HABITAT RESOURCE SELECTION BY GREATER SAGE GROUSE WITHIN OIL AND GAS DEVELOPMENT AREAS IN NORTH DAKOTA AND MONTANA

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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Abstract

HABITAT RESOURCE SELECTION BY GREATER SAGE GROUSE WITHIN OIL AND GAS DEVELOPMENT AREAS IN NORTH DAKOTA AND MONTANA

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Populations of greater sage-grouse (*Centrocercus urophasianus*; hereafter sage grouse) have declined substantially throughout a majority of their range (Connelly and Braun 1997, Schroeder et al. 1999, 2004). There has also been a corresponding decline in sage (*Artemisia* spp.) habitat quantity and quality. Consequently, sage grouse populations have declined in response to a pattern of land-use changes that have reduced and degraded sagebrush ecosystems (Hemstrom et al. 2002). Sage grouse are native to the sagebrush steppe ecosystem, and their distribution closely follows that of sagebrush. Important mineral resources (i.e., gas, oil) are coincident with sage grouse habitats across much of the western United States. Sagebrush steppe habitats along the Cedar Creek Anticline of southeastern Montana and southwestern North Dakota exemplify important sage grouse habitats that overlay mineral resources which are currently being extracted, or have been targeted for development. There are many concerns involving the responses of sage grouse and their use of habitats that have been, or potentially will be impacted by mineral development and associated infrastructure (i.e., roads, power lines, buildings, generators, water outflows). The primary objectives of this study were to: (1) determine the habitat suitability within the oil and gas developed regions of Bowman County, North

Dakota and Fallon County, Montana and (2) determine what factors may cause avoidance.

Vegetation measurements were taken at 67 nest sites and 166 random sites between 2005 and 2009 and analyzed using an Information Theoretic approach with logistic regression. The top model that predicted sage grouse use included total percent vegetation cover, the visual obstruction at the nest bowl, the visual obstruction at one meter away from the nest bowl, 0-m VOR, 1-m VOR grass height, and year affect (AIC*c* weight = 0.54). When I compared the area of intense use to areas of relative non-use, I found that there were four competing models; the top model included total percent vegetation cover and grass height (AIC$_c$ weight = 0.25). When I compared density of roads I found that the area of avoidance contained 120.9 km (0.0317 km/ha) of roads whereas the area of use had 44 km (0.014 km/ha) of roads. Hence, the density of roads within the area of avoidance was about 2.6 times greater than the density within the area of use.

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Introduction

The historical range of greater sage-grouse (*Centrocercus urophasianus*; hereafter sage grouse) has been dramatically reduced since European settlement (Connelly and Braun 1997, Schroeder et al. 2004). The range of sage grouse has been reduced by 45% across North America (Schroeder et al. 2004) with an estimated range-wide population decline of 45-80% and local declines of 17-92% (Connelly et al. 2004). Historically, sage grouse were found throughout the western U.S. where sagebrush and associated plant communities existed (Patterson 1952). In addition, Schroeder et al. (2004) determined that the distribution of sage grouse is clearly associated with the distribution of sagebrush (*Artemisia* spp.). Thus, sage grouse are sagebrush obligates because of their year-round dependence on sagebrush communities (Paige and Ritter 1999).

Sagebrush is required for food, shelter, and as a water source for sage grouse (Swenson 1987, Fischer et al. 1996, Schroeder et al. 1999). During the winter months, sagebrush is the only source of food (Hupp and Braun 1989, Welch et al. 1991) with the sage grouse's diet consisting of leaves and buds (Welch et al. 1991, Homer et al. 1993, Connelly et al. 2000). Sagebrush microhabitat is also important during the reproductive season of the sage grouse; sagebrush coexists with understory forbs that are important for female sage grouse during nesting and brood-rearing (Drut et al. 1994, Crawford 1997, Connelly et al. 2000). Sage grouse nest beneath sagebrush (Patterson 1952, Gill 1966, Connelly et al. 1991, Musil et al. 1994, Sveum et al. 1998), where females may show nest-site fidelity from year to year (Fischer et al. 1993). Klebenow (1969) and Wallestad (1975) found that sagebrush provided female sage grouse with nesting cover and early brood-rearing habitat. In the core of the sage grouse range, females typically chose nest sites with horizontal cover of greater than 73% (Musil et al. 1994, Connelly et al. 2000), tall residual grasses of greater than 18 cm, and medium shrubs from 40-80 cm of height (Gregg et al. 1994, Sveum et al. 1998, Connelly et al. 2000). Recent research on the eastern and northern edges of the range of sage grouse found that sage grouse utilized taller grass cover as a substitute for the lack of height in sagebrush (Aldredge et al. 2008, Kaczor et al. 2011).

The decline of sage grouse populations is intimately linked to widespread sagebrush habitat degradation. The direct and indirect causes of this habitat degradation are associated with altered fire regimes (Wrobleski and Kauffman 2003), grazing and agriculture, urbanization, and the development of oil and gas extraction (Connelly et al. 2004). Of the causes, both direct and indirect, oil and gas development is one the most recent yet the least understood impacts on sage grouse and their habitat. With the discovery of oil and gas throughout the western U.S. beginning in the 1930s and 1940s, wildlife habitats have been directly impacted (Braun 1987). Because the production of oil and gas is predicted to continue for another 20-100 years (Connelly et al. 2004), it is important to understand the impacts of such development. Increasing energy demands of an expanding human population pose varied conservation challenges related to North American wildlife populations (Sawyer et al. 2006, Walker et al. 2007). Once these gas and oil impacts are better understood, it may be possible to plan future resource development in ways that minimize impacts to sage grouse populations.

There are several factors related to oil and gas development that could negatively affect sage grouse populations. Oil and gas developments require a certain level of infrastructure, including construction and usage of roads, erection of well pads, drilling and extraction of natural resources, establishment of both permanent and non-permanent facilities and structures, all of which contributes to sagebrush habitat fragmentation. Consequently, substantial sage grouse population declines have occurred throughout their range (Connelly and Braun 1997). Braun (1987) suggested that the decline in Colorado's sage grouse population is related to the loss of habitat caused by site preparation, road development, noise from pumping stations, power line development, and associated human activities. Energy development is known to impact wildlife directly by altering habitat use (Doherty et al. 2008) and population dynamics (Sorensen et al. 2008), and indirectly by facilitating the spread of invasive plants (Bergquist et al. 2007) and exotic diseases (Zou et al. 2006, Doherty 2007).

The construction of roads results in direct removal of substantial contiguous habitat. Roads related to oil and gas development have been associated with reduced nesting success and increased disturbance during the lekking and brood-rearing periods (Braun 1998, Braun et al. 2002, Holloran 2005). In Wyoming, nesting success increased as distance to nearest road increased (Lyon and Anderson 2003, Holloran 2005). Likewise, when considering habitat fragmentation the construction of a typical well pad requires 0.8-1.9 hectares and compressor stations along pipelines require 5-7 hectares (Connelly et al. 2004, Holloran 2005). The long-term effects of pumping stations, and other permanent facilities are unknown. Direct impacts of oil and gas development on factors such as nesting and lek sites are largely unknown. The placement of these physical structures has varying impacts on wildlife, and opportunities may exist to minimize their effects on wildlife. For example, if structures can be placed close together, rather than farther apart, fewer roads and other related structures may be necessary. Other effects include soil disturbance along roads and near wells, the spread of exotic plants species (e.g. cheatgrass (*Bromus tectorum*) and Canada thistle (*Crisium arvense*)) and structures that provide nest and perch sites for raptors (Connelly et al. 2004). Several studies have reported raptors hunting various prey, including sage grouse, from overhead utility towers and other manmade elevated perches (Wakeley 1978; Graul 1980; Ellis 1984, 1987; Plumpton and Andersen 1997).

