EVALUATION OF HABITAT SELECTION BY NESTING SHARP-TAILED GROUSE AND SURVIVORSHIP OF HENS, MALES, AND NESTS ON THE GRAND RIVER NATIONAL GRASSLAND IN NORTHWEST SOUTH DAKOTA, USA

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Evaluation of Habitat Selection by Nesting Sharp-Tailed Grouse and Survivorship of Hens, Males, and Nests on the Grand River National Grasslands in Northwest South Dakota

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ABSTRACT

Houchen, Dean Joseph., M.S., Natural Resources Management Program, College of Graduate and Interdisciplinary Studies, North Dakota State University, April 2011. Evaluation of Habitat Selection by Nesting Sharp-Tailed Grouse and Survivorship of Hens, Males, and Nests on the Grand River National Grasslands in Northwest South Dakota, USA. Major Professors: Dr. Benjamin Geaumont and Dr. Kevin Sedivec.

Plains sharp-tailed grouse nesting habitat was evaluated on the Grand River National Grasslands (GRNG) in northwest South Dakota, in the spring and summer of 2009 and 2010. Experiment #1 was conducted across the GRNG with hens and males trapped at 11 different lekking sites in 2009 and 2010. Study objectives were to 1) evaluate sharp-tailed grouse nest site selection based on habitat and describe vegetation composition and visual obstruction readings (VOR), 2) compare the use of semi-variance statistics to the commonly used co-efficient of variation to determine patch selection by sharp-tailed grouse, and 3) provide an example of how semi-variance statistical techniques can be used by wildlife scientists to evaluate habitat selection and patch size determination. Experiment #2 was designed to evaluate survivorship of female and male sharp-tailed grouse, and sharp-tailed grouse nests on the GRNG in the spring and summer of 2009 and 2010. Study objectives were to 1) estimate nest survival rates of sharp-tailed grouse on the GRNG in northwest South Dakota, 2) evaluate the effects of abiotic and biotic factors on nest survival rates, and 3) estimate survival of male and female grouse during the nesting season. VOR data was collected at 275 random transects (143 in 2009 and 132 in 2010) and 46 used (nests) transects (22 in 2009 and 24 in 2010). Sharp-tailed grouse were trapped and fitted with necklace style transmitters. Over the two year study 163 sharp-tailed grouse were trapped and 100 of these individuals were fitted with radio collars (44 males and 56 females). Nests were monitored to determine fate. There was a difference ($P \leq 0.05$) in patch

selection compared to what was available in 2009, but no difference in 2010. The comparison of semi-variance (SV) analysis to co-efficient of variation (CV) provided a conflicting report as SV showed selection for variability, while the CV showed a selection for low variability and a uniform height distribution of vegetation. Overall 41 of 56 collard hens initiated nests, with 5 hens initiating a second nest following the predation of her first (18 initial nest and 4 re-nests in 2009, and 23 initial nests and 1 re-nest in 2010). Vegetation measurements were taken at 46 nest sites. Overall, nest survival was 30% (29% in 2009 and 31% in 2010). The best model for nest survival included maximum vegetation height and percent grass canopy cover as vegetation variables most related to nest survival. Nest survival increased with an increase in the maximum vegetation height and with increasing canopy cover of grass. All other models that included other vegetation characteristics as variables were not well supported (i.e., >2 ΔAIC_c units). The constant survival model had more support than any of the models that included time dependent variables such as linear trend of time, maximum daily temperature, and nest age. The model that included a linear trend of time was the best time dependent model (ΔAIC_c = 1.21). The model that combined a linear trend of time with the best vegetation model, maximum vegetation height plus percent canopy cover of grass, received less support than the vegetation model alone (ΔAIC_c 0.77). Survival of male and female sharp-tailed grouse was 49% and 65%, respectively. We recommend managers develop strategies to maintain patches of tall dense vegetation structure. Patches of tall grass cover is an important component to sharp-tailed grouse nesting habitat. Thus, we recommend that management of grazing and use of mechanical treatments that leave patches of tall dense stands of grass in grass dominated ecosystems are beneficial to nesting sharp-tailed grouse.

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This project would not have been possible without funding provided by the United States Forest Service (Dakota Prairie Grasslands), North Dakota State University, and North Dakota State University Hettinger Research Extension Center. I would like to thank Drs. Benjamin A. Geaumont, Kevin K. Sedivec, and Christopher S. Schauer for giving me the opportunity to conduct research on sharp-tailed grouse. The last two years have provided me with the knowledge of sharp-tailed grouse and their associated species I would not have gained any other place. Thank you for providing me with your helpful insight and pointed direction; this was truly a challenging and enjoyable experience.

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CHAPTER 1. GENERAL INTRODUCTION

Sharp-tailed grouse (*Tympanuchus phassianellus*) historically occupied eight Canadian provinces and 21 U.S. states pre-European settlement (Johnsgard 2002). They ranged from as far north as Alaska, south to California and New Mexico, and east to Quebec, Canada (Johnsgard 2002). Following European settlement, the sharp-tailed grouse has been extirpated from California, Kansas, Illinois, Iowa, Nevada, New Mexico, Oklahoma, and Oregon (Johnsgard 1973; Connelly et al. 1998). Their populations have remained steady in South Dakota where they are pursued annually by upland game bird hunters. In fact, Robel et al. (1972) did a study on sharp-tailed grouse population dynamics where they stated "the sharp-tailed grouse is the most abundant game bird in western South Dakota".

Nesting cover is one of the most important habitat types needed by sharp-tailed grouse hens (Manske and Barker 1987, Phillips 1990). Nesting habitat varies widely among the different subspecies of sharp-tailed grouse (Roersma 2001). Hamerstrom Jr. (1939) found the majority of prairie sharp-tailed grouse (*T.p.campestris)* nests occupied dense brush and woods at marsh edges. Gieson and Connelly (1993) reported that Colombian sharp-tailed grouse (*T.p.columbianus*) selected for dense shrub stands with taller, denser shrubs for nest sites. Plains sharp-tailed grouse (*T.p.jamesii*) selected dense residual vegetation with a shrub component for nest sites (Kirby and Grosz 1995; Roersma 2001). However, nest sites are generally characterized by tall, dense residual vegetation (last year's growth) with the presence of woody vegetation either at the nest site or nearby (Manske and Barker 1987; Prose et al. 2002).

Sharp-tailed grouse nesting success has been linked to the presence of shrubs, dense concealment cover, tall residual VOR, and reduced presence of croplands (Prose et al. 2002; Manzer and Hannon 2005; Goddard et al. 2009). Manzer and Hannon (2005) reported a 47% nest success rate of 107 nests in a three-year study conducted in southeastern Alberta, Canada. They noted that nests were four times more likely to succeed in areas with less than 10% crop cover and less than 35% crop and sparse grassland. Goddard et al. (2009) reported a nest success of 43% for 62 nests over a 2-year study in British Columbia, Canada. Of the candidate models that included habitat variables, the best model of nest survival included vertical and grass cover as important covariates (weight 0.21; Goddard et al. 2009).

We conducted two different experiments across the Grand River National Grassland in northwest South Dakota on plains sharp-tailed grouse (*Tymphanucus phasanellus jamesi*). In Experiment 1 we hypothesized that plain's sharp-tailed grouse were selecting for patches of higher VO at nest sites on the Grand River National Grasslands (GRNG). Our objectives were to: 1) Evaluate sharp-tailed grouse nest site selection based on visual obstruction readings (VOR). 2) Compare the use of semi-variance statistics to the commonly used co-efficient of variation to determine patch selection by sharp-tailed grouse, and 3) Provide an example of how semi-variance statistical techniques can be used by wildlife scientists to evaluate habitat selection and patch size determination. In Experiment 2 we studied nest survival of plains sharp-tailed grouse on the GRNG in northwest South Dakota, during the nesting seasons of 2009 and 2010. Sharp-tailed grouse are of interest because they are used by the United States Forest Service (USFS) as an indicator species for grassland health (USDA-USFS 2001). Our study objectives were: 1)

Estimate nest survival rates of sharp-tailed grouse on the GRNG in northwestern South Dakota and evaluate the effects of abiotic and biotic factors on those rates, and 2) Estimate survival of male and female grouse during the nesting season.

An Explanation of the Thesis Organization

This thesis follows the format required for submission into the Journal of Wildlife Management. Chapter 2 is the literature review and Chapters 3 and 4 both represent separate submissions for journal publication.

Throughout chapters 3 and 4 I used the pronoun "we" to give credit to me and my co-authors who provided their professional experience to help comprise different aspects of these two chapters. Chapters 3 and 4 are denoted with a footnote marker that explains the co-authors' contributions to the chapter.

CHAPTER 2. LITERATURE REVIEW

Species Description

The sharp-tailed grouse is a medium sized grouse with a total length of 41-47 cm and weight of 596 g–1,031 g (Connelly et al. 1998). The actual size is dependent upon the subspecies, time of year, and sex, with males being larger than females (Connelly et al. 1998). The sharp-tailed grouse has a rounded body, long central retrices on the tail which gives it a sharp, pointed appearance, and its nostrils and legs feathered (Johnsgard 1973; Connelly et al. 1998). Males are distinguished from females by a large yellow comb above their eyes, which are enlarged during the lekking season (Johnsgard 1973). Both male and female possess elongated crown feathers, which form a crest when erected. However, females crown feathers are lighter in color and more barred than males (Henderson et al. 1967; Johnsgard 1973; Connelly et al. 1998).

The sharp-tailed grouse is a member of the prairie grouse family (*Tympanuchus spp.*) (Silvy and Hagen 2004). The scientific name of the sharp-tailed grouse is *Tympanuchus phasianellus*. *T. phasianellus* includes seven subspecies of which six are still extant (Johnsgard 2002). The genus *Tympanuchus* also includes the closely related greater prairie chicken (*Tympanuchus cupido*), lesser prairie chicken (*Tympanuchus pallidicintus*), and extinct heath hen (*Tympanuchus cupio*). Distinguishing characteristics of sharp-tailed grouse from the lesser and greater prairie chicken are bold V-marks on the under parts, while the prairie chickens are heavily barred on their under parts (Connelly et al. 1998). Male sharp-tailed grouse have violet colored air sacs compared to the prairie chickens' yellow or orange colored air sacs and lack pinnae feathers found on prairie chickens (Connelly et al. 1998).

Sharp-tailed grouse historically occupied eight Canadian provinces and 21 U.S. states pre-European settlement (Johnsgard 2002). They ranged from as far north as Alaska, south to California and New Mexico, and east to Quebec, Canada (Johnsgard 2002). Following European settlement the sharp-tailed grouse has been extirpated from California, Kansas, Illinois, Iowa, Nevada, New Mexico, Oklahoma, and Oregon (Johnsgard 1973; Connelly et al. 1998).

Protection Status

Currently the sharp-tailed grouse is not listed as a threatened or endangered species under the Endangered Species Act (ESA). It is listed in the International Union for Conservation of Nature (IUCN) as a species of least concern. Although the sharp-tailed grouse has the largest range of all the prairie grouse, it has suffered a decline in populations in its southern ranges (Connelly et al. 1998; Silvy and Hagen 2004). The Columbian sharp-tailed grouse subspecies was petitioned to be listed on the ESA, but was rejected (Silvy and Hagen 2004).

Distribution and Abundance

There were seven subspecies of sharp-tail grouse found throughout North America (Connnelly et al. 1998). Of the seven subspecies that are found in North America five of the remaining six subspecies are currently found within the United States of America.

These five subspecies are:

1. T. p. phasianellus (Linneaus) is found in central Canada (northern Manitoba, northern Ontario, and Central Quebec) (Johnsgard 1973; Connelly et al. 1998).
2. T. p. kennicotti (Suckley) is found in the Northwest Territories of Canada around the Great Slave Lake and Mackenzie River watershed (Johnsgard 1973; Connelly et al. 1998).

3. *T. p. caurus* (Ridgway and Friedman 1946) is found in north central Alaska east to the southern Yukon province and northern British Columbia and Alberta. It has white spotting and white and narrow dark edging (Johnsgard 1973; Connelly et al. 1998).
4. *T. p. columbianus* (Ord) is found in the Columbian River Basin and the Great Basin. It occupies sagebrush grasslands and mountain shrub habitats. It is found in the states of Utah and Colorado, and extirpated from northern California (Johnsgard 1973; Connelly et al. 1998).
5. *T. p. campestris* (Ridgway 1884) is found in the central lowlands and prairies of the upper peninsula of Michigan, Wisconsin, Minnesota, southwestern Ontario, and southeastern Manitoba (Johnsgard 1973; Connelly et al. 1998).
6. *T. p. jamesi* (Lincoln 1917) is found throughout the Great Plains. It occupies prairie habitats east of the Rockies in Colorado to North Dakota and south to Kansas. It is also found in central Alberta and Saskatchewan (Johnsgard 1973; Connelly et al. 1998).
7. *T. p. hueyi* (Dickerman and Hubbard 1994) was found in a very small concentration in northeast New Mexico. This species is extinct and was considered part of the plains race, but later determined to be its own separate species (Johnsgard 2002).

The abundance of the sharp-tailed grouse has declined over the past 150 years (Robel et al. 1972). Robel et al. (1972) did a study on sharp-tailed grouse population dynamics where they stated "the sharp-tailed grouse is the most abundant game bird in western South Dakota", a statement which is no longer true. Much of the sharp-tailed grouse population reduction had to do with the passing of the Homestead Act of the mid 1800's. This act allowed individuals to stake claim to land if they could farm and improve the land (Potter and Schamel 1997). The Homestead Act of 1862 led to large expanses of grasslands never before tilled, being cultivated and put into crop and cattle production (Johnsgard 2002). Much of this land was essential habitat for the sharp-tailed grouse.

There currently is no all-encompassing data on the overall status of each subspecies population and abundance. Both subspecies found throughout the central United States, (*T. p. jamesi* and *T. p. phasianellus)* are stable in comparison to other subspecies found in the United States (Connelly et al. 1998). The relative success of these subspecies is believed to be the result of the introduction of the Conservation Reserve Program (CRP) within the 1985 Food Security Act (Clawson and Rottella 1998). No other prairie grouse species has benefited from CRP more than the sharp-tailed grouse (Rodgers and Hoffman 2005).

Reproduction

Sharp-tailed grouse are a lekking bird species. A lek is defined as an assembly area (communal area) where males carry on display and courtship behavior to attract females (Bergerud 1988). During the spring, male sharp-tail grouse attend these leks from mid-March through the end of May. Males display and use "cooing" calls to attract and compete for females (Sisson 1969; Bergerud 1988; and Connelly et al. 1998). Sharp-tailed grouse are polygynous breeders, meaning that there is one male to many females. Bergerud (1988) stated that "sharp-tailed grouse show clumped polygamy", meaning males are clumped close together to defend territories. At the lek, sexual selection is intense and only a few males will do the breeding (Bergerud 1988). Thus, lekking is not an advantage to the competing males. Rather, it is advantageous to the females to select the traits that she wants.

There is no evidence to suggest when females select nesting site before copulation (Bergerud 1988b; Gratson 1988; Connelly et al. 1998) or afterwards. But, selecting the appropriate site for nesting is very important because according to Bergerud (1988b), prairie grouse lose 50% of their nests. Phillips (1990) also noted that lekking birds are susceptible to high nest predation rates, reporting that nest predation in the temperate region can be as high as 60%. Females usually select sites with taller and denser vegetation in or around shrubby vegetation than is available across the landscape (Manzer and Hannon 2005; Goddard et al. 2009). Manske and Barker (1978) found that sharp-tailed grouse, on average, selected for dense vegetation with heavy side and overhead concealment properties on the Sheyenne National Grassland of North Dakota. In this dense vegetation the grouse digs a small depression or nest bowl and lines it with grassy vegetation from the surrounding area. After the nest site is selected, the hen will lay on average about 10.9 - 12.3 eggs (Connelly et al. 1998).

