ECOLOGY OF ISOLATED GREATER SAGE-GROUSE POPULATIONS INHABITING THE WILDCAT KNOLLS AND HORN MOUNTAIN, SOUTHCENTRAL UTAH

by

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A thesis submitted in partial fulfillment
of the requirements for the degree

of

MASTER OF SCIENCE

in

Wildlife Biology

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UTAH STATE UNIVERSITY
Logan, Utah

2010

ABSTRACT

Ecology of Isolated Greater Sage-grouse Populations Inhabiting the Wildcat Knolls and Horn Mountain, Southcentral Utah

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Utah State University, 2010

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Greater sage-grouse (*Centrocercus urophasianus*) currently inhabit about 56% of pre-settlement distribution of potential habitat. In 2005, the Castle Country Adaptive Resources Management Local Working Group (CaCoARM) was formed to address concerns regarding local sage-grouse populations in Carbon and Emery counties. In 2006-2007, CaCoARM identified the Wildcat Knolls and Horn Mountain as areas of special concern for greater sage-grouse conservation. Both sites selected by the group were inhabited by what appeared to be small isolated sage-grouse populations. Factors limiting small isolated greater sage-grouse populations throughout its range are diverse and largely site-specific.

During 2008-2009, I captured, radio-collared, and monitored 43 sage-grouse between the two populations to document their ecology and seasonal habitat use patterns. The sites are only 24 km apart, but the populations appear to be isolated from each other. Sage-grouse on Horn Mountain and Wildcat Knolls are one-stage migratory and non-migratory, respectively. Although nesting and brooding success varied between sites, my results were comparable to those published in studies throughout the species' range. Overall male survival was lower on the Wildcat Knolls than Horn Mountain ($P = 0.003$). Hens that selected brood sites exhibiting increased shrub cover and grass height were more successful than hens that selected sites with lower shrub cover and lower grass height. Potential nesting habitat on the Wildcat Knolls and Horn Mountain were estimated at 2,329 and 5,493 ha, respectively. Hens that selected nest sites farther from non-habitat edge were more successful than hens that selected nest sites that were closer to non-habitat edge on the Wildcat Knolls. Higher nest success observed on the Wildcat Knolls was attributed to less habitat fragmentation.

Isolated populations of greater sage-grouse are more susceptible to lower amounts of genetic diversity that may lead to inbreeding depression and increased rates of disease and parasites. I collected mitochondrial DNA samples from both the Wildcat Knolls and Horn Mountain populations. Although the haplotype frequencies recorded in the Wildcat Knolls and Horn Mountain populations were low, one was shared with several Utah populations. The documented low genetic diversity (especially on Horn Mountain) confirmed the isolation suspected by the local working group. Microsatellite tests may provide insights to enhance understanding of genetic differences among sites, and assist managers in determining whether or not translocations are necessary to maintain population genetic diversity. Biologists should not only continue to take samples for genetic comparison, but also record morphometric and behavior data.

(123 pages)

ACKNOWLEDGMENTS

I admire Terry Messmer's great ability to involve as many people as he can in managing wildlife at the community level. I would like to thank him for giving me the opportunity to grow and develop in a field that I love.

I am very appreciative of the organizations that helped to provide funding for this research: the United States Forest Service, the Utah Division of Wildlife Resources (UDWR), the Jack H. Berryman Institute, SUFCO Mine (Canyon Fuel Company), and the Utah State University Extension Service. I also would like to thank my committee members, Dr. John (Jack) Connelly and Dr. Frank Howe, for their guidance in my research. I appreciate the Castle Country Adaptive Resources Management Local Working Group and their cooperation and insight on sage-grouse research within the region. I would like to specifically thank Wade Paskett, UDWR regional biologist. He was helpful from the very beginning in getting me oriented with the area. I would also like to thank the biologists from the Ferron Ranger District and their help in getting the project started. It was because of their motivation and involvement that the need to further understand sage-grouse issues on the Wildcat Knolls and Horn Mountain was addressed. I would also like to thank SUFCO Mine and their cooperation in the research efforts.

I would like to thank all who spent long nights trapping, in often less than favorable weather conditions. Todd Black was dedicated from beginning to end. He was also very helpful in helping me with all my GIS questions. I am very thankful for all his help. Mike Guttery was not only a very efficient trapper, but was also very instrumental in helping me understand the statistics in my research. I thank Mae Culumber for helping me understand the genetic concepts in my study. I would also like to thank my brother Mike Perkins for all his input and editing all along the way. Dwayne Elmore was always willing to take the time to answer my many questions even before my graduate research began, and I am thankful for his insight. I'd like to thank Dave Dahlgren for introducing me to sage-grouse research. I would also like to thank all the other graduate students who gave me advice along the way. I am thankful for all my technicians who contributed many long days to this work, Bobby Boswell, Tamra Luke, and Armando Aispuro.

I would like to thank all my family and friends who have supported me through good and hard times. Without their support, I would not be where I am today. My parents have always encouraged education, and have given me every opportunity possible to help me become who I am today, and for that, I am forever grateful. I'd especially like to thank my wife for her understanding in helping me accomplish this goal. There have been many long weeks of waiting for the time when she might actually get to see me more than two or three days a week. I am very grateful for the opportunities that I've had in this research, and will never forget my experiences.

Christopher James Perkins

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CHAPTER 1

INTRODUCTION

Historically sage-grouse (*Centrocercus* spp.) were believed to be one of the most abundant and widely distributed native grouse species in the western United States (Dalke et al. 1963). Greater sage-grouse (*C. urophasianus*) currently inhabit about 56% of pre-settlement distribution of potential habitat (Schroeder et al. 2004). Gunnison sage-grouse (*C. minimus*) occur in small isolated populations in southwest Colorado and southeast Utah and inhabit about 10% of pre-settlement distribution of potential habitat (Schroeder et al. 2004). Because of declines in overall sage-grouse populations throughout its entire range, several organizations have petitioned the U.S. Fish and Wildlife Service (USFWS) to list sage-grouse for protection under the Endangered Species Act of 1973 (Connelly et al. 2004). In March 2010, the USFWS designated greater sage-grouse as a candidate species for listing when it determined listing the species was "warranted but precluded" (USFWS 2010).

Sage-grouse occupy sagebrush ecosystems throughout the western U.S. (Patterson 1952, Schroeder et al. 2004) and utilize sagebrush (*Artemisia* spp.) habitats during all life stages, thus their distribution is closely associated with sagebrush species occurrence (Patterson 1952, Connelly and Braun 1997). Greater sage-grouse population declines throughout their range have been largely attributed to habitat loss, degradation, and fragmentation of sagebrush habitats (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Connelly et al. 2004).

DISTRIBUTION

Greater sage-grouse once inhabited 15 states and 3 Canadian provinces (Connelly et al 2004). Breeding populations have declined 17%-47% range-wide (Connelly and Braun 1997, Connelly et al 2004). Sage-grouse populations have been extirpated in Arizona, New Mexico, Oklahoma, Nebraska, and British Columbia (Patterson 1952, Schroeder et al. 2004). Currently, populations occur in southeast Alberta and southwest Saskatchewan, southwest North Dakota and northwest South Dakota, most of Montana and Wyoming, western Colorado, parts of southern and eastern Idaho, north, northeast and southern Utah, northern Nevada, east to northeast California, southeast Oregon, and north-central Washington (Connelly and Braun 1997, Schroeder et al. 2004).

SPECIES DESCRIPTION

As the largest native member of the grouse family in North America, male greater sage-grouse are typically double the size of the smaller female, and can weigh up to 3.2 kg and range from 65-75 cm in length (i.e., measured from the head to tip of the tail). Female sage-grouse can weigh up to 1.8 kg and range from 50-60 cm in length (Patterson 1952, Autenrieth 1981).

Adult male and female sage-grouse are similar in color, but do differ. Females are cryptically colored, and have gray and white markings (Dalke et al. 1963, Schroeder et al. 1999). Males and females both have a black patch on their belly. Males in full breeding plumage have stiff white breast feathers, a black chin, and black and white bands on the throat (Dalke et al. 1963). Other distinguishing characteristics of the males in breeding plumage are long filoplumes that stand up on the back of the neck and two yellow cervical apteria that are visible on the breast during display (Schroeder et al. 1999, Connelly et al. 2004). Juvenile grouse may be distinguished from adults for up to 17 months by examining primary feather characteristics (Dalke et al. 1963, Gill 1967).

In regions where sage-grouse occur with other grouse species, they have sometimes been know to hybridize with blue (*Dendragapus obscurus*) and sharp-tailed grouse (*Tympanchus phasianellus*) (Kohn and Kobriger 1986, Rensel and White 1988). Although sage-grouse hybridization is not common, potential production of fertile hybrids may become more of a concern in smaller populations of sage-grouse that already have low genetic diversity (Aldridge et al. 2001).

GENERAL HABITAT REQUIRMENTS

Seasonal Movements

Greater sage-grouse are classified as sagebrush obligate species, and as such rely on different stages of sagebrush communities throughout the year for food, breeding and winter cover (Patterson 1952, Braun et al. 1976). Because seasonal movements may exceed 75 km, it may be difficult to define specific population annual ranges on a landscape scale (Dalke et al. 1963, Knerr 2007). Biologists have classified sage-grouse movements into 3 types; 1) nonmigratory; 2) one-stage migratory, grouse with two distinct seasonal ranges; and 3) 2-stage migratory, grouse with 3 distinct seasonal ranges (Connelly et al. 2000).

Lekking

Leks are site-specific areas where males display to attract and breed with females. The largest, most dominant males often occupy areas, near the center of the lek. These males typically do most of the breeding. During the breeding season, many greater sage-grouse populations have been documented to have interlek movements, which are more likely to occur among yearling males rather than adults (Dalke et al. 1963, Emmons and Braun 1984, Dunn and Braun1985, Schroeder and Robb 2003). Adult male sage-grouse show more fidelity to lek sites and will visit the same lek throughout the strutting season (Schroeder and Robb 2003).

Leks are in open areas adjacent to sagebrush habitat that is suitable for nesting (Connelly et al. 2000). Distances among nest and nearest leks may range from 1.1 to 6.2 km (Autenrieth et al. 1981, Wakkinen et al. 1992). However, nests have been found to be independent of leks (Bradbury et al. 1989, Wakkinen et al. 1992). Typically, lekking grounds are sparsely vegetated areas with little or no shrub cover (Patterson 1952). Leks may be found in openings in sagebrush, ridge tops, landing strips, old lakebeds, roads, and burned areas adjacent to large expanses of sagebrush (Connelly et al. 1981). For non-migratory populations, the lek may be the average center of the annual range (Eng and Schladweiler 1972, Wallestad and Pyrah 1974). There is little evidence to suggest that lek habitat is a limiting factor in greater sage-grouse populations (Schroeder et al. 1999).

Pre-Laying Females

Female sage-grouse dietary needs change towards the end of the winter season (Barnett and Crawford 1994). In preparation to the nesting season female sage-grouse diets include mixed sagebrush species and forbs which are higher in calcium, phosphorus, and protein. Forb growth and availability prior to nesting influence nest initiation rate, clutch size, and other reproductive factors (Barnett and Crawford 1994).

Nesting

Sage-grouse nests average 6-10 eggs (Schroeder 1997, Connelly et al. 2000), and are mostly commonly found under sagebrush (Patterson 1952, Wallestad and Pyrah 1974), though some nests occur in cover other than sagebrush (Connelly et al. 1991, Knerr 2007). Nests under sagebrush frequently have higher nest success than those in different cover types (Connelly at al. 1991). Major factors that influence nest site selection include canopy cover, lateral cover, ground cover, and surrounding stands of shrubs with high canopy cover (Sveum et al. 1998, Connelly et al. 2000).

Research conducted in north-central Washington by Schroeder (1997) suggested a high (87%) re-nesting effort by female sage-grouse occupying small fragmented habitats. Sage-grouse nest success rates have been found to vary (15-86%) throughout its range (Connelly et al. 1993, Gregg et al. 1994, Schroeder 1997).

Predation is the most common factor in unsuccessful sage-grouse nests. Although it is often difficult to identify actual nest predators without visually observing the depredation event (Coates and Delehanty 2004), most common sage-grouse nest predators include both mammalian and avian species (Ritchie et al. 1994, Schroeder and Baydack 2001) such as badgers (*Taxidea taxus*), coyotes (*Canis latrans*), and common ravens (*Corvus corax*) (Schroeder and Baydack 2001).

Gregg et al. (1994) in Lake County Oregon studied the effects of vegetation cover and height on predation of artificial sage-grouse nests. In this study, the survival of artificial nests was positively associated with tall grass cover and medium height shrub cover. These results suggest that the quality of nesting habitat may be the most important factor in grouse nest success. The importance of habitat quality to nesting success is supported by additional research (Messmer and Rowher 1998), but other research suggests managing predators rather than habitat becomes more important in smaller fragmented grouse populations (Schroeder and Baydack 2001).

Brood-rearing

Although brooding female grouse generally remain close to nest sites after hatching a clutch, there is considerable variation among broods (Knerr 2007). A study conducted in Box Elder County in northwestern Utah, reported successful hens with broods moved 1.4 - 9.4 km from the initial nest locations (Knerr 2007). This study also indicated that successful broods used areas with shrub canopy cover that averaged 24.1%. Often moving into more mesic sites as forbs dessicate on dryer sites **(**Wallestad 1971), female sage-grouse often prefer habitat comprised of big and low sagebrush (*A. tridentata, A. arbuscula*, respectfully) or riparian habitat. Hens with broods often move to places where forb abundance is greatest (Drut et al. 1994a). Published guidelines for brood rearing habitat suggest 10-25% sagebrush canopy cover with 40-80 cm height, and >15% grass-forb canopy cover with variable height (Connelly et al. 2000).

Sage-grouse broods depend on areas that are both diverse and abundant in plant species (Drut et al. 1994b). During the first three weeks of life, sage-grouse chicks depend highly on a diet of insects to survive (Patterson 1952, Johnson and Boyce 1990). Drut et al. (1994b) in a study of sage-grouse diets in southeastern Oregon, reported that chicks consumed 122 different foods, which included 34 genera of forbs, 2 genera of shrubs, 1 genus of grass, and 41 families of invertebrates. Of those items consumed, 10 genera of forbs, 3 families of insects, and sagebrush were classified as primary foods.

Primary insect groups eaten by sage-grouse chicks are beetles, ants, and grasshoppers (Patterson 1952, Drut et al. 1994b). Small burned areas within sagebrush habitat, wet meadows, agricultural lands, and irrigated lawns are important habitat types providing necessary dietary needs during the late-summer (Connelly et al. 1988, Pyle and Crawford 1996).

Because of nesting rates and nest success, broodless hens may constitute a large portion of sage-grouse populations. The survival of broodless hens however plays an important role in maintaining the population (Crawford et al. 2004). Broodless hens often occupy habitat that is similar to brood hens, but will typically move into more mesic areas earlier in the season (Crawford et al. 2004).

Winter

During the winter, taller sagebrush is the preferred cover type of sage-grouse, providing important thermal cover, escape cover, and a food source (Connelly et al. 2000a). Sage-grouse are highly dependent on sagebrush for their winter diet (Patterson 1952). Connelly et al. (2000) suggest maintaining sagebrush heights from 25-35 cm above snow, and 10-30% canopy cover for mesic and arid sites (Connelly et al. 2000). Severe winter conditions generally have little effect on sage-grouse populations unless snow depths cover the sagebrush canopy completely (Crawford et al. 2004). Sage-grouse gain weight during the winter months (Beck and Braun 1978).

FACTORS LIMITING SAGE-GROUSE POPULATIONS

Declines in sage-grouse populations are largely attributed to habitat loss and degradation typically associated with anthropogenic activities. Energy development throughout the west also has become a major factor affecting sage-grouse populations (Beck 2006). Impacts associated with increased energy development may include habitat loss and fragmentation caused by increased roads, wells and pipeline construction (Beck 2006). Much of the published sage-grouse management guidelines were based on populations of sage-grouse that inhabited large contiguous landscapes. With increased fragmentation throughout its range, it is important to understand the basic ecology of sage-grouse that inhabit small isolated regions (Schroeder and Robb 2003). Sage-grouse population dynamics are diverse and mostly depend on late seral and climax sagebrush communities. Throughout the year, different stages of heterogeneous sagebrush habitat types are used. Thus, conservation actions designed to reduce fragmentation and maintain important sagebrush steppe habitat throughout the species range will be essential to sustaining current sage-grouse population distributions.

SAGE-GROUSE IN UTAH

In Utah, sage-grouse have been found in 26 of 29 counties and now inhabit 50 % of their historic range. There has been a 60-70% decline in potential habitat for greater sage-grouse and Gunnison sage-grouse (Beck et al. 2003). Management of sage-grouse is further complicated because of the mosaic of private and public landownership in Utah. Sage-grouse occupy habitats managed by the Bureau of land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), State of Utah, and private landowners.

In 1996, the Western Association of Fish and Wildlife Agencies (WAFWA) recommended the formation of local working groups (LWGs) in each state that birds occupy (Connelly et al. 2004). The complexity of land ownership requires the collaboration of many organizations and private landowners when dealing with sage-grouse issues. The Utah Division of Wildlife Resources (UDWR) estimates that about 50% of Utah sage-grouse habitat and populations occur on private land. In Utah, the greater sage-grouse has been identified as a "species of special concern" (UDWR 2002). To address sage-grouse population declines, the UDWR prepared the Utah Strategic Management Plan for sage-grouse (UDWR 2002). The plan identified regional concerns and actions that needed to be addressed by LWGs to improve declining sage-grouse populations. Utah currently has 10 local working groups. These groups have completed sage-grouse conservation and management plans for specific areas and populations in Utah. These plans include both management and research strategies identified by the groups as critical to the conservation of the species (www.utahcbcp.org).

CASTLE COUNTRY ADAPTIVE RESOURCES MANAGEMENT LOCAL WORKING GROUP

The Castle Country Adaptive Resources Management Local Working Group (CaCoARM) was formed in 2005 to address concerns regarding local sage-grouse populations in Carbon and Emery Counties, and prepare a conservation plan for greater sage-grouse inhabiting those counties (CaCoARM 2006). This plan provided a mechanism for maintaining and improving the abundance and viability of sage-grouse populations and their habitat in the Castle Country area with consideration for historical land uses and long-term socioeconomic issues. The CaCoARM seeks to identify, develop, implement, and evaluate management actions that will sustain sage-grouse populations and healthy sagebrush habitats that are valuable to the existence of other species. Their plan identifies management areas, key local issues, conservation strategies, population information, research and monitoring needs, and long-term funding requirements.

In 2006-2007, CaCoARM identified the Wildcat Knolls and Horn Mountain as areas of special concern for local sage-grouse conservation. Both sites selected by the group were inhabited by what appeared to be small isolated sage-grouse populations. The CaCoARM conservation goals for these areas include obtaining estimates of sage-grouse lek attendance, distribution, habitat-use patterns, and the factors affecting production, and survival (CaCoARM 2006). In 2007, CaCoARM collaborated with Utah State University and the UDWR to study the ecology and habitat use of the sage-grouse populations inhabiting these areas. The information obtained by this study will be provided to managers to help evaluate the factors that may be limiting greater sage-grouse populations on the Wildcat Knolls and Horn Mountain.

PURPOSE AND STUDY OBJECTIVES

Prior to this research, little was known about sage-grouse ecology on the Wildcat Knolls and Horn Mountain in central Utah. Previous data collection efforts, initiated in 1991, were limited to monitoring male attendance on the Wildcat Knolls, South Horn, North Horn, and Barewire Pond leks. However, these counts were inconsistent because of limited accessibility during the early spring months. The purpose of this research is to obtain a better estimate of sage-grouse lek attendance, distribution, habitat-use patterns, and the factors affecting production, and survival. This research will provide the CaCoARM, Canyon Fuel Company (CFC), USFS, and the UDWR with information to guide management actions to enhance habitat conditions for the greater sage-grouse populations that inhabit the Wildcat Knolls and Horn Mountain.

The objectives of this study were:

1) Document greater sage-grouse seasonal distributions and habitat use on HornMountain and Wildcat Knolls.

2) Document greater sage-grouse nesting and brood habitats on Horn Mountain and Wildcat Knolls.

3) Determine the factors that may be limiting greater sage-grouse populations on Horn Mountain and Wildcat Knolls.

4) Document the genetic diversity of greater sage-grouse populations inhabiting Horn Mountain and Wildcat Knolls.

STYLE

The Abstract, Acknowledgments, Contents, and Chapters 1, 2, 3, 4 and 5 are written following the *Wildlife Society Bulletin* and *The Journal of Wildlife Management* 2006 unified style guidelines (Messmer and Morison 2006).

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CHAPTER 2

ECOLOGY OF GREATER SAGE-GROUSE POPULATIONS INHABITING WILDCAT KNOLLS AND HORN MOUNTAINS, SOUTHCENTRAL UTAH

Abstract Factors limiting small isolated greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations throughout its range are diverse and may be site-specific. Utah has several smaller sage-grouse populations that inhabit isolated sagebrush (*Artemisia* spp.) steppe habitats across the state. Little information is known about these populations for application to management. Such is the case for the two populations inhabiting Wildcat Knolls and Horn Mountain in south central Utah. The areas are only 24 km apart, but the populations appear to be isolated from each other. During 2008-2009, I captured, radio-collared, and monitored 43 sage-grouse between the two populations to document their ecology and seasonal habitat use patterns. Sage-grouse on Horn Mountain and Wildcat Knolls are one-stage migratory and non-migratory, respectively. Although nesting and brooding success varied between sites, my results were comparable to those published in studies throughout the species range. Vegetation parameters at brood and nest site locations approximated recommended published guidelines. Overall adult survival was lower on the Wildcat Knolls than Horn Mountain. Lower adult survival on the Wildcat Knolls was attributed to active golden eagle (*Aquila chrysaetos*) nests found in proximity of their nesting habitat. Hens that selected brood sites exhibiting increased shrub cover and grass height were more successful. These results reinforce the importance of escape cover in brood rearing

habitat. Escape cover for broods is limited on both study sites. Thus protection and enhancement of escape cover should remain a high priority conservation strategy.

