. Herbaceous vegetation could not be compared between nest and random sites at Decker. Random sites were, on average, measured a month after nests. Therefore, any differences observed were confounded by progressing season and precipitation events. Shrub characteristics usually do not change due to weather conditions and seasonality (C.E. Wambolt, personal communication, March 2005). Therefore, only shrub characteristics were compared. Differences were considered significant at $P \leq 0.05$. All data were analyzed using SAS® version 9.

The above vegetation parameters, except for nest shrub height and productivity, were tested between brood and random sites to determine they differed in any way from using each brood as the experimental unit. Paired *t*-tests or Wilcoxon ranks sum tests were used to compare brood and random sites near Roundup, while 2-independent sample t-tests or Wilcoxon-Mann-Whitney tests were used for the Decker and Malta data. Since broods were also found in greasewood habitats near Roundup, sagebrush and greasewood brood sites were combined and analyzed as a single shrub habitat category

for this study area. Greasewood brood sites had shrub cover similar to sagebrush brood sites, and often sagebrush was present within the greasewood stands used by broods.

The same vegetation parameters compared between nest and random sites were also compared between successful and failed nest sites, yearling and adult hen nest sites, and yearling and adult hen brood sites using 2-independent sample t-tests or Wilcoxon-Mann-Whitney tests.

To determine if broods used different habitat as they aged, shrub cover, density, and height were compared using a 1-way ANOVA or Kruskal-Wallis test, depending on normality of the data. The experimental unit used to compare vegetation between broods at different ages was brood sites ($\geq$ 1 brood site per individual brood across time). Broods were only measured once within an age class defined by each week (i.e. week 1), and therefore all brood sites within an age class were independent of each other. Herbaceous parameters were not included in this analysis because herbaceous vegetation at sites for older broods was measured later in the growing season.

Shrub canopy cover, density, and height were also compared between nest and brood sites to determine if nesting hens selected different habitat than hens with broods. Herbaceous parameters were not included because brood sites were measured later than nest sites. Shrub variables were compared using 2-independent sample t-tests or Wilcoxon-Mann-Whitney tests.

CHAPTER 4

RESULTS AND DISCUSSION

Roundup Study Area

Nest Sites

A total of 53 nests were measured. Fifty nests were first attempts and 3 were renests. The renests were included in all analyses. Most sage-grouse nested under sagebrush (n = 48), although some nested under greasewood (n = 2), alfalfa (n = 2), and crested wheatgrass (n = 1). When sagebrush and nonsagebrush nest sites were combined, means and P-values remained similar to sagebrush nest sites alone. Therefore, all analyses presented below are for nests within the sagebrush habitat type.

Nest sites were in areas of 19 % sagebrush cover, and cover at random sites was similar at 17 % (Table 1). Connelly et al. (2000b) and Wambolt et al. (2002) noted that nesting sage-grouse use sagebrush cover between 15 and 25 % for nesting and my data fall within this range.

Sagebrush height within 15 m of the nest did not differ between nest and random sites, which indicates hens did not select for this parameter. Average sagebrush height of 26 cm was slightly less than the suggested sagebrush height nesting guideline of 30–80 cm (Connelly et al. 2000b), but this guideline may not be appropriate near Roundup as shrubs may be naturally shorter in this area.

Table 1. Comparisons of vegetation parameter means at nest and random sites, successful and failed nests, and yearling and adult nests in Wyoming big sagebrush habitat.

		Sagebrush Characteristics					Herbaceous Characteristics					
	N	total cover	total density	shrub height	nest shrub height	nest shrub prod.	forb cover	grass cover	total cover	residual cover	grass height	residual height
		(%)	(shrubs/m^2)	------(cm)------		(g)	----------(%)----------				------(cm)-----	
Nest Sites	48	19	1.6	26	48a[1]	60a	3	12	13	12	10	10
Random Sites	48	17	1.5	26	42b	46b	3	12	13	13	10	9
Successful Nests	22	19	1.6	26	46	63	3	13	15	13	11	10
Failed Nests	26	19	1.5	27	50	59	3	11	12	10	10	10
Yearling Nests	14	18	1.7	25	46	57	3	11	12	13	9a	10
Adult Nests	33	19	1.5	27	49	62	3	12	14	12	11b	10

[1] Means for a parameter between comparisons with different lower case letters are significantly different ($P \leq 0.05$).

Nest shrub height and productivity were the only vegetation parameters that differed with random sites (Table 1). Grouse nested under taller sagebrush (48 vs. 42 cm, $P \leq 0.01$) and chose more productive nest shrubs (60 vs. 46 g, $P \leq 0.01$) than random shrubs. Nest site selection within a sagebrush stand appeared to be driven only by selection of a taller and more productive sagebrush to nest beneath. Overall, grouse were selecting to nest in relatively uniform sagebrush stands within 1 km of the nest site. Wakkinen (1990) also noticed that hens selected taller (71 vs. 62 cm, $P \leq 0.01$) and larger (11,108 vs. 7,386 cm^2 crown area, $P \leq 0.01$) nest shrubs than dependent random plots in Idaho.

Total herbaceous cover of 13 % at my study area was less than the suggested 15 % (Connelly et al. 2000b). Grass height averaged 10 cm and was shorter than the 18 cm guideline. The low herbaceous cover and grass height were probably due to extended drought (4+ years) in my study area and low precipitation during the 2004 nesting season. Grass height is also probably lower than the suggested guideline due to the abundance of blue grama, which has a low vegetative growth form (< 5 cm). Blue grama was the third most abundant grass, after Sandberg's bluegrass and western wheatgrass, at nest sites (Appendix A). Forb cover was also extremely low in 2004.

No shrub and herbaceous characteristics differed between successful and unsuccessful nest sites (Table 1). Twenty-one nests in sagebrush were successful and 27 failed for a nest success rate of 44 %. Nest success was low compared with the 76 % success rate reported by Wallestad and Pyrah (1974) in the Yellow Water Triangle area of Montana. However, the 44 % success rate in my study is at the midpoint of the 12 - 86% range reported in the literature summarized by Connelly et al. (2000b). Wallestad

and Pyrah (1974) noted that successful nests were in areas of 33 % sagebrush cover, whereas failed nests averaged 23 % cover in central Montana. In my study, successful and failed nest sites were both in areas of 19 % cover.

Nest success could be lower in my study because available sagebrush stands do not provide as much cover for nests when compared to Wallestad's (1975) study area, although low herbaceous cover in 2004 could also have affected nest success. Predation was the main cause of nest failure in my study (25 of 27 nests, 2 nests abandoned for unknown reasons), and is a common cause of nest failure elsewhere within the range of sage-grouse (Delong et al. 1995). Lower sagebrush and herbaceous cover in my study area could be responsible for my lower nest success when compared with Wallestad (1975) because less cover was available to conceal nests from predators.

Herbaceous cover and height at nest sites did not meet guidelines suggested by Connelly et al. (2000b), therefore it is possible that either these parameters could have decreased nest success in 2004 or that the guidelines are not appropriate for this area. Vegetation parameters at successful and failed nests did not differ, therefore herbaceous vegetation did not appear to influence nest success. However, it is also possible that some parameters that would normally be selected for did not manifest themselves due to drought. Drought may negatively affect sage-grouse populations (Wambolt et al. 2002), and nest success could decrease because of reduced herbaceous cover at the nest. Nests with less grass cover were more likely to be predated in Oregon (Gregg et al. 1994). However, my 44 % nest success rate was average for sage-grouse, therefore, the effect of herbaceous cover and height on nest success may be minor. My data suggest that the herbaceous guidelines suggested by Connelly et al. (2000b) may not be obtainable in

drought conditions near Roundup and also that herbaceous vegetation does not appear to greatly influence nest success in this area.