Oil and gas development will continue to be to significant threat to sage grouse because of improved extraction technology and a continued high demand for resources (Connelly et al. 2004). The U.S. government has already leased more than 7 million hectares of the federal mineral estate, and the number of producing wells has tripled from 11,000 in the 1980's to more than 33,000 in 2007 (Naugle et al. 2011). The impacts of all factors related to oil and gas development need to be understood so that accurate management recommendations can be made. Although data from Colorado (Braun 1987) suggest that gas/oil development can cause a decline in sage grouse populations, the actual reasons for these declines are unknown. As with most wildlife, profound and permanent changes created within important habitats as a result of altering land use and ecological patterns can effect the perpetuation of sage grouse (Patterson 1952). Because of the lack of information concerning the potential impacts of natural gas and oil development within the area, an investigation was prompted concerning the potential impacts of natural gas and oil development on sage grouse populations within the Cedar Creek Anticline in North Dakota and Montana. The primary objectives of this study were to: (1) determine the habitat suitability within the oil and gas developed regions of Bowman County, North Dakota and Fallon County, Montana and (2) determine what factors may cause avoidance.

Herman-Brunson (2007,Herman-Brunson et al. 2009) studied nesting and brood-rearing habitat and associated hen survival of sage grouse in Bowman County, ND and Fallon County, MT during 2005 and 2006. Herman-Brunson's (2007, Herman-Brunson et al. 2009) and Swanson's (2009) studies provided baseline telemetry data that indicates a large area where few, if any, sage grouse occurred. The area not used by sage grouse closely aligns with an area of highly developed oil and gas industry in Bowman County, ND and Fallon County, MT. However, it is unknown whether the areas not used by sage grouse were comprised of suitable or unsuitable habitat. Managers need to know the amount and distribution of suitable sage grouse habitat within the oil and gas development region of southwestern North Dakota and adjacent areas of Montana.

Based on past studies (Herman-Brunson 2007, Herman-Brunson et al. 2009, and Swanson 2009) we know there is an area of avoidance not being utilized by female sage grouse. To better understand the reason of avoidance we need to look at the microhabitat that falls within and around the avoidance area. Once the resources in that particular area are assessed, we can have a better understanding of the observed pattern of avoidance noted by Swanson (2009). Determination of the causes for avoidance of the resources in the development areas will enable us to implement best management practices to obtain optimum sage grouse use and selection.

Study Area

The study area encompassed approximately 30,351 hectares, based on data provided by Herman (2007and Herman-Brunson et al. 2009). The study area was located in Bowman and Slope counties, North Dakota and Fallon County, Montana (Figure 1). Generally, the study area was situated from the junction of the Little Missouri River and the southern North Dakota border to approximately 10 km northwest of Little Beaver Creek in Montana.

This region was considered a semi-arid sagebrush rangeland characterized by gentle slopes to steep buttes and ridges, with elevations that range from 640 to 1225 m above mean sea level (Opdahl et al. 1975, Johnson 1976). Soil orders consisted of Entisols, Alfisols, Mollisols, Inceptisols, Mollisols, and Aridisols (Johnson 1976, Kalvels 1982, Johnson 1988, Smith 2003). Annual precipitation ranged from 35.6 cm to 40.6 cm, with the majority occurring between April and September. Annual summer and winter temperatures ranged from 9.9°C to27.5°C and from -15.6°C to 0.2°C, respectively (Opdahl et al. 1975, Thompson 1978, Smith 2003).

Vegetation was a mixture of grassland and shrubland, with an understory of perennial and annual forbs and graminoids (Johnson and Larson 1999). Dominant shrub species included silver sagebrush (*A. cana*), big sagebrush (*A. tridentata*), western snowberry (*Symphoricarpos occidentalis*), rubber rabbitbrush (*Chrysothamnus nauseosus*), and greasewood (*Sarcobatus vermiculatus)* (Johnson and Larson 1999). Dominant grasses in the area consisted of Kentucky bluegrass (*Poa pratensis*), western wheatgrass (*Agropyron smithii*), Japanese brome (*Bromus japonicus*), needle and thread

(*Stipa comata*), and junegrass (*Koeleria macrantha*). Dominant forbs were common yarrow (*Achillea millefodium*), common dandelion (*Taraxacum officinale*), and textile onion (*Allim textile*) (Johnson and Larson 1999).

Methods

Radio-marking and Monitoring

Female sage grouse were captured using night spotlighting methods between mid-March and late April. All radio-marked sage grouse were captured in Bowman County, North Dakota. Hand-held spotlights were used to locate the birds while approaching sage grouse, observers used the spotlight to shine at them. This enabled observers to get close enough to capture hen sage grouse with a long handled net (Giesen et al. 1982). The captured female sage grouse were aged, sexed, weighed, and fitted with an aluminum leg band and a necklace-type 20 g VHF transmitter (Advanced Telemetry Systems, Isanti, Minnesota). Transmitters were less than 2% of the bird's body weight and were equipped with mortality motion switches. Each bird was released at its capture location.

Previous telemetry data provided by Herman-Brunson (2007) indicated that sage grouse captured in Bowman County, North Dakota used habitat extending into Fallon County, Montana. Field crews relocated sage grouse immediately following capture in early spring through 31 August of each year of the study. Sage grouse were located biweekly, primarily through ground telemetry by using a hand-held three-element yagi antenna, but occasionally by using aerial telemetry methods. Sage grouse locations were recorded using a handheld global positioning system (GPS; UTM NAD 1927; Zone 13) device and then mapped in a geographical information system (GIS) ESRI, Inc. ArcGIS 9.1. Resulting data provided estimates of survival, incubation period, nesting success, and habitat use of brood and broodless hens were obtained.

Habitat Measurements

Vegetation data were collected at 17 nest sites in 2005 and 17 nest sites in 2006 (Herman–Brunson 2007), in 2007 there was vegetation data collected at 27 nest sites, and in 2009 there was vegetation data collected at 9 nest sites. In addition to the nest sites there were vegetation data collected from 17 random sites in 2005 and 33 random sites in 2006 (Herman-Brunson 2007), 47 random sites in 2007, and 69 random sites in 2009. In summary, vegetation measurements were taken at 67 nest sites and 166 random sites between 2005 and 2009 within the oil and gas developed region to determine the proportion of suitable habitat being utilized by sage grouse. Coordinates of nests and random sites were entered into a GPS to facilitate point location in the field. The accuracy of GPS units was usually less than ± 10 m (Garmin-Etrex model).

At each nest and random site, I established four 50-m transects, which were centered over the nest or random point; the transects ran in the four Cardinal directions (N, E, S, and W). I measured sagebrush species height (cm) at each nest and random point. At each 10-m interval (n =20) along each transect I recorded the distance to the nearest sagebrush plant using the pointcentered-quarter method (Cottam and Curtis 1956). For every sagebrush plant that was encountered, I also recorded the height (cm) of the sagebrush. A Robel pole was used to measure horizontal shrub density and maximum grass height (Robel et al. 1970). I estimated visual obstruction recording (VOR) and height of grass using a modified Robel pole delineated in 2.54 cm increments (Robel et al. 1970, Benkobi et al. 2000). Maximum grass heights and VORs were summarized for each of the intervals and the averages were calculated for 0 to 5 m, 1 to 5 m, 10 to 50 m, and the site level (0 to 50 m). In order to avoid trampling on the vegetation, I viewed the pole from three directions for the 1 to 5 m measurement intervals. Daubenmire cover class estimates were used to estimate percent canopy cover of total vegetation cover, grass cover, shrub cover, and to determine the most common shrub species (Daubenmire 1959). Herbaceous canopy cover was estimated at the nest or random point. Vertical cover estimates were systematically collected at 1 m intervals for the first 5 m and at 2 m intervals thereafter along the 50-m transects within 0.10-m^2 quadrates (Daubenmire 1959). I recorded total percent canopy cover, total sagebrush, total grass, total forb, litter, bareground, and dominant shrub species in each quadrate.

Acronym	**Definition**
Total_Co	Percent total vegetative canopy cover
Shrub_H	Percent total shrub cover
Grass_H	Percent total grass cover
Nest_VOR/0-m VOR	Visual obstruction reading for the site
1-m VOR	Average visual obstruction reading for 1-m around site
Litter	Percent total litter cover (ie. residual grasses, rocks, feces)
Bareground	Percent bareground
Effective Grass Hgt	Grass height beneath sagebrush from Robel pole (cm)
Max Grass Hgt	Tallest reading of grass species surrounding Robel pole (cm)
Sagebrush Hgt	Sagebrush height (cm)
Sagebrush density	Sagebrush density/hectare, plants/ha

Selection of Random Sites

The location of the oil and gas developed region was determined using oil and gas structure location data provided by the Bureau of Land Management and displayed using ArcGIS (ESRI, Inc. ArcGIS 9.1). Random points were generated using Arc GISfrom within an area of substantial sage grouse activity, as determined by Herman-Brunson and

Swanson (Herman-Brunson 2007, Swanson 2009). In total there were 167 randomly-generated points; 120 of which were generated in 2009, and 47 of which were generated in 2007. Sampling took place during the months of May through August of 2005 through 2009.