INTRODUCTION

Sage-grouse (*Centrocercus* spp.) occupy sagebrush (*Artemisia* spp.) ecosystems throughout the West (Patterson 1952, Schroeder et al. 2004). Greater sage-grouse (*C. urophasianus*; hereafter sage-grouse) populations however inhabit about 56% of pre-settlement distribution of potential habitat (Schroeder et al. 2004). Breeding populations have declined 17%-47% range-wide (Connelly and Braun 1997). Sage-grouse use sagebrush habitats during all life stages, thus their distribution is closely associated with sagebrush species occurrence (Patterson 1952, Connelly and Braun 1997). Thus, population declines have been largely attributed to habitat loss, degradation, and fragmentation of sagebrush habitats (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Connelly et al. 2004).

In Utah, sage-grouse have been found in 26 of 29 counties and inhabit 50% of their historic range (Beck et al. 2003). Sage-grouse occupy habitats managed by the Bureau of land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), State of Utah, and private landowners. The Utah Division of Wildlife Resources (UDWR) estimates that about 50% of Utah sage-grouse habitat and populations occur on private land. The species has been identified as a “species of special concern” (UDWR 2002).

Management of sage-grouse in Utah is complicated because of the habitat mosaic of private and public landownership. The complexity of land ownership requires the collaboration of many organizations and private landowners when addressing sage-grouse conservation.

In 1996, the Western Association of Fish and Wildlife Agencies (WAFWA) recommended the formation of local working groups in each state that birds occupy to implement conservation actions (Connelly et al. 2004). In 2002, the UDWR published the Utah Strategic Management Plan for Sage-grouse to guide species conservation planning in the state (UDWR 2002). This plan identified regional concerns and actions that needed to be addressed to improve declining sage-grouse populations. The plan also called for the formation of sage-grouse local working groups. Utah currently has 10 local working groups. These groups have completed sage-grouse conservation and management plans for specific areas and populations in Utah (www.utahcbcp.org).

In 2005, the Castle Country Adaptive Resources Management Local Working Group (CaCoARM) was formed to address concerns regarding local sage-grouse populations in Carbon and Emery Counties. In 2006-2007, CaCoARM identified Wildcat Knolls and Horn Mountain as areas of special concern. Both areas appeared to be inhabited by small isolated sage-grouse populations. The CaCoARM identified the need for a better understanding of basic sage-grouse ecology and seasonal habitat-use in these areas to help guide species conservation and management actions.

Prior to this research, little was known about greater sage-grouse ecology on the Wildcat Knolls and Horn Mountain in central Utah. Previous data collection efforts were limited to monitoring male attendance on Wildcat Knolls, South Horn, North Horn, and Barewire Pond leks since 1991. The purpose of my research was to obtain a better estimate of distribution, habitat-use patterns, and the factors affecting production, and survival. I compared my results to current literature and recommended habitat management guidelines (Connelly et al. 2000). This research will provide the CaCoARM with information to guide management actions to enhance habitat conditions for the greater sage-grouse populations that inhabit Wildcat Knolls and Horn Mountain.

STUDY AREA

Ranging from 2500-2900 m in elevation, the Wildcat Knolls and Horn Mountain study areas are located in Emery and Sevier counties on the southeast end of the Manti Mountains (Wasatch Plateau) (Fig. 2-1). Both sites contain isolated sagebrush steppe habitats on the southeast edge of the plateau, and are surrounded by canyons, cliffs, and mountains. The North Fork of the Quitchupah Canyon borders the Wildcat to the west, White Mountain to the north, the Muddy to the Northeast, and the southern edge is bounded by an escarpment of cliffs. The town of Emery is located just about 11 km south of the Wildcat Knolls site in the desert valley below.

The Horn Mountain site is located 24 km to the northeast of Wildcat Knolls. Straight Canyon borders to the north east of the Horn Mountain. The Cap and Long Ridge to the north, Ferron Canyon borders to the west, and an escarpment of cliffs surrounds the south and southeast edge of Horn Mountain. The town of Ferron is located about 6.5 km south west in the valley below. Both sites are managed by the U.S. Forest Service (USFS).

In the late 1800's, early settlers inhabiting the surrounding valleys of the Wasatch Plateau relied heavily on the high elevation plateaus for grazing of mostly sheep and some cattle. By the early 1900's, watershed problems, including flooding and erosion, became critical management concerns. Livestock grazing had also modified the vegetation in many plant communities within the region (Monsen 2004). In 1913, researchers with the Great Basin Experiment Station (formerly known as the Utah Experiment Station) recognized the dramatic change that was occurring in plant communities (Monsen 2004). They focused efforts on restoring sites by natural reestablishment of native species and direct seeding with natives and exotics to help stabilize overgrazed sites. Some livestock, mostly cattle, are still grazed within both study areas today. These allotments are managed by the USFS. In 1941, underground mining began near the Wildcat study area. Today, the Canyon Fuel Company (CFC) employs about 252 people at the SUFCO mine site and is one of the largest producers of coal in Utah (http://geology.utah.gov/utahgeo/energy/coal/coaltour/mines/sufco.htm).

Climate

The average annual precipitation recorded by a Western Regional Climate Center weather station 12 km southwest of Wildcat Knolls, and 32 km south of the Horn Mountain was 33.8 cm recorded over a 23 year average. The average annual temperature was about 6.0°C. The warmest time of the year occurs in July and the coldest weather occurs in January with temperatures reaching as low as -9.6°C. Highest amounts of precipitation occur in August at an average of 4.3 cm. Highest amounts of snowfall occur in January and February with total annual snowfall averaging about 157.5 cm.

Vegetation

Although the rim of the Wildcat Knolls is lined with ponderosa pine (*Pinus ponderosa)*, it is characterized as a mountain big sagebrush (*A. tridentata nut. ssp. vaseyana*) and black sagebrush (*A. nova)* vegetation community. Other common species in the plant community are: serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpus albus*), woods rose (*Rosa woodsii*), and antelope bitterbrush (*Purshia tridentata)*. Serviceberry occurs in areas with wetter and deeper soils. Mountain big sagebrush is primarily found in the drainage corridors, while black sagebrush, dwarf rabbitbrush (*Chrysothamnus depressus)*, and low rabbitbrush (*C. visidiflorus)* occur in drier areas. Herbaceous vegetation is diverse. Dominant grass species include mutton bluegrass (*Poa fendleriana*), smooth brome (*Bromus inermis*), letterman needlegrass (*Achnatherum lettermanii*), and Salina wildrye (*Leymus salinus*). One of the more abundant forbs is goosefoot (*Chenopodium* spp.*).* Plant community structure on the Horn Mountain site is similar to the Wildcat Knolls, except that mountain brush communities are more abundant, including mountain mahogany (*Cercocarpus montanus*) and scattered pinyon pine (*P. edulis)*.

Wildlife

Wildlife species within the study area are diverse. Common avian species include but are not limited to red-tailed hawk (*Buteo jamaicensis*), prairie falcon (*Falco mexicanus*), golden eagle (*Aquila chrysaetos*), northern harrier (*Circus cyaneus*), turkey vulture (*Cathartes aura*), common raven (*Corvus corax*), black-billed magpie (*Pica pica*), western meadowlark (*Sturnella neglecta*), horned lark (*Eremophila alpestris*), sage thrasher (*Oreoscoptes montanus*), northern flicker (*Colaptes auratus*) and mourning dove (*Zenaidura macroura*). In 2008, the UDWR reported 281 golden eagle nests within 24 km radius of the Horn Mountain and Wildcat Knolls study sites. Eleven of the 281 nests were active during my study. Common mammalian species include mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), coyote (*Canis latrans*), red fox (*Vulpes

vulpes), mountain lion (*Felis concolor*), bobcat (*Felis rufus*), badger (*Taxidea taxus*), and white-tailed jackrabbit (*Lepus* townsendii).

Sage-grouse Monitoring

Local UDWR and USFS biologists have monitored sage-grouse within the study area since the late 1980's. In 1991, sage-grouse hunting seasons in parts of Sevier and all of Emery counties were closed in response to declining sage-grouse numbers. Limited accessibility to the study area during the early spring months has often made it difficult to monitor lekking activity. All leks occur on federal land, and range in elevation from 2500-2900 meters. Documented lek monitoring for both sites started in 1990.

Wildcat Knolls: In 1987, UDWR biologists began translocating sage-grouse to the Wildcat Knolls. Over a four year period, 53 sage-grouse were moved to the Wildcat Knolls site from various parts of the state. (Table 2-1). Prior to monitoring efforts that began in 1990, UDWR biologists did not record any sage-grouse activity on the Wildcat Knolls study site. Since the sage-grouse translocations on the Wildcat Knolls, one main lek and several satellite leks have been monitored (Fig. 2-2). In 2008, peak male lek attendance was 17, and dropped to 12 in 2009.

Horn Mountain: Since 1990, four leks have been monitored: South Horn, Barewire Pond, and North Horn. In the late 1990's, there was a period where no lekking activity was observed on any of the Horn Mountain leks. In 2008, the high lek count of male sage-grouse on the South Horn lek was 17 (Fig. 2-3). According to the UDWR, sage-grouse have never been translocated to the Horn Mountain study area (R. Hodson, UDWR, personal communication). Although the Wildcat Knolls and Horn Mountain populations are only 24 km apart, connectivity between the sites is limited.

METHODS

Captures

Highest concentrations of sage-grouse on the Wildcat Knolls site have been observed in January (K. Albrecht, USFS, personal communication). As the early spring lekking season begins on Wildcat Knolls, sage-grouse densities appeared to decrease. Elevation and accessibility during early spring months have made it difficult for biologists to monitor sage-grouse movements during this period.

I used radio telemetry to document the ecology, habitat-use patterns, and distribution of sage-grouse inhabiting the Wildcat Knoll and Horn Mountain sites. To document early spring movements, initial trapping began in January 2008. Sage-grouse were located by spotlighting with binoculars from the back of an ATV and captured with a long-handled net (Wakkinen et al. 1992). At each capture site, the overall health and condition of the grouse were assessed. Age (adult or yearling) and sex were assigned at the time of capture site based on primary feather characteristics (Dalke et al. 1963). Each bird was weighed using a pesola™ (Pesola, Zug, Baar, Switzerland) 2,500-g spring scale. Blood samples from all birds captured or re-captured in 2009 were taken to determine the genetic diversity among both populations. I collected blood from clipped grouse toenails. Silver nitrate was applied to the toenail if bleeding did not stop after applying pressure with a cotton ball.

At the site of each capture, I used a global positioning system (GPS) unit set to Universal Transverse Mercator (UTM) NAD27 to record each capture location. All grouse captured were handled in accordance with protocol approved by the Institutional

Animal Care and Use Committee (IACUC) at Utah State University, protocol file # 1195, and with a Certificate of Registration (COR) from the UDWR, COR # 6BAND7779.

Adult birds were fitted with Holohil Systems Ltd. (112 John Cavanaugh Drive, Carp, Ontario, K0A 1L0, CANADA) necklace style radio transmitters. This type of transmitter has a 36-month battery life (24 hours on), and weighs 17.7 grams. Radio-collared birds were located using triangulations with Telonics, Inc.™ (932 East Impala Avenue, Mesa, AZ 85204) and ICOM America Inc.™ (2380 116th Avenue northeast, Bellevue, WA 98004) receivers, handheld 3-element Yagi folding antennas, and vehicle mounted Omni antennas (RA-2A).

Nesting

I began monitoring hens to determine nest initiation rates in April 2008. Radio-collared hens were located every three to four days until nest initiation began. Hens were monitored to identify nesting habitat, clutch sizes, nesting success rates, and nest predation rates. All potential nest locations were approached carefully with binoculars maintaining a distance of at least 10 meters between the observer and hen to obtain a visual location. If a hen was found under the same bush two days in a row, they were considered to be nesting. Nest locations were then marked discretely using natural materials. At each site, GPS locations and vegetations types were recorded to identify nest site selection.

I estimated nest initiation dates using a 27-day incubation period with one day added for each egg in the nest (Schroeder 1997). All nests were monitored every three days from the time they were located until their fate was determined (i.e., predated, abandoned, or successfully hatched). Successful nests were determined by the presence of one or more eggshells with loose membranes (Griner 1939, Fig. 2-4). Unsuccessful nests were examined to try and determine depredation factors using eggshells, scat, tracks, or hairs (Patterson 1952).

Nest Site Vegetation

At each nest site, I recorded vegetation measurements along 15-meter line transects established in four directions (every 90 degrees starting with a randomly chosen direction). I measured species-specific shrub canopy coverage using the line-intercept method (Canfield 1941). The live shrub canopy intersecting an imaginary vertical plane on the line was measured. Gaps in the foliage less than 5 cm were counted as continuous and gaps greater than 5 cm were not counted on the line as continuous shrub cover. The amount of shrub intersecting the line was summed and then divided by the length of the line to determine total shrub canopy cover (Connelly et al. 2003). The use of this method allows direct comparison with data from many other studies (Connelly et al. 2003). Shrub height was recorded by selecting the tallest live part of each shrub along the transect (Connelly et al. 2003). The percentage of ground vegetation was measured using 20 X 50-cm Daubenmire (1959) frames placed every three meters to quantify herbaceous cover, species present, rock, litter, and bare ground. Nest shrub height, nest shrub width, and grass height were also measured at each nest location to evaluate nesting cover (Connelly et al. 2003, Hagen et al. 2007).

At each nest site, visual obstruction (vertical cover) between the nest and four meters from the nest was measured after hens left the nest using a Robel pole (Robel et al. 1970, Connelly et al. 2003) with painted 10 cm increments. Two measurements were recorded: Robel In (a measure of predator obstruction looking toward the nest from 4 meters out) and Robel Out (a measure of hen's obstruction looking out 4 meters). This measurement was taken on all four line transects at each nest site.

Brood Monitoring

Hens that successfully hatched nests were located two to three times per week and hens without broods were located on a weekly basis. Brood hens were approached carefully with binoculars and could typically be observed without flushing the brood hen. In later brood-rearing stages, hens began to flush as chicks developed the ability to fly. Broods were considered successful if one or more chicks survived to ≥ 50 days (Schroeder 1997). At each collared hen location, the following data were recorded: a GPS coordinate, vegetation type, weather conditions, number of chicks seen, and total number of grouse flushed.

Brood Site Vegetation

Vegetation measurements were recorded at the brood sites 3-5 days after the brood was originally located. To mark the center point of the vegetation measurements, I placed a Robel pole (Robel et al. 1970) in the center of the brood location. Vegetation measurements were recorded along 10-meter line transects in four directions (every 90 degrees starting with a randomly chosen direction). Shrub canopy coverage, shrub height, and the percentage of ground vegetation were measured at brood sites using the identical procedures as those described for nest sites. At each brood site, visual obstruction (vertical cover) between the brood and four meters from the brood was measured using a Robel pole (Connelly et al. 2003). I recorded a Robel In (a measure of concealment) measurement from 4 m from the center on each of the 4 transects.

Arthropod Sampling

Evaluating arthropod abundance at brood site locations is an important component in assessing sage-grouse habitat quality. Each week, one location from each hen with a brood was randomly selected to evaluate insect abundance and diversity. After vegetation measurements were recorded at nest and brood site locations, five pitfall traps were placed flush with the ground along each of the four line-intercept vegetation transects. Pitfall traps were placed at 10 m from center, with another trap in the center. Pitfall traps were filled with water. All traps were open for 48 hours, after which the insects were collected and preserved for later analysis. Preserved insects were placed in a 70% ethylene glycol solution (Pedigo and Buntin 1993) or frozen for future evaluation and identification. Arthropods were divided into four orders and quantified for presence of each to determine relative abundance of each order at different locations from May to July (Connelly et al. 2003).

Survival

In the event of a mortality of a radio-collared bird, I recorded the location, habitat type, and any signs of the predator. It was often difficult to identify type of predator if it had been more than a few days since the mortality occurred. To identify the possible predator, I examined the carcass and feathers for signs of talon, claw, or teeth marks. In some cases it was difficult to assign a predator type because of scavenging activity to the carcass. On some occasions, all that remained at the site of the mortality was the radio collar.

Movements

I re-located radio-collared birds at least once weekly during the spring and summer months, and 2-4 times in the fall and winter months (October – February), grouse were located two to three times using both ground and aerial telemetry. At each location, a GPS location, habitat type, and number of birds present were recorded.

Data Analysis

Descriptive statistics were used to describe differences in nest success, nest site vegetation, brood success, brood site vegetation, arthropod data, and habitat use. Means comparisons where made for all data using the raw data to calculate averages and standard errors. Pooled and Satterwaite t-test for means were used to analyze differences among vegetation parameters at brood and nest site locations. I used a two-tailed z-test to compare differences in nest success, brood survival, and adult survival. I used a t-test to compare the means for arthropod data at brood sites, but in order to meet the assumptions of approximate normality, this t-test was performed on log-transformed data. All tests had a P-value set at 0.05 level of significance. I used SAS Institute Inc.™ (100 SAS Campus Drive, Cary, NC 27513), SAS 9.1 (2002) for descriptive statistical comparisons. Sage-grouse location data were analyzed with ArcGIS 9.2 (ESRI, Redlands, CA) Geographic Information System (GIS) software.

RESULTS

Captures

In 2008, between 26 April and 6 August, I captured and placed radio collars on 18 sage-grouse (9 female and 9 male). The females included three adults, four yearlings, and two juveniles (caught in August) weighing 800-1475 grams. The males consisted of eight adults and one juvenile. Male weights ranged from 800-2700 grams. Sage-grouse were captured in the areas near the leks. Grouse caught later in the summer, were caught among groups of brooding hens. One adult hen was caught on Wildcat Knolls on 14 July, 2008. At the time of capture she had a brood of four chicks. She successfully raised 4 chicks into August. At this time one of her female chicks was caught and fitted with a radio collar. Of the eighteen sage-grouse captured in 2008, 12 were caught on the Wildcat Knolls (6 female and 6 male). On the Horn Mountain I captured 3 yearling females and 3 adult male sage-grouse.

Because of lower winter snow accumulations, trapping success in 2009 was higher than in 2008. From March – May, we were able to capture an additional 37 birds, 24 of which were fitted with radio collars. An additional 17 birds were also sampled for DNA (16 female and 21 male). Females captured included 2 adults and 14 yearlings weighing 1100-1540 grams. Males consisted of seventeen adults and 4 yearlings ranging in weight from 2100-2800 gm. Of the thirty-seven additional sage-grouse captured in 2009, 16 were caught on the Wildcat Knolls (9 female and 7 male) and 20 on the Horn Mountain (7 female and 13 male). On the Wildcat Knolls, 5 male sage-grouse were randomly recaptured within the 5 trapping occasions in 2009. On Horn Mountain, 4 male sage-grouse were randomly recaptured within 4 trapping occasions in 2009. Four birds caught in 2008 were recaptured for DNA sampling in 2009. Blood samples were taken from 41 sage-grouse in 2009. Forty-three sage-grouse were fitted with radio collars from 2008-2009.

Nesting

Wildcat Knolls- In 2008, three of the six hens captured, were caught during the pre-nesting period. Two of the hens initiated nests on May 14th, and the other hen was caught in early June and initiated on June 10 and was probably a hen that re-nested with a clutch of only 4 eggs. Clutch sizes ranged from 4-8 eggs, and averaged 6.3. Of the three nests, two were depredated within about a week of initiation. Suspect predator species appeared to be mammalian.

Ten of (90%) 11 radio-collared hens captured in 2009 initiated nests. Initiation dates ranged from 6-18 May. Clutch sizes ranged from five to eight eggs and averaged 6.7. Of the 60 total eggs, two were infertile. Six of nine nests (66%) were successful. Hatch dates ranged from 28 May to 7 June. Evidence of coyote activity (scat and tracks) where found at two of the three depredated nests. At depredated nest sites, I pieced broken eggs fragments to estimate clutch size. At least one probable re-nesting attempt was recorded in 2009 based on late capture and a small clutch size of 5 eggs. Nest locations were all located within about 4 km of the Wildcat lek (Fig. 2-5).

Horn Mountain- Of the 3 hens monitored in 2008, 2 were captured during the pre-nesting period. One of these hens initiated a nest on 22 May, 2008. This nest contained 7 eggs at the time it was depredated. In 2009, all radio-collared hens (n = 9) initiated nests. Initiation dates ranged from the May 5-14, 2009. Clutch sizes ranged from 5-9 eggs. Two of 58 eggs were infertile. One hen abandoned her nest after incubating for a period of about two weeks. Factors causing the abandonment are unknown.

Of the 9 nests, 5 (55%) hatched between June 2-3. Of the successful nest, three hens (60%) were yearlings, and two (40%) were adults. In the event of predation, broken eggs were pieced together to obtain an estimate of clutch size. Nest locations varied from North Horn to South Horn but were typically located within a few hundred meters of the South Horn lek and other satellite lek sites (Fig. 2-6). In 2009, nest success for Horn Mountain and the Wildcat Knolls sage-grouse hens was similar ($P = 0.779$).