Average grass height was the only vegetation parameter that differed between adult and yearling nest sites (11 vs. 9 cm, $P \leq 0.05$, Table 1). Age of the nesting hen appears to have some influence on nest success because yearling hens were only 36 % (5 of 14 yearling nests) successful while adults were 50 % (17 of 34 adult nests) successful in sagebrush habitat. Wallestad (1975) found that adults were more successful than yearlings in Montana (77 vs. 44 %), although Connelly et al. (1993) found no differences between the 2 age classes in Idaho.

The similarities in habitat between successful and failed and yearling and adult nest sites imply that nest success was influenced by factors other than the vegetation parameters measured. Instead, predator densities or individual hen behavior may have a greater influence on nest success. My nest success rate of 44 % was at the midpoint of the 12–86 % reported range for sage-grouse (Connelly et al. 2000b), therefore predators appeared to have the same influence on nest success as elsewhere. Gregg (1991) and Gregg (1994) indicated that predation limited sage-grouse numbers in Oregon, but Connelly and Braun (1997) did not identify predation as a major limiting factor for sage-grouse over most sage-grouse range. Yearling hens may be less attentive or move more around the nest site than adult hens which could attract predators to the nest site. Holloran (1999) observed that unsuccessful hens remained off their nests for longer periods of time than successful hens. While predation may be the proximate cause for nest failure on my study areas, individual hen behavior may be the ultimate cause.

Brood Sites

Of 44 brood sites measured for 20 individual hens, 31 brood locations were in sagebrush, 4 in greasewood, 2 in wheat fields, 3 in alfalfa fields, and 4 in crested wheatgrass stands. Greasewood and sagebrush brood locations were combined in a single shrub habitat category. Therefore, a total of 35 shrub habitat brood locations were measured. When brood sites in nonshrub habitats were combined with shrub sites, means and P-values remained similar. Therefore, all analyses below are for broods within shrub habitat types.

There were no shrub or herbaceous differences between brood sites and random sites (Table 2). Brood sites had 12 % shrub canopy cover and density of 1.48 shrubs per m^2. Broods in Idaho used areas with less sagebrush cover (8.5 %), but with denser shrubs (1.73 shrubs per m^2) than my study area (Klebenow 1969). Connelly et al. (2000b) suggested that broods need sagebrush cover ranging from 10–25 %, and sagebrush cover in my study area met this guideline. Sagebrush height within 15 m of a nest site at my study area was 25 cm less than the 40–80 cm guideline (Connelly et al. 2000b), but sagebrush appeared to be naturally shorter in my study area.

Forb cover was very low (5–6 %) compared with other studies, but is probably related to the extended drought (4+ years). Schroeder et al. (1995) reported that grass cover should exceed 15 % and my site averaged 14 %. Grass and forb cover may be limiting broods, although this is not possible to determine from my data as brood success was difficult to quantify and, therefore, was not included in my analyses.

Vegetation parameters between adult and yearling brood sites did not differ (Table 2). There may be 2 explanations. First, brood-rearing habitat may be

Table 2. Comparisons of vegetation parameters between brood and random sites, yearling and adult brood sites, and brood and nest sites in shrub habitat.

		Shrub Characteristics			Herbaceous Characteristics					
	N	total cover	total density	shrub height	forb cover	grass cover	total cover	residual cover	grass height	residual height
		(%)	(shrubs/m^2)	(cm)	----------(%)----------				-------(cm)-------	
Brood	20	14	1.5	25	5	14	17	11	11	9
Random	20	16	1.6	23	6	13	16	14	11	10
Yearling	5	15	1.7	24	5	14	16	12	12	9
Adult	14	15	1.5	26	5	13	17	11	11	9
Brood	20	14a[1]	1.5	25	-	-	-	-	-	-
Nest	48	19b	1.6	26	-	-	-	-	-	-

[1] Means for a parameter between comparisons with different lower case letters are significantly different ($P \leq 0.05$).

relatively uniform because brood and random sites did not differ. However, Holloran (1999) believed that yearling and adult habitat selection should not differ because yearling hens often return to their natal area in search of a nest site and broods are raised within the same general area. Therefore, yearling hen nesting and brood-rearing habitat selection is strongly influenced by where they were raised as chicks the year before. No differences should exist between yearling and adult hen brood habitat as sage-grouse show high fidelity for specific nesting areas between years (Fisher et al. 1993). Once a yearling hen selects a nesting and brood-rearing area she will probably continue using that area as an adult.

Thirteen first week , 9 second week, and 13 fourth week brood sites were measured. Broods did not select different shrub characteristics as they aged from 1 to 4 weeks (Table 3). In contrast, Wallestad (1975) noted that broods shifted from upland sagebrush habitats to more mesic greasewood and alfalfa habitats as forbs in upland sites

desiccated. However, this shift tends to occur in mid-July to August when broods are between 6 and 8 weeks of age (Klebenow 1969; Wallestad 1975). Aldridge and Brigham (2002) noticed no differences between early (< 7 weeks) and late (> 7 weeks) brood locations in Alberta, indicating that no shift in brood-rearing habitat occurred. Although I also observed no shift in habitat, nearly all fourth week brood sites were night flushes (83 %) whereas all first and second week sites were daytime use areas. Hausleitner (2003) reported that night-roost locations have less shrub cover (9 vs. 22 %) and shorter shrubs (31 vs. 58 cm) than daytime locations. Therefore, broods at week 4 may have used different daytime habitat from weeks 1 and 2, but this is impossible to determine from my data.

Table 3. Comparison of shrub characteristics between 1, 2, and 4 week brood locations in Wyoming big sagebrush habitat.

		Shrub Characteristics		
	N	total cover	total density	shrub height
		(%)	(shrubs/m^2)	(cm)
Week 1	13	16	1.5	27
Week 2	9	17	2.1	27
Week 4	13	11	1.3	22

No variables were significant at P = 0.05.

Sagebrush cover was the only shrub parameter that differed ($P \leq 0.05$) between nest and brood sites (19 vs. 14 %, Table 2). Nesting sage-grouse appear to need more sagebrush cover than broods, most likely because the nest must remain hidden from predators for the duration of incubation.

Broods were more likely to use non-sagebrush habitat than nesting hens. Thirteen of 44 (30 %) brood sites were not in sagebrush, compared with only 5 of 53 (9 %) nest

sites. Other studies have shown that broods are more likely to use agricultural fields and non-sagebrush habitat than nesting hens, especially as forbs desiccated and became less available on sagebrush uplands (Klebenow 1969; Martin 1970; Wallestad 1975; Drut et al. 1994).

Sagebrush cover was the only parameter at nest and brood sites that fell within the guidelines proposed by Connelly et al. (2000b). Sagebrush cover at nest sites was 19 % which fell within the 15–25 % guideline, and brood sites were in stands of 14 % shrub cover compared with the 10–25 % guideline. Shrub heights within 15 m of a site were 4 and 15 cm lower for nest and brood sites, respectively, than the 30–80 cm and 40–80 cm guidelines proposed by Connelly et al. (2000b). Herbaceous parameters were also lower than the guidelines, but decreased forb and grass cover at nest sites did not appear to influence nest success. Therefore, the guidelines may need to be revised for this area. While the sagebrush cover guideline is adequate, a minimum average sagebrush height of 21 cm for nesting sage-grouse and 25 cm for brood-rearing sage-grouse may be more appropriate near Roundup than the 30 cm minimum suggested by Connelly et al. (2000b).