Once all the eggs are laid, incubation occurs and the hatch is synchronously at 21-23 days (Hammerstrom 1939; Connelly et al. 1998). After hatching occurs the chicks are precocial, meaning their eyes are open, the body is covered in down, have well developed legs, and are able to feed themselves (Connelly et al. 1998). At hatching, they are almost completely independent other than following the hen and learning from her. The chicks reach about half of their full body weight in eight weeks, and by week 12 the chicks reach almost full size (Pepper 1969; Connelly et al. 1998). Robel et al. (1972) conducted a mark-recapture study on populations in South Dakota and determined that annual survival of grouse from year 1 to year 2 was 12 percent.

Primary Food Source

The primary food source for sharp-tailed grouse varies from chicks to adults and by season of year. Chicks forage mainly on insects at a young age, transitioning to forbs by five weeks (Hammerstrom 1963; Manske and Barker 1987; Goddard et al. 2009). Goddard et al. (2009) noted that grasshoppers and beetles were selected most commonly by sharp-tailed grouse young up to seven weeks of age in British Columbia.

Mature grouse still utilize insects in the summer, but the majority of their diet in the spring and summer months consists of forbs, grasses, fruits, and flowers (Swenson 1985; Manske and Baker 1987; Connelly et al. 1998). The different species of plants that grouse target include: Russian olive (*Elaeagnus angustifolia*), skunk brush sumac (*Rhus aromatica*), chokecherry (*Prunus virginia*), common dandelion (*Taraxacum officinale*), clover, and grasses (Swenson 1985; Goddard 2009). In the fall and winter, sharp-tailed grouse shift from utilizing forbs and native prairie species to crop residues, shrub land steppe habitat, and shelter belts. This shift is mainly attributed to snow fall and cold temperatures (Hammerstrom 1963; Swenson 1985; Manske and Barker 1987; Connelly 1998; Goddard et al. 2009). The biggest source of food noted by researchers was small grains (wheat and barley) and crop residue from fields harvested in mid-summer (Hammerstrom 1963; Swenson 1985; Manske and Barker 1987; Goddard et al. 2009). Swenson (1985) noted that when the snow got too deep to forage grain crops, grouse moved to shelter belts to forage on buds and berries.

Habitat Selection

The sharp-tailed grouse is found throughout different prairie ecosystems in North America. They inhabit ecosystems from the pine savannahs of the eastern upper Midwest to the short grass, mid grass, and shrub steppe prairies of the Great Plains and Rocky Mountain Region (Aldrich 1963; Johnsgard 1973; Johnsgard 2002). Selection of specific habitat characteristics and vegetation communities is variable among the different subspecies of sharp-tailed grouse. Selection of these specific habitats depends on the quality of habitat available to grouse (Johnsgard 1973; Kohn 1976; Swenson 1985; Roersma 2001; Goddard et al. 2009).

The major habitats used by sharp-tailed grouse are savannah style prairies with grass dominance and shrub patches mixed throughout, and minimal patches of trees (Hammerstrom 1963; Robel et al. 1972; Moyles 1981; Johnsgard 2002; Goddard et al. 2009). Hammerstrom (1963) stated the taller the woody vegetation, the less of it there should be in the habitat. The savannah style habitat is mostly preferred during the brood rearing months of summer through autumn. This general habitat is used during all four seasons for different features. Habitat selection and usage vary by season, with lekking, nesting, brood rearing, and winter habitats selected and utilized differently.

Lekking Habitat

An important habitat type of the sharp-tailed grouse is the lekking ground (breeding ground) habitat. During the spring, male sharp-tailed grouse attend these leks from March through July with peak attendance in late April, early May (Connelly et al. 1998). These dates do fluctuate from year to year based on the weather. Johnsgard (2002) observed weather delayed lekking of up to two weeks by sharp-tailed grouse in North Dakota. Males select hilltops, ridges, or any place with a good field of view for leks. These high points allow the displaying males to see other surrounding displaying males, approaching females to the dancing ground, and predators (Sisson 1969; Manske and Barker 1987; Johnsgard 2002).

The lek, or dancing ground, is usually comprised of short, relatively flat native vegetation (Manske and Barker 1987; Hanowski et al. 2000). Other habitat types utilized for leks are cultivated lands, recent burns, mowed sites, grazed hill tops, and wet meadows

(Ammann 1957; Kobriger 1965; and Johnsgard 1973; Johnsgard 2002). Manske and Barker (1987) reported sun sedge (*Carex inops*), needle and thread grass (*Hesperostipa comata*), and blue grama (*Bouteloua gracillis*) on lekking grounds in the Sheyenne National Grassland of North Dakota. The males also select for upland or midland habitat type on the tops of ridges or hills (Manske and Barker 1987).

Leks surrounded by high residual vegetation were observed by Kirsch et al. (1973). They noticed lek distribution was influenced by the amount of tall residual vegetation adjacent to the lek. Lek sites eventually became abandoned when vegetation structure got too high. The invasion of woody vegetation and trees into lekking arenas also caused displaying males to abandon leks (Moyles 1981; Swenson 1985). Moyles (1981) observed an inverse relationship of lek attendance by males with an increase in quaking aspen (*Populus tremuloides*) within 0.8 km of arenas in the Alberta parklands. Berger and Baydack (1992) also observed a similar trend in aspen encroachment where 50% (7 of 14) of leks were abandoned when aspen coverage increased to over 56 percent of the total area within 1 km of the lek.

Nesting Habitat

Nesting cover is one of the most important habitat types needed by sharp-tailed grouse hens (Manske and Barker 1987, Phillips 1990). Nesting habitat varies widely among the different subspecies of sharp-tailed grouse (Roersma 2001). Hamerstrom Jr. (1939) found the majority of prairie sharp-tailed grouse (*T.p.campestris)* nests occupied dense brush and woods at marsh edges. Gieson and Connelly (1993) reported that Colombian sharp-tailed grouse (*T.p.columbianus*) selected for dense shrub stands with taller, denser shrubs located at the nest site. Plains sharp-tailed grouse (*T.p.jamesii*) selected nest sites with dense residual vegetation and a shrubby component (Kirby and Grosz 1995; Roersma 2001). However, nest sites are usually characterized by dense tall residual vegetation (last year's growth) with the presence of woody vegetation either at the nest site or nearby (Manske and Barker 1987; Prose et al. 2002).

Goddard et al. (2009) stated that the use of shrub dominated habitats has not been documented by many researchers. Goddard et al. (2009) found that sharp-tailed grouse hens in Alberta, Canada selected more for shrub steppe habitats in their first nest attempts because of increased concealment provided by the shrubs than the residual grass earlier in the breeding season. Roersma (2001) also found that grouse in southern Alberta selected taller, woody vegetation compared to all other habitats assessed, and grouse used this area in greater proportions to other available woody habitat. These findings contradict Prose et al. (2002), who stated that residual vegetation is critical to sharp-tailed grouse nest success due to the early seasonal nesting nature of the grouse.

Brood Habitats

Sharp-tailed grouse are a precocial species, meaning they hatch with their eyes open, are self-reliant, and do not require the mother to feed them. Shortly after hatching, the chicks and mother leave the nest site in search of cover and food. Brood rearing habitats for sharp-tailed grouse have many characteristics including shrubby vegetation for concealment, short vegetation nearby for feeding, and high amounts of forbs present (Hamerstrom 1963; Kohn 1976; Manske and Barker 1987; Roersma 2001; Goddard et al. 2009). The shrub component in brooding habitat provides good canopy protection from direct sunlight and avian predators (Roesmra 2001; Goddard et al. 2009). Hamerstrom (1963) and Goddard et al. (2009) both observed the greatest number of sharp-tailed grouse broods present in open, rather than wooded landscapes. Both hypothesized this use of open landscape was due to an abundance of insects for the chicks and green herbaceous cover for the hen to feed on.

Habitat usage by sharp-tailed grouse broods is a function of time of day, available habitat, and weather (Ammann 1957; Kohn 1976). Brood habitats are made up of many complex habitat types. Broods may utilize shrubby areas or oak grassland savannah type habitats (Hamerstrom 1963). Broods utilize these types of habitats for cover, while remaining close to prime foraging habitats in the form of shorter vegetation with a mixture of native vegetation.

Winter Habitat

Winter habitat usage by sharp-tailed grouse appears to shift toward denser cover, in comparison to breeding and brood rearing habitat, for thermal insulation. Hammerstrom and Hammerstrom (1951) noticed that grouse used thicker edge type habitat more than the open ground during the winter in Michigan and Wisconsin. Hammerstrom and Hammerstrom (1951) also noted that birds, when found in open habitat, were no more than a few 100 m from thicker cover. These birds were usually utilizing grain fields. Swenson (1985) observed the same trend in Montana. Hamerstrom and Hammerstrom (1951) declared that use of forested habitat by sharp-tailed grouse vary by location, noting that sharp-tailed grouse in more semi-arid and arid areas utilize brush less frequently in winter. However, Hammerstrom and Hammerstrom (1951) did report that sharp-tailed grouse in Washington and California were observed using edge type habitats more frequently during winter months. Manske and Barker (1987) noticed a similar trend in winter habitat usage in North Dakota, noting that sharp-tailed grouse in small flocks joined together to form larger flocks in severe weather. These larger flocks moved from open prairie, to shelterbelts, and adjacent croplands with standing corn and sunflowers. Habitat usage in winter varies greatly as a function of snow depth (Swenson 1985). As snow depth increases, habitat selection shifts from cropland and prairie to shelterbelts and woody vegetation. One habitat change observed by Hamerstrom and Hamerstrom (1951) was grouse would select large snow banks to burrow into and keep warm during cold nights. The use of burrows was also noted by Gratson (1988).

Habitat Fragmentation

Habitat fragmentation has been one of the driving factors of sharp-tailed grouse decline across its entire range for all subspecies throughout North America (Silvy and Hagen 2004). The type of habitat fragmentation varies from ecological succession, as shrub/grassland areas transition into forested areas, to fire suppression, tree plantings, limiting logging practices, and an increase of invasive woody species have also led to sharp-tailed grouse habitat fragmentation. The largest contributor to fragmentation of sharp-tailed grouse habitat has been agriculture, particularly farming.

The Homestead Act of 1862 opened up great expanses of virgin prairie in the west to early settlers. By 1905 about 41 million hectares of the west had been homesteaded (Olsen 1997). Much of this land was in semi-arid rangelands with sub-marginal precipitation to support crop production (Olsen 1997). Once this land was plowed, a change in the land characteristic occurred forever. Another aspect of agriculture that affects habitat fragmentation for grouse is unmonitored and excessive cattle grazing (Kirsch et al. 1973; Giesen and Connelly 1993; Kirby and Grosz 1995; Reece et al. 2001; Sidle 2005). Cattle can be an important tool to manage habitat structure for sharp-tailed grouse when managed properly (Evens 1969; Kirby and Grosz 1995; Sidle 2005). Habitat of sharp-tailed grouse was severely affected by early settlers before cattle producers understood the impact of over grazing to the environment.

A secondary affect that early agriculture had during the years of the Dust Bowl and Great Depression in the late 1920s and early 1930s was when homesteaders abandoned unproductive lands (Olsen 1997). The United States government purchased much of this land through the Land Utilization Program with management of this land eventually controlled by the United States Forest Service and the Bureau of Land Management (Wooten 1965; Olsen 1997). During the drought years of the 1930s, these areas were re-vegetated with non-native highly competitive vegetation such as smooth brome (*Bromus inermis)* and crested wheatgrass (*Agropyron cristatum*) (USDA- Forest service 2001). These plants served their purpose by re-vegetating and protecting the soil, but these invaders became great competitors and directly affected adjacent native vegetation. In some instances crested wheatgrass and smooth brome have forced out native vegetation, creating monoculture habitats. Monoculture habitats are not favored by sharp-tailed grouse as they prefer sites with high heterogeneity. Hamerstrom (1939) was quoted as saying "More important than the individual cover plants is the fact that most of the nests of all species were in cover mixtures rather than pure stands".

Habitat Assessment

Research conducted pre-1950 on sharp-tailed grouse habitat was done visually. Hamerstrom (1939) reported sparse vegetation was seldom selected for nesting due to a lack of adequate cover. Habitat generalizations were formed based on the number of individuals found at a given locale. These assumptions were "if" more birds were present at one location and less at another, "then" the first must be the better habitat. Hamerstrom (1963) observed 119 of 207 (57%) grouse broods in savannah style habitat. He concluded that the savannah style habitat was the habitat needed for best management. As the research on habitat for grouse species matured, so did the techniques used for assessment. Cover boards and Robel poles were developed to measure visual obstruction (VO) and create habitat indices (Kobriger 1965; Jones 1968; Robel et al. 1970; Prose 1987).

Cover boards were developed as early as 1930's by Wight (1938) to study white-tailed deer habitat. Wight's (1938) cover board was 6 feet in height, marked and numbered every foot. Visible marks were counted to measure obstruction by plants. This design was later modified by T.D. Nudds (1977) referred to as the Nudd's board. Kobriger (1965) developed a 4 x 4 foot board marked at 3 inch intervals with alternating white and black squares. He placed a camera in the center of the breeding ground at a height of 3 feet. He then placed the cover board 30 feet away taking photographs of the cover board. After compiling all the photographs, they were analyzed with a hand lens to assess the number of squares visible. This number gave him a vegetation index of cover classes. This method of habitat assessment was also used by Jones (1968). This method has recently been modified by Limb et al. (2007). Instead of taking photographs 30 feet away like Kobriger (1965), Limb et al. (2007) took photographs of vegetation back dropped by a 1x1 m cover board at a height of 1 m, 4 m away. These digital photographs were uploaded to Adobe Acrobat and digitized to the 1x1 m backdrop (Limb et al. 2007).

Robel et al. (1970) developed a pole to determine height based on correlated vegetation weight. The pole was duly named the Robel pole. The specifications for building a Robel pole are to paint alternating brown and white decimeter increments on a

1.5 m round pole. The mid-point of each decimeter is marked so the observer can record vegetation to the nearest half decimeter (Robel et al. 1970). Robel et al. (1970) also marked a bamboo stick at 1, 0.8, and 0.5m to standardize observation height. Robel et al (1970) read the pole from a distance of 4, 3, and 2m taking a reading at all three heights on the bamboo pole. The observers read and recorded the last visible mark above the vegetation as a reading (Robel et al. 1970; Reece et al. 2001). In contrast, Benkobi et al. (2000) recorded the top band totally obstructed as the reading. Robel et al. (1970) found that VO measurements taken at a height of 1m and a distance of 4m from the pole gave a reliable index of the amount of vegetation production at a location.

This design and method of use has been modified since its development. The colors have been changed to alternating white and grey (Benkobi et al. 2000; Smith 2008). The increments have been changed from decimeters to inches (Benkobi et al. 2000) and centimeters (Conover and Bongo 2008). The number of readings changed from one facing south to one in all four cardinal directions (4 total readings). These four numbers are summed up and divided by four to get a mean vegetation height at each site (Benkobi et al. 2000; Conover and Bongo 2008). Also, the Bamboo rod has been replaced by a wooden or metal rod attached to the Robel pole at a height of 1m by a 4m long string, eliminating the error of how far away the observer is from the pole.

Hamerstrom et al. (1957) were quoted as saying "height and density of grass were clearly more important to the prairie chickens than species composition" as reported by Robel et al. (1970). This was also believed to be true for the sharp-tailed grouse. These key aspects can now be assessed using the Robel pole, Nudds cover board, and digital photography method effectively and efficiently.

Management

It is apparent that the effects of habitat fragmentation across all habitat types selected by sharp-tailed grouse are impacting this species. The management of sharp-tailed grouse habitat has changed over the years from observational (making sure current habitat is maintained) to more hands on approach. The management of lekking habitat and winter habitat are not as clearly defined in the literature as nesting and brood rearing habitat assessment and management. The development of the Robel pole and cover boards has become a key tool in habitat assessment providing land managers a means to inventory and study habitat preferences based on vegetation structure and density. The Robel pole has become the more favored of the two methods in recent years for habitat assessment. The United States Forest Service (USFS) uses VORs to set stocking rates for cattle based on the previous year's standing residual vegetation (USDA-USFS 2006). This method is currently conducted on the USFS Little Missouri National Grasslands, Sheyenne National Grasslands, Cedar River National Grasslands, and Grand River National Grasslands all within the Dakota Prairie National Grasslands of North and South Dakota (USDA-USFS 2006).