Nest Site Vegetation

Wildcat Knolls- I recorded nest site vegetation measurements for nine different nests in 2009. Vegetation mean values for successful nests were higher than unsuccessful nest (Table 2-2). Among vegetation parameters analyzed for Wildcat Knolls nest sites, average grass height was higher at successful (16.3 cm) than unsuccessful (11.1 cm) nests ($P = 0.042$, $df = 7$).

Horn Mountain- In 2009, I recorded nest site vegetation measurements from nine nest sites (Table 2-2). Vegetation parameters did not differ by hen age and nest success (Table 2-3). When comparing vegetation data among all 18 nests on both sites in 2009, average grass height at the nest bush was higher at successful (26.3 cm,) than at unsuccessful (17.2 cm) nests ($P = 0.045$, $df = 14$).

Nest locations characteristics were measured within 2-4 days after predation or hatching. In 2008-2009 I monitored 22 nests. Twenty-one (95%) of 22 nests were located under mountain big sagebrush. The other nest in 2009 was located under a serviceberry bush and successfully hatched.

Brood Monitoring

Wildcat Knolls- In 2008, only one marked brood was predated. This occurred within a few days of hatching. The fate of the chicks from this brood is unknown. Five of 6 (83%) broods in 2009 were successful. After monitoring the broods 2-3 times a week for 50 days, I located each brood at night with a spotlight and binoculars to obtain a count of chicks brooding with marked hens. Brood sizes ranged from one to six chicks, and averaged 3.4. Seventeen chicks survived up to ≥ 50 days. One hen with a brood of 6 chicks had one chick within the brood that was noticeably smaller suggesting that brood hopping occurred.

Horn Mountain- None of the 3 marked hens in 2008 were observed with broods. In 2009, one (20%) of 5 marked broods raised 2 chicks (≥ 50 days). In 2009, brood success was higher on Wildcat Knolls than Horn Mountain ($P = 0.001$).

Brood Site Vegetation

In 2009, brood site vegetation measurements were recorded for 6 different broods on Wildcat Knolls, and 5 on Horn Mountain (Table 2-4). Shrub cover and grass height differed by study sites for successful and unsuccessful broods (Fig. 2-7). Shrub cover and grass height was greater at successful brood sites (Table 2-5, Fig. 2-8). However because of low sample size, brood site vegetation values for 2008 were not compared statistically.

Brood Site Arthropods

Arthropods collected were divided into four different orders (Hymennoptera, Coleoptera, Lepidoptera, and Orthoptera) and miscellaneous for analysis. Abundance of each was evaluated and compared among individual brood sites, brood hen ages (juvenile or adult), and study sites. The average volume of ants (Hymenoptera) was greater at successful brood site (0.8 ml) than unsuccessful sites (0.8 to 0.2ml, respectively, P = 0.04, df = 9).

Survival

Wildcat Knolls: In 2008, 4 of the 12 (33%) radio-collared birds died. An adult hen was found dead in June, just a few hundred meters west of the main lek site. This mortality was found within a day of the predation event, and based on site evidence, I suspected a raptor (possibly a golden eagle) to be the predator. Hens suspected to be depredated by raptors were found with the breast and neck meat eaten facing up, with plucked feathers surrounding the carcass. Additionally, raptor droppings next to carcasses were also found. Hen survival in 2008 was 83%. Three additional male (3 adults, and 1 juvenile) mortalities occurred during the fall months of October and November. One of the mortalities appeared to be caused by a raptor, but because of scavenging, it was difficult to assign a predator-type in the other mortalities. Male survival was 33% in 2008.

In 2009, 9 of 22 (41%) radio-collared grouse died. In late March, an adult female that appeared to be predated by a raptor was found in a group of ponderosa pines a few hundred meters away from the north satellite lek. Three other male mortalities (1 juvenile and 2 adult) were also found in March, but do to scavenging activity, I was unable to assign a predator type. In June, an adult female mortality was found about 400 meters south west of the north satellite lek, with a raptor being the suspect predator. Also in June, an adult male mortality was found about 250 m south of the main lek with a raptor being the suspect predator. Another adult male mortality was found in July about 300 meters north west of the main lek in a group of ponderosa pines, again with a raptor being the suspect predator. In October, 2 juvenile female mortalities were found, but the cause of death could not be determined.

Horn Mountain: In 2008, no radio-collared grouse mortalities occurred. Four mortalities were found in 2009. In July, 2 mortalities occurred (1 adult female and an adult male), both were found within a few hundred meters of the Barwire pond lek. The suspect predator was a coyote or red fox, but because of scavenging it was difficult to be certain of the predator type. The other two mortalities were found in November in the North Horn area (one juvenile female and an adult male). I could not determine the predator in either case.

Movements

Wildcat Knolls: Radio-marked sage-grouse movements on the Wildcat site were localized in comparison to Horn Mountain. None of radio-collared birds moved more than 5.4 km from the main lek from spring 2008 to fall 2009. The farthest movement documented was a yearling hen that nested about 5.2 km from the Wildcat lek. The majority of the brooding and nesting activity occurred within about 2 km of the main lek (Fig. 2-5). In 2009, lekking behavior was inconsistent with that observed in 2008. In 2008, peak male lek attendance was 17, and dropped to 12 in 2009. Peak male attendance was observed in late March in 2009. Eight radio-collared male grouse were monitored on 4 different occasions through April and the first week May 2009. Peak male attendance during this period was 2.

Horn Mountain: Peak lek attendance on the South Horn lek was observed in mid to late April in both 2008 and 2009, with high counts of 17 male sage-grouse both years. In 2009, 7 male sage-grouse were radio collared prior to the lekking season. Two of the male sage-grouse caught the first week of April in 2009, were caught on the North Horn Satellite lek. One of these yearling males was randomly recaptured about 8 km to the south west near Barewire Pond 2 nights after its initial capture, and moved back and forth between the Barewire Pond and North Horn satellite leks throughout the lekking season.

One yearling male was caught on the Barewire Pond satellite lek, and remained there throughout the lekking season. The 4 remaining males were adult males caught in 2008 and 2009 on the South Horn Lek. All 4 adult males were observed displaying together at the South Horn lek 3 times throughout the lekking period in 2009. Some marked individuals moved up to 14.5 km within a 2-day span just after the lekking period. Movements from South to North Horn were observed mostly in males and broodless hens. Bird movement back to South Horn typically occurred in November, where the majority of the marked birds spent the winter.

Hens with broods on South Horn and the Barewire Pond area did not move much more than 2 km. One juvenile hen that nested in the North Horn area moved her brood 3.4 km to the north west of Mahogany Point towards the Cap after 14 days of brooding where she spent the remainder of the summer and fall (Fig. 2-6).

DISCUSSION

Capture Techniques

The highest concentrations of sage-grouse on the Wildcat Knolls site have been observed in winter flocks during January (K. Albrecht, USFS personal communication). Elevation and accessibility during early spring months have made it difficult for local managers to monitor sage-grouse movements that time of year. To document early spring movements, initial trapping began in January 2008. Radio collars were placed on male and female sage-grouse to evaluate distribution and habitat use across the landscape throughout the year. Winter trapping in 2008 was very difficult. High snow pack (1-2 m) through mid-March made trapping difficult, even by snowmobile. Because of lower winter snow accumulations, trapping success in 2009 was higher than in 2008. The majority of the birds were captured starting the last week of March through mid April on both the Wildcat Knolls, and Horn Mountain.

Nesting

Research conducted throughout many sage-grouse habitats indicate that nest success rates are highly variable and may range between 12-86% (Connelly et al. 2000). Although slight differences in nest success were recorded between Wildcat Knolls (66%) and Horn Mountain (55%) both site were well within published ranges. Average clutch size (6.4) in 2009 fell within the range of what has been reported in other studies (6.3-9.1) (Connelly et al. 2004).

In 2009, average grass height at each nest bush was higher at successful nests. Hagen et al. (2007) reported similar results in Oregon. Because these nest sites exhibited nesting cover that was taller than the surrounding area average, my observations suggest that the successful female sage-grouse I studied selected nest sites affording greater concealment. Gregg et al. (1994) also reported a relationship between tall grass cover and higher sage-grouse nest success. Thus, availability of tall grass cover for nesting may be a limiting factor to sage-grouse production on both sites.

Brood Monitoring

Shrub cover and grass height was also higher at successful brood sites. Management guidelines for brood rearing habitat suggest 10-25% sagebrush canopy cover (Connelly et al. 2000). Average total shrub cover for successful broods in my study was 33% compared to 22 % for unsuccessful broods. Total shrub cover for successful broods was higher than unsuccessful broods, and reinforces the need for maintaining shrub cover to provide escape cover in fragmented habitats. Average grass height was also higher at successful sites. Differences in grass height among successful and unsuccessful broods also documents the importance of maintaining grass height as escape cover in brood rearing habitats on the Wildcat Knolls and Horn Mountain.

Forb canopy cover was similar at successful and unsuccessful brood sites. Forb height was higher at successful brood sites. This may have contributed to the greater arthropod abundance recorded at successful brood sites. Research conducted by Johnson and Boyce (1990) in Wyoming suggest that arthropod abundances play an essential role in brood survival (Patterson 1952). I used pitfall traps to capture arthropods and estimate abundance (Morrill 1975, Connelly et al. 2003). Arthropod data from successful brood sites on the Wildcat Knolls and Horn Mountain suggest that broods occupying these areas had access to greater abundances of ants.

Differential brood success recorded between both sites may be related to increased observations in red fox abundance on the Wildcat Knolls. Local trapping activity has been consistent in identifying apparent red fox invasions on the Wildcat Knolls, while the effects and abundance of red fox on Horn Mountain is largely unknown.

Survival

Annual survival rates among sage-grouse populations are highly variable (Connelly et al. 2000). Survival rates for both male and female grouse on the Wildcat Knolls and Horn Mountain are comparable to other studies, but because of the variability in the literature, it is important to evaluate survival on a local scale. This information is of increased importance to CoCaARM because estimated population sizes from lek counts for both sites are low.

The Wildcat Knolls and Horn Mountain sites are only about 24 km apart, but differences in survival were readily evident. Male and female survival were both lower on the Wildcat Knolls. Male survival on the Wildcat Knolls was lower (36%) than the Horn Mountain (75%). All 5 of the positively identified sage-grouse mortalities on the Wildcat Knolls were raptor-related (possibly golden eagle). Evidence of higher raptor mortality on the Wildcat Knolls may be caused by habitat availability and concentration of active golden eagle nests. In 2008, 6 active golden eagle nests were reported by the UDWR within close proximity (< 24 km) of the Wildcat Knolls. Although adult survival is higher on Horn Mountain, brood success was much lower (20%) than the Wildcat Knolls (83%).

Over the last several years, local trappers have consistently trapped coyotes and red fox on the Wildcat Knolls. Trappers on the Wildcat Knolls began observing red fox about 5 years ago. Since then, they have trapped about 1 to 2 per year. In 2009, 17 red fox were trapped on the Wildcat Knolls by local trappers (K. Albrecht, USFS personal communication).

Increased numbers of red fox may be detrimental to sage-grouse on the Wildcat Knolls and may indicate an indirect interaction of a mesopredator release from local control of coyote populations (Palomares et al. 1995, Mezquida et al. 2006). Coyotes have been known to exclude red foxes because of interspecific interactions (Voigt and Earle 1983, Sargeant et al. 1987). An experiment conducted by Henke and Bryant (1999) showed an increase in foxes, badgers, and jackrabbits after the removal of coyotes. Sovada et al. (1995) reported that waterfowl nest success was higher in areas where coyotes were the dominant meso-predator compared to areas were red fox dominanted. Increased observations of red fox numbers may indicate the need to reduce control efforts on coyotes as a natural alternative to reduce red fox populations. Local trapping efforts on Horn Mountain are unknown, but biologist reported sightings of red fox. Although it has not been properly monitored, differences in trapping efforts between Horn Mountain and Wildcat Knolls may be another factor effecting brood success and adult survival on both sites.

Lek Attendance

Peak male lek attendance of (n =17) was recorded at both sites in 2008. The available roosting and nesting habitat near the leks for both populations can be best described as isolated and fragmented due to natural habitat boundaries that surround each site. Telemetry data from radio-collared males indicated erratic lekking behavior of male sage-grouse on the Wildcat Knolls. In 2008, peak male lek attendance (17) on the Wildcat knolls occurred in late April. In 2009, we began monitoring the lekking season with 8 radio-collared adult male sage-grouse and observed there behavior on three different occasions in April and once the first week of May. During this period we observed a high lek count of 2 adult males. Other radio-collared males were found scattered within about a 3 km radius of the main Wildcat lek site not displaying.

Several factors may be influencing this behavior. Male sage-grouse have been found to establish lek sites adjacent to potential nesting habitat, and may be responding to low densities of hens and or reduced availability of nesting habitat (Connelly et al. 2000). Winter snow accumulations were higher in 2008. Differences in winter snow accumulations may have limited nesting habitat availability from 2008 to 2009, influencing lek site locations, although the winter of 2008-2009 was milder than 2007-2008. Additionally, in fall 2008, habitat treatments were conducted on the Wildcat Knolls that removed mono-cultured stands of crestedwheat grass (*Agropyron cristatum)* and reduced sagebrush canopy cover in late seral class mountain big sagebrush stands. Major habitat areas within 2 km of the main Wildcat lek were disked and harrowed at this time, and may have removed and disturbed critical habitat for breeding sage-grouse (Gibson 1996, Herket et al. 2003, Aldridge and Boyce 2007, Walker et al. 2007). Changes in late seral stands of mountain big sagebrush may have also influenced grouse distribution during late winter and early spring months (Hupp and Braun 1989). The cause of the erratic lekking behavior on the Wildcat Knolls is yet to bet determined, but I believe it may be related to density of hens and/or reduced availability of winter and breeding habitat. The cause of inconsistent lekking behavior needs to be further evaluated.

Habitat Factors

Several factors may have influenced survival on both sites, but differences in habitat structure were most apparent. Sage-grouse breeding habitat on the Wildcat Knolls is broken into patches surrounded by ponderosa-pine dominated woodlands.

Habitat on Horn Mountain is comparable to the Wildcat Knolls, but differs in percent shrub cover, and dominant woodland species. Woodland habitats that border grouse habitat on the Horn are comprised primarily of mountain mahogany and pinyon pine.

Compared to larger sage-grouse populations throughout the west that inhabit large contiguous habitats, published management guidelines (Connelly et al. 2000) suggest that small non-contiguous habitats like those found within the Wildcat Knolls and Horn Mountain have very little room for error in management. Habitat that is available does approximate published management guidelines, but its availability potentially limits stability in sage-grouse populations. The habitat that surrounds quality sage-grouse habitat is ideal for golden eagles and other predators. Topography that surrounds both sites (canyons, cliffs, mountain ranges, and woodland habitats) appears to be impeding movement between the Wildcat Knolls and Horn Mountain populations.

Movements

Understanding population movements and determining a population's migratory status is an important part of population management and should be identified before management decisions are made (Connelly et al. 2000). Grouse movements among the two study sites differed. On Horn Mountain, some marked individuals moved up to 14.5 km within a 2-3 day period just after lekking. These birds moved from the South Horn lek to the North Horn area and stayed in that area until mid to late fall. Movement of birds from North to South Horn occurred during October and November. These types of movement patterns suggest that birds on Horn Mountain are a one-stage migratory population (Connelly et al. 2000).

Radio-marked sage-grouse movements were relatively localized on the Wildcat Knolls. None of the radio-collared birds monitored throughout the year moved more than 5.4 km from the main lek in 2008-2009. Bird movements on the Wildcat Knolls appear to be nonmigratory (Connelly et al. 2000). In contrast to Schroeder and Robb (2003) who reported greater movements in smaller fragmented habitats, sage-grouse on the Wildcat Knolls appear to be limited in movements because of isolation. Although only 24 km apart, no movement of radio-collared birds between the Horn Mountain and Wildcat Knolls study sites occurred in 2008-2009.

MANAGEMENT IMPLICATIONS

Greater sage-grouse productivity and survival on the Wildcat Knolls and Horn Mountain were affected by multiple factors. Grass height at the nest bush was an important component in nest success for both sites and should be continually monitored to it provides adequate nesting cover. Lower brood success on Horn Mountain was attributed increased habitat fragmentation. Overall nesting and brooding success on both sites was affected by the presence and quality of shrub and grass cover to provide as escape cover from predators. Lack of escape cover may be limiting sage-grouse production potentials. Late seral stands of sagebrush should be maintained for nesting and wintering habitat. Compared to Horn Mountain, male survival is lower on the Wildcat Knolls. Several factors affected adult and brood survival on both sites. Lower adult survival on the Wildcat appears to be related to higher adult raptor predation (golden eagles). Maintaining escape cover will be critical for grouse on both Horn Mountain and the Wildcat Knolls that are isolated and have no where else to go. To understand limiting factors affecting adult survival and brood success, local trapping activity needs to be evaluated.

Knowledge of seasonal sage-grouse movements and habitat use across the landscape is critical in understanding basic population biology and responses to habitat management. My data suggested the sage-grouse on the Wildcat Knolls are nonmigratory, in which case it is important to carefully identify and manage all aspects of sage-grouse habitat components. In small nonmigratory populations, habitat alterations within sagebrush habitats should be conducted with extreme caution or completely avoided. Funds allocated for future habitat alterations should be used to continue monitoring efforts using radio telemetry. Additional monitoring of radio collared male sage-grouse should be continued to help identify the cause of inconsistent lekking behavior on the Wildcat Knolls. Greater sage-grouse on the Horn Mountain appear to have two distinct seasonal ranges, and should be managed as a one-stage migratory population. Both populations of sage-grouse are small and occur in small isolated habitats. I recommend that nesting and brooding habitat be monitored for at least the next 3-4 years with radio telemetry to further evaluate its validity of my initial conclusions. Continued monitoring efforts should also focus on mitigating the impacts of fragmentation by preserving existing habitat quality, continued monitoring using radio telemetry, and increasing genetic diversity through well conceived translocations.

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Table 2-1. Capture locations and number of greater sage-grouse (*Centrocercus urophasianus*) released on Wildcat Knolls, Utah, 1987-1990.

Date released	# of Hens	# Males	Capture location
7/30/1987	8	1	Diamond Mountain
7/8/1988	0	2	Emma Park
8/9/1989	19	1	Diamond Mountain
8/31/1989	6	1	Parker Mountain
4/10/1990	2	13	Emma and Whitemore Parks

Table 2-2. Nest site vegetation composition for successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) on the Wildcat Knoll and Horn Mountain, Utah, 2009.

SITE	Success	N Obs	Variable	Mean	Std Error	Lower 95% CL for Mean	Upper 95% CL for Mean
HORN	No	4	ShrubCov	19.23	2.57	11.06	27.39
			ShrubHt	19.78	3.97	7.15	32.4
			RobelIn	4.5	0.65	2.45	6.55
			RobelOut	2.5	0.87	-0.26	5.26
			ForbCov	4.06	0.78	1.58	6.54
			ForbHt	8.6	1.52	3.78	13.42
			NestGrassHt	18	2	9.39	26.61
			GrassCov	17.41	1.39	12.98	21.84
			GrassHt	13.88	0.41	12.58	15.17
			NestDiameter	126	17.16	71.39	180.61
			NestHt	57.75	8.11	31.95	83.55
	Yes	5	ShrubCov	23.84	3.62	13.78	33.9
			ShrubHt	26.84	3.62	13.78	33.9
			RobelIn	5.2	0.97	2.51	7.89
			RobelOut	2.8	0.97	0.11	5.49
			ForbCov	7.84	2.14	1.91	13.77
			ForbHt	10.42	1.45	6.39	14.45
			NestGrassHt	26.6	5.41	11.58	41.62
			GrassCov	18.31	1.41	14.38	22.24
			GrassHt	14.25	0.71	12.27	16.22
			NestDiameter	133.6	7.97	111.48	155.72
			NestHt	70	9.47	43.7	93.69
WILDCAT	No	3	ShrubCov	25.73	2.17	16.4	35.07
			ShrubHt	39.03	1.92	30.79	47.27
			RobelIn	6	0.58	3.52	8.48
			RobelOut	4.67	0.33	3.23	6.1
			ForbCov	5.65	2.18	-3.73	15.03
			ForbHt	7.61	0.58	5.12	10.09
			NestGrassHt	16.33	0.88	12.54	20.13
			GrassCov	12.83	6.26	-14.09	39.76
			GrassHt	11.14	0.73	7.98	14.3
			NestDiameter	150.33	6.06	124.24	176.43
			NestHt	76.33	4.37	57.52	95.14
	Yes	6	ShrubCov	33.13	5.16	19.86	46.4
			ShrubHt	40.18	5.32	26.5	53.87
			RobelIn	6.17	0.48	4.94	7.39
			RobelOut	3.5	0.56	2.05	4.95
			ForbCov	3.69	1.62	-0.47	7.85
			ForbHt	10.03	1.2	6.94	13.13
			NestGrassHt	26	3.75	15.57	36.43
			GrassCov	23.75	3.26	15.37	32.13
			GrassHt	16.28	1.37	12.75	19.81
			NestDiameter	145	13.76	109.63	180.37
			NestHt	87.17	8.78	64.59	109.75

Table 2-3. Nest site vegetation comparisons by age for successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) broods on the Wildcat Knoll and Horn Mountain, Utah, 2009.