Decker Study Area

Nest Sites

A total of 58 nest sites were measured near Decker, Montana. Forty-nine nests were first attempts and 9 were renests, for a total of 50 individual hens nesting in 2003 (only the renest of 1 hen was measured). All nest sites were in sagebrush habitat. Only 53 of the 58 nests were used in the analysis due to incomplete data for 5 nests.

Nest sites had greater sagebrush cover (22 vs. 14 %, $P \leq 0.01$), density (1.1 vs. 0.6 shrubs per m^2, $P \leq 0.01$), and taller shrubs within 15 m (52 vs. 42 cm, $P \leq 0.01$) than random sites (Table 4). Sagebrush nest shrubs averaged 75 cm, but a comparison to random sites could not be made because random nest shrubs were not measured.

Table 4. Comparisons of vegetation parameters between nest and random sites, successful and failed nest sites, and yearling and adult nest sites in Wyoming big sagebrush habitat.

		Sagebrush Characteristics				Herbaceous Characteristics			
	N	total cover	total density	shrub height	nest shrub height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	------(cm)------		----------(%)----------			(cm)
Nest	53	22a[1]	1.1a	52a	75	8	26	33	23
Random	53	14b	0.6b	42b	--	--	--	--	--
Successful	29	22	1.2	53	75	10	22	33	24
Failed	24	22	1.1	51	74	13	27	36	23
Yearling	19	20	1.1	53	77	8	24	31	23
Adult	34	23	1.2	52	73	13	25	36	24

[1] Means for a parameter between comparisons with different lower case letters are significantly different ($P \leq 0.05$).

Other studies have shown similar trends with canopy cover and shrub heights. Aldridge and Brigham (2002) reported that nest sites had 32 % sagebrush cover compared with 16 % at random sites in Alberta. Sveum et al. (1998) observed that nest sites had sagebrush cover between 51–59 % and sagebrush height of 59–63 cm compared with 6–7 % sagebrush cover and 13–15 cm sagebrush height at random sites in Washington. Shrub density, however, did not differ between nest and random sites (1.0 vs. 0.9 shrubs per m^2) in Idaho (Wakkinen 1990). Sagebrush cover of 22 % at nest sites was lower near Decker than the 27 % reported in central Montana by Wallestad (1975), although sagebrush was taller (52 cm vs. 40 cm). Sagebrush cover and height at nest

sites near Decker were within the 15–25 % cover and 30–80 cm height nesting habitat guidelines suggested by Connelly et al. (2000b). Therefore, the guidelines appear to be good indicators of sage-grouse nesting habitat in this area.

Total cover for forbs and grasses was 8 % and 26 %, respectively, at nest sites. Total herbaceous cover was 33 % and exceeded the ≥ 15 % cover guideline suggested by Connelly et al. (2000b). Although the guideline was met in 2003 because of adequate precipitation between January and May, forb and grass cover values could change from year to year depending on temperature and the timing and intensity of precipitation events. While 2003 provided adequate herbaceous cover for nesting sage-grouse, other years may not.

Western wheatgrass, Sandberg's bluegrass, and Japanese brome were the most abundant grass species (Appendix B). Japanese brome is an introduced annual similar to cheatgrass (*Bromus tectorum* L.) that can increase fire frequencies (Wambolt et al. 2002; Crawford et al. 2004). While prescribed fire has been used to manage sagebrush habitats, there is little evidence that fire enhances Wyoming big sagebrush habitat for sage-grouse (Wambolt et al. 2002; Crawford et al. 2004). Connelly et al. (2000a) observed that prescribed burning of Wyoming big sagebrush during a drought resulted in a decline > 80 % of a sage-grouse breeding population in southeastern Idaho. Therefore, suppression of invasive species including Japanese brome in and near sage-grouse habitat has been suggested and is tied directly to fire management and habitat loss (Wambolt et al. 2002).

Vegetation parameters did not differ between successful and failed nest sites (Table 4). Twenty-nine of 53 nests were successful for a success rate of 54 %. This success rate is within the 12–86 % reported range for the species (Connelly et al. 2000b)

but was low compared to 64 % in central Montana (Wallestad 1975). Predation was the main cause of nest failure (16 of 24 failed nests), although 7 nests were abandoned. Two additional nests failed, 1 for unknown reasons and the other because the hen was killed.

No shrub and herbaceous characteristics differed between yearling and adult hen nest sites (Table 4). Eighteen of the 50 hens that nested were yearlings and 32 were adults. Yearling hens were 47 % (8 of 17 yearling nests) successful and adults were 67 % (24 of 36) successful including renests. Wallestad (1975) also found that adults were more successful than yearlings in central Montana (13 vs. 9 successful nests), although Connelly et al. (1993) found no differences between the 2 age classes in Idaho.

The difference in success between adult and yearling hens appears to be due to factors other than the vegetation parameters measured. Holloran (1999) noted that unsuccessful hens remained off their nests for longer periods than successful hens. Yearling hens may be less attentive and/or move more around the nest than adults, thereby attracting predators and decreasing their nest success.

Brood Sites

Seventy-three brood locations for 28 individual broods were measured. All brood sites were located in sagebrush habitat. Sagebrush density was the only parameter that differed between brood and random sites. Brood sites were in denser sagebrush (0.9 vs. 0.6 shrubs per m^2, $P \leq 0.05$) than random sites (Table 5). Klebenow (1969) also noted that sagebrush density was the most important variable distinguishing brood from non-brood habitat in Idaho. Brood sites near Decker had 13 % sagebrush cover compared with 9 % in Idaho, although sagebrush was not as dense near Decker at 0.9 shrubs per m^2

versus 1.7 shrubs per m^2 (Klebenow 1969). Brood sites were in areas with 13 % sagebrush cover, which was similar to the 14 % in southwestern Montana (Martin 1970). Connelly et al. (2000b) suggested that broods need sagebrush cover ranging from 10–25 % and sagebrush height ranging from 40–80 cm. Sagebrush cover at 13 % and sagebrush height at 43 cm for brood sites in my study area met these guidelines but were at the low end of the range reported by Connelly et al. (2000b).

Table 5. Comparisons of vegetation parameters between brood and random sites and yearling and adult brood sites in Wyoming big sagebrush habitat.

		Shrub Characteristics			Herbaceous Characteristics			
	N	total cover	total density	shrub height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	(cm)	----------(%)----------			(cm)
Brood	28	13	0.9a[1]	43	8	26	33	23
Random	53	12	0.6b	44	10	29	36	24
Yearling	6	8a	0.6a	37a	7	29	35	21
Adult	22	14b	1.0b	44b	9	25	32	23
Brood	28	13a	0.9a	43a	-	-	-	-
Nest	53	22b	1.1b	52b	-	-	-	-

[1] Means for a parameter between comparisons with different lower case letters are significantly different ($P \leq 0.05$).