The Robel pole is a non-destructive method for inventorying vegetative biomass (Robel 1970; Benkobi et al. 2000). This method was used to create a habitat suitability index based on vegetation visual obstruction (VO), ranging from 0-30.5cm with a suitability index rating of 0-1.0 (Prose 1987). Studies of nesting habitat by Prose et al. (2002) in the Nebraska Sandhills found that nesting sharp-tailed grouse selected nest sites with VORs of more than 4 cm. Similarly, Reece et al. (2001) observed that sites with a VO of less than 5cm near potential nesting locations indicated a decline in quality nesting habitat as average VO declined.

The use of the Robel pole to assess habitat for sharp-tailed grouse has given managers a target height of vegetation structure to have at the end of the grazing season. This allows managers to set the appropriate stocking rate to best attain a desired vegetation height. The USFS uses an average VOR reading for suitable grouse nesting habitat as 3.5 in (8.89 cm) across a landscape (USDA USFS 2001).

Lekking habitat can be managed by burning, mowing, clear cutting, and grazing across the entire range of the sharp-tailed grouse subspecies. Ammann (1957) found that leks which contained woody vegetation did not exceed 30 % of the total lek area. Similarly, Moyles (1981) found a negative correlation with increased aspen trees (*Populus tremuloides*) on lekking sites and the number of displaying males present. Trees may provide perches for avian predators, but further work needs to be done on the effects of tree encroachment (Manzer and Hannon 2005)

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CHAPTER 3. NEST SITE SELECTION OF SHARP-TAILED GROUSE[1]

[1] This chapter is co-authored by Dean Houchen , Dr. Jack Norland, Dr. Benjamin Geaumont and Dr. Kevin Sedivec. Dean Houchen (graduate student) was the main co- author responsible for collecting data, running the statistics, interpreting statistical results, and comprising the information presented in this chapter. Dr. Norland provided insight on semi-variance analysis. Also, he provided help with how to interpret the data analysis. Dr. Geaumont and Dr. Sedivec helped with editing the chapter and added professional insight into my discussion and management suggestion sections.

INTRODUCTION

Sharp-tailed grouse (*Tympanuchus phassianellus*) historically occupied eight Canadian provinces and 21 U.S. states pre-European settlement (Johnsgard 2002). They ranged from as far north as Alaska, south to California and New Mexico, and east to Quebec, Canada (Johnsgard 2002). Following European settlement, the sharp-tailed grouse has been extirpated from California, Kansas, Illinois, Iowa, Nevada, New Mexico, Oklahoma, and Oregon (Johnsgard 1973; Connelly et al. 1998). Their populations have remained steady in South Dakota where they are pursued annually by upland game bird hunters. In fact, Robel et al. (1972) did a study on sharp-tailed grouse population dynamics where they stated "the sharp-tailed grouse is the most abundant game bird in western South Dakota".

Sharp-tailed grouse are found throughout different prairie ecosystems in North America. They inhabit ecosystems from the pine savannahs of the eastern upper Midwest to the short grass, mid grass, and shrub steppe prairies of the Great Plains and Rocky Mountain West (Aldrich 1963; Johnsgard 1973; Johnsgard 2002). Selection of specific habitat characteristics and vegetation communities is variable among the different subspecies of sharp-tailed grouse. Selection of these specific habitats depends on the quality of habitat available to grouse (Johnsgard 1973; Kohn 1976; Swenson 1985; Roersma 2001; Goddard et al. 2009).

Nesting cover is one of the most important habitat types needed by sharp-tailed grouse hens (Manske and Barker 1987, Phillips 1990). Nesting habitat varies widely among the different subspecies of sharp-tailed grouse (Roersma 2001). Hamerstrom Jr. (1939) found the majority of prairie sharp-tailed grouse (*T.p.campestris)* nests occupied dense brush and woods at marsh edges. Gieson and Connelly (1993) reported that Colombian sharp-tailed grouse (*T.p.columbianus*) selected for dense shrub stands with taller, denser shrubs for nest sites. Plains sharp-tailed grouse (*T.p.jamesii*) selected dense residual vegetation with a shrub component for nest sites (Kirby and Grosz 1995; Roersma 2001). However, nest sites are generally characterized by tall, dense residual vegetation (last year's growth) with the presence of woody vegetation either at the nest site or nearby (Manske and Barker 1987; Prose et al. 2002).

Here, we quantify patch selection at a fine scale (readings at nest bowl) and large scale (readings across a transect) based on visual obstruction (VO) by nesting plains sharp-tailed grouse hens on the Grand River National Grassland (GRNG) in Northwestern South Dakota. Consistent with Mayor et al. (2007), we used a geo-statistical analysis, which uses spatially continuous data to represent patterns of heterogeneity at differing scales in habitat assessment. We combined the use of geo-statistical analysis with the disproportionate use of available resources by sharp-tailed grouse. Mayor et al. (2007) looked at similar use of habitat in woodland caribou noting "when animals select for good (and avoid bad) habitat, the variance of selected habitat should be reduced at used sites relative to available sites". We analyzed data with a distance approach using variograms (Matheron 1963), a geostatistical tool that compares variation across pairs of samples at given separation distances (Meisel and Turner 1998; Mayor et al. 2007; Schaefer and Mayor 2007).

We hypothesize that sharp-tailed grouse are selecting for patches of higher VO at nest sites on the GRNG. Our objectives were to: 1) Evaluate sharp-tailed grouse nest site selection based on visual obstruction readings (VOR). 2) Compare the use of semi-variance statistics to the commonly used co-efficient of variation to determine patch selection by sharp-tailed grouse, and 3) Provide an example of how semi-variance statistical techniques can be used by wildlife scientists to evaluate habitat selection and patch size determination.

STUDY AREA

Our study was conducted on the Grand River National Grassland (GRNG) located in northwestern South Dakota in Corson and Perkins counties (Figure 3.1). The GRNG is approximately 62,638 hectares (626.38 km^2) of land owned and managed for multiple uses by the United States Forest Service (USFS) (Olsen 1997). The GRNG is intermingled with private lands consisting of cropland, hay land, idle lands such as Conservation Reserve Program land (CRP), and urban areas (Svingen et al. 2005). Mean annual precipitation was 35.6 cm-45.7 cm in the central and eastern region of our study area with the majority of the precipitation falling from March through July (Figure 3.2; USDA NRCS ESD Database).

The vegetation community is consistent with that of the northern mixed prairie (USFS 2001), described as a wheatgrass-needlegrass ecotype (Barker and Whitman 1989). Commonly encountered graminoids were western wheatgrass *(Pascopyrum smithii)*, green needlegrass *(Nassella viridula)*, needle and thread *(Hesperpstipa comata)*, blue grama *(Bouteloua gracilis)*, and threadleaf sedge *(Carex filifolia)*. Crested wheatgrass *(Agropyron cristatum)*, an introduced species, dominates most of the western pasture allotments of the study area. Crested wheatgrass was introduced in the 1930's to re-seed areas that had been tilled during the drought years of the dust bowl and great depression (Christian and Wilson 1999, Forest Service 2001). Forbs found in the study area includes heath aster *(Symphyotrichum ericoides)*, western ragweed *(Ambrosia psilostachya)*, yellow sweetclover *(Melilotus officinalus)*, and common dandelion *(Taraxacum officinale)*. Woody vegetation found in our study area included western snowberry *(Symphoricarpos occidentalis)*, skunkbrush sumac (*Rhus aromatica*), buffalo berry (*Sherpedia argentea*), chokecherry (*Prunus virginiana*), and silver sagebrush *(Artemisia cana)*.

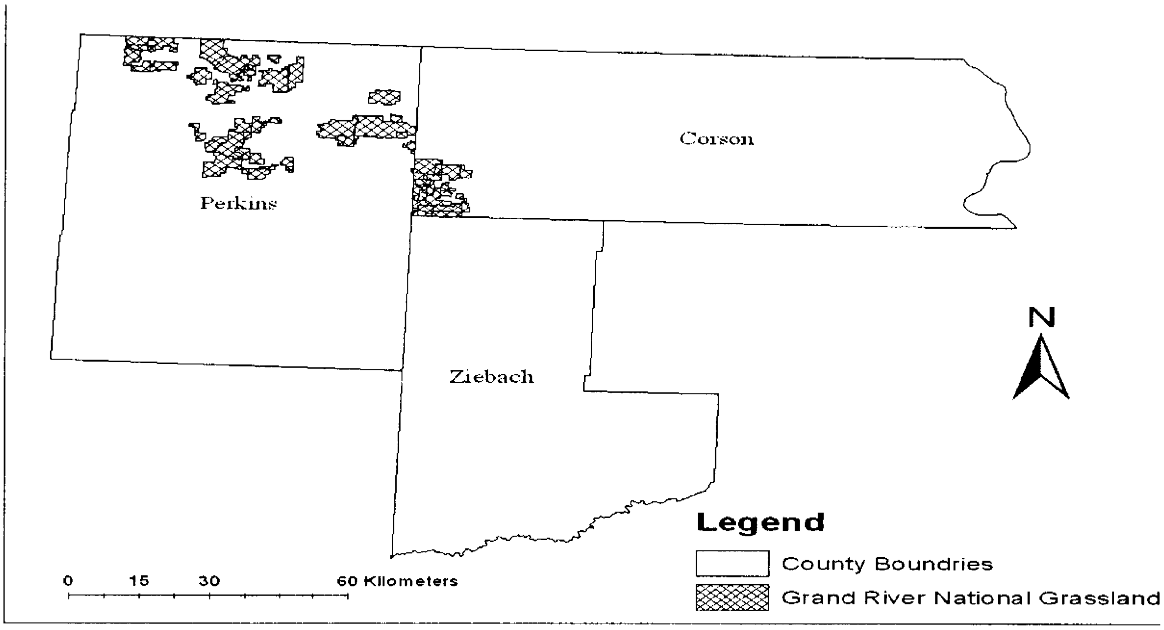


Figure 3.1 The Grand River National Grassland is Corson, Perkins, and Zibach counties in northwestern South Dakota, USA.

The GRNG was formed when large tracts of sub-marginal farm lands were purchased by the federal government between 1933 and 1946 (Wooten 1965). The federal government assessed and monitored sub-marginal farm lands through the National Resource Board, which in 1934 recommended that the federal government purchase 30.4 million hectares of sub-marginal farm land, of which approximately 4.6 million hectares were acquired under the Land Utilization Program (Wooten 1965). All land acquired by the federal government was sold voluntarily by its owners and land titles secured under the provisions of the Emergency Relief and Industrial Recovery Acts and the Bankhead-Jones Farm Tenant Act of the 1930's (Wooten 1965). Of the 4.6 million hectares, 3.8 million hectares were acquired and placed into agricultural land use adjustment projects. In 1961 an estimated 2.8 million hectares were utilized for grazing, 1 million hectares were classified as forest and 728,000 hectares used as parks and wildlife refuges (Wooten 1965).

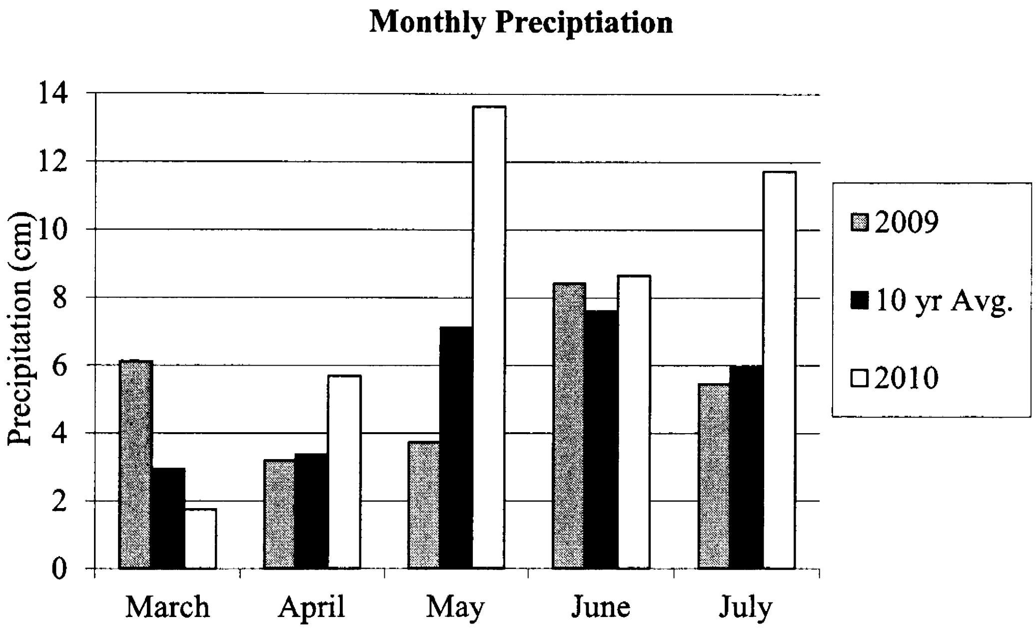


Figure 3.2. Average monthly precipitation for the Grand River National Grasslands for 2009, 2010, and 10 year average. Data provided from the Shadehill, SD climate station monitored by the High Plains Regional Climate Center (Lincoln, NE 68583).

Reclaimed lands were delegated by the Secretary of Agriculture to be managed by the Forest Service in 1954, and on 23 June 1960 1.5 million hectares were designated as "National Grasslands" (Wooten 1965). The Perkins-Corson project was established as the Grand River National Grassland in 1960 (Wooten 1965).

Livestock grazing is an important management tool in achieving desired vegetation and habitat conditions to address rangeland health and other issues (USDA USFS 2006a). The USFS has adopted a modified Robel·pole method (Benkobi et al. 2000) as a means to inventory visual obstruction readings across the GRNG. The VOR is used to assess the amount and distribution of vegetative structure remaining after the grazing season (USDA USFS 2006b). The USFS measures residual biomass in the fall months after the grazing season to determine patterns of use by livestock and nesting structure for ground nesting birds the following spring (USDA USFS 2006a).

METHODS

Data Collection

Female Capture

Female sharp-tailed grouse were captured at lekking sites across the GRNG utilizing techniques described by Toepfer et al. (1987) and Schroeder and Braun (1991). Traps consisted of chicken wire leads that led into larger cylindrical shaped traps made of galvanized fence. Each cylindrical trap had one to three entrances. Traps were placed around the lekking arena in various configurations.

Radio Telemetry Methods

Captured birds were weighed, sexed, and banded with butt-end aluminum leg bands. Female sharp-tailed grouse were fitted with 14 gram necklace style radio transmitters (Advanced Telemetry Systems (ATS); Isanti Minnesota). Radio collared grouse were monitored weekly using handheld three element Yagi antennas and model R2000 receivers (ATS; Isanti Minnesota).

Necklace style radio transmitters were utilized opposed to backpack style or body harness radios to limit the effect of the radios on natural bird movement (Amstrup 1980). The body harness radios were believed to change behavior and lower survival (Amstrup 1980). Marks and Marks (1987) used the body harness radios on Columbian sharp-tailed grouse and observed that the radios did not seem to alter flight but did alter the appearance and sound in flight. Body harness radios are believed to change behavior and lower survival by causing lacerations, restricting mobility, altering natural body weight, and changing body coloration (Amstrup 1980, Marks and Marks 1987). None of these factors seemed to affect grouse that we monitored. Like Amstrup (1980), we visually observed male grouse on lekking grounds displaying and competing for females unhindered by the necklace style radio transmitters. The North Dakota State University Institutional Animal Care and Use Committee approved trapping and handling techniques (Protocol #0929).