T-Tests

Variable	**Method**	**Variances**	**DF**	**t Value**	**Pr > |t|**
SHRUBCOV	Pooled	Equal	4	0.01	0.9936
SHRUBCOV	Satterthwaite	Unequal	2.44	0.01	0.9938
SHRUBHT	Pooled	Equal	4	-0.03	0.9811
SHRUBHT	Satterthwaite	Unequal	3.91	-0.03	0.9812
ROBELIN	Pooled	Equal	4	-0.38	0.7247
ROBELIN	Satterthwaite	Unequal	2.47	-0.38	0.7355
ROBELOUT	Pooled	Equal	4	0.17	0.8722
ROBELOUT	Satterthwaite	Unequal	3.27	0.17	0.8739
FORBCOV	Pooled	Equal	4	-0.82	0.4582
FORBCOV	Satterthwaite	Unequal	2.44	-0.82	0.4845
FORBHT	Pooled	Equal	4	0.63	0.5630
FORBHT	Satterthwaite	Unequal	3.19	0.63	0.5710
NESTGRASSHT	Pooled	Equal	4	-0.66	0.5477
NESTGRASSHT	Satterthwaite	Unequal	2.26	-0.66	0.5724
GRASSCOV	Pooled	Equal	4	0.14	0.8975
GRASSCOV	Satterthwaite	Unequal	2.41	0.14	0.9015
GRASSHT	Pooled	Equal	4	-1.84	0.1396
GRASSHT	Satterthwaite	Unequal	3.89	-1.84	0.1416
NESTDIAM	Pooled	Equal	4	0.45	0.6758
NESTDIAM	Satterthwaite	Unequal	3.13	0.45	0.6819
NESTHT	Pooled	Equal	4	-0.41	0.7007
NESTHT	Satterthwaite	Unequal	2.34	-0.41	0.7144

Table 2-4. Brood site vegetation composition for successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) broods on the Wildcat Knoll and Horn Mountain, Utah, 2009.

Site	**Success**	**N Obs.**	**Variable**	**Mean**	**Std Error**
Horn Mountain	NO	16	Percent Shrub Cover	19.4	2.6
			Shrub Height	31.7	5.4
			Visual Obstruction	4.3	0.73
			Percent Forb Cover	6.5	0.94
			Forb Height	8.5	0.7
			Percent Grass Cover	17.9	1.4
			Grass Height	16.8	0.63
	YES	6	Percent Shrub Cover	21.2	2.5
			Shrub Height	29.9	3.6
			Visual Obstruction	4	0.64
			Percent Forb Cover	11.1	2.8
			Forb Height	10	1.1
			Percent Grass Cover	20.8	1.4
			Grass Height	19.5	1.9
Wildcat Knolls	NO	4	Percent Shrub Cover	34.3	3.4
			Shrub Height	31.1	6.8
			Visual Obstruction	4.3	0.75
			Percent Forb Cover	9	1.9
			Forb Height	9.9	0.72
			Percent Grass Cover	28.6	4.1
			Grass Height	13.9	0.9
	YES	34	Percent Shrub Cover	34.9	2.5
			Shrub Height	37.9	2.3
			Visual Obstruction	5.7	0.5
			Percent Forb Cover	7.9	0.82
			Forb Height	12.2	0.74
			Percent Grass Cover	21.9	1.3
			Grass Height	20.6	0.9

Table 2-5. Brood site vegetation comparisons for successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) broods on the Wildcat Knoll and Horn Mountain., Utah, 2009.

T-Tests

Variable	**Method**	**Variances**	**DF**	**t Value**	**Pr > |t|**
SHRUBCOV	Pooled	Equal	58	-2.80	0.0069
SHRUBCOV	Satterthwaite	Unequal	47.9	-3.06	0.0036
SHRUBHT	Pooled	Equal	58	-1.19	0.2372
SHRUBHT	Satterthwaite	Unequal	27.3	-1.04	0.3076
ROBEL	Pooled	Equal	58	-1.60	0.1158
ROBEL	Satterthwaite	Unequal	38.8	-1.61	0.1159
FORBCOV	Pooled	Equal	58	-1.03	0.3087
FORBCOV	Satterthwaite	Unequal	49.5	-1.13	0.2621
FORBHT	Pooled	Equal	58	-3.06	0.0034
FORBHT	Satterthwaite	Unequal	55.6	-3.58	0.0007
GRASSCOV	Pooled	Equal	58	-0.85	0.4014
GRASSCOV	Satterthwaite	Unequal	37	-0.84	0.4083
GRASSHT	Pooled	Equal	58	-3.47	0.0010
GRASSHT	Satterthwaite	Unequal	58	-4.25	<.0001

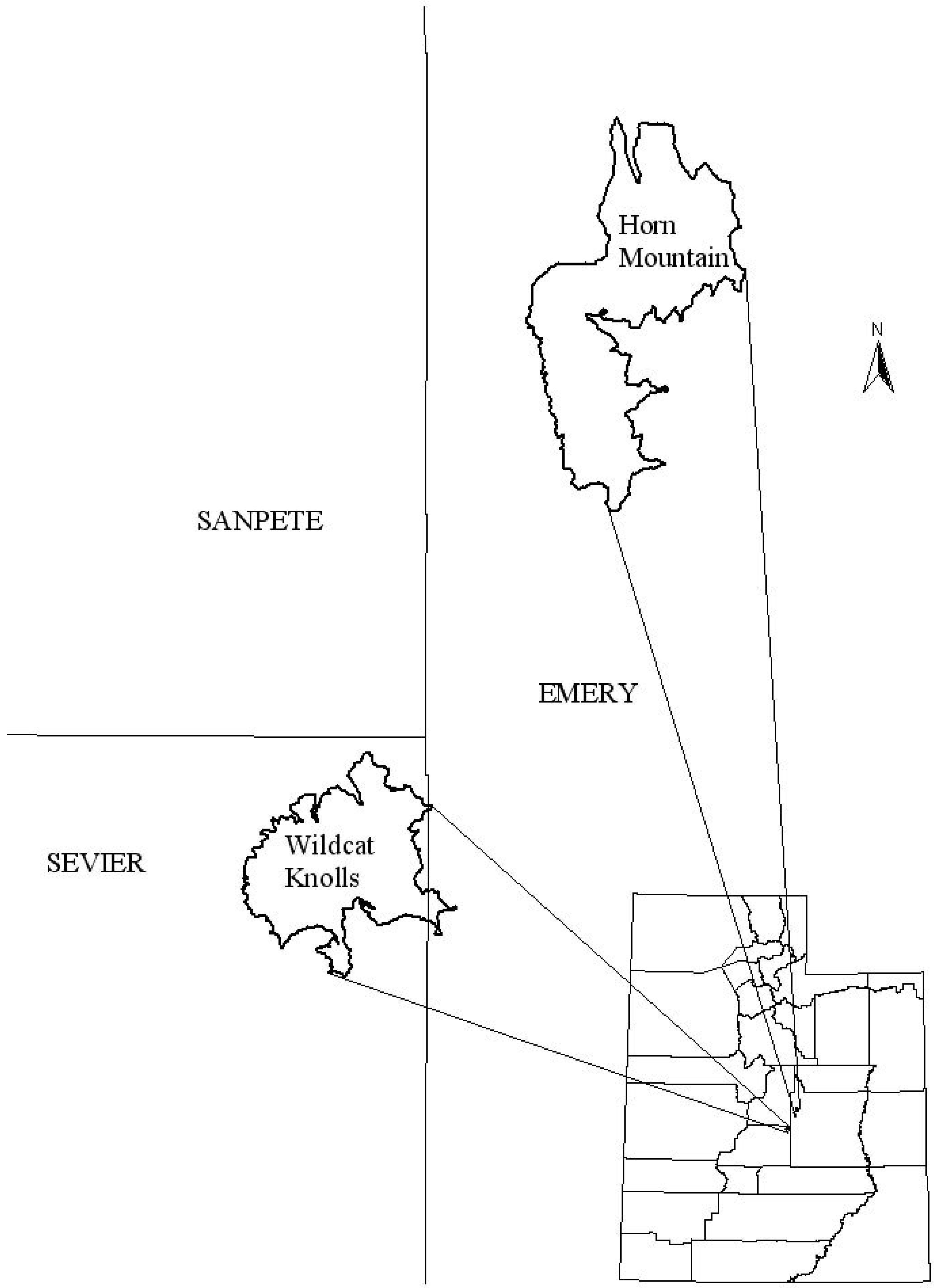

Figure 2-1. Study area of the Wildcat Knolls and Horn Mountain, Utah, 2009.

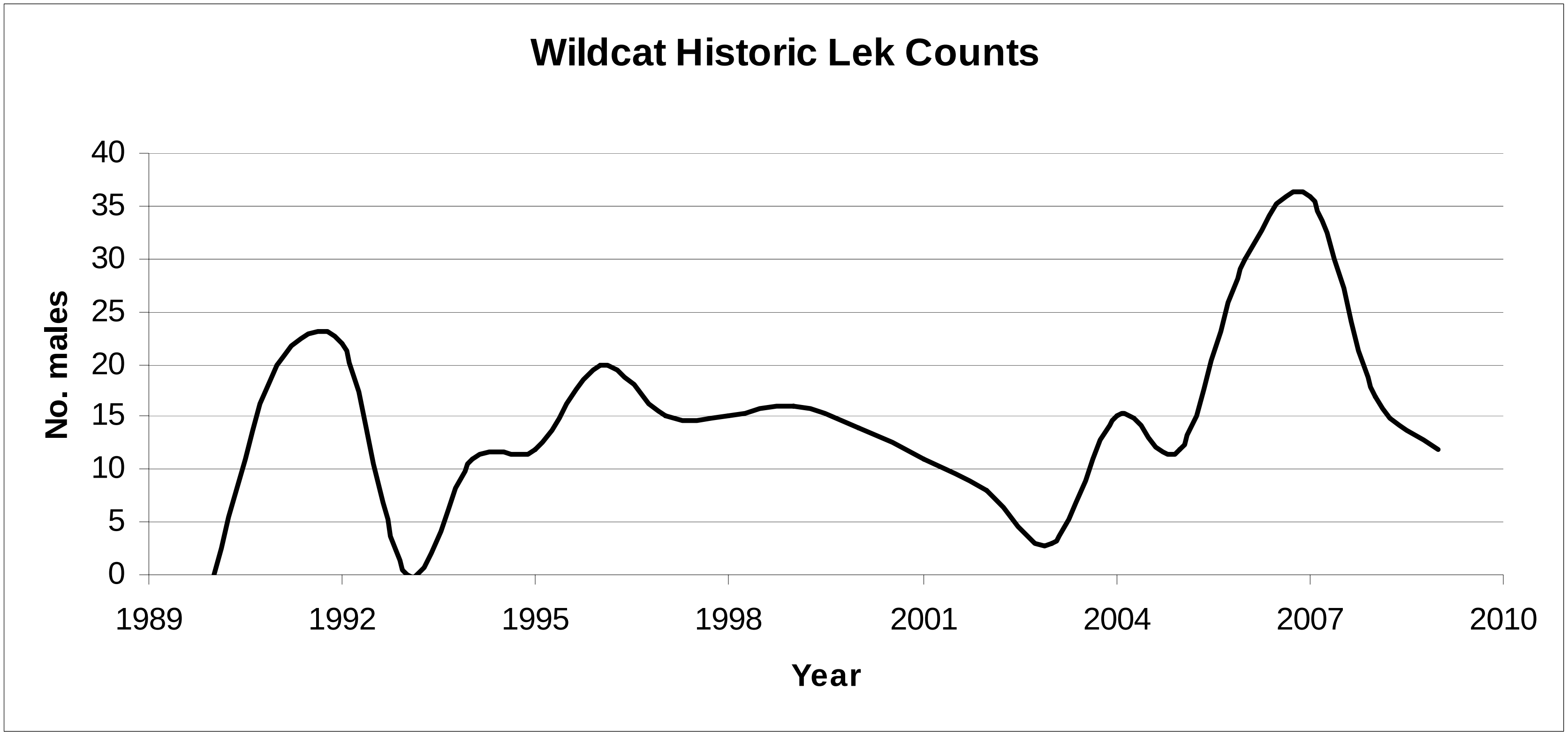

Figure 2-2. Wildcat Knolls male greater sage-grouse (*Centrocercus urophasianus*) lek attendance, Utah, 1990-2008.

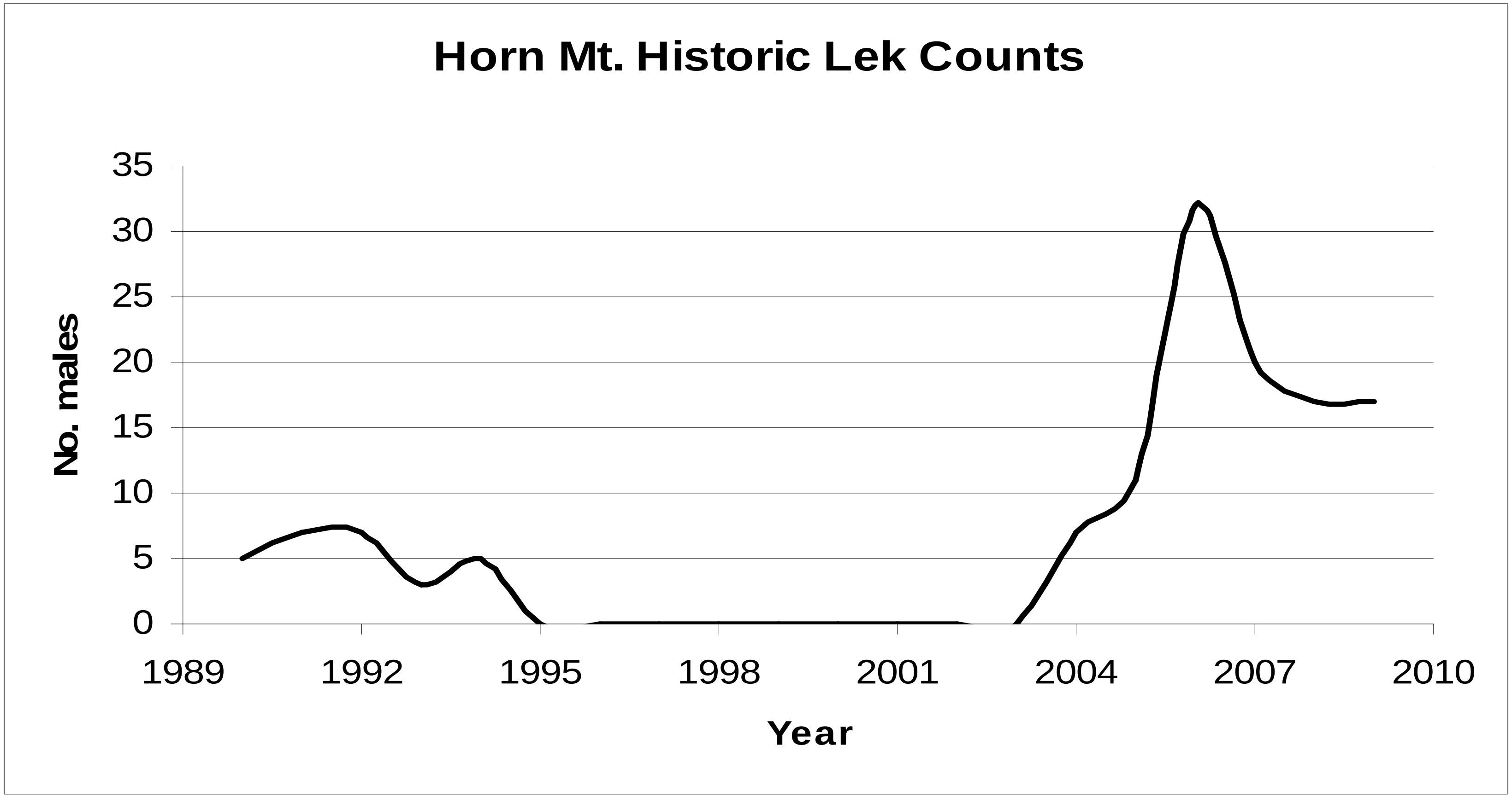

Figure 2-3. Lek surveys of male greater sage-grouse (*Centrocercus urophasianus*) attending Horn Mountain lek sites, Utah, 1990-2008.


Figure 2-4. Successfully hatched greater sage-grouse (*Centrocercus urophasianus*) nest on the Wildcat Knolls, Utah, 2009.

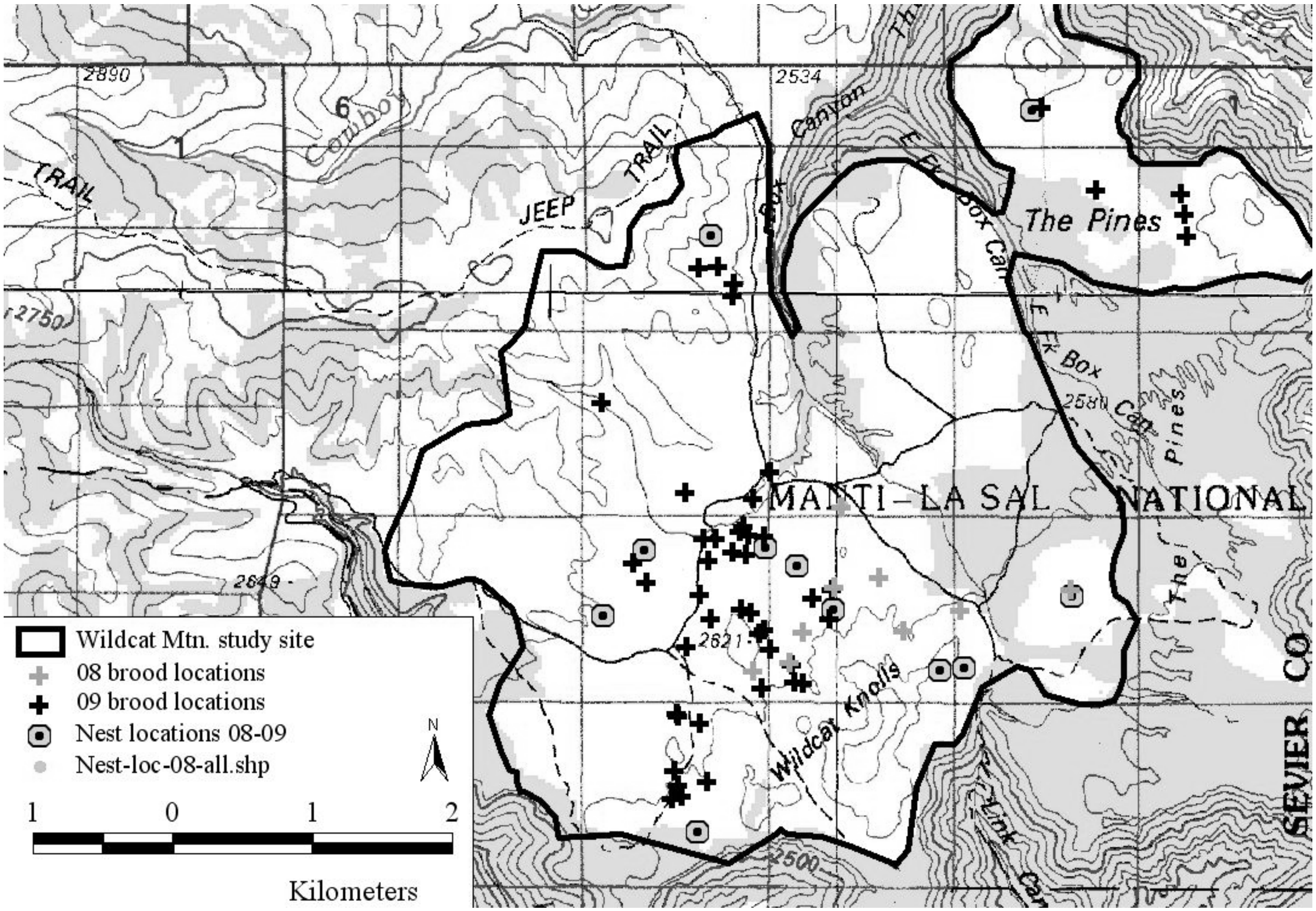

Figure 2-5. Greater sage-grouse (*Centrocercus urophasianus*) nesting and brood locations, Wildcat Knolls, Utah, 2008-2009.