Forb cover of 8 % was lower than found earlier in central Montana with 27 % in 1968 and 17 % in 1969 (Wallestad 1971). However, Wallestad's (1971) study area receives more precipitation during the summer months than my study area (WRCC 2005), which could explain the increased forb cover. Forbs are the most important food item for broods until winter (Klebenow and Gray 1968), and are an important source of protein (Drut et al. 1994). My total herbaceous cover of 33 % exceeded the minimum 15 % guideline suggested by Connelly et al. (2000b).

Adult hen brood sites had more sagebrush cover (14 vs. 8 %, $P \leq 0.05$), denser sagebrush (1.0 vs. 0.6, $P \leq 0.05$), and taller shrubs (44 vs. 37, $P \leq 0.05$) than yearling hen brood sites (Table 5). The reasons for this are unclear, although my results could be influenced by a relatively small sample size for yearling hens (6 yearlings compared with 22 adults). Holloran (1999) did not detect differences between adult and yearling hen brood sites and believed that habitat selection should not differ between these two age classes. No differences should exist because nesting grouse frequently return to their natal area to nest and rear broods (Dunn and Braun 1985) and have high site fidelity between years (Fischer et al. 1994). However, my data indicate that adult hens may be using more sagebrush cover, higher densities, and taller shrubs. Although yearling hens may use the same general area to raise their broods as adult hens, adults may be selecting specific sagebrush stands with more cover because of previous brood-rearing experiences.

Broods of different ages were not in areas of different shrub characteristics (Table 6). A total of 21, 22, 16, and 8 locations were measured for 1–10 day, 11–20 day, 21–30 day, and 31–40 day visits, respectively. Five brood locations were measured after 40 days and were removed from the brood age vegetation analysis. Klebenow (1969), Martin (1970), and Wallestad (1975) noted that broods tend to use less sagebrush cover and density as they grow older. Although I found no trend, the average sagebrush cover at 13 % for all brood ages was similar to the 14 % cover reported by Martin (1970) in southwestern Montana.

Nest sites had more sagebrush cover (22 vs. 13 %, $P \leq 0.01$), denser sagebrush (1.1 vs. 0.9 shrubs per m^2, $P \leq 0.05$), and taller shrubs (52 vs. 43 cm, $P \leq 0.01$) than brood

sites (Table 5). Nesting hens appear to need more cover than hens with broods, perhaps because nesting hens must remain hidden from predators for the duration of incubation while broods are more mobile and can actively avoid or hide from predators. Increased cover around the nest site may also help conceal chicks in the first few days after hatch.

Table 6. Comparison of sagebrush characteristics of brood sites at 1–10, 11–20, 21–30, and 31–40 days after hatch.

	N	Sagebrush Characteristics		
		total cover	total density	shrub height
		(%)	(shrubs/m^2)	(cm)
1 - 10 days	19	11	0.8	41
11 - 20 days	21	14	1.0	45
21 - 30 days	16	12	0.9	41
31 - 40 days	8	13	0.8	44

No variables were significant at P = 0.05.

Malta Study Area

A total of 45 nests were measured in 2003. All nest sites were in Wyoming big sagebrush habitat that averaged 19 % cover, 1.5 shrubs per m^2, and average shrub height of 30 cm (Table 7). Sage-grouse nested in areas with taller shrubs (30 cm) within 15 m of the nest site than the 26 cm at random sites ($P \leq 0.05$). Sveum et al. (1998) also noted that grouse nested in areas of taller shrubs (25 vs. 9 cm in 1992 and 22 vs. 10 cm in 1993) in Washington. Wallestad and Pyrah (1974) observed that grouse used a similar sagebrush cover at 24 % in Petroleum County, Montana, although their nests were in areas of denser sagebrush with 3.1 shrubs per m^2 compared with 1.5 shrubs per m^2 in my study area. Pyrah (1972), however, reported a range of 1.2–2.3 shrubs per m^2 around the nest site in Petroleum County, with successful nests in denser areas.

Nest sites fell within the 15–25 % sagebrush cover and 30–80 cm height guidelines for nesting sage-grouse proposed by Connelly et al. (2000b), although my values were near the lowest values reported. Total herbaceous cover at 27 % met the > 15 % forb and grass cover guideline for nesting sage-grouse. Yellow sweetclover (*Melilotus officinalis* (L.) Lam.) was the most abundant forb in 2003 (Appendix C). Grass height

Table 7. Comparison of vegetation parameters between nest and random sites in shrub habitat.

		Sagebrush Characteristics					Herbaceous Characteristics			
	N	total cover	total density	shrub height	nest shrub height	nest shrub prod.	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	-----(cm)-----		(g)	----------(%)----------			(cm)
Nest	45	19	1.5	30a[1]	48	50	7	21	27	14
Random	45	16	1.3	26b	45	49	7	24	30	13

[1] Means for a parameter between comparisons with different lower case letters are significantly different ($P \leq 0.05$).

was lower at 14 cm than the 18 cm guideline proposed by Connelly et al. (2000b). However, blue grama was the dominant grass in this area (Appendix C) and vegetative growth for this species rarely reaches 18 cm in height. Therefore, the grass height guideline is not appropriate for this area.

Nesting habitat appeared to be relatively uniform across the landscape, as all vegetation parameters except sagebrush height did not differ between nest and random sites.

Moynahan (2004) determined that apparent nest success for this population was 46 %. The 46 % apparent nest success was at the midpoint of the range reported in the literature (12–86 %, Connelly et al. 2000b), although Moynahan (2004) cautioned that

apparent nest success could be overestimated without incorporating individual, environmental, and habitat covariates.

Moynahan's (2004) shrub coverage estimate of 9 % for Phillips County in 2003 was lower than the 17 % I observed at actual nest sites and the 14 % at my random sites. Grass cover was similar between Moynahan's random sites and our actual nest sites at 22 and 21 %, respectively. Forb cover was also similar between Moynahan's random sites 6 %) and our nest (7 %) and random sites (7 %). However, we intensively sampled nest-site locations, whereas Moynahan was examining vegetation on the landscape scale by visually estimating shrub and herbaceous cover using 426 $1m^2$ quadrats.

This study area has some of the largest, most intact stands of sagebrush left in Montana (Moynahan 2004, MSGWG 2002). Sage-grouse populations in this area are stable and relatively large (MSGWG 2002), most likely due to the abundance of sagebrush habitat. Nesting sage-grouse used areas with similar vegetation as random sites. Sagebrush cover and height within 15 m of the nest site met the guidelines suggested by Connelly et al. (2000b) but were at the lowest values of these guidelines. Grass height did not meet the nesting habitat guideline suggested by Connelly et al. (2000b), probably due to the abundance of blue grama, therefore, this guideline may not be appropriate in this area.

CHAPTER 5

SUMMARY OF NESTING AND BROOD-REARING HABITAT IN MONTANA

Nesting Habitat

Sage-grouse in Montana almost always used sagebrush habitat for nesting. Ninety-one percent of nests were in sagebrush near Roundup (48 / 53), and all nests near Decker (53 / 53) and Malta (45 / 45) were in sagebrush. Therefore, of 156 nests measured, 97 % were located in sagebrush habitat. Wallestad and Pyrah (1974) noted that all of their nests were in sagebrush in central Montana. My data support the idea that sagebrush habitat is necessary for nesting sage-grouse.