Locating and Monitoring Nests

Radio collared birds were located 1-2 times per week from early May to mid-July. A roof mounted di-pole antenna was used to gain a general location of each bird. Once the general location of a bird was determined, a three element Yagi antenna was used to home in on the bird's actual location. We approached birds on foot to minimize disturbance and to reduce the risk of accidently damaging a nest if present. The location at which each bird was found was marked on a hand held Global Positioning System (GPS) unit (Garmin Ltd., Olathe, KS). If a nest was present, the number of eggs was counted, which was used to help determine the approximate day of nest initiation and current status. We estimated the day each nest was initiated assuming 1 egg laid per day and a 23 day incubation period, with incubation commencing on the day the last egg was laid. All nest sites were marked on a hand held GPS unit. Nest sites were monitored every 3-5 days to determine fate (Klett et al. 1988). After the nest hatched or was found depredated, vegetation sampling was conducted at the nest site. A nest was considered successful if at least 1 egg hatched.

Habitat Measurements

Lek Sites

Vegetation structure at lek sites was sampled using a Robel pole method (Robel et al. 1970) as modified by Benkobi et al. (2000). The modified Robel pole was colored in alternating white and grey bands, 2.54 cm in width (Benkobi et al. 2000). The last mark totally obstructed was recorded as the VOR. The VORs were taken at five meter increment along two perpendicular 125 meter transects for a total of 52 VORs per site. The two transects intersected at the lek center. Visual obstruction readings were gathered at each lek site where at least one female was captured. Visual obstruction readings were collected utilizing the same method at distances of 150 m, 500 m, 1000 m, and 1250 m in all cardinal directions from the lek center to determine structure availability for nesting sharp-tailed grouse. Due to the inaccessibility of some private lands, VORs were not collected on private lands. We chose to collect VORs out to 1250 meters based on results reported in the literature which suggest that on average nesting sharp-tailed grouse hens chose nest sites within 1200 m of the lek where copulation occurred (Christenson 1970; Gratson 1988; Phillips 1990; Johnsgard 2002). Furthermore, we chose to collect VORs at the 150 m, 500 m, 1000 m, and 1250 m intervals to eliminate the possibility of transect overlap due to the large size of the sampling transects. We collected a minimum of 25 readings to be adequate enough to sample the semi-variance data. Schaefer and Mayor (2007) collected thirty readings along there transects to adequately measure semi-variance.

Nest Sites

Nest sites were sampled with 125 m x 125 m transects for VOR in a similar fashion as previously described, with the center (62.5 m) directly over the nest bowl. Nests were classified as the "used" sites, while random sites at or around the leks were classified as "available" sites. One VOR was taken with the Robel pole centered inside the nest bowl to obtain a nest bowl specific reading. We considered each nest bowl reading as a micro-site.

Data Analysis

We used Microsoft excel to compile the average VOR at each random and used locations in 2009 and 2010. The two perpendicular transects were averaged together to form one column of averages across both transects. These averages were used to compute standard deviation (SD), standard error (SE), coefficient of variation (CV), and semi-variance (SV) of the VO measurements.

Descriptive Statistics

Each individual Robel reading from available locations was recorded (*n*=7,436) in 2009 and (*n*=6,812) 2010, then plotted against each Robel reading at the nest bowl to plot used [0] vs available [1] at the micro-site level. Then all Robel readings at each transect were averaged together (*n*=143) in 2009 and (*n*=132) 2010. Standard error, SD, and CV were calculated from the overall transect averages

Semi-variance

Semi-variance analysis is a statistical procedure that examines the contribution to the total sample variance (γ) made by half the average variance of all pairs of points that are separated by a specific lag distance (h) (Meisel and Turner 1998; Schaefer and Mayor 2007). The standard equation for SV is:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{n(h)} (x_i - y_i)^2$$

Semi-variance was calculated for the VOR on the average values at each distance of the combined x-shape transects. The use of the average values from the combined transects accounts for anisotropic variation. Semi-variance was calculated for each lag distance where each lag distance is 5 m apart and lag distance 1 = 5m. The SV values were plotted in a semi-variogram.

Semi-variance for each used and available locations were calculated using a geo-statistical analysis program GS+ (Gamma Design Software LLC, Plainwell, MI, USA).

The resulting semi-variograms were fit to the four permissible models normally used in geo-statistical analysis (Goovaerts 1998). These four permissible models were Gaussian, exponential, spherical, and linear. The resulting models were then used to determine if the sites were considered patchy, random, or gradient (Figure 3.3; a, b, and c). Semi-variograms that fit the Gaussian, exponential, and spherical models were determined to be patchy. Semi-variograms that fit the linear model and had a positive slope were considered gradient, while semi-variograms that fit the linear model with a zero slope were considered random. We developed three rules to keep the data consistent: 1) The range was kept at 14 if models were fit to points outside the data range, 2) We limited the number of lags to 17 so the models were not fitting to extreme data points at the transect end, and 3) The R^2 value needed to be ≥ 0.20 to be considered patchy or gradient otherwise the semi-variogram was considered random. Special considerations were given to points that showed a definitive pattern consistent with patchy dynamics if a model did not fit the semi-variance distribution; that is if the R^2 value fell below 0.20, then interpreter discretion was used. We used a chi-square test with Yates correction for small sample size (Zar 1984) to determine if there was a difference among the different categories between year 2009 and 2010.

Coefficient of Variation

The CV was calculated with the SD of the VOR at used and available sites divided by the averages of the VOR. We calculated and plotted the CV between used and available sites to investigate the variability amongst the averages of VOR.

Logistic Regression

We used Proc LOGISTIC in SAS (SAS software version 9.2) to calculate the logistic regression of used vs. available SV values, average VOR, and CV values within the years. Logistic regression tests whether selection of used is different from available and calculates the selection probability. Semi-variance values at lags 1, 7, and 14 were analyzed allowing us to investigate the variability at different scales to determine if sharp-tailed grouse are selecting nest sites based on a particular range of variability in vegetation structure.

We calculated odds ratios and 95% confidence intervals from the logistic analysis if the P-value ≤ 0.05. P-value was calculated from the likelihood statistic. Histogram of the used and available values for all factors were calculated and graphed to provide a visual comparison of what was available versus that being selected for by nesting hens. We fitted a probability of use function curve to the histogram to determine what preference, if any, sharp-tailed grouse had for visual obstruction and its role in selection of nesting habitat across the landscape.

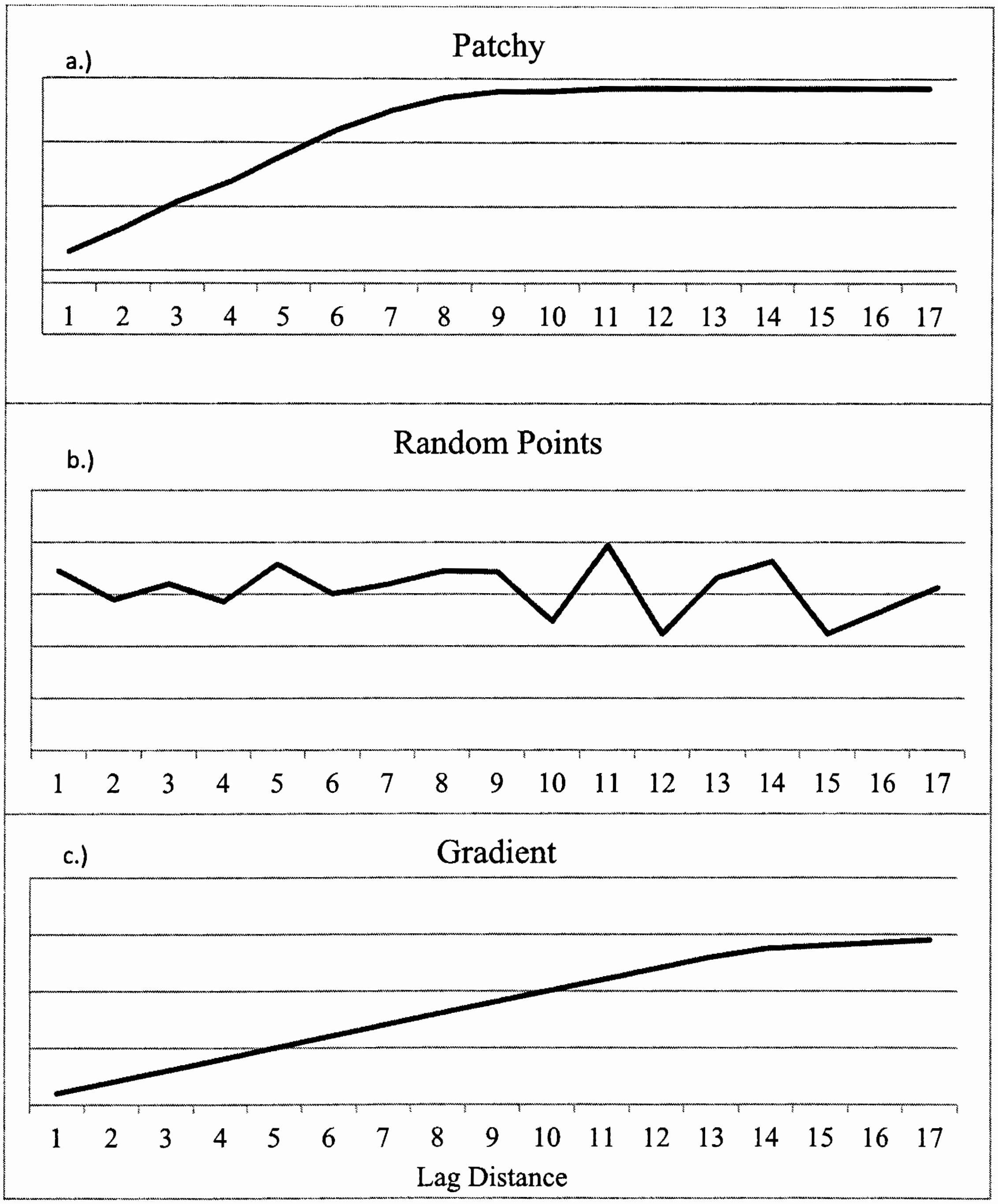


Figure 3.3. a. Patchy distribution of visual obstruction characterized by a rise and plateau, b. Random distribution of visual obstruction characterized by no rise and plateau, just random points, and c. Gradient distribution of visual obstruction characterized by a steady rise with no plateau. Each model above is based off a lag distance of 0-17 as modeled in GS plus geo-statistical software.

RESULTS

Trapping

Trapping of sharp-tailed grouse occurred from 21 April through 12 June 2009 and 15 March through 30 May 2010. Eighty-six sharp-tailed grouse, 29 females and 57 males, were captured at 11 different leks during 2009. In 2010, we trapped 27 females and 50 males on 11 different lekking sites.

During the two year study we successfully collard and monitored 58 female sharp-tailed grouse. In 2009, 62% (18/29) of sharp-tailed grouse initiated a nest. The other females were either non-nesters (2/29), predated (3/29), radio fell off (2/ 29), or left the study area (4/29) and never relocated. In 2010, 67% (18/ 27) of female sharp-tailed grouse initiated a nest. The other hens were either non-nester (1/27), predated (3/27), or left the study area (5/27). Four grouse that initiated nesting in 2010 were hens previously captured and monitored in 2009.

Overall, 73% (41 of 56) of monitored female sharp-tailed grouse initiated a nest in one of the two years of the study. In 2009, four hens initiated a second nest following the predation of their first nesting attempt. One sharp-tailed grouse hen initiated a second nest in 2010. Over the course of the study we did not observe any nest abandonments, with all initiated nests either successful (21/ 41) or predated (20/41).

We collected VOR data at 22 nest location in 2009, with the average nesting distance from lek of capture 1377 m ±305 m (Figure 3.4). We collected VOR data at 24 nest locations in 2010, with the average nesting distance from lek of capture 1250 m ±102 m (Figure 3.4).

Visual Obstruction Readings

Over the two year study, the VOR was analyzed at 237 transects (n=143 in 2009 and n=130 in 2010) at the lek and around leks where female sharp-tailed grouse were captured. We collected and assessed VOR at 46 sharp-tailed grouse nests over the 2 year study period (n=22 in 2009 and n=24 in 2010).

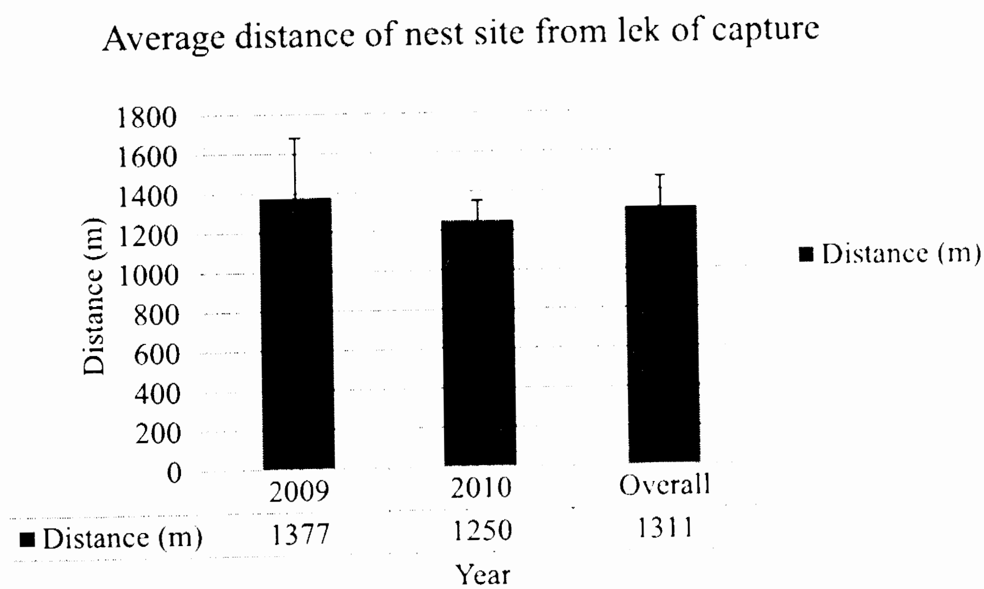


Figure 3.4. Average distance and standard error (SE) of nest sites from lek of capture for 2009, 2010, and overall mean.

Semi-variance

We found available nesting structure showed a uniform semi-variogram distribution (random) with a low spatial variability in direct contrast to what was used in 2009 (Figure 3.5a). Sharp-tailed grouse selected for patchy semi-variogram distribution with high initial viability and patches ranging between lag distances 5 to 11 (25 m-55 m) in size. Available nesting structure showed a patchy semi-variogram distribution of high initial variability and patches ranging between lag distances 13 to 15 (65 m-75 m) in size in 2010, which was a contrast to what was available in 2009 (Figure 3.5a and b.). Sharp-tailed grouse selected for similar semi-variogram distribution at lag distances of 5 to 11 (25 m-75 m) in size during 2010.