Analytical Methods

Data collected from the random points were analyzed to establish selection of suitable habitat characteristics. Shapefiles were created to isolate area of avoidance from areas of use within the study area (Figure 4). Habitat selection was characterized by comparing vegetation at randomly selected sites within the area of use (n=69) and randomly selected sites within the area of avoidance (n=41). Kilometers of roads were then calculated within each area of interest (area of use/area of avoidance separately) and the calculation of the number of sage grouse locations was completed by using the select by location tool in ArcMap and setting the parameters to select from the layer "Sage Grouse Locations" that are completely within specific layers.

All statistical analyses were conducted using SPSS version 11.5 for Windows (SPSS Inc., Chicago, IL). The large number of variables measured was reduced by running each through binary logistic regression and examining the likelihood ratio test statistics to identify the important predictors between use and non-use sites (Hosmer and Lemeshow 2000). I ran the models using logistic regression and used the Information Theoretic Approach (Burnham and Anderson 2002) to rank all candidate models. Due to sample size relative to the number of parameters to be estimated, I used Akaike's Information Criterion corrected for small sample sizes (AIC_c) to select the most parsimonious models. I considered models within 2 ΔAIC_c units to be equally supported. I calculated Akaike weights (w_i) as an indication of model support (Burnham and Anderson 2002) and used the Hosmer-Lemeshow goodness-of-fit test to assess model fit (Hosmer and Lemeshow 2000), with $p > 0.05$ indicative of appropriate fit. I developed 28 *a priori* models including variables from the previous literature (Herman-Brunson 2007) to predict nest-sites. All of the candidate models included vegetative variables of percent vegetative cover, sagebrush height, 0m VOR, 1m VOR, and grass height from the Robel pole. Year was included in all candidate models.

GIS Component

Use Area vs. Area of Avoidance

An oval-shaped area (Figure 6) of 8,609.20 m^2 was delineated around the area of avoidance. A second buffer oval, with the same area, was generated to the outside of Area1(area of avoidance) using the buffer tool in ArcToolbox. The end result were two ovals, both the same size, one highlighting the use area selected by sage grouse and a second oval highlighting the non-use area. In order to try and determine whether or not road density had an effect on sage grouse locations the "select by location" tool was used in ArcMap to determine how many sage grouse locations fell within each oval.

To obtain road density near sage grouse locations, 350 m buffers were created in ArcMap 9.3.1 using the buffer tool from ArcToolbox. I selected a 350 m buffer because Naugle et al. (2006) used a 350 meter buffer around wells, roads, power line and other infrastructure; and he found it to be an accurate predictor of direct and indirect impacts of development. Naugle selected a 350-m buffer around roads, power lines, and CBNG wells for 2 reasons. First, quantitative estimates of the distance at which infrastructure affects habitat use or vital rates of sage grouse were not available, and 350-m is a reasonable distance over which to expect impacts to occur, such as increased risk of predation near power lines or increased risk of vehicle collisions near roads. Second, we also wished to maintain a consistent relationship between well, road, and power line variables and the amount of area affected by each feature (Naugle et al. 2006).

After the 350 m buffers were created the roadlayers for Montana and North Dakota were then merged into one layer. The intersect tool (from ArcToolbox) was then utilized to compute the length of the road segments that fell within each buffered area. This tool recognizes the buffer boundaries and therefore clipped any road segments spanning through two or more buffered areas (Figure 2). The intersect process writes all features which overlap in all layers (in this case the merged roads and the buffered areas) to the output feature class. This made it possible to identify which road segments corresponded to which buffered area. The last step taken to make computation of road density/buffered area possible was to convert road segment length into kilometers. Once the road segments were obtain and computed into kilometers I then found the density/hectare by taking road kilometers divided by hectare.

Results

Resource Selection

Nest Points versus Random Points

Vegetation measurements were taken at 67 nest sites and 166 random sites between 2005 and 2009. When I compared the 67 nest sites to the 166 random sites I found that there were four competing models (Table 1). The best-approximating model (AIC*c* weight = 0.54) included total percent vegetation canopy cover, 0-m VOR, grass height, and year affect. The top models indicated that the variables positively affected resource selection for female sage grouse when choosing for a nest site. A second, competing model included total percent vegetation canopy cover, average sagebrush height and visual obstruction at 0-m. (AIC*c* weight = 0.20).

Distributions of total percent vegetation canopy cover, sagebrush height, grass height, visual obstruction 0-m, and visual obstruction at 1m differed (P <0.05) between nest sites in 2005, 2006, 2007, and 2009 (Table 2). Visual obstruction at 0- m was significant, thus having a positive affect on resource selection, all other variables were not significantly different. Year effect was evident in data for random sites, therefore all logistic models included the design variable year (Table 1). When I compared nest sites to randomly generated sites I found the average vegetation measurements for nest sites were larger than for random points (Figure 3). This indicates that nest sites were selected because they had more suitable resources available compared to the randomly selected sites.

Area of use versus area of avoidance

Once I identified the top models for predicting nest selection, I re-ran all 28 *a-priori* models to develop the top models to predict vegetative resource selection within the study area (Figure 4). When I compared the area of use sites to the area of avoidance sites I found that there were four competing models; the best- approximating model included total percent vegetation canopy cover and grass height (AIC*c* weight = 0.25) (Table 4). The variables in the top models indicated that the variables positively affected resource selection for use and non-use areas, it indicates that total percent canopy cover and grass height were two top factors in determining whether or not an area may be used or avoided. A second competing model included total percent canopy cover, grass height and visual obstruction at the 0- m mark(AIC*c* weight = 0.19) both as positive correlates of use.

When comparing area of use to area of non-use, I found that in all comparisons the average vegetation measurements within the area of use were larger (Figure 5). Thus indicating that resource selection from female sage grouse favored taller vegetation and higher percent canopy cover. Distributions of percent vegetation canopy cover, shrub height, grass height, 0 m VOR, and 1 m VOR differed (P <0.05) between area of use sites and area of avoidance sites in 2005, 2006, 2007, and 2009 (Table 3). Of the five variables that were measured four ended up being significantly different, showing that even though marginal resources were available in both areas (area of use vs. area of avoidance) the resources that had more suitable resources (higher percent canopy cover and taller vegetation) present were the areas chosen by sage grouse.

Road Density

When I compared the area of avoidance (8,609.20 ha) to the area of use (8,609.20 ha; Figure 6), I found that the area of avoidance had 432 sage grouse locations compared to 1,388 sage grouse locations within the area of use. When I compared density of roads I found that the area of avoidance contained 120.9 km (0.0317 km/ha) of roads whereas the area of use had 44 km (0.014 km/ha) of roads. Hence, the density of roads within the area of avoidance was about 2.6 times greater than the density within the area of use (Figure 7).

Once I identified the top models for predicting nest site resource selection and best models for determining vegetation differences between avoidance area and use area, I re-ran the models to include a combination of all 56 *a-priori* models for comparison of both nest site resource selection and for the area of avoidance and the area of use. The 56 *a-priori* models included 28 *a-priori* models without road density and 28 *a-priori* models with road density. This was done to assess whether roads were a factor in resource selection by sage grouse. Two different comparisons were made, the first comparison was nest sites vs. random sites and the second comparison was made between use area vs. non-use area. Road density was included with vegetative variables at randomly selected sites (n=166) and compared to actual nest sites (n=67) this was the nest site vs. random comparison. In addition, road density was also included with vegetative variables for the comparison of area of use vs. area of non-use in this comparison random sites within the area of use were compared to the area of non-use (use sites, n=69 and non-use sites n=41); this was the second comparison indicating the differences between use area vs. non-use areas.