Nesting sage-grouse near Roundup selected taller and more productive nest shrubs than random sites located within 1 km of the nest. Nesting sage-grouse near Decker were selecting stands with greater sagebrush cover and with taller, denser sagebrush, and nesting grouse near Malta were in areas of taller shrubs within 15 m of the nest than what random sites located 5 km from a lek indicated was available. This indicates that on large scales, grouse may select for sagebrush stands with specific characteristics and that these stands are relatively uniform within 1 km of a nest.

Wakkinen (1990) found that only nest shrub characteristics at the nest site were different from dependent random sites within 200 m of the nest in Idaho, and actual nest shrubs were taller and provided more cover than random nest shrubs. Wakkinen (1990) also found that grass height was the only variable that differentiated nests from independent random sites within his study area. Therefore, at small scales within 1 km of

a nest site, nest site selection appears to be driven by the selection of a nest shrub. At larger scales, sage-grouse select sagebrush stands with certain characteristics, but not all of these characteristics were similar between areas. Sagebrush height within 15 m of a nest differed between nest and independent random sites near Decker and Malta, therefore, this parameter may be a good indicator of sage-grouse nesting habitat at the large-scale in central Montana and northern Wyoming.

The amount of sagebrush cover has been recognized as important to nesting sage-grouse (Crawford et al. 2004). At the Roundup, Decker, and Malta study areas, nest sites had 19–22 % sagebrush cover (Table 8), which falls within the range of the 15–25 % guideline proposed by Connelly et al. (2000b). Sagebrush cover only distinguished nests from random sites near Decker. No single vegetation variable differed between nest and random sites between all study areas, indicating that no one habitat characteristic may differentiate nests from random sites across the state of Montana.

Collectively, nest sites were in areas of 3–8 % forb cover, 12–26 % grass cover, 13–33 % total herbaceous cover, and had grass heights of 10–23 cm (Table 8). Pyrah (1972) noted that nests in Petroleum County were in areas of 14 % forb cover, 38 % grass cover, and 51 % total herbaceous cover. Connelly et al. (2000b) suggested that grass and forb cover should exceed 10 % and 15 %, and that grass heights should be greater than 18 cm. My forb coverages were lower than the forb cover guideline. This may have been influenced by a series of dry growing seasons. Lower grass height near Roundup and Malta was due to the abundance of blue grama, which typically does not reach 18 cm.

Table 8. Nest site habitat characteristics near Roundup, Decker, and Malta in Montana.

Location	N	Sagebrush Characteristics				Herbaceous Characteristics			
		total cover	total density	avg. height	nest shrub height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	---------(cm)--------		----------(%)----------			(cm)
Roundup	48	19	0.4	26	48	3	12	13	10
Decker [1]	53	22	1.1	52	75	8	26	33	23
Malta	45	19	1.5	30	48	7	21	27	14

[1] Includes 1 study area from Campbell County, WY.

The guidelines proposed by Connelly et al. (2000b) may not be appropriate for central Montana and northern Wyoming. Sagebrush cover was the only parameter that consistently met the suggested guidelines. Sagebrush height was lower than the guideline at Roundup, greater at Decker, and at the suggested minimum value at Malta. Forb cover was consistently lower than the guideline in all three study areas, and grass heights were also lower than the guideline at Roundup and Malta. Nesting sage-grouse in Montana were using areas of 21–52 cm sagebrush heights. A minimum average sagebrush height of 20 cm may be more appropriate near Roundup than the 30 cm minimum suggested by Connelly et al. (2000b).

Although extended drought in my study areas could have reduced forb production, especially at Roundup, it is also possible that the guidelines proposed by Connelly et al. (2000b) may overestimate the potential productivity of these areas. Grass height was lower at Roundup and Malta at 10 and 14 cm than the suggested 18 cm minimum, due to the abundance of blue grama. However, grass cover and height met the guidelines at Decker, likely because of adequate precipitation in early spring. Therefore, it may be difficult to meet these guidelines because of differences in potential

productivity and species composition, but also due to annual, unpredictable changes in the timing and intensity of precipitation events.

The abundance of Japanese brome at Decker could put sagebrush habitats at risk in this area, especially if fire frequencies change. Therefore, efforts should be taken to minimize the spread of this exotic annual grass at Decker and elsewhere within the range of sage-grouse.

Vegetation parameters did not differ between successful and failed nests at any of the three study areas I sampled (Table 9). This suggests that nest success is influenced by factors other than the vegetation parameters measured in my study. Wallestad and Pyrah 1974) observed that sagebrush cover and density influenced nest success in Petroleum

Table 9. Habitat characteristics of successful and failed nest sites near Roundup, Decker, and Malta in Montana.

		Sagebrush Characteristics				Herbaceous Characteristics			
Location	N	total cover	total density	avg. height	nest shrub height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	------(cm)------		----------(%)----------			(cm)
Successful Nests									
Roundup	22	19	2.8	26	46	3	13	15	11
Decker [1]	29	22	1.2	53	75	10	22	33	24
Failed Nests									
Roundup	26	19	2.7	27	50	3	11	12	10
Decker [1]	24	22	1.1	51	74	13	27	36	23

[1] Includes 1 study area from Campbell County, WY.

County. Successful nests had more sagebrush cover at 27 % than the 20 % cover at failed nests in Petroleum County. Predation was the main cause of nest failure, and is a common cause of nest failure elsewhere (Connelly et al. 2000b). However, nest success rates (44 % for Roundup, 54 % for Decker, and 46 % for Malta) were within the 12–86 %

reported range for sage-grouse (Connelly et al. 2000b), therefore predators appeared to have the same influence on nest success as elsewhere.

Yearling and adult hen nest sites were similar in Roundup and Decker (Table 10). Only grass height differed between yearling and adult nests near Roundup. Yearling hens had a lower success rate than adult hens at both Roundup (36 vs. 50 %) and Decker (47 vs. 67 %). Holloran (1999) observed that unsuccessful hens remained off their nests longer than successful hens. Yearling hens may be less attentive and move around the nest more than adults, thereby attracting predators and decreasing their nest success.

Table 10. Habitat characteristics of yearling and adult nest sites near Roundup, Decker, and Malta in Montana.

		Sagebrush Characteristics				Herbaceous Characteristics			
Location	N	total cover	total density	avg. height	nest shrub height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	---------(cm)--------		----------(%)----------			(cm)
Yearling Hens									
Roundup	14	18	3.0	25	46	3	11	12	9
Decker [1]	19	20	1.1	53	77	8	24	31	23
Adult Hens									
Roundup	33	19	2.7	27	49	3	12	14	11
Decker [1]	34	23	1.2	52	73	13	25	36	24

[1] Includes 1 study area from Campbell County, WY.

Brood-Rearing Habitat

Broods in Montana were located primarily in Wyoming big sagebrush. Seventy percent (35 / 44) of brood sites near Roundup and 100 % of brood sites near Decker (73 / 73) were located within sagebrush habitat. Wallestad (1971) also noted that in general broods used upland sagebrush-grassland types in Petroleum County, especially early in

the summer. Although 8 % of all brood locations were in nonsagebrush habitats, 92 % brood locations were in sagebrush. Therefore, sagebrush habitat is important for broods in central Montana and northern Wyoming.

Broods near Roundup and Decker were in areas of 12–13 % sagebrush cover, 0.9–1.6 sagebrush per m^2, and 22–43 cm shrub heights (Table 11). Sagebrush cover was the only variable that differed between nest and brood-rearing sites within Decker (13 vs. 20 %, $P \leq 0.01$) and Roundup (12 vs. 20 %, $P \leq 0.01$). Martin (1970) observed that sagebrush cover for broods in Beaverhead County in southwestern Montana averaged 19 %, while Wallestad and Pyrah (1974) noted that broods used areas with 13 % shrub

Table 11. Brood habitat characteristics near Roundup and Decker, Montana.