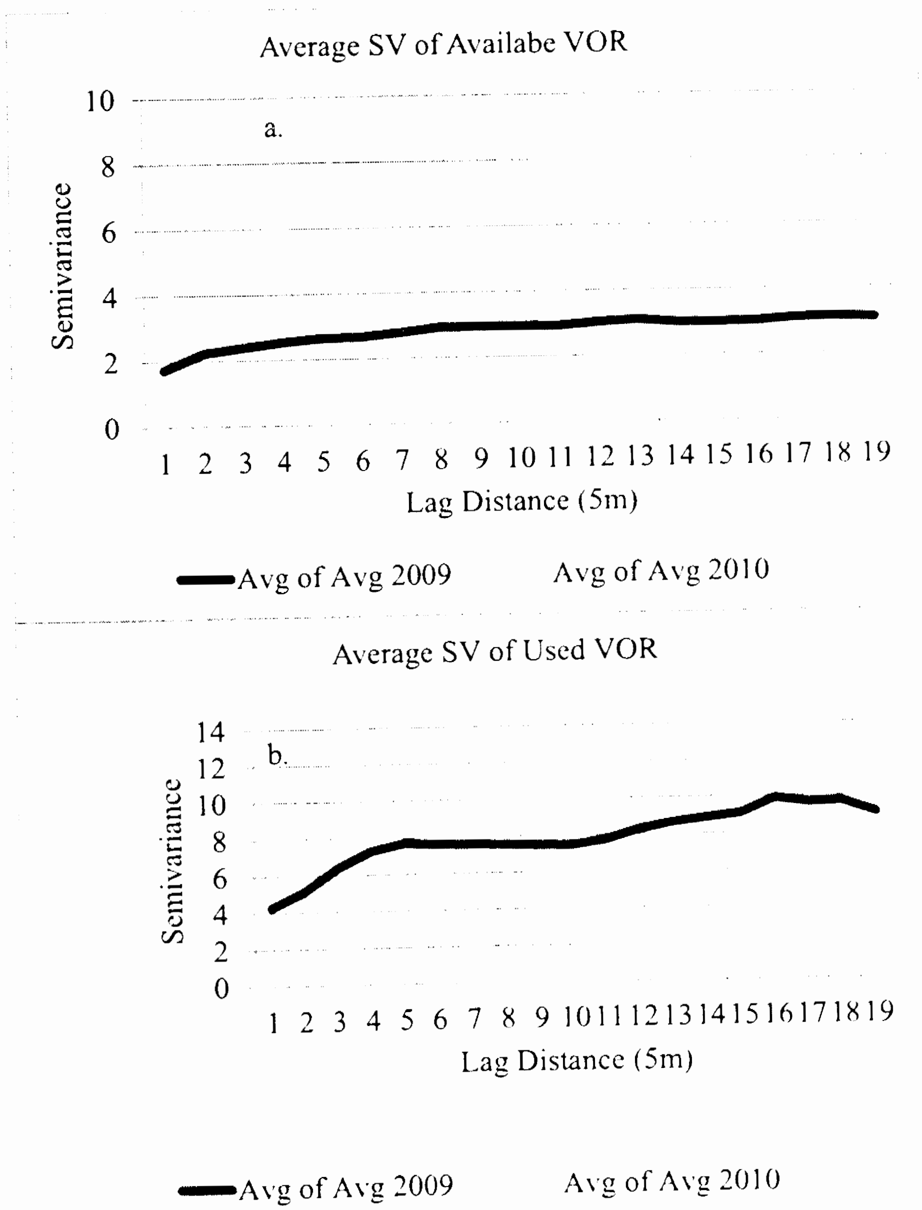


Figure 3.5. a. Average semi-variance for available sites (n=143) in 2009 and (n=130) in 2010, compared to b. used sites (n=22) in 2009 and (n=24) in 2010.

An evaluation of lag distances 1, 7, and 14 showed there was a significant difference ($P \leq 0.05$) at all three lag distances in 2009 (Figure 3.6a: $P \leq 0.01$ lag 1, $P \leq 0.01$

lag 7, and P ≤ 0.01). Unit odds ratios (Table 3.1) showed that sharp-tailed grouse were selecting nesting sites with higher variability and patchiness over the three lag distances compared to what was available in 2009. In 2010, there was no difference (P>0.05) in selection over the three lag distances.

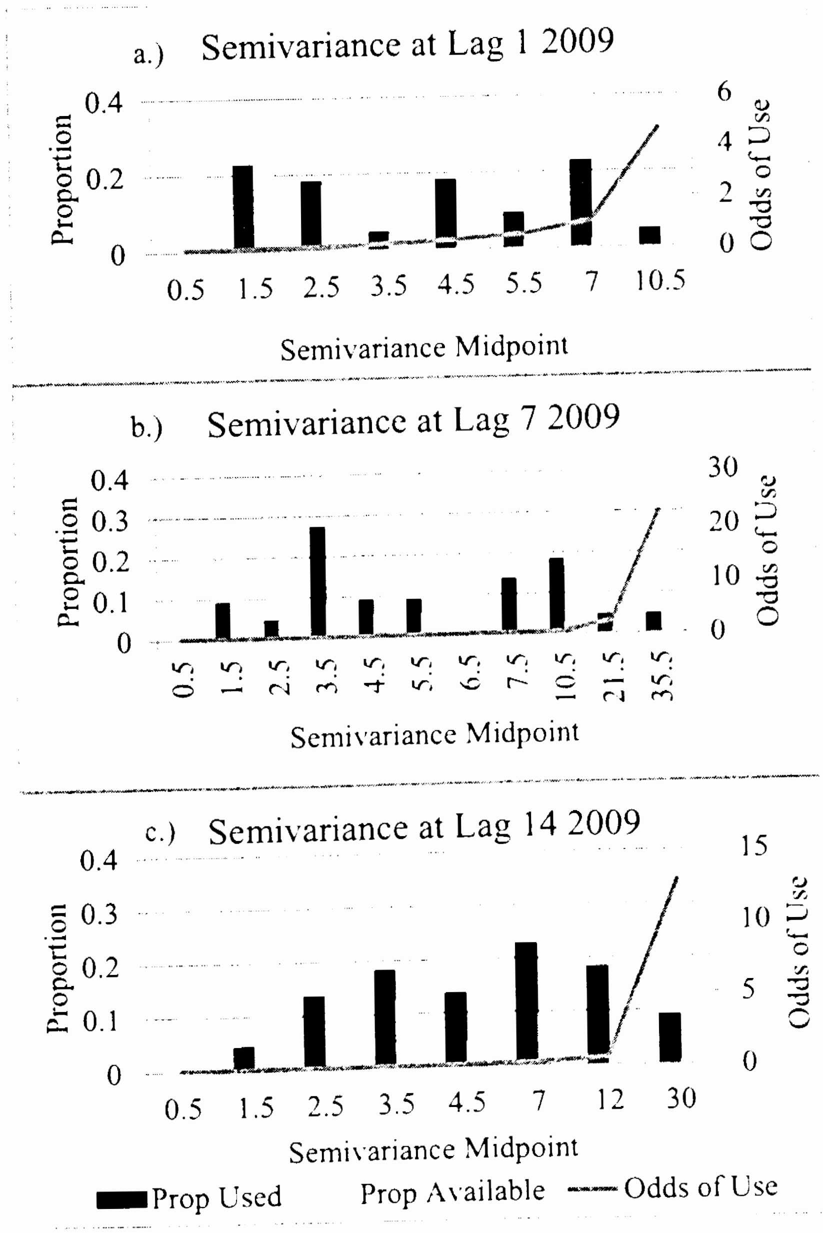


Figure 3.6. a. Semi-variance reading at lag 1 plotted with used vs. available. b. Semi-variance reading at lag 7 plotted with used vs. available, and c. Semi-variance reading at lag 14 plotted with used vs. available.

Table 3.1. Odds ratios (OR), 95% confidence intervals, and P-value from univariate logistic regressions comparing used site readings and available site readings for sharp-tailed grouse on the Grand River National Grasslands in northwest, South Dakota USA in 2009 and 2010.

	2009				2010		
	P Value	OR[a]	95% CI		*P* Value	OR[a]	95% CI
SV Lag 1	≤0.01	1.53	1.21 - 1.94	SV1	0.15	1.08	0.973 - 1.19
SV Lag 7	≤0.01	1.17	1.05 - 1.30	SV7	0.11	1.04	0.991 - 1.09
SV Lag 14	≤0.01	1.19	1.06 - 1.34	SV14	0.06	1.04	0.998 - 1.09
CV	0.03	0.05	0.003-0.75	CV	0.06	0.04	0.002 - 1.13
VOR at nest bowl	≤0.01	1.51	1.38 - 1.66	VOR at nest bowl	≤0.01	1.22	1.150 - 1.29
Avg. VOR across transects	≤0.01	2.89	1.89 - 4.39	Avg. VOR across transects	≤0.01	1.42	1.15 - 1.75

[a]OR >1 indicates a positive relationship and OR <1 indicates a negative relationship between response variable when P-values are ≤0.05.

GS+ Analysis

There was no difference (P>0.05) between patchy, gradient, or random models of SV in 2009 and 2010 (Table 3.2). There was a difference (P≤0.05) in the available distributions between years.

Table 3.2. Number of patchy, gradient, and random models that were created using GS+ software for each year and used vs. available sites that were sampled on the Grand River National Grasslands in northwest, South Dakota USA in 2009 and 2010.

	2009			2010	
	Used Sites	Available Sites		Used Sites	Available sites
Patchy	9	46	Patchy	15	64
Gradient	7	33	Gradient	2	35
Random	6	64	Random	7	37
Total	22	143	Total	24	136

Average VOR

There was a difference between the average heights of VOR used vs. available in 2009 (Figure 3.7; X^2=24.46, $P\leq$ 0.01) and 2010 (Fig. 2.7; X^2=10.76, $P\leq$ 0.01). We fitted the graph with a line which references the USFS management objective of maintaining 8.9 cm of VO following the grazing season (Figure2.7). The histogram was also fitted with an Odds of Use curve. The odds of use increased as VO height increased between years in 2009, with nests having higher VOR (odds ratio 2.89 and $P\leq$0.01) than available sites. In 2010, nests had higher VOR (odds ratio 1.22 and $P\leq$0.01) than available sites.

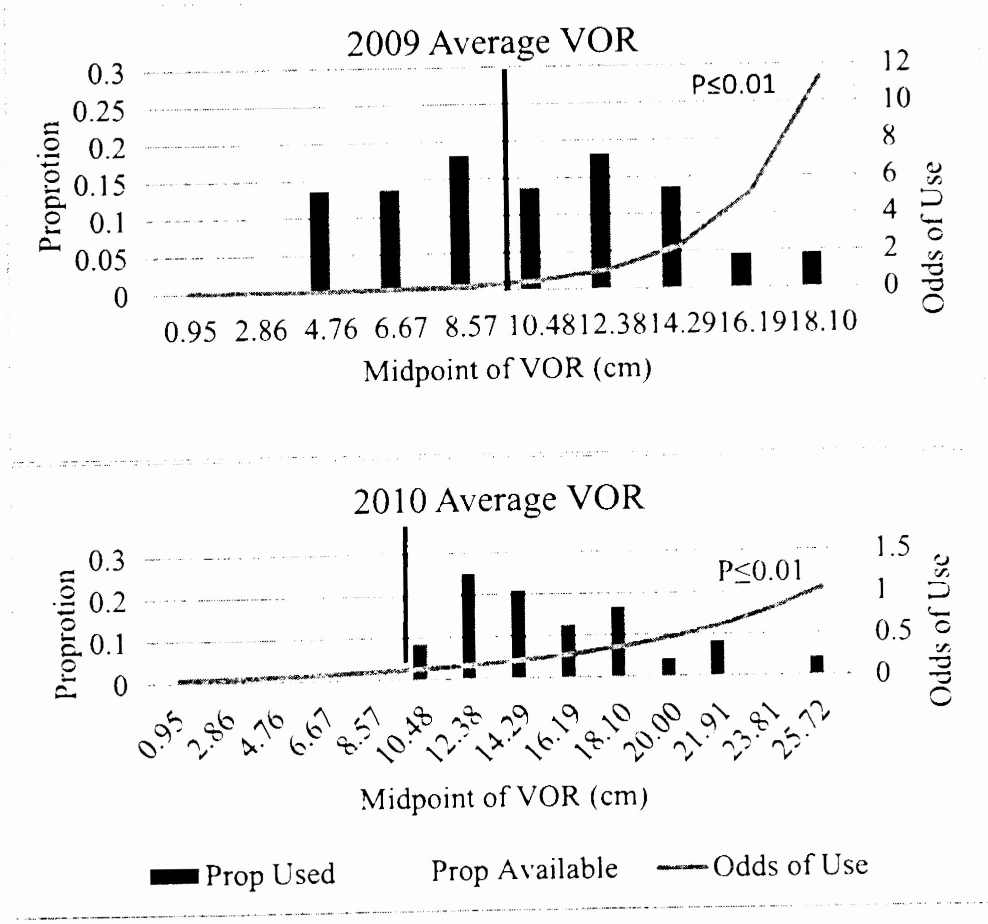


Figure 3.7. Average visual obstruction readings of transects located at sharp-tailed grouse nests for 2009 and 2010. Each graph is fitted with a black vertical line to indicate where the USDA Forest Service mandates 8.89 cm in comparison to used vs. available.

Our investigation of micro-site VO selection showed similar trends in comparison with the averaged transects. In 2009 (Figure 3.8a odds ratio 1.51 $P \leq 0.01$) and 2010 (Figure 3.8b odds ratio 1.22 $P \leq 0.01$), sharp-tailed grouse nest sites had higher VOR than available. Visual obstruction reading at nest bowls averaged 21.16 cm and 26.01 cm in 2009 and 2010 was higher than available sites which averaged 5.81 cm and 11.02 cm; respectively.

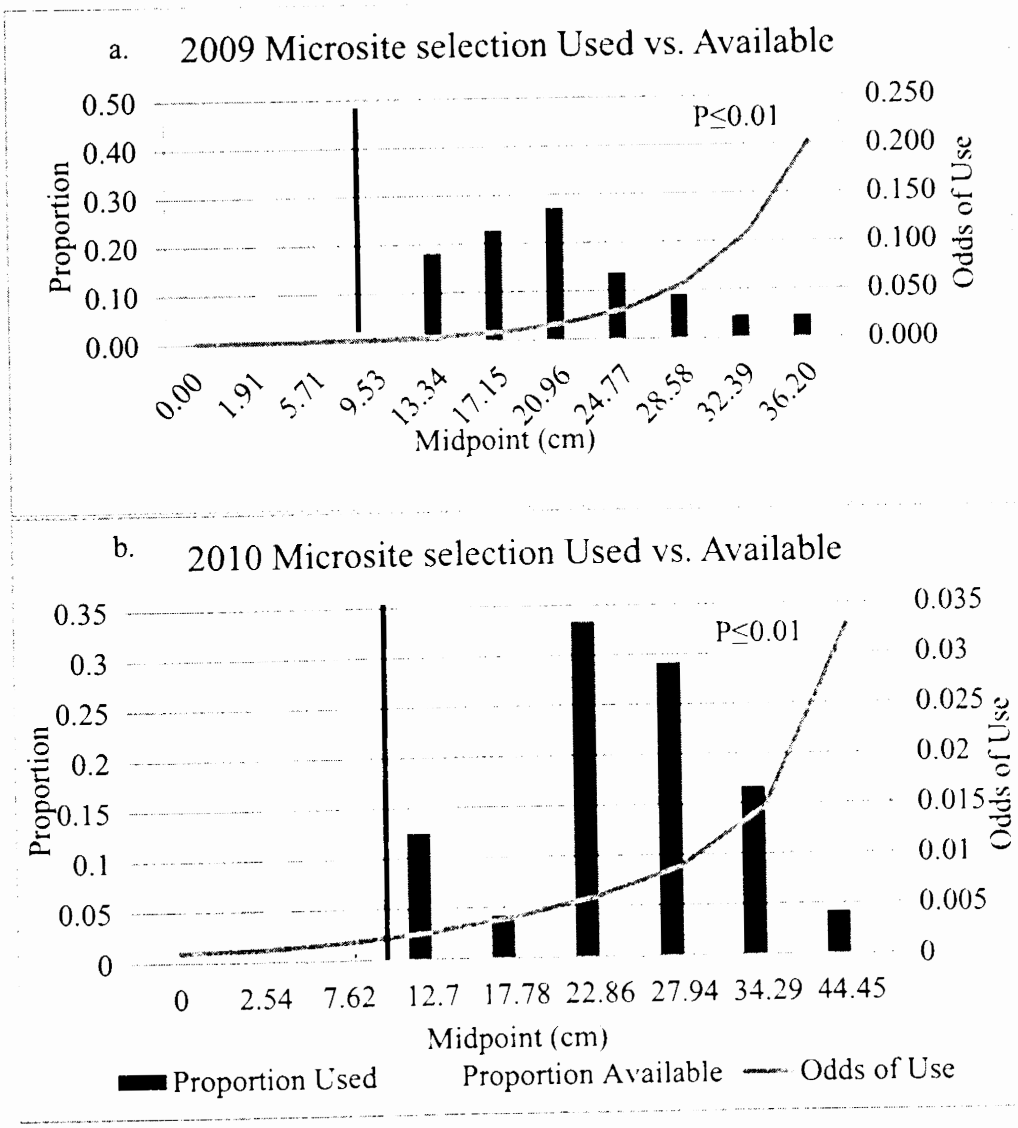
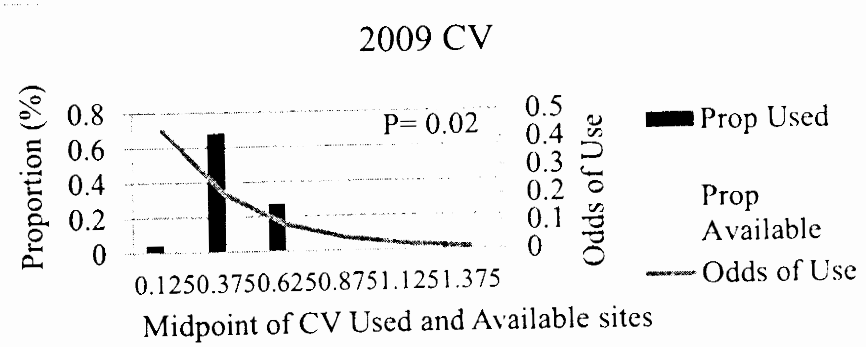


Figure 3.8. Average visual obstruction readings of nest bowls for 2009 and 2010. Each graph is fitted with a black vertical line to indicate where the USDA Forest Service mandate 8.89cm in comparison to used vs. available.