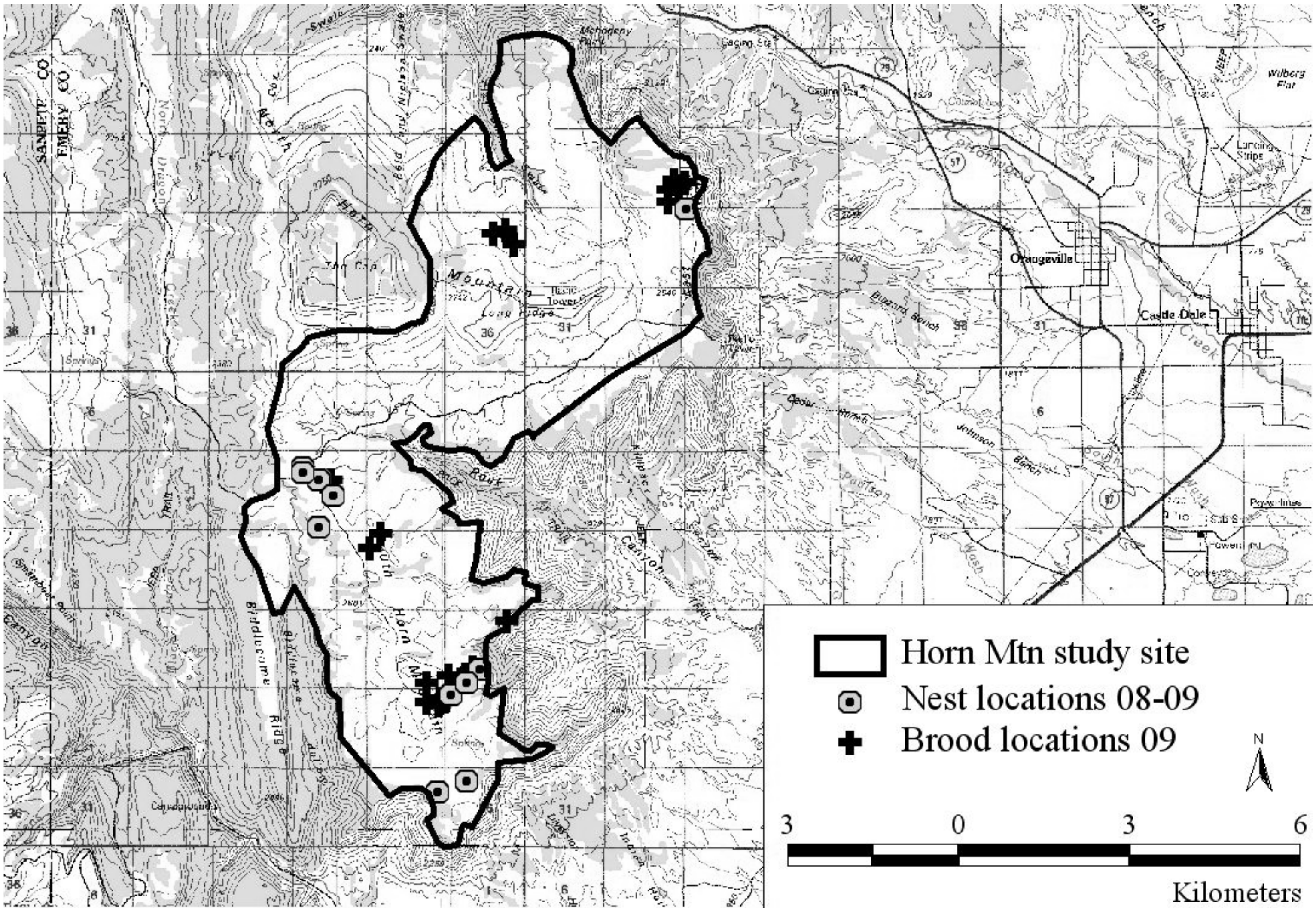

Figure 2-6. Greater sage-grouse (*Centrocercus urophasianus*) nesting and brood locations, Horn Mountain, 2008-2009.

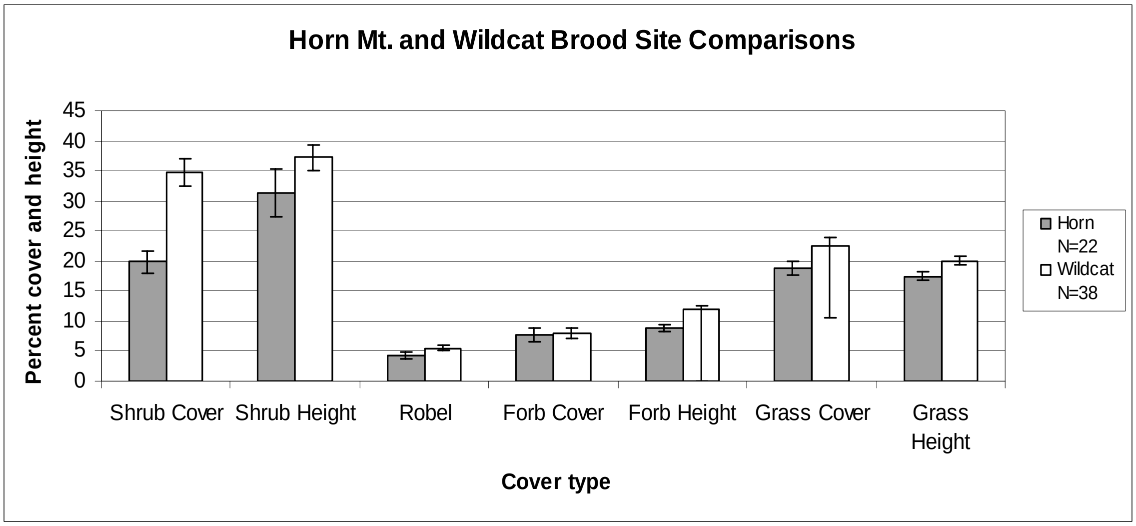

Figure 2-7. Greater sage-grouse (*Centrocercus urophasianus*) brood site vegetation mean differences between the Horn Mountain and Wildcat Knolls, Utah, 2009.

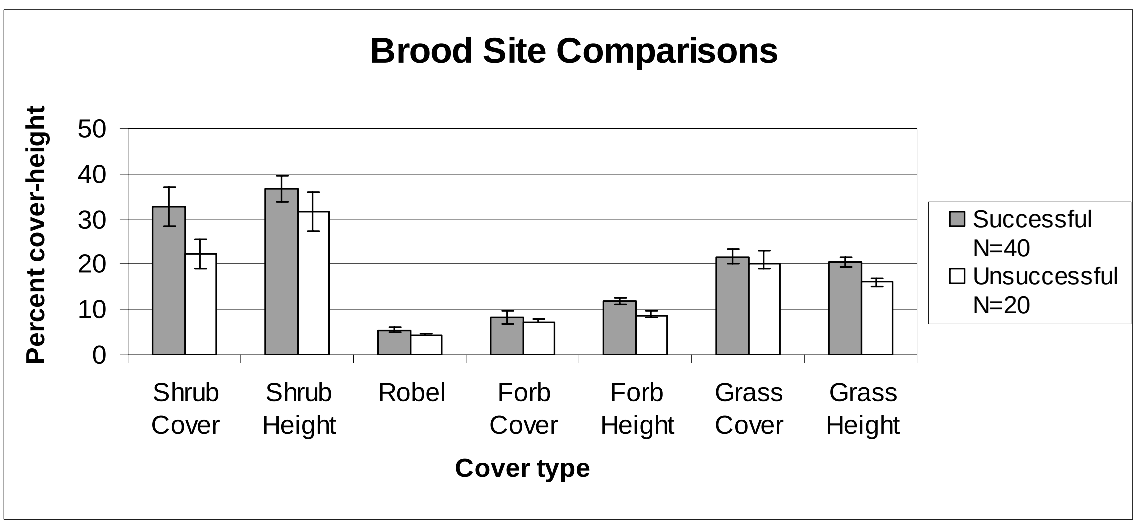

Figure 2-8. Greater sage-grouse (*Centrocercus urophasianus*) brood site vegetation differences between successful and unsuccessful broods on the Wildcat Knolls and Horn Mountain., Utah, 2009.

CHAPTER 3

THE IMPACT OF HABITAT FRAGMENTATION ON SMALL POPULATIONS OF GREATER SAGE-GROUSE IN CENTRAL UTAH

Abstract The biology and potential factors limiting greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations range wide have been well studied. However, little information is readily available regarding the potential effects of management actions on the nesting ecology and population dynamics of isolated populations inhabiting fragmented habitats. Utah has several small sage-grouse populations (< 500 breeding pairs) that inhabit spatially-isolated sagebrush-steppe (*Artemisia* spp.) habitats. Two such populations inhabit Wildcat Knolls and Horn Mountain located in south central Utah. These sites are high elevation sagebrush-dominated plateaus separated by canyons and a straight line distance of 24 km. During 2008-2009, I monitored nest success, habitat use, and movements relative to available breeding habitat of 12 and 9 sage-grouse hens on Wildcat Knolls and Horn Mountain, respectively. Potential nesting habitat on Wildcat Knolls and Horn Mountain were estimated at 2,329 and 5,493 ha, respectively. Vegetation parameters measured within this available habitat approximated published sage-grouse management guidelines. Grass height (cover) for successful nests at both sites was higher than unsuccessful nests. Additionally hens that selected nest sites farther from non-habitat edge were more successful on Wildcat Knolls. The higher nest and brood success observed on Wildcat Knolls was attributed to less habitat fragmentation. Female survival was lower on Wildcat Knolls and higher on Horn Mountain. Lower survival on Wildcat Knolls may be attributed to higher concentrations of active golden eagle (*Aquila chrysaetos)* nests found

within closer proximity (< 24 km) of sage-grouse nesting habitat. Because of the difficulties associated with reestablishing sagebrush cover, my results reinforce the importance of maintaining existing vegetation cover to mitigate the effects of fragmentation on sage-grouse nest success and survival in small populations inhabiting spatially isolated locations.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations throughout the west inhabit about 56% of pre-settlement distribution of potential habitat (Schroeder et al. 2004) and declines have been largely attributed to habitat loss, degradation, and fragmentation of sagebrush (*Artemisia* spp.) habitats (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Connelly et al. 2004). Sage-grouse populations are spatially diverse, but appear to be more productive in contiguous sagebrush habitats (Aldridge and Boyce 2007). Thus activities that result in loss or fragmentation of occupied sagebrush habitats exacerbate management concerns particularly in smaller populations that may be geographically isolated.

In Utah, sage-grouse inhabit 26 of the state's 29 counties. However, the current range of the species is believed to be 50% of the historic range (Beck et al. 2003). Management of sage-grouse in Utah may be further complicated because of the mosaic of private and public landownership in Utah. Sage-grouse occupy habitats managed by the Bureau of land Management (BLM), U.S. Forest Service (USFS), National Park Service (NPS), State of Utah, and private landowners. The Utah Division of Wildlife Resources (UDWR) estimates that about 50% of Utah sage-grouse habitat and populations occur on private land (UDWR 2002, 2009). The complexity of land ownership requires the collaboration of many organizations and private landowners when dealing with sage-grouse issues.

Of the 26 Utah counties reported to contain sage-grouse populations, only 5 are considered to be stable and productive enough (> 500 breeding pairs) to sustain an annual harvest. Most of the other Utah sage-grouse populations are characterized as being small (< 500 breeding pairs) and occupying spatially-separated sagebrush steppe habitats (UDWR 2009). Two small populations representative of this spatial separation and thus presenting unique conservation challenges inhabit Wildcat Knolls and Horn Mountain located in central Utah. These are high elevation sagebrush dominated plateaus separated by 24 km straight line distance.

During 2008-2009, I monitored radio-collared hens to describe the breeding ecology and habitat use of sage-grouse inhabiting Wildcat Knolls and Horn Mountain relative to habitat availability and potential. Prior to this research, little was known about sage-grouse populations inhabiting these areas. Previous data collection efforts were limited to monitoring male attendance. This research provides land and wildlife managers information to guide management actions to enhance habitat conditions for greater sage-grouse populations that inhabit isolated areas.

STUDY AREA

Ranging from 2500-2900 m in elevation, the Wildcat Knolls and Horn Mountain study areas are in Emery and Sevier counties on the southeast end of the Manti Mountains (Wasatch Plateau) (Fig. 3-1). Both sites are on public land managed by the USFS. They consist of isolated openings on the southeast edge of the plateau, and are surrounded by canyons, cliffs, and mountains. The North Fork of the Quitchupah Canyon borders the Wildcat to the west, White Mountain to the north, the Muddy to the Northeast, and the southern edge is bounded by an escarpment of cliffs. The town of Emery is located just about 11 km south of Wildcat Knolls in the valley below. Within the Wildcat Knolls study area (4146.6 ha), I estimated that 2,329 ha (56.2%) of was sagebrush shrubsteppe that constituted potential sage-grouse nesting habitat (Fig. 3-2)

The Horn Mountain site is 24 km to the northeast of Wildcat Knolls. Straight Canyon borders to the northeast of Horn Mountain. The Cap and Long Ridge borders to the north, Ferron Canyon borders to the west, and an escarpment of cliffs surrounds the south and southeast edge of Horn Mountain. The town of Ferron is about 6.5 km south west in the desert valley below. Within the Horn Mountain study area (6,806.9 ha), I estimated that 5,493 ha (80.7%) was sagebrush shrub steppe habitat that constituted potential sage-grouse nesting habitat (Fig. 3-3).

Climate

The average annual precipitation recorded by a Western Regional Climate Center weather station was about 33.8 cm recorded over a 23-year average. This weather station is located 12 km southwest of the Wildcat site, and 32 km south of the Horn Mountain study area. The average annual temperature was about 6.0°C. The warmest time of the year occurs in July and the coldest weather occurs in January with temperatures reaching as low as -9.6°C. Highest amounts of precipitation occur in August at an average of 4.3 cm. Highest amounts of snowfall occur in January and February with total annual snowfall averaging about 157.5 cm.

Vegetation

Although the rim of the Wildcat Knolls is lined with ponderosa pine (*Pinus ponderosa)*, it can be characterized as a mountain big sagebrush (*A. nut. ssp. vaseyana*) and black sagebrush (*A. nova)* vegetation community. Other common species in the plant community are: serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpus albus*), woods rose (*Rosa woodsii*), and antelope bitterbrush (*Purshia tridentata)*. Serviceberry occurs in areas with wetter and deeper soils. Mountain big sagebrush is primarily found in the drainage corridors, while black sagebrush, dwarf rabbitbrush (*Chrysothamnus depressus)*, and low rabbitbrush (*C. visidiflorus)* occur in drier areas. Herbaceous vegetation is diverse. Dominate grass species include mutton bluegrass (*Poa fendleriana*), smooth brome (*Bromus inermis*), letterman needlegrass (*Achnatherum lettermanii*), and Salina wildrye (*Leymus salinus*). One of the more abundant forbs is goosefoot (*Chenopodium* spp.*)*. Plant community structure on the Horn Mountain site is similar to the Wildcat Knolls, except that mountain brush communities are more abundant, including mountain mahogany (*Cercocarpus montanus*) and scattered pinyon pine (*P. edulis)*.

METHODS

Potential Nesting Habitat

Availability of potential nesting habitat was determined by sorting the study sites into 2 habitat types: potential nesting habitat (sagebrush) and non-habitat (ponderosa pine, pinyon-juniper, and other woody habitat types). Using these 2 categories, I used 2006 NAIP 1 m color photo imagery to estimate availability of potential nesting habitat relative to locations of radio-marked individuals. Aldridge and Boyce (2007) used similar methods to estimate availability and quality of sagebrush cover in nesting and brooding habitats.

To further evaluate effects of fragmentation on nest site selection, I plotted nest locations of radio-marked hens, and measured distance to non-habitat edge of successful and unsuccessful nest locations. Non-habitat polygons were then buffered based on average distance to edge for successful and unsuccessful nests to evaluate the availability of potential nesting habitat.

Captures

Sage-grouse were located by spotlighting with binoculars from the back of an ATV and captured with a long-handled net (Wakkinen et al. 1992a). At each capture, the overall health and condition of the grouse were assessed.

I used a global positioning system (GPS) unit set to Universal Transverse Mercator (UTM) NAD27 to record each capture location. All grouse captured were handled in accordance with protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University, protocol file # 1195, and with a Certificate of Registration (COR) from the UDWR, COR # 6BAND7779.

Adult birds were fitted with Holohil Systems Ltd. (112 John Cavanaugh Drive, Carp, Ontario, K0A 1L0, Canada) necklace style radio transmitters. This type of transmitter has a 36-month battery life (24 hours on), and weighs 17.7 grams. Radio-collared birds were located using Telonics, Inc.™ (932 East Impala Avenue, Mesa, Az 85204) and ICOM America Inc.™ (2380 116th Avenue northeast, Bellevue, Wa 98004) receivers, handheld 3-element Yagi folding antennas, and vehicle mounted Omni antennas (RA-2A).

Nesting

Radio-collared hens were re-located every 3-5 days until nest initiation began. All nest locations were approached carefully with binoculars maintaining a distance of at least 10 m between the observer and hen to obtain a visual location. A hen found under the same bush 2 days in a row was considered to be nesting. Nest locations were then marked discretely using natural materials. At each site, GPS locations and vegetation types were recorded to identify nest site selection. Vegetation characteristics of the nest sites, nesting habitat selected, clutch sizes, and nest fate were recorded.

Nest initiation dates were estimated using a 27-day incubation period with one day added for each egg in the nest (Schroeder 1997). All nests were monitored every three days from the time they are located until their fate was determined (i.e., predated, abandoned, or successfully hatched). Successfully hatched nests were determined by the presence of one or more eggshells with loose membranes (Griner 1939). Unsuccessful nests were examined to try and determine depredation factors using eggshells, scat, tracks, or hairs (Patterson 1952).

Nest Site Vegetation

Nest site vegetation measurements were recorded along 15-m line transects in four directions (every 90 degrees starting with a randomly chosen direction). I measured species-specific shrub canopy coverage using the line-intercept method (Canfield 1941). The live shrub canopy intersecting an imaginary vertical plane on the line was measured. Gaps in the foliage less than 5 cm were counted as continuous and gaps greater than 5 cm were not counted on the line as continuous shrub cover. The shrub intersecting the line was summed and then divided by the length of the line to determine total shrub canopy cover (Connelly et al. 2003). The use of this method allows direct comparison with data from other studies (Connelly et al. 2003). Shrub height was recorded by selecting the tallest live part of each shrub along the transect (Connelly et al. 2003). The percentage of ground vegetation was measured using 20 X 50-cm Daubenmire (1959) frames placed every 3 meters to quantify herbaceous cover, species present, rock, litter, and bare ground. Nest shrub height, nest shrub width, and grass height were also measured at each nest location to evaluate nesting cover (Table 3-1) (Connelly et al. 2003, Hagen et al. 2007).

At each nest site, visual obstruction (vertical cover) between the nest and four meters from the nest was measured using a Robel pole (Robel et al. 1970, Connelly et al. 2003) with painted 10 cm increments. Two measurements were recorded: Robel In (a measure of predator obstruction) and Robel Out (a measure of hen's obstruction). This measurement was taken on all four line transects at each nest site.

Survival

In the event of a mortality of a radio-collared bird, I recorded the location, habitat type, and any signs of the predator. In trying to identify the predator, I examined the carcass and feathers for signs of talon, claw, or teeth marks. In some cases it was difficult to assign a predator type because of scavenging activity to the carcass. On some occasions, all that remained at the site of the mortality was the radio-collar.

Data Analysis

Descriptive statistics were used to describe differences in nest success, and nest site vegetation. Means comparisons where made for all data using the raw data to calculate averages and standard errors. All tests had a p-value set at 0.05 level of significance. I used SAS Institute Inc.™ (100 SAS Campus Drive, Cary, NC 27513), SAS 9.1 (2002) to compare mean differences. I used a 2-tailed z-test to compare differences in nest success, brood survival, and adult survival. Sage-grouse nest location data was analyzed with ArcGIS 9.2 (ESRI, Redlands, CA) Geographic Information System (GIS) software. I used ArcGIS 9.2 to heads up digitize non-habitat. I also used 2006 NAIP 1 m color photo imagery made available by the Utah AGRC to help determine potential nesting habitat and non-habitat categories.

RESULTS

Potential Nesting Habitat

Once I digitized non-habitat (woodland) polygons, I assumed that all remaining areas constituted potential nesting habitat (sagebrush). To assess the accuracy of this decision, I compared radio telemetry locations of male and female sage-grouse from 2008-2009. Most ($\geq$ 90 %) of the radio telemetry locations were within habitat classified polygons.

Wildcat Knolls: After digitizing non-habitat polygons, I determined the average distance to non-habitat edge for successful and unsuccessful nests as 536.4 m and 163.4 m, respectively. After I plotted a buffer of 163.4 m around non-habitat polygons, potential nesting habitat decreased from my previous estimate of 2,329 ha to 1,576 ha (Fig. 3-4).

Horn Mountain: After digitizing non-habitat polygons, I found that the average distance to non-habitat edge for successful and unsuccessful nests was 195m and 232 m, respectfully. Because the distances to habitat edges for successful and unsuccessful nests were similar, I used an average distance of 213 m to non-habitat edge to create a buffer around non-habitat polygons to assess potential nesting habitat. After the buffer of 213 m was placed around non-habitat polygons, potential nesting habitat decreased from my previous estimate of 5,491.8 ha to 2,852.6 ha (Fig. 3-5). Although there is more potential nesting habitat on Horn Mountain, nest and brood success was lower, and may be related to different habitat structure across the site.

Nesting

Wildcat Knolls- In 2008, 3 out of the 6 hens captured were caught during the pre-nesting period. Two of the hens initiated nests on 14 May and the other hen was caught in early June and initiated on 10 June. Of the 3 nests, 2 were depredated within about a week of initiation. Of the 11 radio-collared hens in 2009, nine (81%) initiated nests. Six hens (66%) were successful. Nest locations were all located within about 4 km of the Wildcat lek.

Horn Mountain- Of the 3 hens monitored in 2008, 2 were captured during the pre-nesting period. Only one of these hens initiated a nest, which occurred on 22 May. This nest was depredated. In 2009, all radio-collared hens (n = 9) initiated nests. One hen abandoned her nest. Of the 9 nests, 5 (55%) successfully hatched. Nest locations varied in location from North Horn to South Horn, and were typically found within a few hundred meters of the South Horn, Barewire Pond and North Horn lek sites.

DISCUSSION

Potential Nesting Habitat

Differences in habitat structure between the Wildcat Knolls and Horn Mountain sites were evident. Although the Horn Mountain site had more than double the amount of potential nesting habitat than Wildcat Knolls, its average nest distance to edge (successful averaged with unsuccessful) was less (213 m) than the Wildcat Knolls (350 m). Differences among successful nests between sites were even greater. The average nest distance to edge for successful nests on the Wildcat Knolls was 536 m and 195 m on Horn Mountain. These differences suggest that although there is more potential nesting habitat on Horn Mountain, it was more fragmented. Aldridge and Boyce (2007) suggested that sage-grouse avoided nesting areas containing large amounts of edge habitat, and that female sage-grouse may be responding to perceived increased predation risks (Herket et al. 2003, Sheperd 2006). Lower nest success on Horn Mountain may be directly related to increased habitat fragmentation from mountain brush communities and other woodland habitats, about 1315.1 ha of these types of habitats separated potential nesting habitat.