Location	N	Sagebrush Characteristics			Herbaceous Characteristics			
		total cover	total density	avg. height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	(cm)	----------(%)----------			(cm)
Roundup	14	12	1.6	22	4	11	14	11
Decker [1]	28	13	0.9	43	8	26	33	23

[1] Includes 1 study area from Campbell County, WY.

cover. Connelly et al. (2000b) suggested that broods need 10–25 % sagebrush canopy cover, and shrub cover for brood sites in my study areas fall within this range. Connelly et al. (2000b) also suggested that broods need sagebrush height greater than 40 cm. Sagebrush height at Roundup did not meet this guideline, therefore, this guideline may not be applicable in this area.

Sagebrush density at brood sites is not frequently reported in the literature but may be an important characteristic for brood-rearing sage-grouse. Near Decker, broods were in areas with denser sagebrush at 0.9 shrubs per m^2 than the 0.6 shrubs per m^2 at

random sites. Klebenow (1969) observed that broods used less dense sagebrush habitat at 1.7 shrubs per m^2 than in the overall sagebrush habitat type at 2.9 shrubs per m^2 in Idaho. Holloran observed that broods were in areas of 2.5 shrubs per m^2 in Wyoming. Martin (1965) noted that broods were in areas of 1.1 shrubs per m^2 in southwestern Montana. Therefore, broods use areas with sagebrush densities ranging 0.9 to 2.5 shrubs per m^2 in big sagebrush (*Artemisia tridentata* L.) habitats.

Canopy coverage values for forbs, grasses, and all herbaceous vegetation ranged from 4–8 %, 11–26 %, and 14–33 %, respectively, and grass heights ranged from 11–23 cm (Table 11). Connelly et al. (2000b) suggested that broods need a combined grass and forb cover that is greater than 15 %, although they noted that grass heights are variable depending on the grass species present. While Decker met these guidelines, Roundup did not. Low herbaceous vegetation at Roundup could be influencing brood success, but this was impossible to determine from my data.

Yearling and adult hens with broods did not use different habitat at Roundup, but yearling hens used greater sagebrush cover, density, and height than adults at Decker (Table 12). Holloran (1999) did not detect differences between adult and yearling hen brood sites and believed that habitat selection should not differ because hens frequently return to their natal area to nest and rear broods (Dunn and Braun 1985). My data indicated that yearling hens may use the same general area to raise their broods as adults, but adults select areas with more sagebrush cover.

Table 12. Habitat characteristics of yearling and adult brood sites near Roundup and Decker, Montana.

Location	N	Sagebrush Characteristics			Herbaceous Characteristics			
		total cover	total density	avg. height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	(cm)	----------(%)----------			(cm)
Yearling Hens								
Roundup	5	15	1.7	24	5	14	16	12
Decker [1]	6	8	0.6	37	7	29	35	21
Adult Hens								
Roundup	14	15	1.5	26	5	13	17	11
Decker [1]	22	14	1.0	44	9	25	32	23

[1] Includes 1 study area from Campbell County, WY.

Management Implications

My data support that sagebrush habitats are vital for nesting and brood-rearing sage-grouse. Ninety-seven percent of nests and 92 % of brood locations were in sagebrush habitat. Nest and brood sites near Roundup, Decker, and Malta fell within the sagebrush cover guidelines suggested by Connelly et al. (2000b). However, sagebrush cover was the only parameter in central Montana and northern Wyoming that consistently met the suggested guidelines. Sagebrush heights were lower at Roundup and Malta than the suggested guideline. Therefore, the sagebrush cover guideline proposed by Connelly et al. (2000b) appears to be is an appropriate indicator of nesting and brood-rearing habitat in Montana, but the sagebrush height guideline does not.

Sagebrush cover at my study areas did not exceed 31 or 35 % that nesting and brood-rearing sage-grouse, respectively, did not use in Idaho (Klebenow 1969), nor did cover at my study areas exceed the guideline suggested by Connelly et al. (2002b). Although herbaceous vegetation was low at Roundup, total herbaceous cover met the guidelines at Decker and Malta.

The results that describe the influence of sagebrush on herbaceous vegetation are varied. Winward (1991) stated that Wyoming big sagebrush stands with cover greater than 15 % would restrict the growth of herbaceous vegetation, but Welch and Criddle (2003) disputed this claim. Also, Pearson (1965) observed that big sagebrush cover within an 11-year old exclosure was 34 % with an understory grass cover of 39 %, whereas outside the exclosure sagebrush cover was 11 % and grass cover was 22 %. Therefore, sagebrush cover less than the maximum threshold of 35 % that nesting sage-grouse use does not appear to influence understory herbaceous vegetation.

Precipitation and site potential productivity may have a greater effect on herbaceous vegetation than sagebrush cover in my study areas. Sagebrush in these areas should not be controlled or manipulated as cover did not exceed 35 % threshold which was selected against by sage-grouse in other studies. Sagebrush control should also be avoided because sagebrush was relatively short at Roundup and Malta, and nesting sage-grouse were selecting for taller and more mature nest shrubs in Roundup. Removing sagebrush could also reduce the amount of sagebrush available above snow which is critical for sage-grouse foraging in winter (Hupp and Braun 1989).

I suggest that a minimum sagebrush height of 20 cm may be more accurate for describing nesting and brood-rearing habitat, respectively, in central Montana and northern Wyoming. These areas are less productive areas than the areas which had 30–40 cm heights suggested by Connelly et al. (2000b). Nesting and brood-rearing sage-grouse would likely use sites with taller sagebrush if these sites were available.

Sagebrush density is not frequently reported in the literature, nor have guidelines been suggested for brood sites. I observed that broods were located in areas 0.9–1.6

sagebrush per m^2 in my study areas. Broods at Decker were in areas with denser sagebrush at 0.9 shrubs per m^2 than the 0.6 shrubs per m^2 at random sites. Klebenow (1969) observed that broods used less dense sagebrush habitat at 1.7 shrubs per m^2 than in the overall sagebrush habitat type at 2.9 shrubs per m^2 in Idaho. Therefore, broods mainly use areas with sagebrush densities ranging 0.9 to 2.5 shrubs per m^2 in big sagebrush (*Artemisia tridentata* L.) habitats. However, sagebrush density needs to be measured in other areas of the range of sage-grouse before the importance of this parameter can be determined for broods.

Herbaceous cover at nest and brood sites did not meet the suggested guidelines at Roundup. Forb cover was also low in all three study areas. Although extended drought in my study areas could have reduced forb production, it is also possible that the guidelines do not reflect the potential conditions in these areas. Grass height was also lower than the suggested guidelines in Roundup and Malta, due to the abundance of blue grama. Therefore, the guidelines suggested by Connelly et al. (2000b) may be difficult to meet in certain areas of Montana due to species composition and low site productivity.

Herbaceous vegetation can vary greatly from year to year depending on temperature and the timing and intensity of precipitation events. While adequate herbaceous cover was available for nesting sage-grouse at Decker and Malta in 2003, herbaceous cover may not meet the suggested guidelines in other years. Japanese brome was abundant at Decker, therefore sagebrush habitats in this area could be at risk if fire frequencies change. Efforts should be taken to minimize the spread of this exotic annual grass (Wambolt et al. 2000).