Coefficient of Variation

The CV was calculated for each averaged transect at available and nest sites. We compared the calculations of CV for used to available sites and plotted the results against each other with an odd of use function (Figure 3.9). There was a difference between used and available CV in 2009 (mean CV used 0.42, mean CV available 0.53; $P \leq 0.01$) and in 2010 (mean CV used 0.37, mean CV available 0.44; $P \leq 0.04$). Data showed there was a selection for low CV odds of ratio was 0.05 and 0.04 in 2009 and 2010 respectively, indicating sharp-tailed grouse selected for low variability and uniformity across all transects.



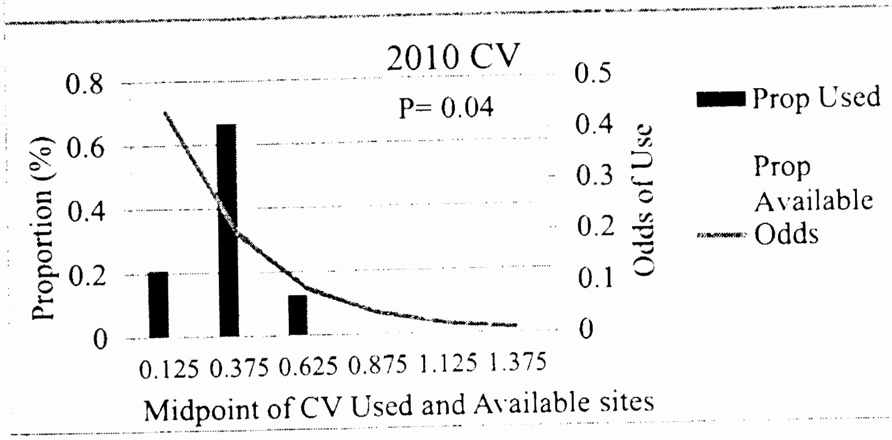


Figure 3.9. Coefficient of variation for 2009 and 2010 comparing proportion used vs. available in both years with the odds of use declining as variability increases along the (X axis).

DISCUSSION

Nesting sharp-tailed grouse selected for areas with higher VO at nest sites in 2009 and 2010. The individual nest sites in 2009 showed a greater increase in the odds of use than in 2010. This was perhaps due to more patches of taller vegetation available to nesting sharp-tailed grouse in 2010 than in 2009. In 2009, sharp-tailed grouse were limited in what was available for patches of dense taller vegetation structure. We believe this was due to higher precipitation levels in 2010, which subsequently resulted in an increase in vegetation production. Vegetation production was at a level that the cattle utilizing the grass for roughage were not able to significantly reduce the vegetation height through grazing. The increased precipitation and low stocking rate created more available high structure patches across the landscape for nesting females to select, as opposed to seeking out patchier stands of vegetation.

The CV is not a good discriminator of variation across distances like the SV analysis. The CV showed that nesting sharp-tailed grouse were selecting for low CV and small scale variability with the odds of use reducing to almost zero for the higher the variability. In contrast, the SV showed that nesting sharp-tailed grouse were selecting for high variability and patchiness across the entire transect as represented in lags 1, 7, and 14. At lag 1 small scale distances, lag 7 mid-range distances, and lag 14 long range distances across the transect, grouse selected for high variability with odds of use increasing as variability increased. What the CV tells managers is to manage the grassland for little to no variation with uniform distribution across the landscape. In contrast, the SV indicates that managing for uniform distribution is not necessary and that grouse will seek out patches of higher VO that is available to them across the grassland.

We compared the CV against the SV to determine which statistical analysis presented data more representative of what was available to nesting sharp-tailed grouse hens across the GRNG. We found the CV gave a poor representation of the vegetation structure. The CV is a point estimator and not a measure of spatial variance. The CV for this study implied that management for VOR should be uniform with little to no variability.

The utilization by sharp-tailed grouse of areas with higher VORs at nest sites has been documented in other parts of their range (Pepper 1972, Kohn 1976, Prose et al. 2002, Goddard et al. 2009). We found there was a difference in selection between VO at the nest site compared to what was available across the landscape. By using the SV analysis to interpret patch selection of nesting sharp-tailed grouse, we were able to detect a definite difference in 2009 between patch selections for nest sites compared to what was available (Figure 1.4a and b). In 2010, we hypothesize that detection of patch selections was inhibited by an increase in precipitation across the landscape that increased the amount of available patches with higher VO compared to 2009.

We believe that the use of a geo-statistical approach to measure variability in data collected based on VO is more beneficial in showing how habitat structure that nesting sharp-tailed grouse select for compared to what is available across the landscape than using just the average VOR data or the CV. The use of averaged data tells the manager what the average height of VOR that the grouse are selecting for, not the variability or patch size that the VOR measurements falls within. The CV is a poor method to utilize when measuring variation across a landscape because it lacks the ability to discriminate between distance variables, giving land managers the wrong impression of what needs to be found across the landscape for structure.

MANAGEMENT IMPLICATIONS

We believe the use of the geo-statistical semi-variance analysis to analyze VOR measured in a spatial manner shows a better representation of the nesting habitat structure than using the averages of the data or the co-efficient of variation. In our case, the co-efficient of variation actually gave us the inverse of what the semi-variance analysis indicated.

Our results suggest that nesting females are selecting for sites with higher VO and patchiness compared to what is available across the landscape. If our results are confirmed by future studies, we recommend that sharp-tailed grouse habitat be managed in a manner that allows for patchiness and random distributions of grass patches with higher VO than found on average across the grassland. The plains sharp-tailed grouse occupies grasslands that include the mixed grass and steppe-like grasslands found in the northern high plains where minimal precipitation limits the land use practice to livestock grazing and small grain cropping systems (Johnsgard 2003). We believe patches and random distribution of VO can be attained through active management strategies that use applications of grazing by livestock and mechanical treatments that alter the vegetation structure in a manner that creates patchiness across the landscape instead of a homogenous height of structure.

ACKNOWLEDGEMENTS

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CHAPTER 4. SURVIVORSHIP OF NESTS, HENS, AND MALES DURING THE BREEDING SEASON[2]

[2] This chapter is co-authored by Dean Houchen . Dr. Benjamin Geaumont and Dr. Kevin Sedivec. Dean Houchen (graduate student) was the main co- author responsible for collecting data, running the statistics, interpreting statistical results, and comprising the information presented in this chapter. Dr. Geaumont provided help with the use and interpretation of the statistical program Program MARK. Both Dr. Geaumont and Dr. Sedivec helped with editing the chapter and added professional insight into the discussion and management suggestion sections.

INTRODUCTION

Sharp-tailed grouse (*Tympanuchus phassianellus*) historically occupied 8 Canadian provinces and 21 U.S. states pre-European settlement (Johnsgard 2002). They ranged from as far north as Alaska, south to California and New Mexico, and east to Quebec, Canada (Johnsgard 2002). Following European settlement, the sharp-tailed grouse has been extirpated from California, Kansas, Illinois, Iowa, Nevada, New Mexico, Oklahoma, and Oregon (Johnsgard 1973; Connelly et al. 1998). Their populations have remained steady in South Dakota were they are still pursued annually by upland game bird hunters. Robel et al. (1972) did a study on sharp-tailed grouse population dynamics where they stated "the sharp-tailed grouse is the most abundant game bird in western South Dakota".

Nesting cover is one of the most important habitat types needed by sharp-tailed grouse hens (Manske and Barker 1987, Phillips 1990). Nesting habitat varies widely among the different subspecies of sharp-tailed grouse (Roersma 2001). Hamerstrom Jr. (1939) found the majority of prairie sharp-tailed grouse (*T.p.campestris)* nests occupied dense brush and woods at marsh edges. Gieson and Connelly (1993) reported that Colombian sharp-tailed grouse (*T.p.columbianus*) selected for dense shrub stands with taller, denser shrubs located at the nest site. Plains sharp-tailed grouse (*T.p.jamesii*) selected nest sites with dense residual vegetation and a shrubby component (Kirby and Grosz 1995; Roersma 2001). However, nest sites are usually characterized by dense tall residual vegetation (last year's growth) with the presence of woody vegetation either at the nest site or nearby (Manske and Barker 1987; Prose et al. 2002).

Understanding nest success and the identification of factors that contribute to nest success are two growing concepts receiving increased attention in prairie grouse studies.

One reason is due to the potential rate of predation on prairie grouse nest (40-60% Phillips 1990). Riley et al. (1992) reported a loss of 65% of nests to predators in a study on lesser prairie chickens (*T. pallidicintus*) in New Mexico. McKee et al. (1998) reported a 35% mean nest success rate over a 3-year study on greater prairie chickens (*T. cupido*) in southwestern Missouri. Nest success of greater sage grouse (*Centrocercus urophasianus*) has been reported in a range from 15-86% (Schroeder et al. 1999; Schroeder and Baydeck 2001; Kolada et al. 2009). Sharp-tailed grouse nesting success has been reported at 50-72% (Schroeder and Baydeck 2001).

Sharp-tailed grouse nesting success has been linked to the presence of shrubs, dense concealment cover, tall residual VOR, and reduced presence of croplands (Prose et al. 2002; Manzor and Hannon 2005; Goddard et al. 2009). Manzer and Hannon (2005) reported a 47% nest success rate of 107 nests in a three-year study conducted in southeastern Alberta, Canada. They noted that nests were four times more likely to succeed in areas with less than 10% crop cover and less than 35% crop and sparse grassland. Goddard et al. (2009) reported a nest success of 43% for 62 nests over a 2-year study in British Columbia, Canada. Of the candidate models that included habitat variables, the best model of nest survival included vertical and grass cover as important covariates (weight 0.21; Goddard et al. 2009).

This experiment studied nest survival of plains sharp-tailed grouse (*T.p. jamesi*) on the Grand River National Grasslands (GRNG) in northwest South Dakota, during the nesting seasons of 2009 and 2010. These sharp-tailed grouse are of interest because they are used by the United States Forest Service (USFS) as an indicator species for grassland health (USDA-USFS 2001). Our study objectives were: 1) Estimate nest survival rates of sharp-tailed grouse on the GRNG in northwestern South Dakota and evaluate the effects of abiotic and biotic factors on those rates, and 2) Estimate survival of male and female grouse during the nesting season. We hypothesized shrubs would be utilized by nesting sharp-tailed grouse as was noted by Goddard et al. (2009). Denser and taller vegetation was also predicted to be a key component to nest site selection (Prose 1987; Manske and Barker 1987; Connelly et al. 1998). We also included visual obstruction as a potential variable of interest due, in part, to its importance as a management tool for grassland management (USDA-USFS 2006a).

STUDY AREA

Our study was conducted on the Grand River National Grasslands (GRNG) located in northwestern South Dakota in Corson and Perkins counties (Figure 4.1). The GRNG is approximately 62,638 hectares (626.38 km^2) of land owned and managed for multiple uses by the United States Forest Service (USFS) (Olsen 1997). The GRNG is intermingled with private lands consisting of cropland, hay land, idle lands such as conservation reserve land (CRP), and urban areas (Svingen et al. 2005). Mean annual precipitation was 35.6 cm-45.7 cm in the central and eastern region of our study area with the majority of the precipitation falling from March through July (Figure 4.2; USDA NRCS ESD Database).

The vegetation community is consistent with that of the northern mixed prairie (USDA-USFS 2001), described as a wheatgrass-needlegrass ecotype (Barker and Whitman 1989). Commonly encountered graminoids were western wheatgrass *(Pascopyrum smithii)*, green needlegrass *(Nassella viridula)*, needle and thread *(Hesperpstipa comata)*, blue grama *(Bouteloua gracilis)*, and threadleaf sedge *(Carex filifolia)*. Crested wheatgrass *(Agropyron cristatum)*, an introduced species, dominates most of the western pasture allotments of the study area. Crested wheatgrass was introduced in the 1930's to re-seed areas that had been tilled during the drought years of the dust bowl and great depression (Christian and Wilson 1999; USDA-USFS 2001). Forbs found in the study area includes heath aster *(Symphyotrichum ericoides)*, western ragweed *(Ambrosia psilostachya)*, yellow sweetclover *(Melilotus officinalus)*, and common dandelion *(Taraxacum officinale)*. Woody vegetation found in our study area included western snowberry *(Symphoricarpos occidentalis)*, skunkbrush sumac (*Rhus aromatica*), buffalo berry (*Sherpedia argentea*), chokecherry (*Prunus virginiana*), and silver sagebrush *(Artemisia cana)*.

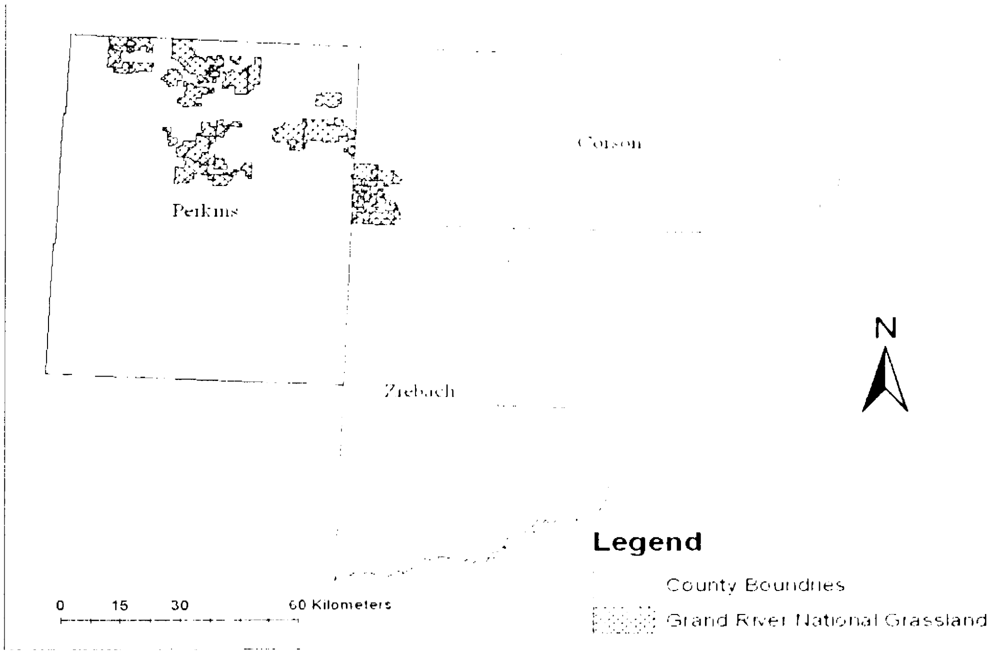

Figure 4.1. The Grand River National Grasslands in Corson, Perkins, and Zibach counties in northwestern South Dakota, USA.