When looking at the nest site resource selection, the resulting models indicated that there were four competing models. The best-approximating model (AIC*c* weight = 0.27) included density of roads (km/ha), percent total canopy cover at the site level, VOR at the 0-m mark, VOR at the 1-m mark, grass height, and year affect (Table 5). A second model included percent total canopy cover at the site level, VOR at the 0-m mark, grass height, and year affect (AIC*c* weight = 0.22). Both top models revealed that each variable within the model are important when it comes to the selection of resources; however, the top model shows that road density plays a larger role in whether or not a sage grouse will chose an area for nesting. When running these models the road density variable shifted to the top of the models indicating that it is an important factor when sage grouse select a nest area.

When looking at the area of use and the non-use area, the resulting models indicated that there were four competing models. The best-approximating model (AIC*c* weight = 0.24) included density of roads (km/ha), percent total canopy cover at the site level, and grass height (Table 6). A second model included density of roads (km/ha), percent total canopy cover at the site level, VOR at the 0-m mark, and grass height (AIC*c* weight = 0.16). These models also indicate that road density play a major role in selection of resources. These models illustrate that road density may be a major factor influencing why an area may be avoided even when marginal resources are present.

Discussion

Resource Selection

Female sage grouse in North Dakota and Montana selected nest sites with higher sagebrush cover and placed their nests beneath sagebrush plants which afforded greater visual obstruction. Several studies have established the importance of sagebrush canopy cover (Patterson 1952, Wallestad and Pyrah 1974, Wakkinen 1990, Fischer 1994, Sveum et al. 1998) and herbaceous canopy cover (Wakkinen 1990, Connelly et al. 1991, Sveum et al. 1998). In a previous study that took place in the same area, it was noted that sage grouse nesting habitat, shrub density, and nest site VOR were also important predictors of sage grouse nests (Herman-Brunson 2009). Connelly et al. (2000) recommended 15-25% sagebrush canopy coverage for nesting sage grouse. I found that shrub height, grass height, and nest site VOR also played an important and crucial role in resource selection. In western North Dakota and eastern Montana, female sage grouse selected the best available resources; however, in most cases these resources were marginal compared to the recommendations from the core of the sage grouse range and sagebrush distribution. In contrast to sagebrush, grass structure in North Dakota exceeded both management recommendations (Connelly et al. 2000) and range-wide averages (Hagen et al. 2007). Western North Dakota and eastern Montana forms a transition zone between the northern wheatgrass-needlegrass prairie that dominates most of the Dakotas and the big sagebrush plains of Wyoming (Johnson and Larson 1999). Thus, while North Dakota and Montana appeared to have less than optimal sagebrush cover for sage grouse, the favorable grass structure may have compensated for the sagebrush component. Both Herman-Brunson

(2007) in North Dakota,and Kaczor (2008) in a South Dakota study suggested that despite low sagebrush density and canopy cover, the amount of grass cover around nests suggests that grass was also an important cover component of sage grouse nests. Kaczor (2008) also found grass structure was highly correlated with annual precipitation and in periods of drought it may not provide adequate protection for sage grouse nests. Taller live and residual grass surrounding nests also increased nest success in Alberta (Aldridge and Brigham 2002), and was found to provide ample nest concealment in both sagebrush and non-sagebrush over stories in Washington (Sveum et al. 1998). Sage grouse were able to utilize grass cover for nest concealment in areas where sagebrush density and height were suboptimal. However, there was still a requirement to maintain sagebrush on the landscape because of its importance as a food source.

Across their range, female sage grouse usually select sagebrush patches with percent shrub canopy cover of 15- 25% for nests. They generally avoid sparse or excessively dense patches (Connelly et al. 2000). In southwestern North Dakota and southeastern Montana, hens selected habitats with characteristics that offer marginal but adequate cover, however they avoided high density road areas; this could be due to habitat fragmentation or vehicle disturbance or a combination of both. Resources within used areas had better overall vegetation structural quality when compared to avoided areas with high road densities. Previous studies noted that hens selected nest sites with the tallest available brush and which had the greatest stem diameter (Gray 1967, Klebenow 1969, Wallestand and Pyrah 1974, Autenreith 1981). Herman-Brunson (2007) found that hens did not select for taller sagebrush at nests. Herman-Brunson (2007) also stated that sage grouse can inhabit areas of lower sagebrush height and density than reported in existing literature, if additional cover in the form of graminoids are available. Previous studies have also documented the importance of cover from grasses within shrub stands (Wakkinen 1990, Connelly et al. 1991, and Kaczor et al. 2011) which are associated with higher nest success rates (Gregg et al. 1994), and can offer additional nest protection. When directing our attention to the area of avoidance verses the area of use I found nine nest locations that fell within the area of avoidance and 26 nest locations that fell within the area of use.

When I compared the area of avoidance and area of use there was a noticeable difference in vegetation means, differences between vegetation showed to be significant in most cases when comparing the area of use to the area of avoidance. The area of use had taller vegetation and had higher percent cover then that of the non-use area making the area of use more appealing for the utilization of resources. However, the area of avoidance vegetation means still fell within marginal habitat requirements within the published literature (Connelly et al. 2000, Hagen et al. 2007). Because of this, I examined other influencing factors, and chose road density because it was a logical indicator of the intensity of oil and gas development within the area. When I included road density into the vegetative models of resource selection, the road density variable became a variable that was present in all of the top-rated models. This suggested that road density was a key factor in resource selection.

To date no studies have specifically investigated road density effects on sage grouse populations. Studies do suggest that some sage grouse population declines are related to the loss or fragmentation of habitat caused by oil and gas site preparation, road development, noise from pumping stations, power line development, and associated human activities (Braun 1987). Within the Cedar Creek Anticline, male abundance at leks decreased by 52 percent at sixteen leks with more than one well pad per 2.6 square kilometers within 3.2 kilometers, and no males were counted in 2009 at four of the sixteen impacted leks that had multiple displaying males in 2008 (Tack 2009). Energy development is also known to impact wildlife directly by altering habitat use (Doherty et al. 2008). Because the area avoided by radio-marked sage grouse had a higher density of roads than the area of more intense use; hence the density of roads may be contributing to the avoidance in this area. Additionally, higher road densities lead to greater fragmentation of the landscape, thereby reducing its value as habitat for sage grouse.

Management Implications and Future Research Needs

Sage grouse in the United States are listed as a candidate for listing under the Endangered Species Act. In 2010, after a second review, the Department of the Interior assigned the sage grouse status as "warranted but precluded”. If sage grouse populations continue to decline and shrink in distribution, sagebrush steppe conservation and enhancement could be top a priority for land management agencies. Particularly, efforts to conserve the limited range of sagebrush within southwestern North Dakota and southeastern Montana will be vital to maintaining sage grouse populations.

Management for greater grass cover and height, reduced conversion to tillage agricultural, and minimizing habitat fragmentation from activities such as energy development could be a goal for resource managers. In addition, annual grazing utilization should not exceed 35% in order to improve rangeland conditions, particularly to maintain sagebrush cover (Holechek et al. 1999). I suggest that managers develop strategies to preserve the integrity of sagebrush steppe in southwestern North Dakota and southeastern Montana. Range management practices that could increase sagebrush and grass cover and height might include: rest-rotation grazing, where the pasture is not grazed until early July to allow for undisturbed nesting, or reduced grazing intensities and/or season of use to reduce impact on sagebrush and grass growth (Adams et al. 2004). I would also recommend against using prescribed fire in areas with sagebrush, it is documented that Wyoming big sagebrush typically takes 50-120 years to recover from a fire (Baker 2006).

Oil and gas development creates a complex network of roads, well pads, pipelines, pumping stations, and other infrastructure features across a landscape. Roads are widely recognized by the scientific community as having a variety of direct, indirect, and cumulative effects on wildlife and their habitats (Trombulak and Frissell 2000, Gucinski et al. 2001, Gaines et al. 2003, Wisdom et al. 2004a, Wisdom et al. 2004b, New Mexico Department of Game and Fish 2005). Increasingly, studies have demonstrated many of the negative effects of oil and gas developments specific to wildlife populations (Colorado Department of Wildlife et al. 2008, Wyoming Game and Fish Department 2004, Confluence Consulting 2005, Holloran 2005, Sawyer et al. 2006, Berger et al. 2006). This study illustrates that road density could be a key factor influencing sage grouse avoidance of potentially useable habitats, particularly when the vegetative characteristics within those habitats may be marginal at the onset. However, additional research is needed to understand the specific boundaries and standards that must be set to maintain the integrity of sagebrush steppe resources.