Montana is one of only three states left within the range of sage-grouse that has a sage-grouse population greater than 20,000 (Braun 1998). Habitat loss is the primary cause of sage-grouse declines across the range of this species (Braun et al. 1977; Schroeder et al. 2000; Wambolt et al. 2002). The relatively large, stable populations of sage-grouse in Montana are due to large, fairly contiguous sagebrush stands available for nesting and brood-rearing (MSGWG 2002). Therefore, sagebrush habitats in Montana should be managed to maintain the current size and connectivity of sagebrush stands to sustain sage-grouse populations over the long-term.

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APPENDICES

APPENDIX A

Roundup Study Area
Supplemental Tables

Table 13. Nest and brood site vegetation in Musselshell and Golden Valley counties near Roundup, Montana, in 2004.

		Shrub Characteristics			Herbaceous Characteristics					
Study Area	N	shrub cover	shrub density	shrub height	forb cover	grass cover	total cover	residual cover	grass height	residual height
		(%)	(shrubs/m^2)	(cm)	----------(%)----------				------(cm)-----	
Nest Sites										
Golden Valley	19	20	1.8	25	2	9	10	11	10	11
Musselshell	29	18	1.4	27	3.7	14	16	13	10	10
Brood Sites										
Golden Valley	7	12	1.6	22	4	11	14	12	11	10
Musselshell	13	15	1.5	27	5	15	18	11	11	9

Table 14. Average cover values for grass, forb, and other plant species near Roundup in 2004.

Grass Species	Nest	Random	Brood	Random
Achnatherum hymenoides	-	0.0[1]	-	-
Agropyron cristatum	0.5	0.1	0.2	0.0
Bouteloua gracilis	2.2	2.3	1.2	1.6
Bromus inermis	0.2	0.1	0.0	-
Bromus japonicus	0.0	0.1	0.8	0.1
Bromus tectorum	0.1	0.2	0.2	0.7
Carex filifolia	1.9	1.3	1.6	1.6
Distichlis stricta	0.0	0.1	0.0	0.1
Elymus canadensis	-	0.0	0.0	0.0
Hesperostipa comata	0.8	0.6	0.9	0.5
Hordeum jubatum	-	-	0.0	-
Koeleria cristata	0.2	0.2	0.3	0.4
Nassella viridula	0.7	1.1	1.1	1.4
Pascopyrum smithii	3.0	2.8	3.5	3.5
Poa secunda	3.3	4.0	4.5	3.8
Psuedoroegneria spicata	0.6	0.2	0.1	0.2
Thinopyron intermedium	0.4	0.8	1.1	1.2
Vulpia octoflora	0.1	0.1	0.1	0.1
Forb Species				
Achillea millefolium	0.0	0.0	0.0	0.0
Agoseris spp.	0.0	-	-	-
Allium spp.	0.3	0.4	0.4	0.4
Alyssum alyssoides	-	0.0	0.2	0.0
Aster spp.	-	0.0	-	-
Astragalus spp.	-	-	0.0	0.0
Brassica campestris	0.1	0.0	0.2	0.3
Brassica spp.	0.0	0.0	0.1	0.0
Camelina microcarpa	0.0	-	0.0	0.0

Table 14 cont.

Lygodesmia juncea	-	-	0.6	0.0
Medicago sativa	-	0.0	-	0.0
Melilotus officinale	-	-	-	0.0
Monolepis nuttalliana	0.0	0.0	0.5	0.5
Phlox hoodii	0.3	0.5	0.3	0.5
Plantago patagonica	-	0.0	0.0	0.0
Psoralea tenuiflora	0.0	-	0.0	0.0
Senecio integerrimus	-	-	0.0	-
Sphaeralcea coccinea	1.1	0.9	1.0	1.7
Taraxacum officinale	0.1	0.1	0.3	0.2
Thermopsis montana	0.0	0.0	0.3	0.1
Tragopogon dubius	0.0	0.0	-	-
Trifolium spp.	0.0	0.0	0.1	0.1
Umbelliferae	0.5	0.4	0.6	0.4
Vicia americana	0.3	0.6	0.7	1.0
Zygadenus venenosus	0.0	0.1	-	0.0
Other Species				
Artemisia frigida	0.3	0.5	0.5	0.5
Artemisia ludoviciana	-	-	-	0.0
Atriplex gardneri	0.2	0.1	0.0	0.1
Ericameria nauseosa	0.1	0.1	0.0	0.0
Gutierrezia sarothrae	0.1	0.1	0.1	0.1
Krascheninnikovia lanata	0.1	0.1	0.1	0.0
Opuntia spp.	1.5	1.1	1.2	1.0
Rosa spp.	0.0	0.0	0.0	-
Selaginella densa	0.6	0.5	2.2	0.2

[1] Zero does not imply absence but indicates a species was present in minute amounts.

APPENDIX B

Decker Study Area
Supplemental Tables

Table 15. Nest and brood site vegetation in CX, Padlock, and Spotted Horse study areas near Decker, Montana, in 2003.

Comparison	Shrub Characteristics			Herbaceous Characteristics			
	total cover	total density	shrub height	forb cover	grass cover	total cover	grass height
	(%)	(shrubs/m^2)	(cm)	----------(%)----------			(cm)
Nest Sites							
CX	24	1.1	50	8	20	28	21
Padlock	21	1.2	55	16	30	42	27
Spotted Horse	23	1.1	50	9	19	30	23
Brood Sites							
CX	13	0.8	41	6	22	27	22
Padlock	13	1.0	44	10	28	37	24
Spotted Horse	12	0.8	43	7	29	33	21

Table 16. Average cover values for grass, forb, and other plant species near Decker in 2003.

Grass Species	Nest	Brood	Random
Aegilops cylindrica	-	-	0.3
Agropyron cristatum	0.8	0.1	1.8
Aristida longiseta	0.0[1]	0.0	0.0
Bouteloua curtipendula	0.1	0.1	0.1
Bouteloua gracilis	1.3	2.2	1.7
Bromus commutatus	0.1	-	0.3
Bromus hordeaceus	0.0	-	4.4
Bromus inermis	0.0	0.0	-
Bromus japonicus	2.6	3.3	0.0
Bromus spp.	0.0	-	-
Bromus tectorum	0.5	1.3	-
Calamagrostis longifolia	0.0	0.0	0.1
Calamagrostis montanensis	-	-	0.4
Carex eleusinoides	0.3	0.4	1.6
Carex filifolia	0.3	0.5	0.5
Carex spp.	-	-	0.5
Distichlis stricta	-	0.0	0.0
Festuca idahoensis	0.6	0.0	0.0
Hesperostipa comata	1.4	2.2	0.0
Hesperostipa spartea	0.0	-	2.3
Hordeum jubatum	0.0	0.3	-

Table 16 cont.