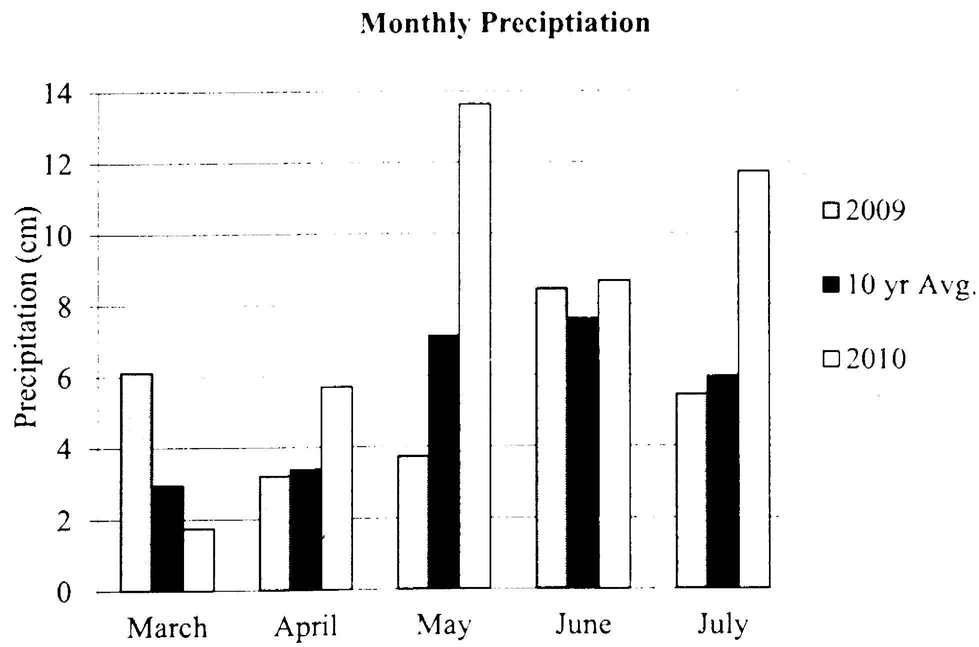

Figure 4.2. Average monthly precipitation for the Grand River National Grasslands for 2009, 2010, and 10 year average. Data provided from the Shadehill, SD climate station monitored by the High Plains Regional Climate Center (Lincoln, NE 68583).

The GRNG was formed when large tracts of sub-marginal farm lands were purchased by the federal government between 1933 and 1946 (Wooten 1965). The federal government assessed and monitored sub-marginal farm lands through the National Resource Board, which in 1934 recommended that the federal government purchase 30.4 million hectares of sub-marginal farm land, of which approximately 4.6 million hectares were acquired under the Land Utilization Program (Wooten 1965). All land acquired by the federal government was sold voluntarily by its owners and land titles secured under the provisions of the Emergency Relief and Industrial Recovery Acts and the Bankhead-Jones Farm Tenant Act of the 1930's (Wooten 1965). Of the 4.6 million hectares, 3.8 million hectares were acquired and placed into agricultural land use adjustment projects. In 1961 an estimated 2.8 million hectares were utilized for grazing, 1 million hectares were classified as forest, and 728,000 hectares were used as parks and wildlife refuges (Wooten 1965).

Reclaimed lands were delegated by the Secretary of Agriculture to be managed by the USFS in 1954, and on 23 June 1960, 1.5 million hectares were designated as "National Grasslands" (Wooten 1965). The Perkins-Corson project was established as the GRNG in 1960 (Wooten 1965).

Livestock grazing is an important management tool in achieving desired vegetation and habitat conditions to address rangeland health and other issues (USDA USFS 2006a). The USFS has adopted a modified Robel pole method (Benkobi et al. 2000) as a means to inventory Visual Obstruction Readings (VOR) across the GRNG. The VOR is used to assess the amount and distribution of vegetative structure remaining after the grazing season (USDA USFS 2006b). The USFS measures residual biomass in the fall months after the grazing season to determine patterns of use by livestock and nesting structure for ground nesting birds the following spring (USDA USFS 2006a).

METHODS

Data Collection

Trapping

Sharp-tailed grouse were captured at lekking sites across the GRNG utilizing techniques described by Toepfer et al. (1987) and Schroeder and Braun (1991). Traps consisted of chicken wire leads, which led into larger cylindrical shaped traps made of galvanized fence. Each cylindrical trap had one to three entrances. Traps were placed around the lekking arena in various configurations.

Radio Telemetry Methods

Captured birds were weighed, sexed, and banded with butt-end aluminum leg bands. All female and randomly selected male sharp-tailed grouse were fitted with 14 gram necklace style radio transmitters (Advanced Telemetry Systems (ATS); Isanti Minnesota). Radio collared grouse were monitored weekly using handheld three element Yagi antennas and model R2000 receivers (ATS; Isanti Minnesota).

Necklace style radio transmitters were utilized opposed to backpack style or body harness radios to limit the effect of the radios on natural bird movement (Amstrup 1980). The body harness radios were believed to change behavior and lower survival (Amstrup 1980). Marks and Marks (1987) used the body harness radios on Columbian sharp-tailed grouse, observing that the radios did not seem to alter flight, but they did alter the appearance and sound in flight. Body harness radios are believed to change behavior and lower survival by causing lacerations, restricted mobility, altering natural body weight, and changing body coloration (Amstrup 1980, Marks and Marks 1987). None of these factors seemed to affect any of the grouse that we monitored. Like Amstrup (1980), we visually observed male grouse on lekking grounds displaying and competing for females unhindered by the necklace style radio transmitters. The North Dakota State University Institutional Animal Care and Use Committee approved trapping and handling techniques (Protocol #0292).

Locating and Monitoring Nest

Radio collared birds were located 1-2 times per week from early May to mid-July. A roof mounted di-pole antenna was used to gain a general location of each bird. Once the general location of a bird was determined, the three element Yagi antenna was used to home in on the bird's actual location. We approached birds on foot to minimize disturbance and to reduce the risk of accidently damaging a nest if present. The location at which each bird was found was marked on a hand held Global Positioning System (GPS) unit (Garmin Ltd., Olathe, KS). If a nest was present, the number of eggs was counted and this data was used to determine the approximate day of nest initiation and the current stage of each nest. We estimated the day each nest was initiated assuming one egg laid per day and a 23 day incubation period, with incubation commencing on the day the last egg was laid. All nest sites were marked on the GPS. Nest sites were monitored every 3-5 days to determine fate (Klett et al. 1988). After the nest hatched or was found depredated, vegetation sampling was conducted at the nest site. A nest was considered successful if ≥ 1 egg hatched.

Nest Site Vegetation Sampling

Nest vegetation was sampled using the Robel pole method (Robel et al. 1970) as modified by Benkobi et al. (2000) to obtain VORs. Nests were sampled using 24 by 24 m transects with tape measures stretched in the North/South (NS) and East/West (EW) cardinal directions with the middle (12.5 m) falling directly over the nest bowl. VORs and maximum vegetation height measurements were recorded at two meter increments along two perpendicular 25 meter transect for a total of 26 readings per site. The two transects intersected with one another at nest center. One VOR reading was taken directly at the nest bowl, with the Robel pole placed directly in the center of the nest bowl. This sample made up the nest Robel readings.

A one m^2 frame was used to estimate canopy cover by plant species, bare ground, and litter cover at the nest site by ocular estimates along each 24 m by 24 m transect using a modified Daubenmire technique (Daubenmire 1959). The modification was the use of a one m^2 frame versus a Daubenmire frame and classes were 0-100% for each parameter recorded. Ocular estimates were replicated every two m from NS and EW (n=26).

Data Analysis

Nest Survival and Modeling

We estimated the daily survival rate (DSR) for nests using program MARK (White and Burnham 1999) for the 35 day incubation period. We standardized the nesting season among years with the first day of the nesting season being 18 May and last day 17 July for a 61 day nesting season. May 18 represents the first day we observed a nest and 17 July represents the last day a nest was monitored over the two year study. Nest age (in days) was then coded relative to 18 May. Incubation period (35 days) was based off of an average clutch size of 12 eggs laid and an egg a day with a 23 day incubation period.

Factors Influencing Nest Survival

We used the nest analysis tool in program MARK (White and Burnham 1999) to estimate nest survival probabilities from continuous habitat variables. Continuous habitat variables included maximum vegetation height, grass cover, forb cover, shrub cover, grass like vegetation cover, litter cover (LC), bare ground (BG), VOR at nest bowl, and transect VOR. Time dependent variables included nest age, minimum and maximum daily temperature, and daily precipitation. Models within two units of the minimum Akaike's Information Criterion corrected (AICc) were considered best approximating models explaining variation of nest survival data (Burnham and Anderson 1998). We compared variables with constant DSR using the Akaike's Information Criterion corrected for small sample size (AICc; Akaike 1973; Burnham and Anderson 2002).

Male and Female Survival

We estimated survival of male and female sharp-tailed grouse during the nesting season with the program MARK known fate model. Models were created based on constant survival, sex, year, and sex plus year.

RESULTS

Trapping

Trapping of sharp-tailed grouse occurred from 21 April through 12 June in 2009 and 15 March through 30 May during 2010. Eighty-six sharp-tailed grouse (29 females and 57 males) were captured at eleven different leks during 2009. In 2010, we trapped 27 females and 50 males on 11 different lekking sites. During the two year study, 163 sharp-tailed grouse were captured across the GRNG (56 females and 107 males), with 100 sharp-tailed grouse (56 females and 44 males), collard and monitored.

Nest Attempt

In 2009, 62% (18/29) of the female sharp-tailed grouse collard initiated a nest. The other females were either non-nesters (2/29), predated (3/29), radio fell off (2/ 29), or left the study area (4/29) and never relocated. In 2010, 67% (18/ 27) of the female sharp-tailed grouse collard initiated a nest. The other hens were either non-nesters (1/27), predated (3/27), or left the study area (5/27). Four of the grouse that initiated nesting in 2010 were hens previously captured and monitored in 2009.

Overall, 73% (41 of 56) of monitored female sharp-tailed grouse initiated a nest in one of the two years of the study. Four and one hen re-nested in 2009 and 2010, respectively. Over the course of the study we did not observe any nest abandonments, with all initiated nests either successful (21/ 41) or predated (20/41).

Nest Initiation

Estimated first nest initiation dates in 2009 ranged from 28 April to 12 June, with a mean initiation date 15 May. Estimated first nest initiation dates in 2010 ranged from 26

April to 4 June, with a mean initiation date of 11 May. Nesting in 2010 was two days earlier and last nest initiated was eight days earlier compared to 2009. Mean initiation date was 4 days earlier in 2010 compared to 2009. Overall range of first nest initiation dates during the two year study was 26 April to 12 June, with a mean initiation date of 13 May (Table 4.1). Overall average clutch size of first nest initiators was 12.2 eggs ±0.4. Overall mean initiation dates for re-nesters over the two year study was 11 June, with an average clutch size of 12 eggs.

Table 4.1. Average first nest and re-nest initiation dates with average hatch date and clutch size for nesting sharp-tailed grouse on the Grand River National Grasslands in northwestern South Dakota, USA.

	First Nest			Re-nest		
year	Initiation date	Hatch Date[a]	Clutch size	Initiation date	Hatch Date[b]	Clutch Size
2009	15 May n=18	18 June n=9	11.8±0.49 n=18	7 June n=4	11 July n=1	12±0.41 n=4
2010	11 May n=23	13 June n=10	12.6 ±0.44 n=23	16 June n=1	17 July n=1	12 n=1
Overall	13 May n=41	16 June n=19	12.2±0.4 n=41	11 June n=3	14 July n=3	12±0.41 n=5

Hatch Date[a] Figured for successful first nesters
Hatch Date[b] Figured for successful re-nestes

Nest Site Distance from Lek of Capture

We collected vegetation data at 22 nest locations with the average nesting distance from lek of capture 1377 m ±305 m in 2009. In 2010, we collected vegetation data at 24 nest locations with the average nesting distance from lek of capture 1250 m ±102 m. Successful nests (n= 10) averaged 846 m±139 m from lek of capture, with unsuccessful nests (n=12) averaging 1820 m ± 522 m from lek of capture in 2009. Successful nests averaged 1209 m±181 m (n=11) from lek of capture and unsuccessful nest averaging 1284 m ± 117 m (n=13) from lek of capture in 2010. On average for both years, the average distance of successful nests (n=21) was 1036m±120m from lek of capture while unsuccessful nests (n=25) averaged 1541 ± 258 m away from lek of capture (Figure 4.3).

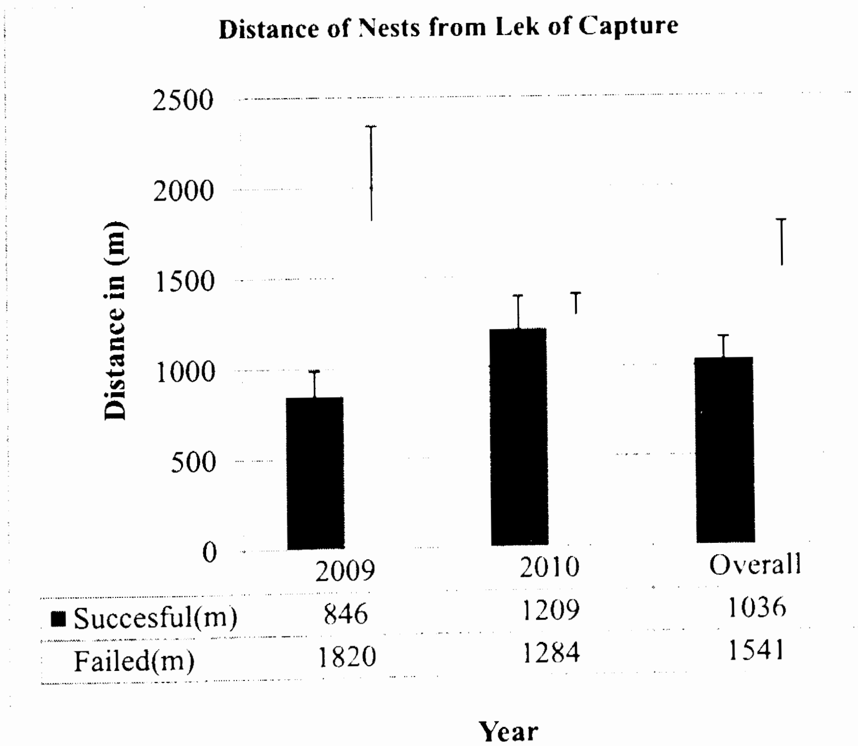

Figure 4.3. Mean distance and standard error from lek of capture to nest site of failed and successful nests on the Grand River National Grasslands in NW South Dakota.

Nest Survival and Modeling

Nest survival was 29% and 31% in 2009 and 2010, respectfully. Overall nest success was 30%. Of the general models constructed, the constant model (weight = 0.72) that did not include year was the most supported.