Because sage grouse have not been listed on the Endangered Species Act it is imperative to have long-term (>30 yrs) partnerships and quality incentives for local land owners. This will require cooperation from state wildlife agencies, federal land management agencies, local natural resource conservation districts, and committed landowners. Private landowners should be encouraged to participate in programs that are directed at maintaining and improving sage grouse habitats on private lands. Good working relationships and good education about sage grouse and their resource requirements is a key component for their success.

Table 1. Results from logistic regression models predicting greater sage grouse nest sites (n=67) versus random sites (n=166) in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

Models[1]	**AICc**	**ΔAIC**	*Wi*	**K**
Total_Co + Nest_VOR + Grass_H +yr1 + yr2 + yr3	210.770	0.00	0.54	8
Total_Co + Shrub_H + Nest_VOR + Grass_H + yr1 +yr2 +yr3	212.750	1.98	0.20	9
Total_Co + Nest_VOR + 1m_VOR + Grass_H + yr1 + yr2 + yr3	212.934	2.16	0.18	9
Total_Co + Shrub_H + Nest_VOR + 1m_VOR + Grass_H + yr1 +yr2 +yr3	214.933	4.16	0.07	10

[1]A total of 28 models were considered
a Akaike's Information Criterion adjusted for small sample size (*AICc)*
b Difference in AICc *(Δ AICc)*
c Akaike weights (*wi)*
d Number of parameters (*K).*

Table 2. Mean vegetation characteristics of nest sites and random sites over years 2005, 2006, 2007, and 2009 for greater sage grouse used in logistic regression models in southwestern North Dakota and northeastern Montana, USA.

Variable	**Random (n=167)**	**Nest (n=64)**	**p-value**
Total Cover %	74.97	79.06	0.185
Sagebrush Height (cm)	54.52	56.51	0.481
Grass Height (cm)	31.85	34.1	0.243
Visual Obstruction 0m (cm)	10.68	12.74	<0.001
Visual Obstruction 1m (cm)	7.54	7.36	0.804

Table 3. Mean vegetation characteristics of random points inside area of use and random sites in area of avoidance over years 2005, 2006, 2007, and 2009 for greater sage grouse used in logistic regression models in southwestern North Dakota and northeastern Montana, USA.

	Area Inside (n=41)		Area Outside (n=69)		
Variable	**Mean**	**SE**	**Mean**	**SE**	**p-vale**
Total_Co	57.39	3.42	71.54	2.46	<0.001
Shrub_Height	44.52	2.08	52.30	2.26	0.02
Grass_Height	31.14	1.94	34.22	1.48	0.21
0m_VOR	7.90	0.69	10.45	0.60	0.01
1m_VOR	5.46	0.65	7.30	0.52	0.03

Table 4. Results from logistic regression models predicting greater sage grouse area of use (n=69) versus area of avoidance (n=41) in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

Models[1]	**AICc**	**ΔAIC**	***Wi***	**K**
Total_Co + Grass_H	137.801	0.00	0.32	4
Total_Co + Nest_VOR + Grass_H	139.107	1.31	0.17	5
Total_Co + Nest_VOR + 1m_VOR + Grass_H	140.389	2.59	0.09	6
Total_Co + Shrub_H + 1mVOR + Grass_H	140.448	2.65	0.08	6

[1]A total of 28 models were considered.
a Akaike's Information Criterion adjusted for small sample size (*AICc)*
b Difference in AICc *(Δ AICc)*
c Akaike weights (*wi)*
d Number of parameters (*K).*

Table 5. Results from logistic regression models predicting greater sage grouse nest sites with road density in km as a variable (n=67) versus random sites (n=166) in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

Models[1]	**AICc**	**ΔAIC**	***Wi***	**K**
RD + Total_Co + Nest_VOR + 1m_VOR + Grass_H +yr1 +yr2+yr3	210.355	0.00	0.27	10
Total_Co + Nest_VOR + Grass_H +yr1 + yr2 + yr3	210.769	0.415	0.22	8
RD + Total_Co + Nest_VOR + Grass_H + yr1 +yr2 +yr3	212.064	1.709	0.11	9
RD+ Total_Co + Shrub_H + Nest_VOR + Grass_H + yr1 +yr2 +yr3	212.133	1.778	0.11	10

[1]A total of 56 models were considered
a Akaike's Information Criterion adjusted for small sample size (*AICc)*
b Difference in AICc *(Δ AICc)*
c Akaike weights (*wi)*
d Number of parameters (*K).*

Table 6. Results from logistic regression models predicting greater sage grouse nest sites with road density in km as a variable (n=41) versus random sites (n=69) in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

Models	AICc	ΔAIC	*Wi*	**K**
RD + Total_Co + Grass_H	132.181	0.00	0.24	5
RD+ Total_Co + Nest_VOR + Grass_H	132.968	0.79	0.16	6
RD +Total_Co + Nest_VOR + 1m_VOR + Grass_H	133.438	1.26	0.13	7
RD+ Total_Co + Shrub_H + 1mVOR + Grass_H	133.518	1.34	0.12	7

[1]A total of 56 models were considered
a Akaike's Information Criterion adjusted for small sample size (*AICc)*
b Difference in AICc *(Δ AICc)*
c Akaike weights (*wi)*
d Number of parameters (*K).*