Koeleria cristata	1.7	2.6	0.0
Nassella viridula	1.8	1.9	-
Oryzopsis hymenoides	-	-	2.2
Pascopyrum smithii	5.1	8.9	5.7
Phleum pratense	0.0	0.1	0.0
Poa bulbosa	0.0	-	0.0
Poa cusikii	0.0	-	0.4
Poa paucispicula	0.6	0.5	0.0
Poa pratensis	0.6	0.3	0.0
Poa sandbergii	2.9	3.3	0.8
Poa spp.	0.0	0.3	2.9
Psuedoroegneria spicata	2.1	2.9	4.4
Schizachyrium scoparium	0.0	-	0.1
Secale cereale	-	-	0.1
Sporobolus cryptandrus	-	-	0.1
Thinopyron intermdium	0.4	0.0	0.3
Triticum aestivum	-	-	1.2
Vulpia octoflora	0.1	0.1	0.0
Forb Species			
Achillea millefolium	0.9	0.7	1.6
Agoseris glauca	0.5	0.1	0.8
Allium spp.	0.1	0.1	2.2
Alyssum alyssoides	0.7	0.2	0.0
Alyssum desertorum	1.0	1.5	0.0
Antennaria spp.	0.2	0.1	0.0
Arnica sororia	0.4	0.1	0.2
Artemisia campestris	-	-	0.1
Artemisia frigida	0.8	0.9	0.0
Artemisia ludoviciana	0.2	0.3	1.2
Aster spp.	0.0	-	0.2
Astragalus bisulcatus	0.0	-	0.0
Astragalus drummondii	0.0	-	0.0
Astragalus missouriensis	0.1	0.1	-
Astragalus spp.	0.2	0.3	0.0
Balsamorhiza sagittata	0.0	-	0.0
Berteroa incana	0.0	-	0.0
Calochortus gunnisonii	-	-	-

Table 16 cont.

Calochortus nuttallii	0.0	0.0	0.1
Camelina microcarpa	0.0	0.0	0.0
Campanula rotundifolia	0.0	-	0.0
Chenopodium album	-	-	-
Cirsium arvense	0.0	0.1	0.0
Cirsium spp.	0.0	0.0	0.0
Cirsium undulatum	0.0	0.0	0.1
Convolvulus arvensis	0.1	-	-
Danthonia unispicata	0.0	-	0.0
Delphinium bicolor	0.0	-	-
Erigeron divergens	0.0	0.0	0.1
Eriogonum spp.	0.0	0.0	-
Euphorbia esula	0.0	-	0.0
Gaura coccinea	0.0	-	0.0
Geum triflorum	-	0.0	0.0
Glycyrrhiza lepidota	0.1	0.0	0.0
Heterotheca villosa	0.0	0.0	-
Hypochaeris radicata	-	0.0	0.1
Kochia scoparia	-	-	0.1
Lappula occidentalis	0.0	0.0	0.2
Linum lewisii	0.1	0.0	-
Lomatium spp.	0.2	0.1	0.0
Lupinus spp.	0.0	0.1	0.0
Machaeranthera grindelioides	-	-	0.1
Medicago sativa	0.0	0.0	0.4
Melilotis officinalis	0.2	0.1	0.0
Monarda fistulosa	0.0	-	0.0
Oenothera albicaulis	-	0.0	-
Orthocarpus luteus	-	-	0.2
Oxytropis spp.	0.0	0.0	0.0
Pediocactus simpsoni	0.0	0.0	0.0
Pediomelum esculentum	0.1	0.2	0.2
Penstemon albidus	0.3	0.0	-
Perideridia gairdneri	-	0.0	0.0
Petalostemon candidus	-	-	-
Phacelia linearis	0.1	0.1	1.4
Phlox hoodii	1.1	1.4	0.0
Plantago patagonica	0.1	0.4	0.0

Table 16 cont.

Psoralidium tenuiflorum	0.0	0.3	0.2
Ratibida columnifera	-	-	0.2
Rosa arkansana	0.1	0.1	0.0
Sisymbrium altissimum	0.1	-	0.0
Sisymbrium loeselii	0.0	0.0	0.3
Sphaeralcea coccinea	0.6	0.7	0.1
Stephanomeria runcinata	-	-	0.7
Thermopsis rhombifolia	-	0.1	0.2
Toxicodendron rydbergii	-	-	-
Tragopogon dubius	0.1	0.2	0.0
Vicia americana	0.6	0.5	0.1
Wyethia amplexicaulis	0.0	0.0	0.4
Zigadenus venenosus	0.0	0.0	-
Other Species			
Ericameria nauseosa	0.0	0.0	0.0
Gutierrezia sarothrae	0.1	0.4	0.0
Juniperus communis	0.0	0.0	0.0
Juniperus scopulorum			0.0
Krascheninnikovia lanata	0.1	0.0	0.2
Opuntia polyacantha	0.4	0.3	-
Pinus ponderosa	0.0	0.0	0.0
Prunus virginiana	-	0.0	0.0
Rhus trilobata	0.0	0.0	0.0
Ribes spp.	0.0	0.0	-
Sarcobatus vermiculatus	-	-	-
Symphoricarpos spp.	0.0	0.0	0.0
Tetradymia canescens	0.0	-	0.0
Yucca glauca	0.0	-	0.0

[1] Zero does not imply absence but indicates a species was present in minute amounts.

APPENDIX C

Malta Study Area
Supplemental Tables

Table 17. Nest site vegetation in CMR, Dry Fork, Little Horse, and Sun Prairie study areas near Malta, 2003.

Comparison	N	Shrub Characteristics			Herbaceous Characteristics			
		total cover	total density	shrub height	forb cover	grass cover	total cover	grass height
		(%)	(shrubs/m^2)	(cm)	----------(%)----------			(cm)
Nest Sites								
CMR	11	18	1.5	34	13	21	31	15
Dry Fork	5	14	1.3	21	10	30	36	10
Little Horse	15	16	1.3	29	5	21	23	14
Sun Prairie	14	24	1.8	32	5	19	23	15

Table 18. Average cover values for grass, forb, and other plant species near Malta in 2003.

Grass Species	Nest	Random
Agropyron cristatum	1.1	1.0
Aristida longiseta	0.3	-
Bouteloua gracilis	9.1	11.8
Bromus tectorum	0.0[1]	0.0
Calamagrostis montanensis	0.1	-
Carex filifolia	1.2	0.7
Elymus canadensis	0.1	0.0
Elymus trachycaulus	0.2	0.9
Hesperostipa comata	2.0	1.9
Hordeum jubatum	0.0	0.0
Koeleria cristata	1.9	2.2
Muhlenbergia cuspidata	0.0	0.0
Nassella viridula	1.2	0.9
Pascopyrum smithii	4.4	3.3
Poa secunda	0.9	1.3
Psuedoroegneria spicata	0.2	0.2
Schedonnardus paniculatis	0.0	0.1
Sitanion hystrix	0.0	0.0
Vulpia octoflora	0.1	0.0
Forb Species		
Achillea millefolium	0.1	0.1
Allium spp.	0.2	0.1
Antennaria spp.	0.5	-
Brassica spp.	0.0	0.1
Chrysopsis villosa	0.0	-
Chrysothamnus spp.	0.2	0.3
Dalea purpurea	0.0	0.0
Iva axillaris	0.0	0.0

Table 18 cont.

Melilotus officinale	1.1	1.7
Plantago patagonica	0.2	0.2
Sphaeralcea coccinea	0.6	0.4
Taraxacum officinale	0.3	0.4
Tragopogon dubius	0.0	-
Vicia americana	0.6	0.5
Other Species		
Artemisia frigida	2.4	2.6
Artemisia ludoviciana	0.0	0.0
Gutierrezia sarothrae	-	0.0
Opuntia spp.	1.0	0.5
Selaginella densa	16.7	8.6

[1] Zero does not imply absence but indicates a species was present in minute amounts.