Nest Survival and Vegetation Characteristics

Of the candidate models that included habitat variables, the best model of nest survival included maximum vegetation height (64.44 cm in 2009 and 51.29 cm in 2010; Table 4.2) and grass canopy cover (weight = 0.61097). This model had 7.3 times more support and was 3.98 AICc units better than the second best model which contained grass canopy cover only (Table 4.3). Other variables that were measured and modeled were average transect VOR, percents of litter cover, bare ground, shrubs, forbs, and grass like plants (Table 4.2). Sharp-tailed grouse nest survival increased with increasing vegetation height and grass canopy cover (Figure 4.4). The estimate from the best model for the additive effect of maximum height on survival of sharp-tailed grouse nests was positive; β= 0.039 (1 se = 0.05, 95% CL = 0.02, 0.22) on a logit scale. The estimate from the best model for the additive effect of grass on nest survival was positive; β 0.039 (1 se = 0.016, 95% CL = 0.007, 0.07) on a logit scale. The remaining models had delta AICc values of greater than two and therefore, did not receive substantial support (Burnham and Anderson 2002).

Table 4.2. Total average of vegetation variables and standard error measured in 2009 and 2010 on the Grand River National Grasslands in northwestern South Dakota, USA.

Year	Transect VOR (cm)	Veg. Max. ht. (cm)	LC (%)	BG (%)	Grass (%)	Forbs (%)	Shrubs (%)	Grass-like (%)
	10.46	64.44	2.94	14.91	43.96	18.45	6.79	11.81
2009	±1.04	±2.58	±0.60	±1.72	±3.39	±1.62	±1.88	±1.99
	15.69	51.59	12.26	2.96	54.83	18.92	2.97	7.91
2010	±0.64	±2.35	±1.06	±0.80	±2.71	±2.05	±1.05	±1.99

The constant survival model received more support than any model that included a time dependent variable (weight = 0.2557; Table 4.4). The constant model had 1.8 times more support than the next best model which included a linear trend of time (date). Many of the other time dependent covariate models had ΔAIC_c values of less than two. Adding the covariate date to the most well supported vegetation model did not improve model fit (Table 4.5).

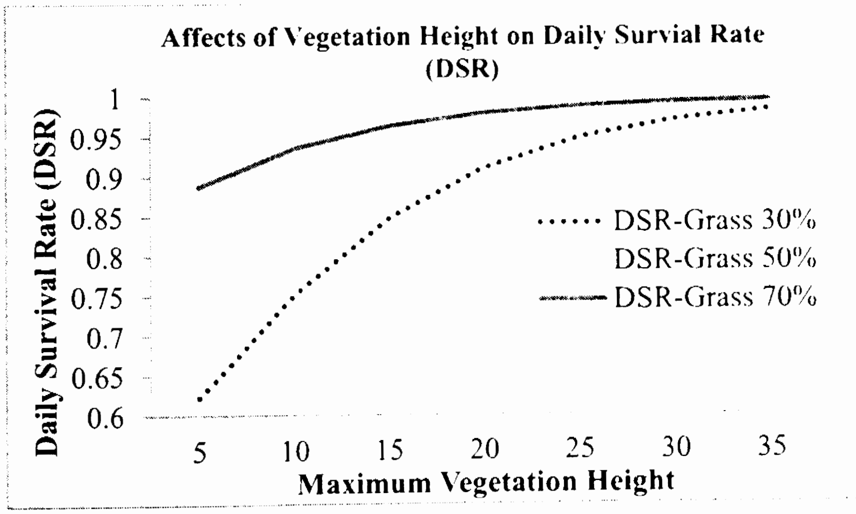

Figure 4.4. Daily survival rate as a function of vegetation height (%) and grass canopy cover on the Grand River National Grasslands in northwestern South Dakota, USA.

Male and Female Survival

Male and female survival was monitored through the nesting season. The best model for sharp-tailed grouse survival during the nesting season contained the variable for sex (weight=0.38; Table 4.6), but was only slightly better than the constant survival model (weight=0.35). The year and sex model also had a ΔAIC value of less than two and was the third best model. Male survival was 49 percent and female survival was 65 percent based off estimates from the best fit model.

Table 4.3. Results for nest survival models including habitat variables for sharp-tailed grouse nesting on the Grand River National Grasslands in northwestern South Dakota, USA in 2009 and 2010.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{S(MXHT + Grass)}	144.6685	0	0.61097	1	3	138.6336
{S(Grass)}	148.6446	3.9761	0.08368	0.1370	2	144.6272
{S(MXHT)}	148.8013	4.1328	0.07737	0.1266	2	144.7839
{S(.)}	149.6478	4.9793	0.05067	0.0829	1	147.6420
{S(NSTROBEL)}	150.5196	5.8511	0.03277	0.0536	2	146.5022
{S(Forbs)}	150.6320	5.9635	0.03098	0.0507	2	146.6146
{S(GRASSLIKE)}	150.8863	6.2178	0.02728	0.0447	2	146.8689
{S(BG)}	150.9075	6.2390	0.02699	0.0442	2	146.8901
{S(TRNROBEL)}	151.4669	6.7984	0.02041	0.0334	2	147.4494
{S(LC)}	151.4764	6.8079	0.02031	0.0332	2	147.4589
{S(Shrubs)}	151.6563	6.9878	0.01856	0.0304	2	147.6389

S=Survival
S(.)=Constant Survival
{S(MXHT + Grass)} = Survival based on max grass height
{S(Grass)} Survival based on grass percentage
{S(MXHT)} =Max vegetation height
{S(NSTROBEL)} Survival base on nest VOR averages
{S(Forbs)} Forb habitat component
{S(GRASSLIKE)}Grass like vegetation habitat component
{S(BG)} Bare ground habitat component
{S(TRNROBEL)} Survival base on Transect VOR averages
{S(LC)} Litter cover habitat component
{S(Shrubs)} shrub habitat component

Table 4.4. Results for nest survival models of sharp-tailed grouse including time-dependent variables in northwestern South Dakota, USA.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{S(.)}	149.6478	0	0.25570	1	1	147.6420
{S(Date)}	150.8645	1.2167	0.13916	0.5442	2	146.8471
{S(MaxTemp)}	151.0183	1.3705	0.12886	0.5040	2	147.0008
{S(Date + MAXTemp)}	151.0825	1.4347	0.12479	0.4880	3	145.0476
{S(Nest AGE)}	151.3726	1.7248	0.10794	0.4221	2	147.3552
{S(MinTemp)}	151.5727	1.9249	0.09766	0.3819	2	147.5553
{S(Precip)}	151.6270	1.9792	0.09505	0.3717	2	147.6096
{S(Date + Quad)}	152.8787	3.2309	0.05083	0.1988	3	146.8438

S(.)=constant survival
S(Date)=Nest success varies across the nesting season
S(MaxTemp)=Nest success as a function of daily maximum temps by year
S(NestAge)=Nest survival varies with nest age
S(MinTemp)=Nest survival as a function of daily minimum temps by year
S(precip)=Nest Survival as a function of daily precipitation by year
S(Date + Quad)=Nest success varies in a quadratic fashion across the nesting season

Table 4.5. Results for nest survival models of sharp-tailed grouse including the best supported co-variables from the time-dependent and vegetation models in northwestern South Dakota, USA.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{S(MXHT + GRASS)}	144.6685	0	0.56734	1	3	138.6336
{S(MXHT + GRASS + Date)}	145.4408	0.7723	0.38560	0.6797	4	137.3826
{S(.)}	149.6478	4.9793	0.04705	0.0829	1	147.6420

{S(MXHT + GRASS)} Max height of vegetation and Grass canopy cover
{S(MXHT + GRASS + Date)} Max height of vegetation and Grass canopy cover with variation of nest success across nesting season
{S(.)} Constant Survival

Table 4.6. Results for adult survival constant variables of sex, constant survivorship, and year on the Grand River National Grasslands in northwestern South Dakota, USA.

Model	AICc	ΔAICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{S(sex)}	244.8613	0	0.37973	1	2	240.8353
{S(constant)}	245.0214	0.1601	0.35051	0.9231	1	243.0127
{S(year + sex)}	246.8560	1.9947	0.14006	0.3688	3	240.8037
{S(year)}	247.0098	2.1485	0.12970	0.3416	2	242.9838

{S(sex)}= Sex comparison of survival
{S(constant)}= Constant survival
{S(year + sex)}= Year and sex
{S(year)}=Survival based on year

DISCUSSION

Seventy three percent of our collard hens initiated a nest with an average clutch size of 12 eggs and a mean initiation date of 13 May. These findings are consistent with Kirby and Grosz (1995) in North Dakota and Hammerstom (1939) in Minnesota. Connelly et al. (1998) reported peak lek attendance by female's occurred in late April to mid-May with one to three day nest initiation following copulation. Sharp-tailed grouse on the GRNG showed a similar trend with nest initiation generally occurring in May. Females nest site initiation averaged 1350 m from breeding leks in this study. Other studies have theorized to the importance of nesting within 1200 m of the lek (Christenson 1970; Gratson 1988; Phillips 1990; Johnsgard 2002). We believe that females selected nest sites close to lek of copulation because nesting structure was more preferential than adjacent areas. Roersma (2001) believed that sharp-tailed grouse moved further away from the lek because shrub patches were covered by an unseasonable snow storm on the Milk River Ridge in southern Alberta, Canada.

Females may also nest close to leks because the males could act as sentinels (lookouts) or decoys to predators approaching the lek, so females nesting close to the lek would go undetected (Phillips 1990). This might be an explanation why female survivorship in our study area was 16% higher than males (65% for females and 49% for males). Our study findings were lower in comparison to Roersma (2001) who reported 77% hen survival in his study in southern Alberta, Canada. Roersma (2001) did not look at male survival. Another factor that may contribute to survivorship could be age. More experienced individuals may survive longer than juveniles. We cannot address this because we did not determine age of our grouse.

Overall nest success of sharp-tailed grouse on the GRNG was 30%. This finding is lower than reported nesting success of other subspecies of sharp-tailed grouse (Roesmra 2001; Goddard et al. 2009). However, nest success in our study area was higher than Kirby and Grosz (1995) in their un-grazed treatments at the Central Grasslands Research Center in south central North Dakota. They reported nest success of 44% in grazed pastures and 26% success in the un-grazed pastures.

Specific nesting habitat attributes could be a driver in nest success. Our study found that increased grass canopy cover and maximum vegetation height increased nest survival of sharp-tailed grouse, but it failed to find an important effect of shrubs and VOR. These habitat attributes contradict Kirby and Grosz (1995), Roersma (2001), and Goddard et al. (2009) in that only 52% of our nests were found in a shrub community. These studies looked at habitat preference, not survivability of nests based on the habitat attribute selected by sharp-tailed grouse. The shrub canopy cover percentage making up the overall transect average in our study was very low. Roersma (2001) reported that shrubs comprised 25.5% of the canopy cover at 47 nest sites. Shrub canopy cover at our 46 nest sites was only 5.8%. The general lack of shrub cover found at nest sites could be because the majority of our study area was reclaimed after the dust bowl years of the 1930's and was reseeded to crested wheatgrass, creating a monoculture stand with low species diversity in these areas. Selection of one habitat characteristic or specific vegetation community may depend on the quality of habitat available to nesting females, as well as the subspecies of sharp-tailed grouse (Goddard et al. 2009).

Hamerstrom (1939) and Goddard et al. (2009) observed shrub usage as a key component of grouse nests. Both studies looked at subspecies that occupy heavily wooded and shrub eco regions. Hamerstrom (1939) studied prairie sharp-tailed grouse *T. p. campestris* and prairie chickens in Wisconsin, USA, and Goddard et al. (2009) studied *T. p. columbianus* in British Columbia, Canada. Selecting shrubs in an ecosystem that have a large shrub component, like the pine barrens of Wisconsin and the shrub steppe of British Columbia, is more frequently observed than in areas lacking a large amount of shrub production like our study area.

Although we had a lack in shrub usage compared to other findings, our VOR were consistent with Manske and Barker (1987), Kirby and Grosz (1995), and Goddard et al. (2009); who reported large VOR and tall vegetation readings. One thing is apparent in our study, as the percent canopy cover of grass and maximum height of vegetation increased around the nest, the likelihood of nest survival in our study area increased. This again may be attributed to the grouse selecting what was available. Our overall average of transect grass canopy cover averaged 49.4% between 2009 and 2010 transect data collected at nests. There was almost a 2:1 grass ratio to any other vegetation component at nest sites. Other studies have reported average grass canopy cover at 32% and 38% (Roersma 2001; Goddard et al. 2009). Maximum vegetation height was also a key variable in improving nest success in our study. Overall, mean vegetation height across nest transects was 58.0 cm. This number is relatively small compared to Goddard el al (2009) vegetation height of 81.1 cm. Kirby and Grosz (1995), Roersma (2001), and Goddard et al. (2009) all looked at nest site selection based on vegetation characteristics or grazing treatments. None of these studies looked at nest success based on the habitat attributes that were selected. No studies have been conducted on sharp-tailed grouse habitat selection and its direct effect on nest success.

MANAGEMENT IMPLICATIONS

Habitat attributes selected by sharp-tailed grouse on the Grand River National Grasslands showed significance in nest success. Our results suggest nest success was dependent on maximum vegetation height and percent grass canopy cover. If our results are confirmed by future studies, we recommend that sharp-tailed grouse habitat be managed for patches with tall vegetation height with a high percentage of grass canopy cover. But, due to the lack of information on habitat characteristics effects on nest success of sharp-tailed grouse, we recommend management strategies that include assessment and inventory of available nesting habitat to nesting sharp-tailed grouse irrespective of subspecies and presumptions of habitat usage by sharp-tailed grouse. Instead managers should monitor nests of sharp-tailed grouse and see what habitat features are affecting nest success in their localized eco region. Habitat types may change between subspecies, but two things seem to be consistent in the literature; maximum vegetation height seems to play an important role in grouse nest success and distance from lek seems to be an important factor in nest site selection.

We suggest that managers implement a management strategy that will maximize areas with tall vegetation height and increased grass canopy cover within 1250 m of active lekking locations. Attaining suitable vegetation height may be attained through limiting grazing impacts near lekking grounds later in the grazing season to insure that residual vegetation around the lek is present for the following nesting season.

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CHAPTER 5. GENERAL CONCLUSIONS

Over the course of two years we successfully captured 163 sharp-tailed grouse across the GRNG [56 females (34%) and 107 males (66%)], we collard and monitored 100 sharp-tailed grouse 56 females (56%) and 44 males (44%).

Overall, 73% (41 of 56) of monitored female sharp-tailed grouse initiated a nest in one of the two years of the study. In 2009, four hens re-nested while one hen re-nested in 2010. Over the course of the study we did not observe any nest abandonments; all initiated nests were either successful (21/ 41) or predated (20/41). Specific nesting habitat attributes could be a driver in nest success. Our study found that increased grass canopy cover and maximum vegetation height increased nest survival of sharp-tailed grouse, but it failed to find an important effect of shrubs and VOR.

Estimated first nest initiation dates in 2009 ranged from 28 April to 12 June, with a mean initiation date 15 May. Estimated first nest initiation dates in 2010 ranged from 26 April to 4 June, with a mean initiation date of 11 May.

Overall survival of nests, females, and males through the nesting season was 30%, 65%, and 49%; respectively, over the two year study. Nesting sharp-tailed grouse selected for areas with higher VO at nest sites in 2009 and 2010. The individual nest sites in 2009 showed a greater increase in the odds of use than in 2010. This was perhaps due to more patches of taller vegetation available to nesting sharp-tailed grouse in 2010 than in 2009. In 2009, sharp-tailed grouse were limited in what was available for patches of dense taller vegetation structure. We believe this was due to higher precipitation levels in 2010, which subsequently resulted in an increase in vegetation production. The increased precipitation and low stocking rate created more available high structure patches across the landscape for nesting females to select, as opposed to seeking out patchier stands of vegetation.

We believe that the use of a geo-statistical approach to measure variability in data collected based on VO is more beneficial in showing how habitat structure that nesting sharp-tailed grouse select for compared to what is available across the landscape than using just the average VOR data or the CV. The use of averaged data tells the manager what the average height of VOR that the grouse are selecting for, not the variability or patch size that the VOR measurements falls within. The CV is a poor method to utilize when measuring variation across a landscape because it lacks the ability to discriminate between distance variables, giving land managers the wrong impression of what needs to be found across the landscape for structure.