Compared to larger sage-grouse populations throughout the west that inhabit large contiguous habitats, published management guidelines (Connelly et al. 2000) suggest that small non-contiguous habitats like those found within Wildcat Knolls and Horn Mountain have very little room for error in management. Habitat within both sites does approximate published management guidelines, but its availability potentially limits stability in sage-grouse populations. Habitat that surrounds quality sage-grouse habitat is ideal for golden eagles and other predators. Topography that surrounds both sites

(Canyons, cliffs, mountain ranges, and woodland habitats) appears to impede movement among the Wildcat Knolls and Horn Mountain populations.

No movement of radio-collared birds between the Horn Mountain and Wildcat Knolls study sites were recorded during my study. Research conducted by Knerr (2007), shows that seasonal movements may exceed 75 km in larger contiguous habitats. On Horn Mountain, some marked individuals moved up to 14.5 km within a 2-3 day period just after lekking. Movement patterns of birds on Horn Mountain, suggest the population was one-stage migratory (Connelly et al. 2000).

Radio-marked sage-grouse movements were relatively localized on the Wildcat Knolls. None of the radio-collared birds monitored throughout the year moved more than 5.4 km from the main lek in 2008-2009. Bird movements on the Wildcat Knolls appear to be nonmigratory (Connelly et al. 2000). In contrast to Schroeder and Robb (2003) who reported greater movements in smaller fragmented habitats, sage-grouse on the Wildcat Knolls appear to be limited in movements because the population movement were restricted to the plateau.

Nest success for sage-grouse throughout its range is highly variable and has been found to range between 12 and 86% (Connelly et al. 2000, Schroeder et al. 1999). Aldridge and Boyce (2007) in Alberta, evaluated the nest success of 111 sage-grouse nests from 2001-2004. The overall nest success in their study was lower at 39%. The authors attributed this to reduced availability of quality habitat. However even given the habitat fragmentation and limited availability of nesting habitat, nest success on the Wildcat Knolls and Horn Mountain in 2009 was within the mid to upper range of other reported in previous studies.

This observation may be explained by comparing vegetation among all 18 nests from both sites in 2009. The average grass height at each nest bush for successful nest was higher than at unsuccessful nests. Hagen et al. (2007), also reported that female sage-grouse typically select nest sites with more sagebrush cover and taller grass height. Gregg et al. (1994), also reported a relationship between taller grass cover and higher sage-grouse nest success. On the Wildcat Knolls, hens that selected sites with higher grass height averages surrounding the nest bush were more successful. Availability of grass and other protective cover may be a limiting factor to sage-grouse production on both sites.

Annual survival rates among sage-grouse populations are highly variable and have been found to range between 35 and 85% (Connelly et al. 2000). Survival rates for female grouse on the Wildcat Knolls and Horn Mountain are comparable to other studies, but because of the variability in the literature, it is important to evaluate survival on a local scale. Adult survival, in particular female survival may be more critical in smaller population.

Survival of radio-collared females on the Wildcat Knolls and Horn Mountain in 2009 was 64 and 78%, respectively. All of the positively identified grouse mortalities on the Wildcat Knolls were raptor-related (possible golden eagle). Higher raptor mortality on the Wildcat Knolls may be attributed to reduced habitat availability and concentration of active golden eagle nests. In 2008, 6 active golden eagle nests were reported by the UDWR within close proximity (< 24km) of the Wildcat Knolls and three within close proximity (< 24 km) of Horn Mountain.

MANAGEMENT IMPLICATIONS

Although the vegetation parameters measured in the habitats used by sage-grouse on Wildcat Knolls and Horn Mountain approximated published management guidelines, the limited habitat availability and demonstrated population isolation, suggests managers must proceed with caution before implementing management actions that would reduce escape cover. Sage-grouse access to and the availability of shrub and grass cover on both sites was a critical component in nesting success, and may be a limiting long term sage-grouse production. Average shrub canopy cover for successful nests on the Wildcat Knolls was higher than unsuccessful nest. Lower adult survival on the Wildcat Knolls appeared to be caused by raptor predation (golden eagles). Maintaining escape cover and preventing further habitat fragmentation will be critical for grouse on both the Horn Mountain and Wildcat Knolls that are isolated and have no where else to go.

Understanding population movements and habitat use across the landscape is critical in understanding basic population biology and habitat management. My data suggested the sage-grouse on the Wildcat Knolls are non-migratory, in which case it is important to carefully identify and manage all aspects of sage-grouse habitat components. Potential nesting habitat needs to be carefully monitored with radio telemetry to insure that proper shrub and grass cover is always maintained. In small non-migratory populations, habitat alterations within sagebrush habitats should be conducted with extreme caution or completely avoided. Overall nesting success on both the Wildcat Knolls and Horn Mountain was affected by several factors. Distance to non-habitat edge affected nest success on the Wildcat Knolls, indicating that on average successful hens selected nest sites that were 3.5 times farther from non-habitat edge than unsuccessful hens. Continued monitoring of radio collared hens within identified potential nesting habitat on the Wildcat

Knolls will be vital in understanding sage-grouse production. I recommend that smaller sections of woodland habitats that separate larger sagebrush habitats on the Wildcat Knolls be removed to improve connectivity. Although more potential habitat exists on the Horn Mountain compared to Wildcat Knolls, it is subject to different types of fragmentation, and because of this, future monitoring needs to focus in understanding the connectivity of sagebrush habitats that are separated by mountain brush communities and other woodland habitats. Mountain shrub treatments that have already occurred north of South Horn should be implemented down through South Horn. Stands of pinion juniper and mountain mahogany that occur near the South Horn lek could be removed to reduce fragmentation and open new areas for nesting. Greater sage-grouse on the Horn Mountain appear to have two distinct seasonal ranges, and should be managed as a one-stage migratory population. Continued monitoring efforts should focus on: the impacts of fragmentation, impacts of habitat treatments in and around lek and nesting habitat, survival, habitat connectivity, and genetic diversity.

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Table 3-1. Nest site vegetation composition for successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) on the Wildcat Knolls and Horn Mountain, Utah, 2009.

SITE	Success	N Obs	Variable	Mean	Std Error	Lower 95% CL for Mean	Upper 95% CL for Mean
HORN	No	4	ShrubCov	19.23	2.57	11.06	27.39
			ShrubHt	19.78	3.97	7.15	32.4
			RobelIn	4.5	0.65	2.45	6.55
			RobelOut	2.5	0.87	-0.26	5.26
			ForbCov	4.06	0.78	1.58	6.54
			ForbHt	8.6	1.52	3.78	13.42
			NestGrassHt	18	2	9.39	26.61
			GrassCov	17.41	1.39	12.98	21.84
			GrassHt	13.88	0.41	12.58	15.17
			NestDiameter	126	17.16	71.39	180.61
			NestHt	57.75	8.11	31.95	83.55
	Yes	5	ShrubCov	23.84	3.62	13.78	33.9
			ShrubHt	26.84	3.62	13.78	33.9
			RobelIn	5.2	0.97	2.51	7.89
			RobelOut	2.8	0.97	0.11	5.49
			ForbCov	7.84	2.14	1.91	13.77
			ForbHt	10.42	1.45	6.39	14.45
			NestGrassHt	26.6	5.41	11.58	41.62
			GrassCov	18.31	1.41	14.38	22.24
			GrassHt	14.25	0.71	12.27	16.22
			NestDiameter	133.6	7.97	111.48	155.72
			NestHt	70	9.47	43.7	93.69
WILDCAT	No	3	ShrubCov	25.73	2.17	16.4	35.07
			ShrubHt	39.03	1.92	30.79	47.27
			RobelIn	6	0.58	3.52	8.48
			RobelOut	4.67	0.33	3.23	6.1
			ForbCov	5.65	2.18	-3.73	15.03
			ForbHt	7.61	0.58	5.12	10.09
			NestGrassHt	16.33	0.88	12.54	20.13
			GrassCov	12.83	6.26	-14.09	39.76
			GrassHt	11.14	0.73	7.98	14.3
			NestDiameter	150.33	6.06	124.24	176.43
			NestHt	76.33	4.37	57.52	95.14
	Yes	6	ShrubCov	33.13	5.16	19.86	46.4
			ShrubHt	40.18	5.32	26.5	53.87
			RobelIn	6.17	0.48	4.94	7.39
			RobelOut	3.5	0.56	2.05	4.95
			ForbCov	3.69	1.62	-0.47	7.85
			ForbHt	10.03	1.2	6.94	13.13
			NestGrassHt	26	3.75	15.57	36.43
			GrassCov	23.75	3.26	15.37	32.13
			GrassHt	16.28	1.37	12.75	19.81
			NestDiameter	145	13.76	109.63	180.37
			NestHt	87.17	8.78	64.59	109.75

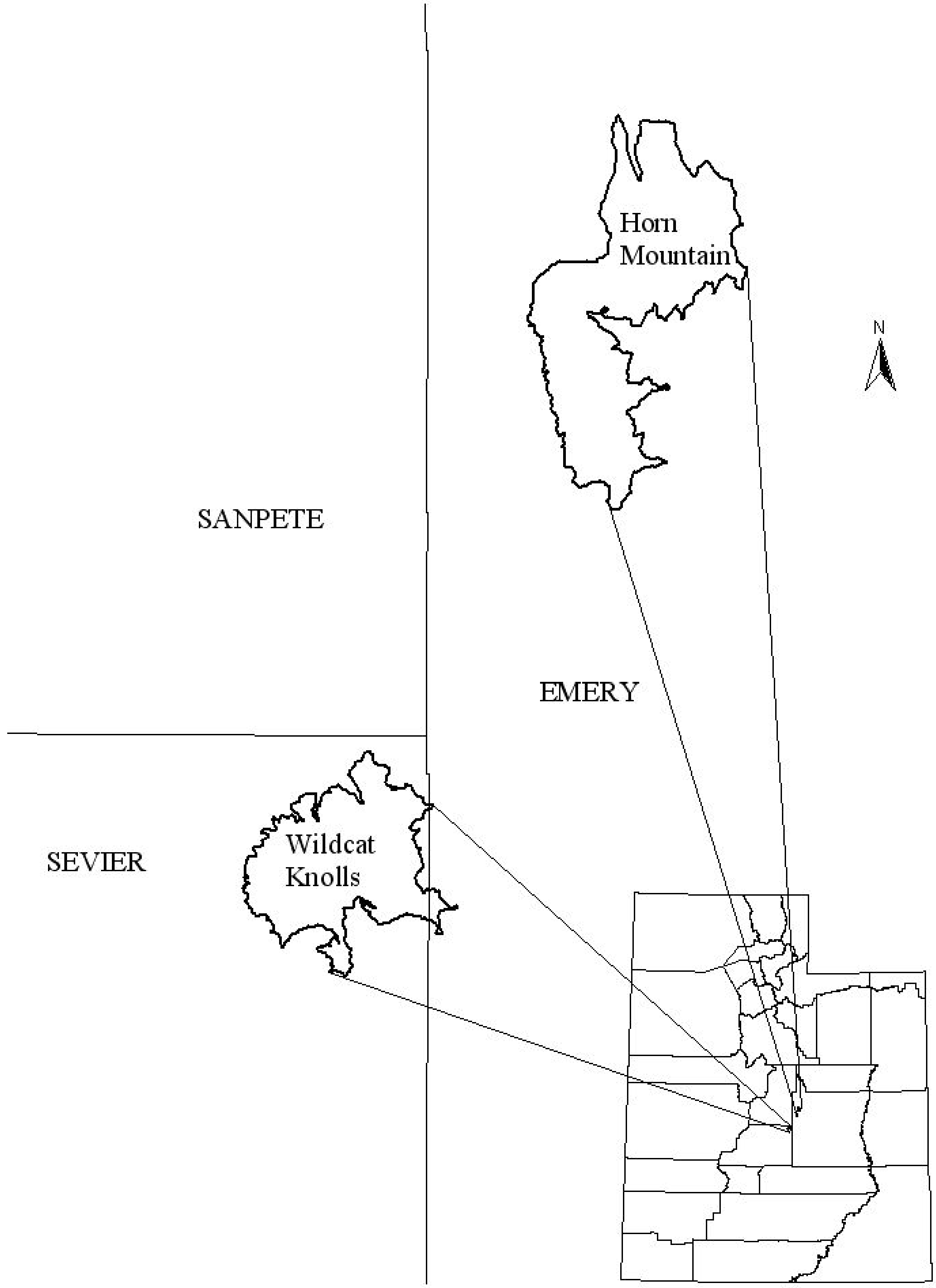

Figure 3-1. Study area of the Wildcat Knolls and Horn Mountain, Utah, 2009.

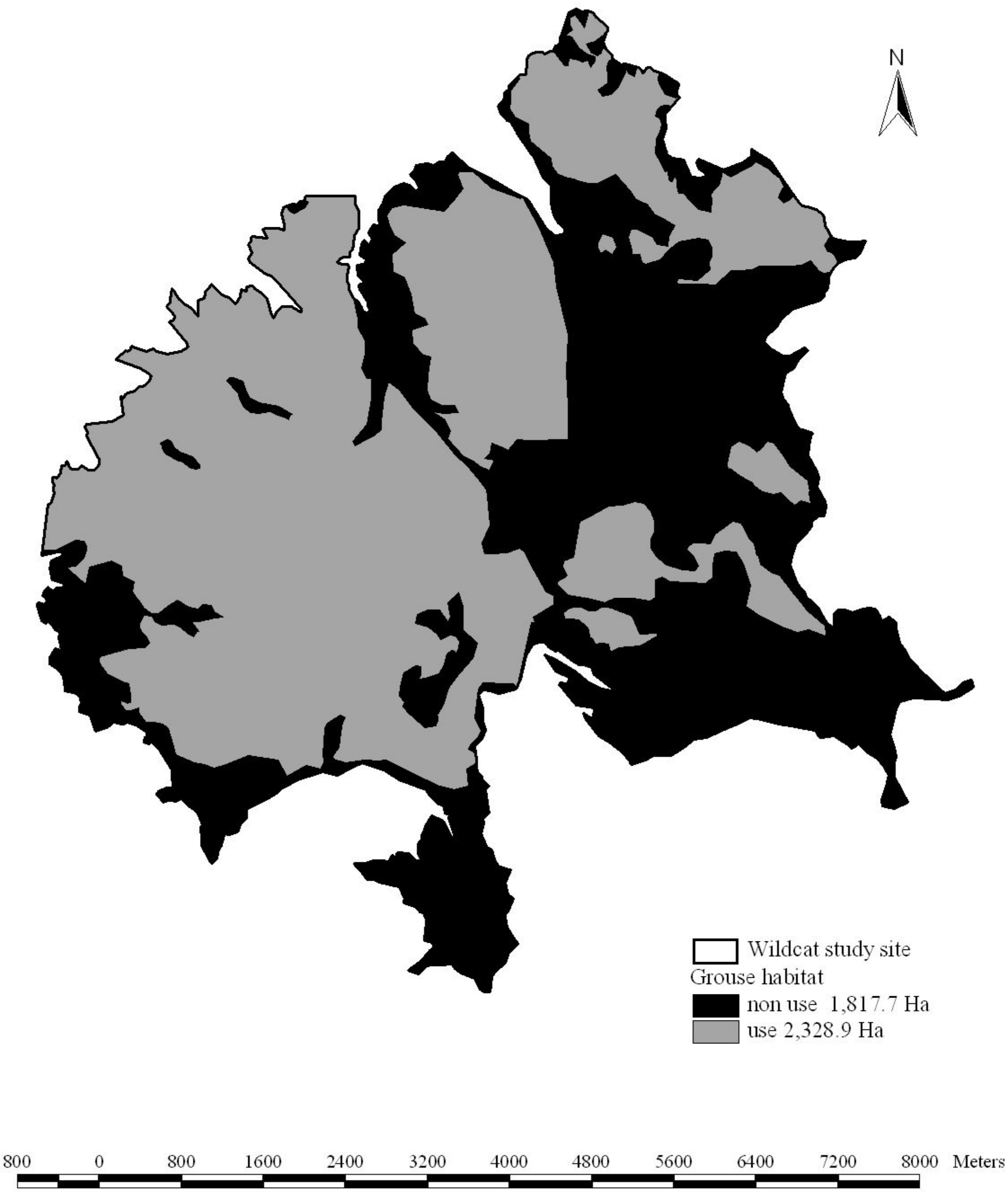

Figure 3-2. The potential nesting habitat on the Wildcat Knolls, Utah, 2009.

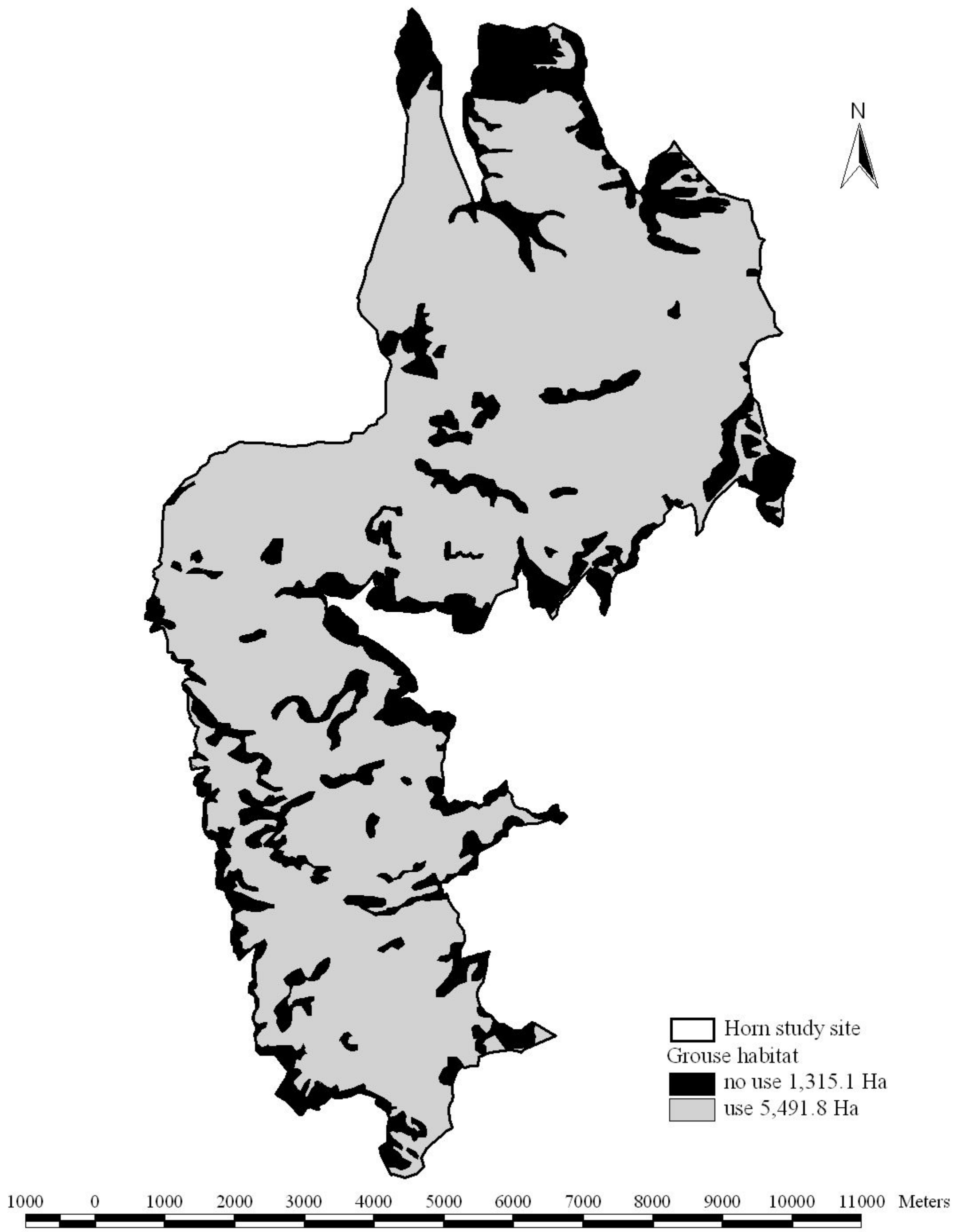

Figure 3-3. The potential nesting habitat on Horn Mountain, Utah, 2009.