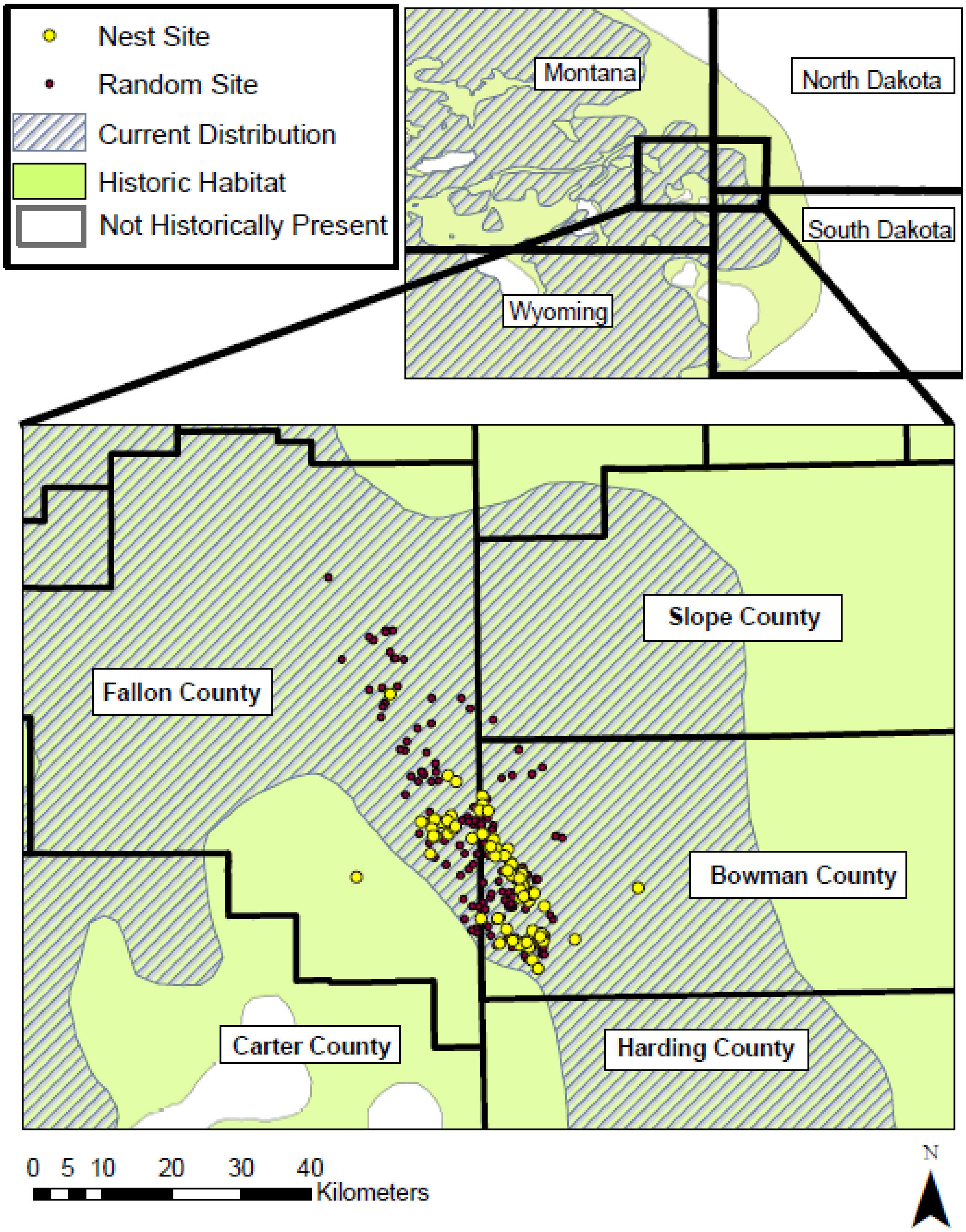


Figure 1. Study area of Bowman and Slope counties, North Dakota and Fallon County, Montana with vegetation sample locations documented during 2005, 2006, 2007, and 2009. The dashed area shows current range and green area shows historic range (Schroeder et al. 2004).

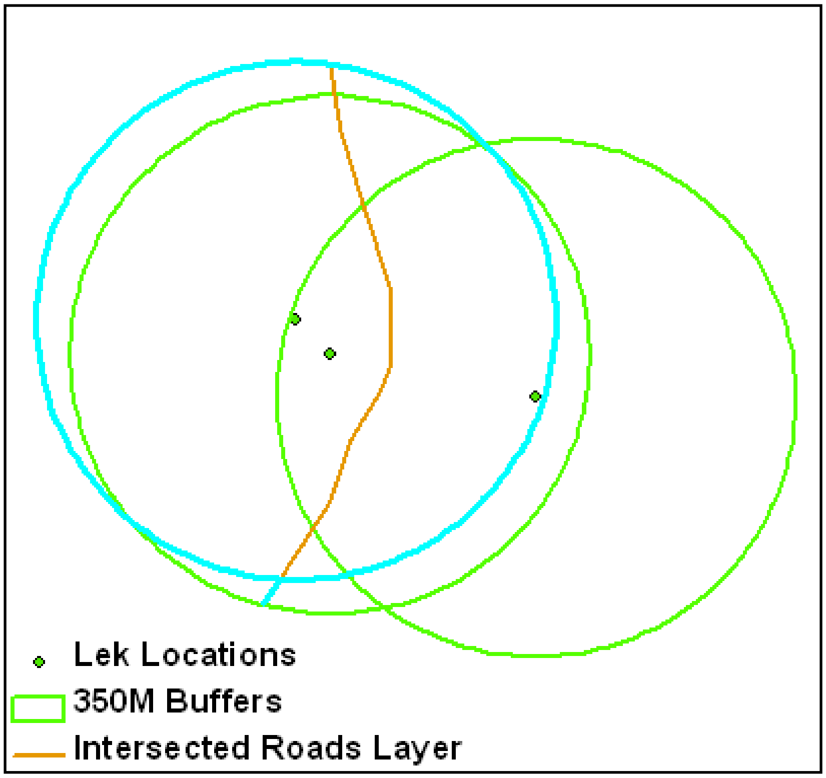
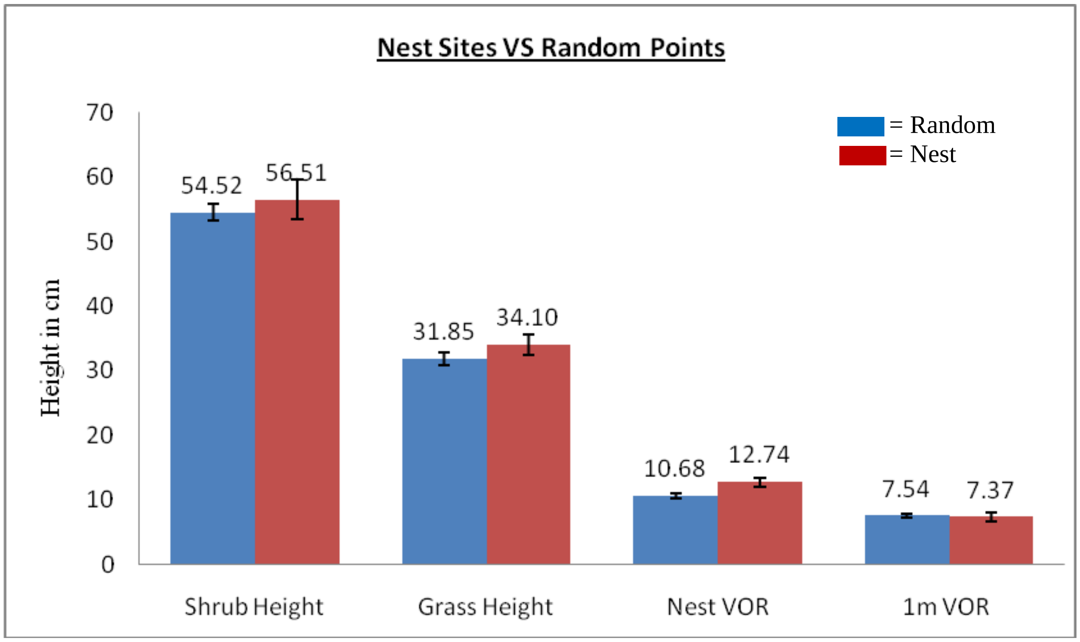


Figure 2. Demonstration of intersect method used and highlights a 350M buffer area and a portion of the road segment for better understanding.



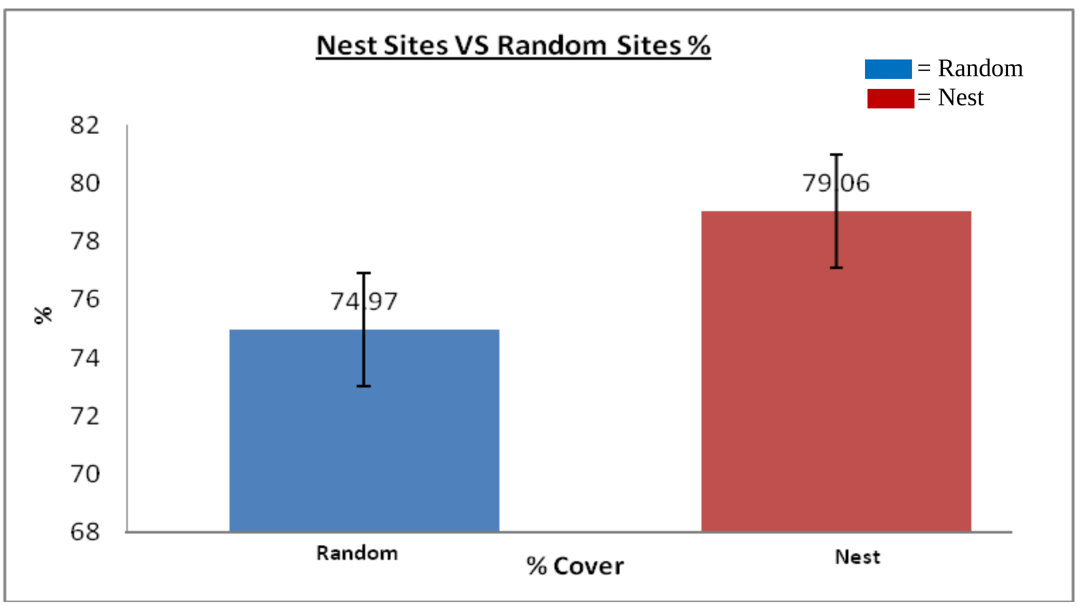


Figure 3. Vegetative height (3a) and total percent cover (3b) comparison between nest sites and random points in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