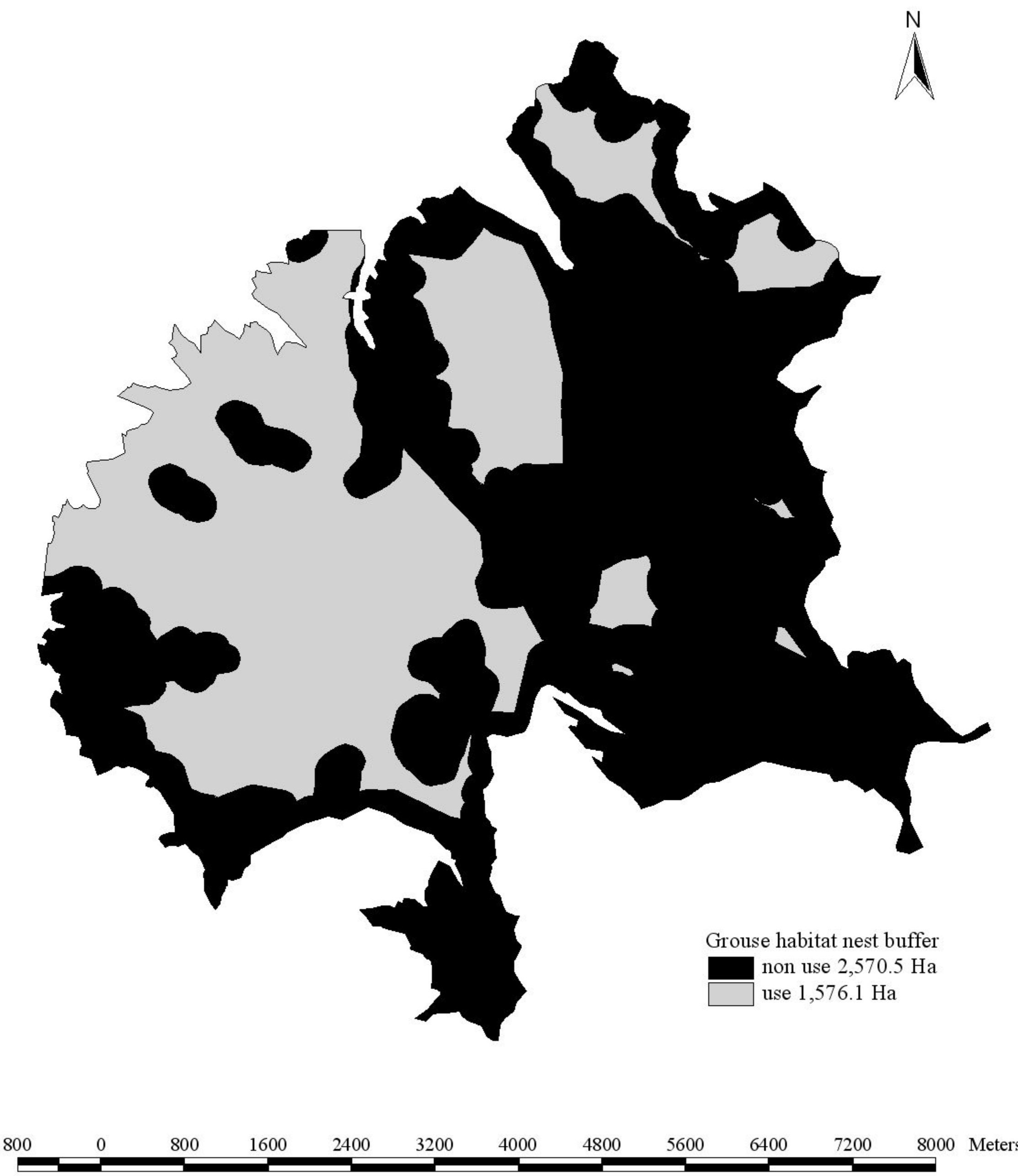

Figure 3-4. The potential nesting habitat with a 164 m buffer on the Wildcat Knolls, Utah, 2009.

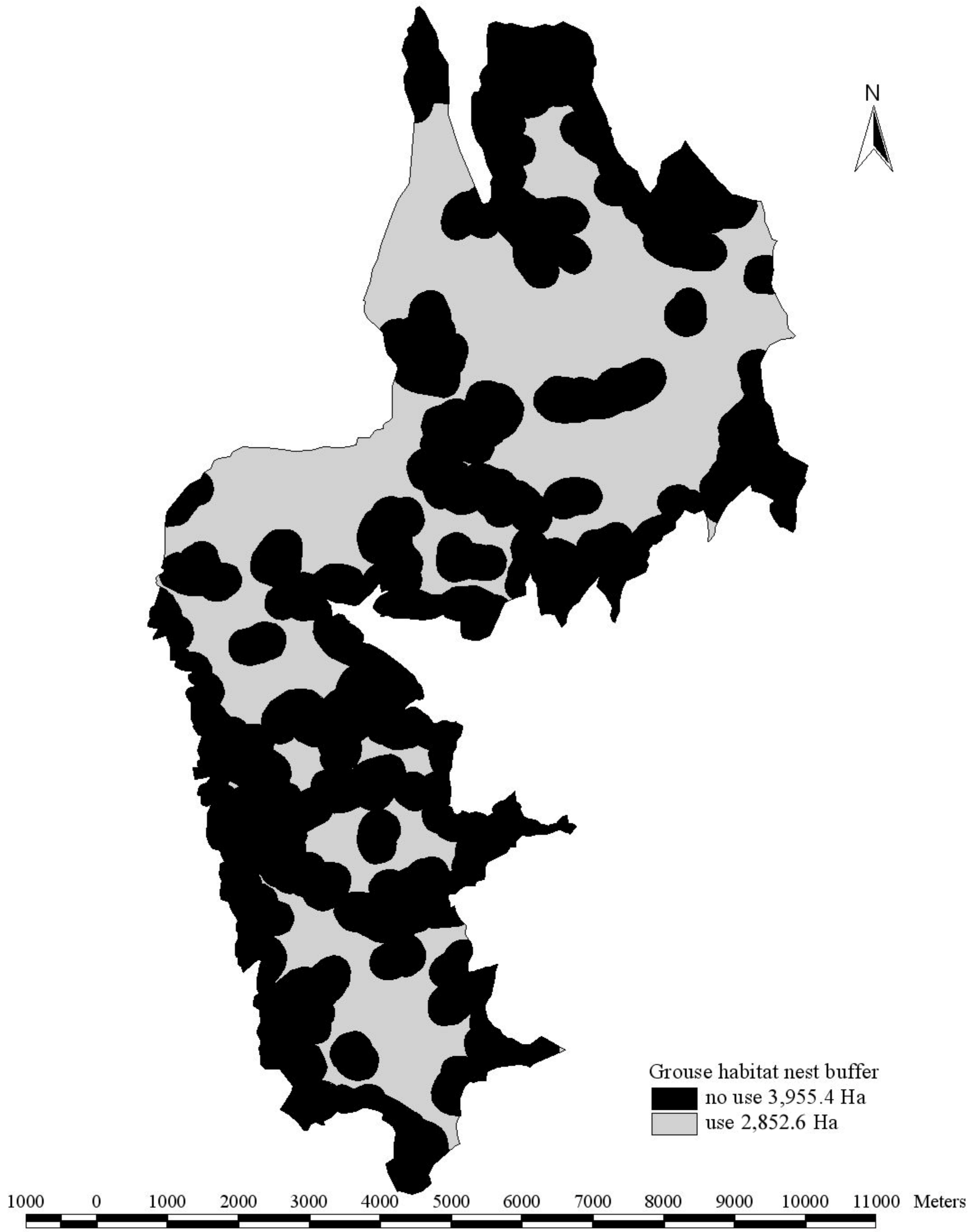

Figure 3-5. The potential nesting habitat with a 213 m buffer on Horn Mountain, Utah, 2009.

CHAPTER 4

THE EVALUATION OF MITOCHONDRIAL HAPLOTYPE DIVERSITY AMONG GREATER SAGE-GROUSE POPULATIONS INHABITING HIGH ELEVATION PLATEAUS IN CENTRAL UTAH

Abstract Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) once inhabited 15 states and 3 Canadian providences. Breeding populations have declined 17%-47% range-wide. With increased habitat loss and fragmentation, it is important to understand the amount of genetic diversity within populations that may be geographically isolated. Isolated populations tend to exhibit lower genetic diversity which may lead to inbreeding depression and increased susceptibility to disease and parasites. I collected mitochondrial samples from two small isolated populations inhabiting the Wildcat Knolls and Horn Mountain located in south central Utah. These sites are high elevation sagebrush-dominated plateaus separated by canyons and a straight line distance of 24 km. Although haplotype frequencies on the Wildcat Knolls and Horn Mountain showed some similarity with several Utah populations, low diversity (especially on Horn Mountain) may be a result of isolation. Microsatellite analysis can increase managers understanding of the potential effects genetics can have on local populations, and help them to determine is translocation are necessary to increase and or maintain genetic diversity among both populations. Additionally, microsatellite analysis prior to translocation can ensure that unique genetic diversity in small populations is maintained by bringing in grouse from populations that have similar genes to reduce the potential effects of outbreeding depression. Biologists should not only continue taking samples for genetic comparison, but should also collect morphometric and behavior data.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations throughout the west inhabit about 56% of pre-settlement distribution of potential habitat (Schroeder et al. 2004). Greater sage-grouse population declines throughout their range have been largely attributed to habitat loss, degradation, and fragmentation of sagebrush (*Artemisia* spp.) habitats (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Connelly et al. 2004). With increased habitat loss and fragmentation it is important to understand the amount of genetic diversity within in populations that may be geographically isolated (Oyler-McCance et al. 2005). Isolated populations are more susceptible to lower amounts of genetic diversity that may lead to inbreeding depression and increased rates of disease and parasites (Frankham 1995, Oyler-McCance et al. 2005). Conservation genetics throughout the sage-grouse range have been used to describe the distribution of genetic variation (Kahn et al. 1999, Oyler-McCance et al. 1999, Benedict et al. 2003, Oyler-McCance et al. 2005). Genetic research (Kahn et. al 1999, Oyler-McCance et al. 1999) in combination with morphological (Hupp and Braun 1991) and behavioral data led to the identification of a new grouse species (Young et al. 2000), the Gunnison sage-grouse (*C. minimus*).

In a range-wide study, Oyler-McCance et al. (2005), found that movement among neighboring populations of greater sage-grouse was common, but that large movements across the range of sage-grouse were uncommon. Localized gene flow with isolation by distance may be why genetic variation shows a gradual shift range-wide (Oyler-McCance et al. 2005). Microsatellite data from the same study indicated that the

Strawberry Valley, UT and Parker Mountain, UT sage-grouse populations demonstrated localized patterns of gene flow, likely due to fragmentation and isolation.

Management of sage-grouse in Utah may be further complicated because of the mosaic of private and public landownership in Utah. Sage-grouse occupy habitats managed by the Bureau of land Management (BLM), U.S. Forest Service (USFS), U.S. Park Service (UPS), State of Utah, and private landowners. The Utah Division of Wildlife Resources (UDWR) estimates that about 50% of Utah sage-grouse habitat and populations occur on private land (UDWR 2002, 2009). The complexity of land ownership requires the collaboration of many organizations and private landowners when dealing with sage-grouse issues.

In Utah, sage-grouse have been found in 26 of 29 counties and inhabit 50% of their historic range (Beck et al. 2003). Two small populations representative of spatial separation and thus presenting unique conservation challenges inhabit the Wildcat Knolls and Horn Mountain located in southcentral Utah. These are high elevation sagebrush dominated plateaus separated by 24 km straight line distance.

In 2009, I collected blood samples from all birds captured on the Wildcat Knolls and Horn Mountain populations to determine mitochondrial haplotype diversity. Prior to this research, nothing was known about the genetic diversity of sage-grouse populations inhabiting these areas. Previous data collection efforts were limited to monitoring male attendance. Understanding the amount of mitochondrial genetic diversity will help determine connectivity among both populations, and help understand whether or not translocations from other related populations are warranted to enhance population fitness. This research will provide local wildlife managers information to guide management actions in maintaining and or enhancing genetic diversity for the greater sage-grouse populations that inhabit Wildcat Knolls and Horn Mountain.

STUDY AREA

Ranging from 2500-2900 m in elevation, the Wildcat Knolls and Horn Mountain study areas are in Emery and Sevier counties on the southeast end of the Manti Mountains (Wasatch Plateau) (Fig. 4-1). Both sites are on public land managed by the USFS. They consist of isolated openings on the southeast edge of the plateau, and are surrounded by canyons, cliffs, and mountains. The North Fork of the Quitchupah Canyon borders the Wildcat to the west, White Mountain to the north, the Muddy to the Northeast, and the southern edge is bounded by an escarpment of cliffs. The town of Emery is just about 11 km south of the Wildcat site in the desert valley below.

The Horn Mountain site is located 24 km to the northeast of the Wildcat Knolls. Straight Canyon borders to the northeast of Horn Mountain. The Cap and Long Ridge borders to the north, Ferron Canyon borders to the west, and an escarpment of cliffs surrounds the south and southeast edge of Horn Mountain. The town of Ferron is about 6.5 km southwest in the desert valley below.

Local state and federal biologists have monitored sage-grouse within the study area since the late 80's. In 1987, UDWR biologists began translocating sage-grouse to the Wildcat Knolls. Fifty-three grouse were moved to the Wildcat Knolls site from 4 different populations within Utah over a 4- year period (Table 4-1), of the 4 populations, haplotype frequencies were described in 2 populations (Parker Mountain and Diamond Mountain) in 2005 by Oyler-McCance et al. These results described 9 halpotypes within the Diamond Mountain population, 8 within the Parker Mountain, and 11 total unique haplotyes between both populations. Prior to monitoring efforts that began in 1990, UDWR biologists did not record any sage-grouse activity on the Wildcat Knolls study site. Since the sage-grouse translocations on the Wildcat Knolls, one main lek and several satellite leks have been monitored. In 2008, peak male lek attendance was 17, and dropped to 12 in 2009. In 2008 and 2009, the high lek count of male sage-grouse on the South Horn lek was 17. According to the UDWR, sage-grouse have never been translocated to the Horn Mountain study area (R. Hodson, UDWR personal communication).

METHODS

Capture and Sampling

Previous efforts by the UDWR to monitor sage-grouse populations on the study area were hindered by elevation accessibility during early spring months further compromised by logistical and time constraints. To address these issues, Utah State University (USU), UDWR, and the USFS initiated a fulltime research effort to document sage-grouse ecology in the area. To document early spring movements, initial trapping began in January 2008. Sage-grouse were located by spotlighting with binoculars from the back of an ATV and captured with a long-handled net (Wakkinen et al. 1992). At each capture site, the overall health and condition of the grouse were assessed. Age (adult or juvenile) and sex were assigned at the time of capture site based on primary feather characteristics (Dalke et al. 1963). Each bird was weighed using a pesola™ (Pesola, Zug, Baar, Switzerland) 2,500-g spring scale. Blood samples from all birds captured or re-captured on both the Wildcat Knolls and Horn Mountain in 2009 were taken from clipped grouse toenails on Nobuto blood filter strips, silver nitrate was applied to the toenail if bleeding did not stop after applying pressure with a cotton ball.

At the site of each capture, I used a global positioning system (GPS) unit set to Universal Transverse Mercator (UTM) NAD27 to record each capture location. All grouse captured were handled in accordance with protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University (USU), protocol file # 1195, and with a Certificate of Registration (COR) from the UDWR, COR # 6BAND7779.

Adult birds were fitted with Holohil Systems Ltd. (112 John Cavanaugh Drive, Carp, Ontario, K0A 1L0, CANADA) necklace style radio transmitters. This type of transmitter has a 36-month battery life (24 hours on), and weighs 17.7 grams. Radio-collared birds were located using Telonics, Inc.™ (932 East Impala Avenue, Mesa, AZ 85204) and ICOM America Inc.™ (2380 116th Avenue northeast, Bellevue, WA 98004) receivers, handheld 3-element Yagi folding antennas, and vehicle mounted Omni antennas (RA-2A).

DNA Extraction and Amplification

The DNA extraction, amplification, and sequencing were conducted by Dr. Karen Mock's lab at Utah State University. The DNA extractions were conducted using a salting-out extraction method modified from Sunnucks and Hales (1996). Blood samples were incubated with proteinase K in 300 microliters (ul) TNES buffer (1 M Tris-HCl (pH 8.0), 0.5 M EDTA (pH 8.0), 5 M NaCl, and 10% SDS) overnight at 55°C. After incubation, 85 ul of NaCl was added followed by centrifuging at 13,500 RPM for 10 minutes to pellet the proteins. The supernatant was pipetted into a new tube. An equal volume of cold 100% EtOH was added to the supernatant and it was spun again for another 10 minutes to pellet the DNA. The EtOH was carefully poured off making sure the DNA pellets remained in the tube. The DNA pellets were rinsed a final time using 75% EtOH, and spun down for 5 minutes. The EtOH was removed again, and the pellets were dried in microvials for a few minutes before being suspended in 40 ul of 0.1X TE.

Polymerase Chain Reaction (PCR) was performed using previously described primers 16775L (Quinn 1992) and 521H (Quinn and Wilson 1993), followed by a nested PCR with primer 418H (Quinn and Mindell 1996) to amplify a highly variable section of mitochondrial control region I (Kahn et al. 1999). Amplifications were carried out on Applied Biosystems Inc. (ABI) 2720 and 9700 thermalcyclers (Applied Biosystems, Inc., Forest City, CA) in 25 ul volumes with 200gM 2'-Deoxyadenosine 5'- Triphosphate, 2'-Deoxycytidine 5'-Triphosphate, 2'-Deoxyguanosine 5'-Triphosphate, and 2'-Deoxythymidine 5'-Triphosphate (dNTPs), 1.5mM MgCl, lx PCR buffer, 0.3gM primers, 0.5 Units of Taq polymerase (New England Biolabs Inc., Ipswich, MA), and 50 ng DNA template. Conditions consisted of preheating to 92°C for 2 minutes followed by 30 cycles of amplification consisting of denaturing 94°C for 30 seconds, annealing 56°C for 30 seconds, and an extension at 72°C for 2 minutes. A final extension was carried out for 10 minutes at 72°C.

The quantity and quality of PCR products was assessed with electrophoresis. Two ul of PCR product was electrophoresed through a 0.7 % agarose gel in 1X TBE and 10 mg/mL Ethidium bromide (EtBr) and visualized with a UV box. The PCR product was purified using the Qiagen QIAquick PCR purification Kit.

Mitochondrial Sequencing

Sequencing reactions were conducted with an ABI BigDye Terminator Kit v3.1 and reaction products were separated and visualized using an ABI PRISM_ 3730 Genetic Analyzer. Contiguous sequences for each individual were constructed and aligned using SEQMAN and MEGALIGN software (DNASTAR Inc., Madison, WI).

Data Analysis

I used MEGA 4.0.2 (Tamura et al. 2007) software to compare sequenced haplotypes and to construct a phylogram comparing the distance between haplotypes. Location data was analyzed with ArcGIS 9.2 (ESRI, Redlands, CA) Geographic Information System (GIS).

RESULTS

Captures

Due to lower winter snow accumulations, trapping success in 2009 was higher than in 2008. Blood samples were taken from 41 sage-grouse in 2009. Of the 41 samples taken, 19 were taken from the Wildcat Knolls and 22 from Horn Mountain. Through the months of March – May, we were able to capture 37 birds, 24 of which were fitted with radio collars, and 17 that were captured for blood sampling purposes (16 female and 21 male). Four birds caught in 2008 were recaptured for blood sampling in 2009. Females captured included 2 adults and 14 yearlings weighing 1100-1540 grams. Males consisted of seventeen adults and 4 yearlings ranging in weight from 2100-2800 grams. Of the thirty-seven additional sage-grouse captured in 2009, 16 were caught on

Wildcat Knolls (9 female and 7 male) and 20 on Horn Mountain (7 female and 13 male). Forty-three sage-grouse were fitted with radio collars from 2008-2009.

Mitochondrial Analysis

Haplotypes from Wildcat Knolls and Horn Mountain fell into both of the distinct monophyletic clades (clade I and clade II) described by Kahn et al. (1999). Five mtDNA haplotypes were identified of the 41 individuals assayed (Table 4-2). Of the 5 haplotypes, all were found on the Wildcat Knolls. One haplotype was found on Horn Mountain, and fell within clade I.

DISCUSSION

Patchy habitat availability due to glacial change throughout North America is thought to have led to 2 distinct haplotype clades within isolated sage-grouse populations that occurred 85,000 years ago during the Pleistocene (Kahn et al. 1999, Benedict et al. 2003, Oyler-McCance et al. 2005). The separation between the two populations is thought to be caused by geographic isolation (Kahn et al. 1999, Benedict et al. 2003). Since the divergence of the 2 ancestral populations, habitat conditions range-wide have changed. The 2 ancestral populations may have re-converged, thus range-wide studies have found haplotypes from both clades in most sage-grouse populations (Kahn et al. 1999, Benedict et al. 2003, Oyler-McCance et al. 2005).

Haplotype data has been described among 11 sage-grouse populations throughout Utah (Fig. 4-2, Table 4-2). Only one haplotype (DT) of 22 samples was found in the Horn Mountain population. This haplotype (DT) falls within clade I, and is common among most of the Utah sage-grouse populations. Haplotype DT has only been described in one population outside of Utah (Kemmerer, WY) (Oyler-McCance et al. 2005). The narrow distribution of this haplotype (DT) may be related to microsatellite data collected by Oyler-McCance et al. (2005), which indicated that the Strawberry Valley, UT and Parker Mountain, UT sage-grouse populations demonstrated localized patterns gene flow due to fragmentation and isolation.

Five haplotypes (DT, DW, DZ, DX, and B) of 19 samples were found among the Wildcat Knolls population. Haplotype B is widely distributed in most sage-grouse populations throughout the intermountain west (Kahn et al. 1999, Benedict et al. 2003, Oyler-McCance et al. 2005). Haplotypes DW, DZ, and DX were all very similar to haplotype DT (Fig. 4-3). Haplotype DW only differed by one transition from DT, and was the most common haplotype on the Wildcat Knolls. DZ and DX both differed by 2 transitions from DT. Although little data other than lek counts is available, translocations that occurred on the Wildcat Knolls in the late 80's appears to have been somewhat successful. Microsatellite data may give more insight to the genetic stability and or change that may have occurred from translocated sage-grouse and the populations that they came from.

Differences in haplotype proportions between Wildcat Knolls and Horn Mountain are shown in diversity of haplotypes, and are similar in the DT haplotype. This does indicate similarity between the 2 sites, but low haplotype diversity on Horn Mountain may indicate isolation between both sites. The closet population known to have similar haplotype frequencies is located about 45 km to the south in Wayne County, UT on Parker Mountain. The DT and B haplotypes are common within the Parker Mountain population (Oyler-McCance et al. 2005). Of the 11 haplotypes described by Oyler-

McCance et al. 2005 found within populations (Parker Mountain and Diamond Mountain) where birds were translocated from in the late 1980's, only 2 of those haplotypes were found among the Wildcat Knolls populations in 2009. Microsatellite test may give proper insight in understanding genetic differences among sites, and help determine whether or not translocations are necessary to increase and or maintain genetic diversity among both populations.

Mitochondrial DNA is maternally inherited, so movements of male grouse between Wildcat Knolls and Horn Mountain could go undetected. Although only 24 km apart, no movement of radio-collared birds between the Horn Mountain and Wildcat Knolls study sites occurred in 2008-2009. Habitat and topological features that surround both sites (Canyons, cliffs, mountain ranges, and woodland habitats) appear to impede movement among the Wildcat Knolls and Horn Mountain populations.

Telemetry data from radio-collared males indicated erratic lekking behavior of male sage-grouse on the Wildcat Knolls. Several factors may be influencing this behavior. Although habitat quality and availability probably have the greatest influence on this behavior, sage-grouse translocations that occurred on the Wildcat Knolls in the late 80's may have also contributed. The benefits of local adaptation may have been lost in genetic differences among translocated sage-grouse, and the effects of outbreeding depression may have influenced lekking behavior (Oyler-McCance et al. 2005). The exact cause of inconsistent lekking behavior is unknown, and needs be further evaluated.

MANAGEMENT IMPLICATIONS

Although haplotype frequencies on Wildcat Knolls and Horn Mountain do show some similarity with several Utah populations, low diversity (especially on Horn

Mountain) may be a result of isolation. Genetic differences that may have influenced erratic lekking behavior on the Wildcat Knolls may only be observed in microsatellites.

Translocations may become necessary to help simulate gene flow and maintain genetic stability among these fragmented and isolated populations. To aid in understanding this need, differences among the two sites need to be well understood. Biologist should not only continue taking samples for genetic comparison, but should also collect morphometric, and behavior data among both populations.

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Table 4-1. Capture locations and number of greater sage-grouse (*Centrocercus urophasianus*) released onto the Wildcat Knolls, Utah, 1987-1990.

Date released	# of Hens	# Males	Capture location
7/30/1987	8	1	Diamond Mountain
7/8/1988	0	2	Emma Park
8/9/1989	19	1	Diamond Mountain
8/31/1989	6	1	Parker Mountain
4/10/1990	2	13	Emma and Whitemore Parks

Table 4-2. Greater sage-grouse (*Centrocercus urophasianus*) haplotype frequencies found on the Wildcat Knolls, UT and Horn Mountain, UT compared to haplotype frequencies that have been described throughout Utah. Haplotype data from Blue Mountain, UT, Diamond, UT, Strawberry, UT, Rich County, UT, Parker Mountain, UT, Box Elder County, UT is from Oyler-McCance et al. (2005). Data from Anthro Mountain, UT, Deadman Bench, UT, Seep Ridge, UT is from Smith (2009).

					Haplotypes																						
Location	N	Clade I	Clade II	Number of haplotypes	A	DT	DR	AA	AG	DR	DU	DW	DZ	DX	AC	EF	EC	FA	FB	B	C	T	W	EU	ER	S	EX
Wildcat	**19**	**4**	**1**	**5**		**3**						**8**	**2**	**2**						**4**							
Horn Mtn.	**22**	**1**	**0**	**1**		**22**																					
Box Elder	28	5	2	7	10	2		1	1								1			12							1
Parker Mtn.	25	4	4	8	6	4		1							1					7			4			1	1
Rich	26	7	2	9	3	5		1							1		1	1	1	6	4		4			1	
Diamond Mtn.	26	5	4	9	9	1		1							2	1				6	2	1				3	
Blue Mtn.	18	3	2	5				1							2	1				11	3						
Strawberry	23	1	3	4			15													3	4		1				
Anthro	7	7	0	7						6	1																
Deadman bench	4	0	4	1																4							
Seep ridge	6	0	3	3																3				1	2		

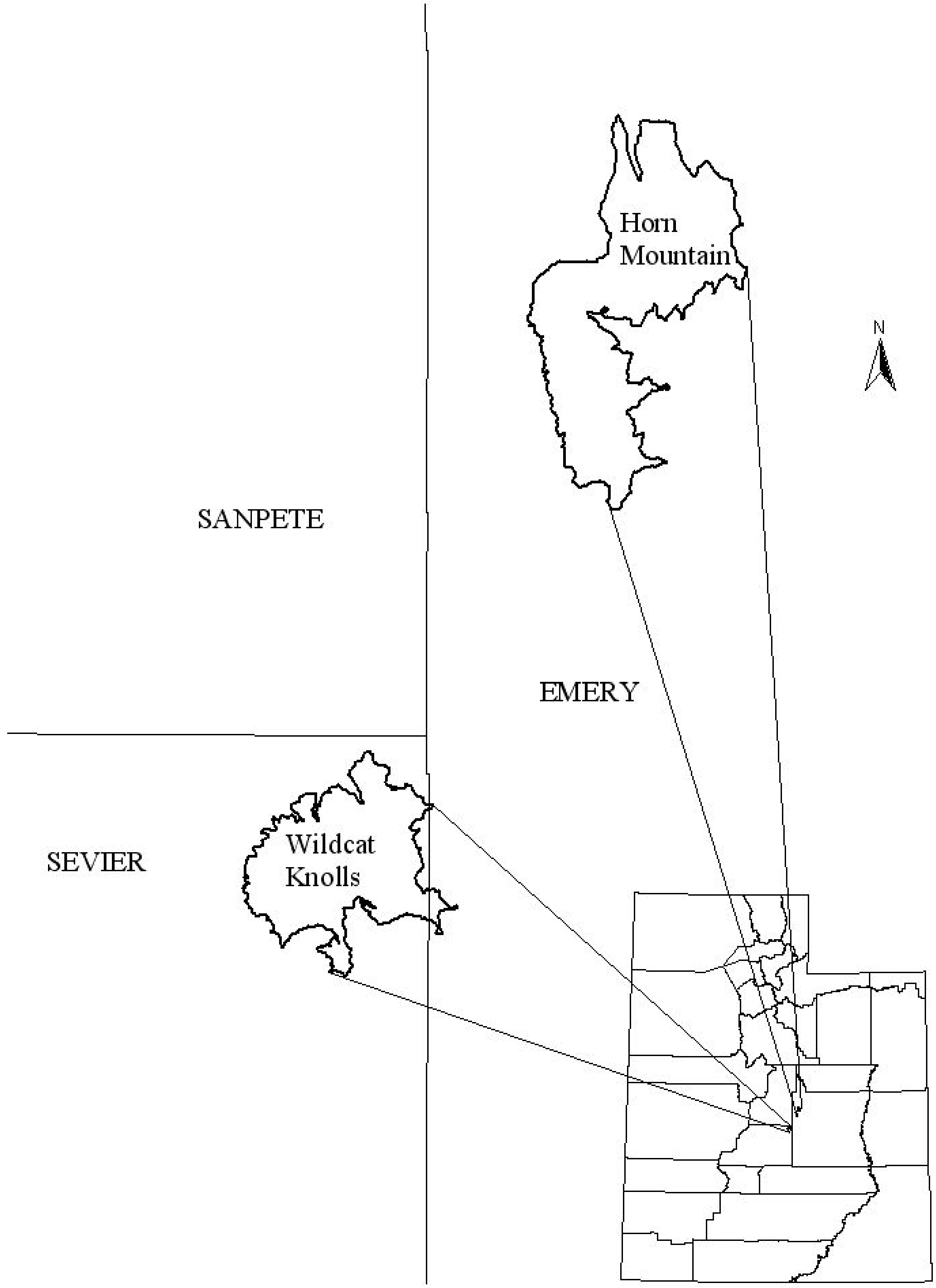

Figure 4-1. Study area of the Wildcat Knolls and Horn Mountain, Utah, 2009.

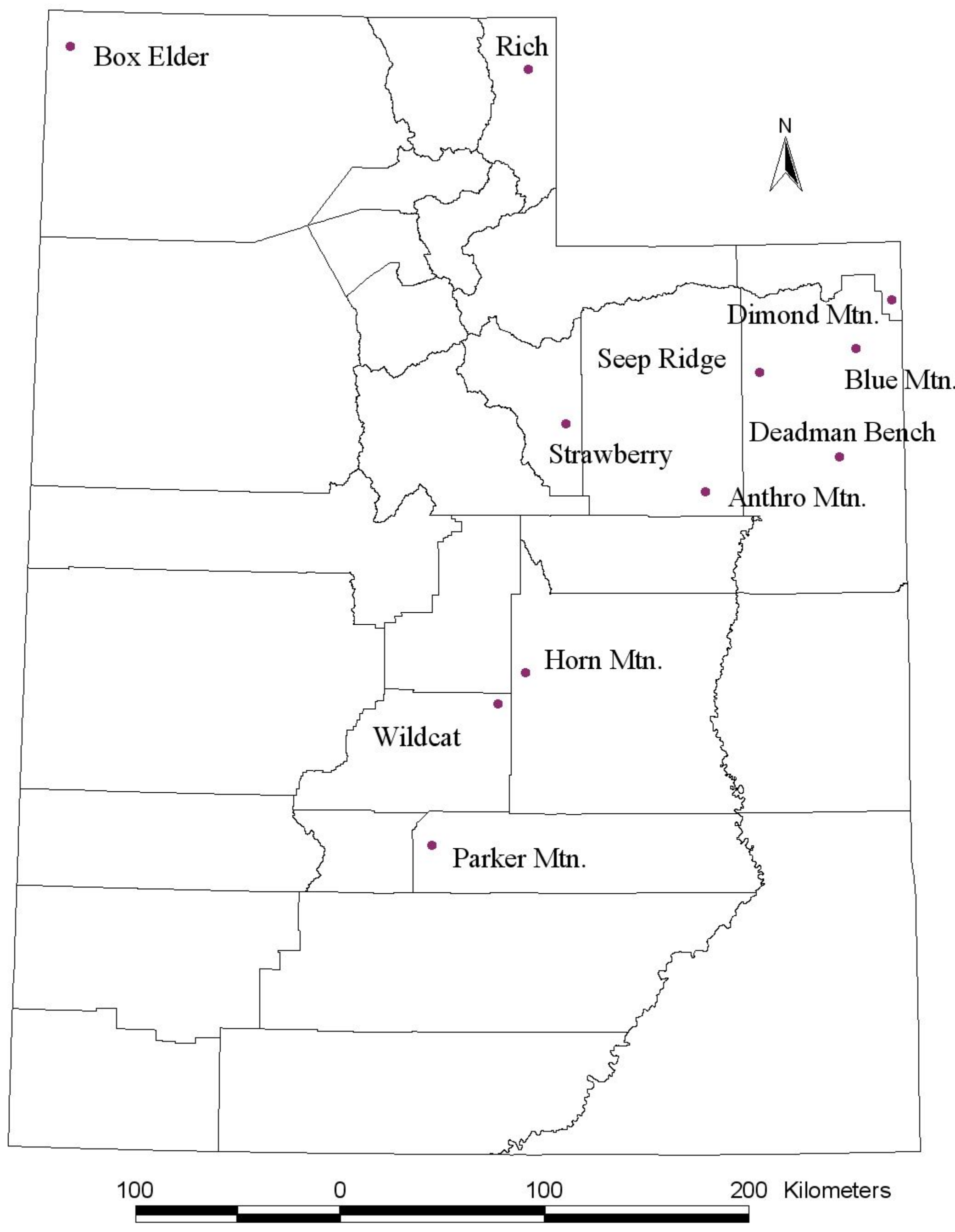

Figure 4-2. Utah greater sage-grouse (*Centrocercus urophasianus*) populations were haplotype frequencies have been described, Utah, 2009.

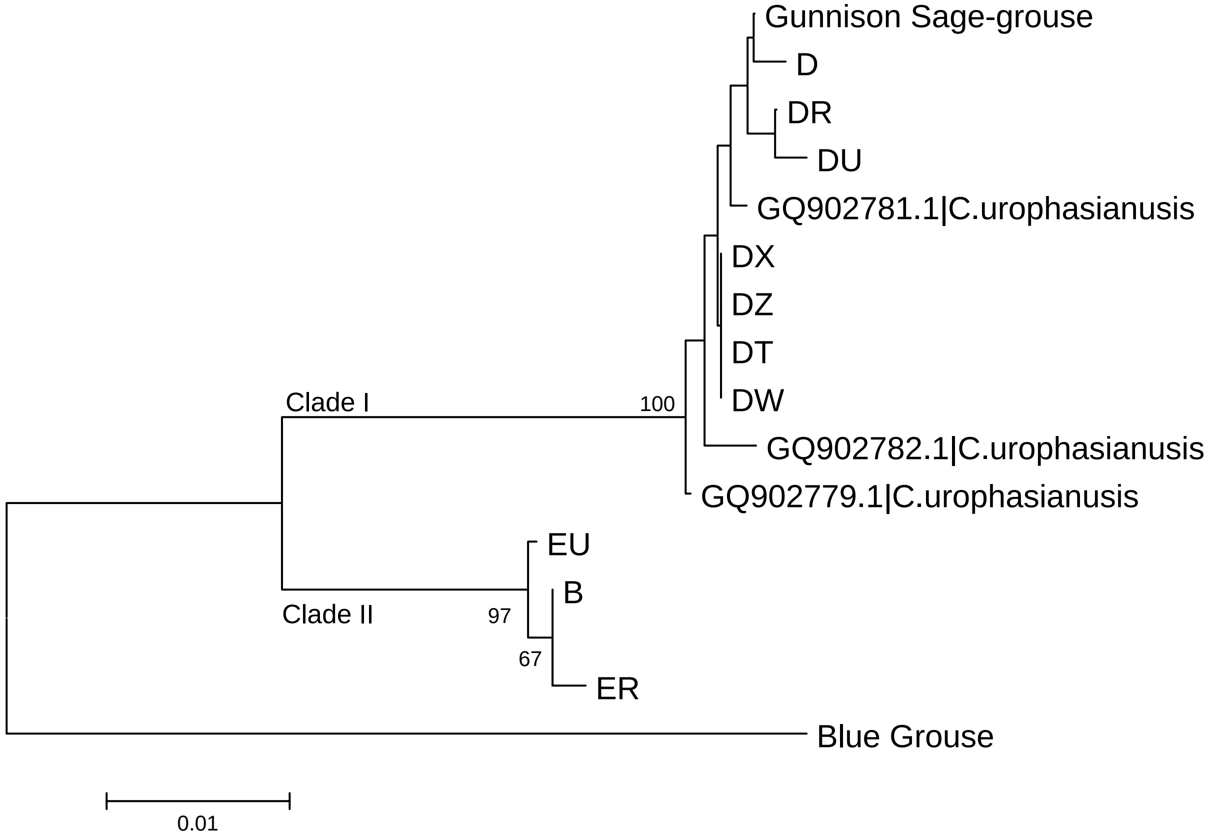

Figure 4-3. Phylogram showing the 5 haplotypes found within the Horn Mountain, UT and Wildcat Knolls, UT greater sage-grouse (*Centrocercus urophasianus*) populations in comparison to other haplotypes. Haplotypes ER, EU, DU, DR, and D are from Smith (2009). Boot strap values > 50% are shown on the branches of the tree.

CHAPTER 5

CONCLUSIONS

Range wide declines in greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations prompted several organizations to petition the U.S. Fish and Wildlife Service (USFWS) to list sage-grouse for protection under the Endangered Species Act of 1973 (Connelly et al. 2004). Declines in greater sage-grouse populations are largely attributed to habitat loss and degradation typically associated with anthropogenic activities. Currently, energy development throughout the west has become a major factor affecting sage-grouse populations (Beck 2006). Impacts associated with increased energy development may include habitat loss and fragmentation caused by increased roads, wells and pipeline construction (Beck 2006). Much of the published sage-grouse management guidelines are based on populations of sage-grouse that inhabit large contiguous landscapes. With increased fragmentation throughout its range, it is important to understand the basic ecology of sage-grouse that inhabit small isolated regions (Schroeder and Robb 2003).

The Wildcat Knolls and Horn Mountain support small populations, spatially separated, and present unique conservation challenges. These are high elevation sagebrush dominated plateaus separated by 24 km straight line distance. Prior to this research, little was known about sage-grouse ecology on the Wildcat Knolls and Horn Mountain in central Utah. Previous data collection efforts were limited to monitoring male attendance on the Wildcat Knolls, South Horn, North Horn, and Barewire Pond leks since 1991. However, these counts were inconsistent because of limited accessibility during the early spring months. The purpose of this research was to obtain a better estimate of sage-grouse lek attendance, distribution, habitat-use patterns, and the factors affecting production, and survival. This research will be used to provide the Castle Country Adaptive Resources Management Local Working Group (CaCoARM), Canyon Fuel Company (CFC), USFS, and the UDWR with information to guide management actions to enhance habitat conditions for the greater sage-grouse populations that inhabit the Wildcat Knolls and Horn Mountain. The objectives of my thesis were to: 1) document greater sage-grouse seasonal distributions and habitat use on Horn Mountain and Wildcat Knolls, 2) document greater sage-grouse nesting and brood habitats on Horn Mountain and Wildcat Knolls, 3) determine factors that may be limiting greater sage-grouse populations on Horn Mountain and Wildcat Knolls and 4) document the genetic diversity of greater sage-grouse populations inhabiting Horn Mountain and Wildcat Knolls.

My data suggest sage-grouse on the Wildcat Knolls are non-migratory, in which case it is important to carefully identify and manage all aspects of sage-grouse habitat components. In small non-migratory populations, habitat alterations within sagebrush habitats should be conducted with extreme caution or completely avoided. Compared to larger sage-grouse populations throughout the west that inhabit large contiguous habitats, published management guidelines (Connelly et al. 2000) suggest that small non-contiguous habitats like those found within Wildcat Knolls and Horn Mountain have very little room for error in management. Sage-grouse response of habitat treatments conducted in the fall of 2008 need to be continually monitored and evaluated. Additional radio telemetry efforts should be continued to help identify the cause of erratic lekking behavior on the Wildcat Knolls. Greater sage-grouse on the Horn Mountain appear to have two distinct seasonal ranges, and should be managed as a one-stage migratory population. Topography that surrounds both sites (Canyons, cliffs, mountain ranges, and woodland habitats) apparently impedes movement among the Wildcat Knolls and Horn Mountain populations.

Differences in survival were readily evident between Wildcat Knolls and Horn Mountain. Male and female survival rates were lower on Wildcat Knolls. Male survival on Wildcat Knolls was much lower (36%) than Horn Mountain (75%). All 6 of the positively identified grouse mortalities on the Wildcat Knolls were raptor-related (possibly golden eagle). Evidence of higher raptor mortality on Wildcat Knolls may be caused by habitat availability and concentration of active golden eagle nests. Additional research should include evaluating the effects of raptors on sage-grouse survival in relation to lagamorph abundances and other raptor prey species. Although adult survival was higher on Horn Mountain, brood success was much lower (20%) than the Wildcat Knolls (83%).

Several factors influenced survival on both sites, but differences in habitat structure were most apparent. Sage-grouse breeding habitat on Wildcat Knolls is broken into patches surrounded by ponderosa pine-dominated woodlands. Sage-grouse habitat on Horn Mountain is comparable to Wildcat Knolls, but differs in percent shrub cover and dominant woodland species. Habitats that border grouse habitat on Horn Mountian are comprised primarily of mountain brush, mountain mahogany, and pinyon pine communities. Available habitat approximates published management guidelines, but its limited size and fragmented structure potentially limits stability in sage-grouse populations. Habitat that surrounds quality sage-grouse habitat is ideal for golden eagles and other predators. Given the high densities of golden eagles, future alterations of sagebrush habitat surrounding lek and nesting areas should be avoided.

Overall sage-grouse productivity and survival on the Wildcat Knolls and Horn Mountain were affected by multiple factors. Distance to non-habitat edge affected nest success on the Wildcat Knolls, indicating that on average successful hens selected nest sites that were 3.5 times farther from non-habitat edge than unsuccessful hens. I recommend that smaller sections of woodland habitats that separate larger sagebrush habitats on the Wildcat Knolls be removed to improve connectivity. On Horn Mountain, future monitoring should also focus in understanding the connectivity of sagebrush habitats that are separated by mountain brush communities and other woodland habitats.

Overall nesting and brooding success on both sites may be affected by the presence and quality of shrub and grass cover as escape cover from predators. Lack of escape cover may be limiting sage-grouse production. Nesting and brooding habitat needs to be continually monitored with radio telemetry to evaluate its availability and use with breeding sage-grouse.

Haplotype frequencies on the Wildcat Knolls and Horn Mountain show some similarity with several Utah populations, but low diversity (especially on Horn Mountain) may be a result of isolation. To give proper insight in understanding genetic differences among sites, microsatellite test may help determine whether or not translocations are necessary to increase and or maintain genetic diversity among both populations (Oyler-McCance et al. 2005). Translocations may become necessary to help simulate gene flow and maintain genetic stability among these fragmented and isolated populations. To aid in understanding this need, differences among the 2 sites need to be well understood.

Management efforts should focus on mitigating the impacts of fragmentation by preserving existing quality habitat, continued monitoring using radio telemetry, and increased understanding of genetic diversity among sites to aid managers in there decisions to conduct well conceived translocations.

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