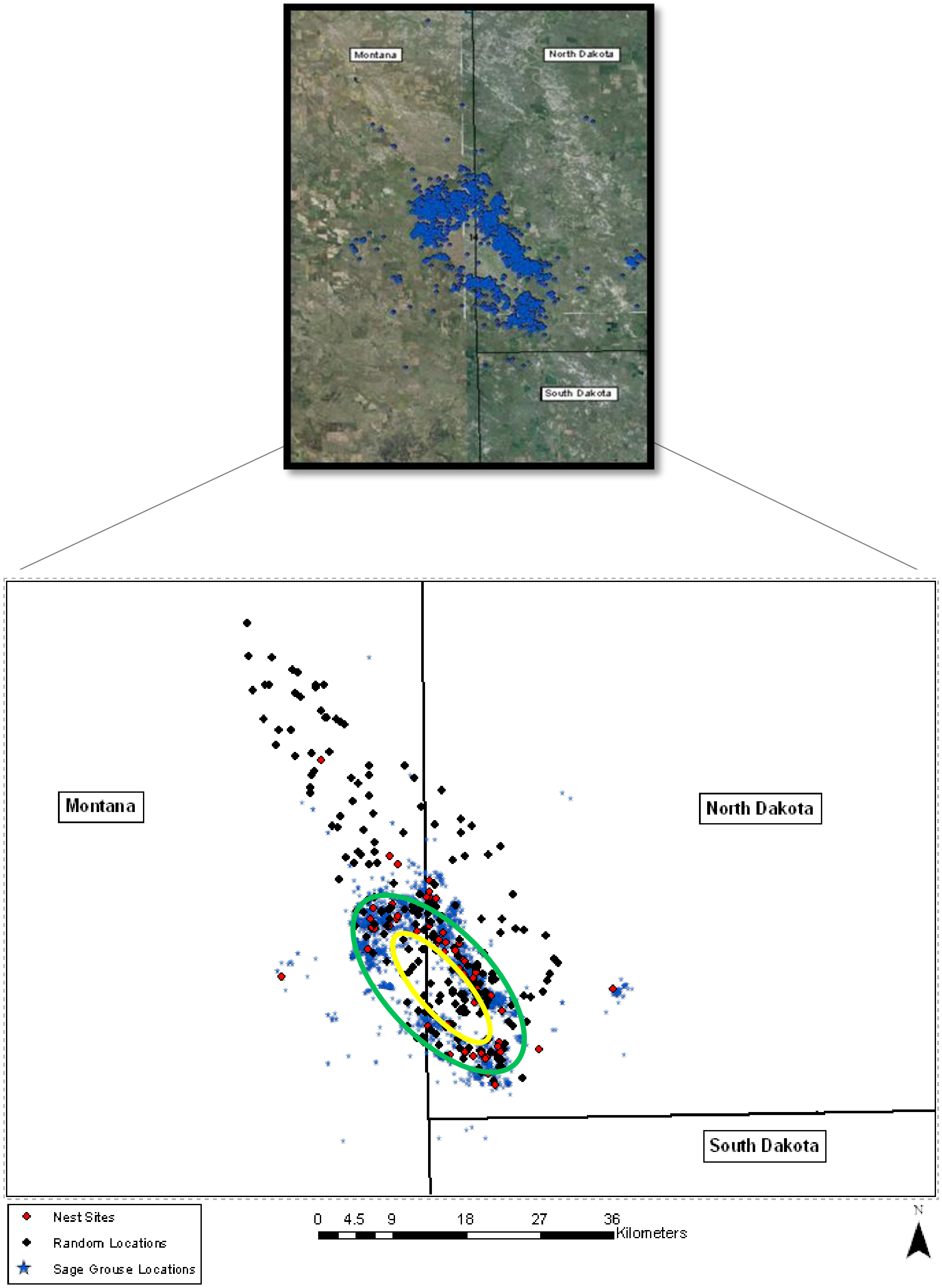
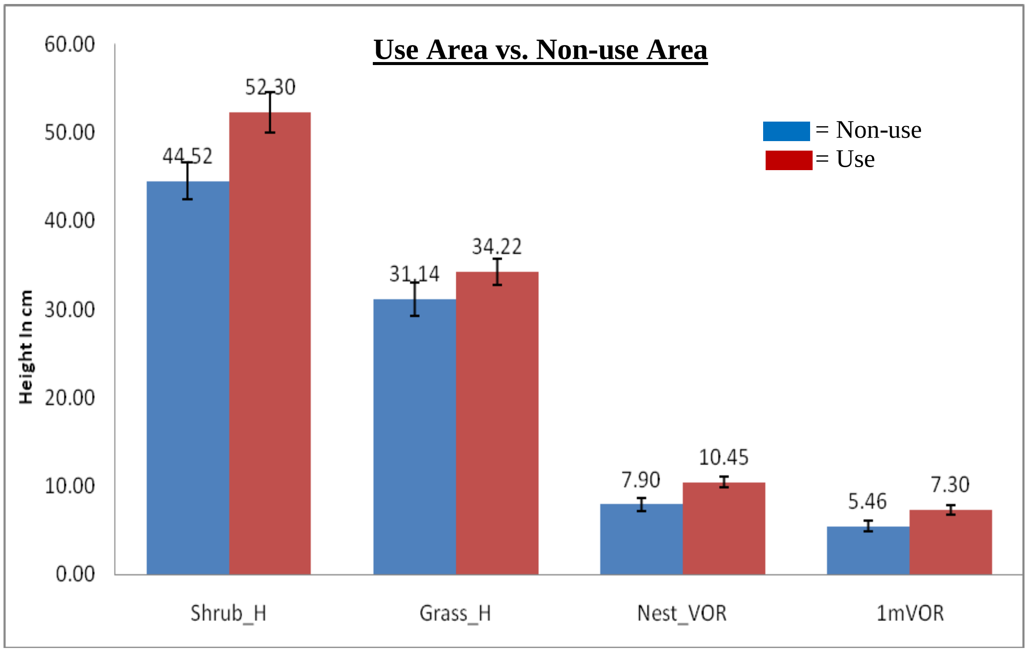


Figure 4. Sage grouse locations from previous work (Swanson, 2009 Herman-Brunson 2007) along with random selected vegetation sampled locations and nest sites. Area of avoidance circled in yellow and area of use circled in green in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.



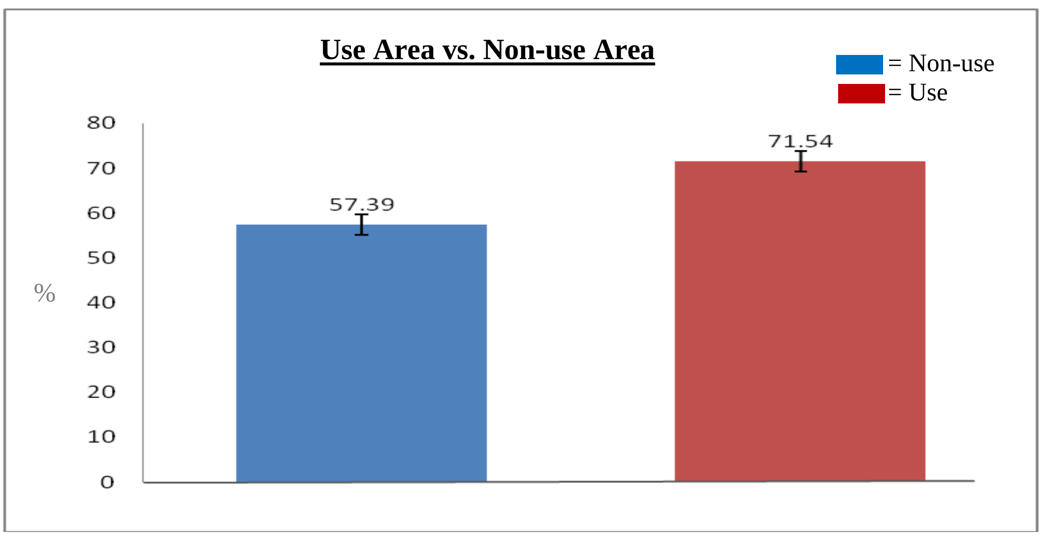


Figure 5. Vegetative height (5a) and total percent cover (5b) comparison between random locations within area of use compared to random locations that fall within area of avoidance in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

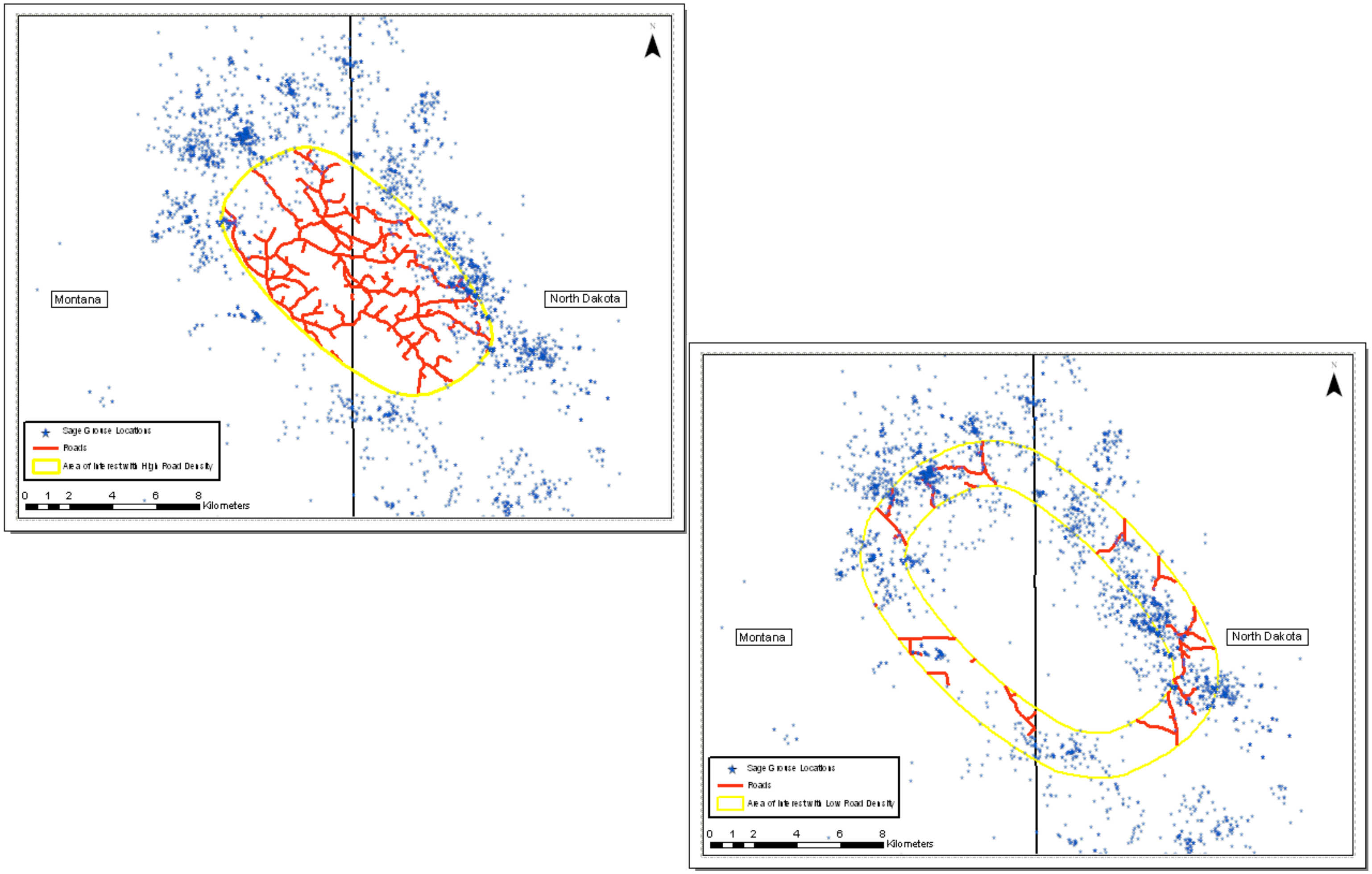


Figure 6. High density road areas (area of avoidance-top) from areas with lower road densities (area of use-bottom) within the study area in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009.

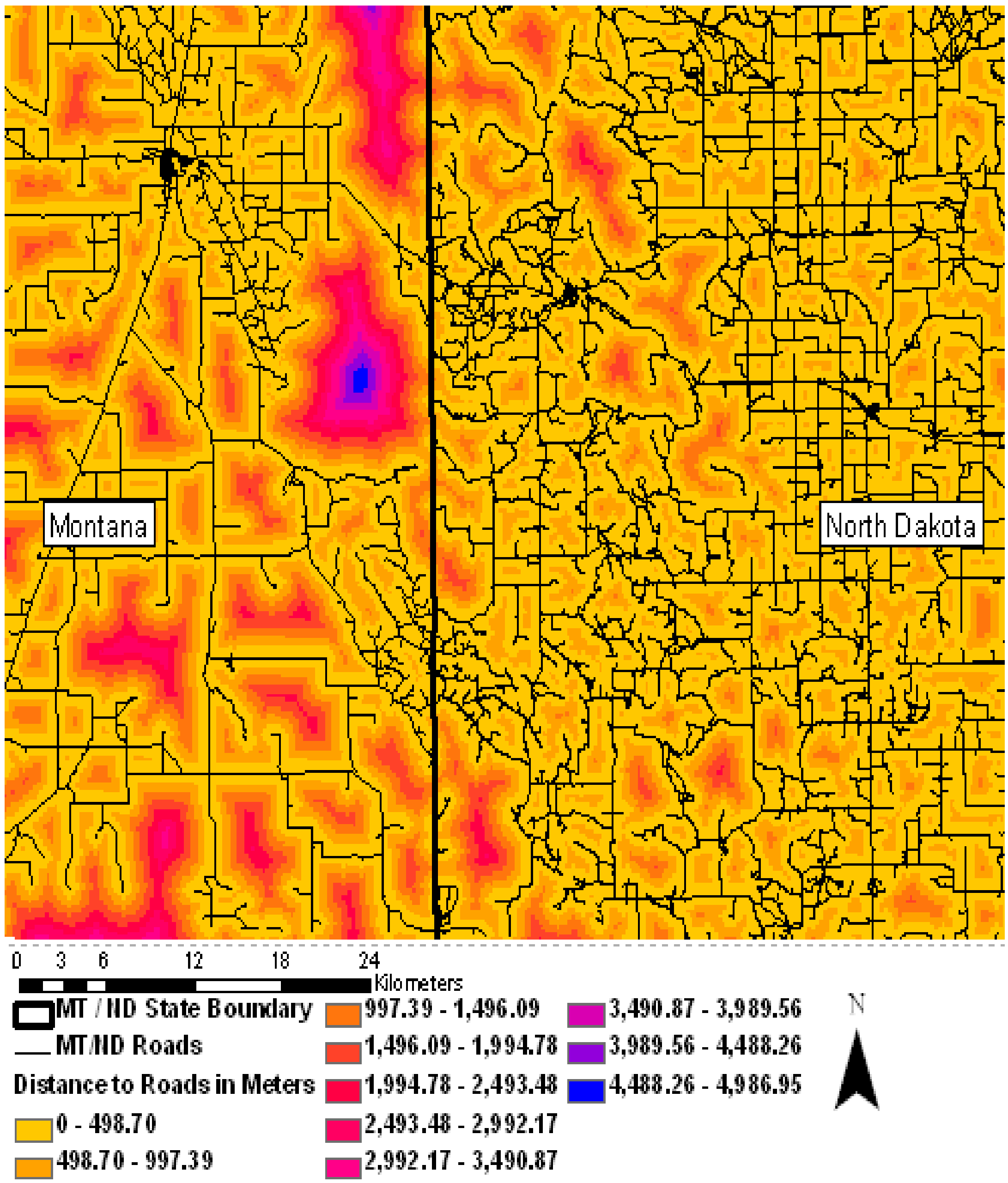


Figure 7. Distance interpolation for road density in southwestern North Dakota and northeastern Montana, USA, 2005, 2006, 2007, and 2009. Dark = Less Roads, Bright = More Roads

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