GREATER SAGE-GROUSE ECOLOGY

IN WESTERN BOX ELDER COUNTY, UTAH

by

Jan S. Knerr

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Approved:

Terry A. Messmer Major Professor	Michael R. Conover Committee Member
Christopher A. Call Committee Member	Byron R. Burnham Dean of Graduate Studies

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ABSTRACT

Greater Sage-grouse Ecology in Western Box Elder County, Utah

by

Jan S. Knerr, Master of Science

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Major Professor: Dr. Terry A. Messmer
Department: Wildland Resources

I studied the ecology and movement patterns of the greater sage-grouse (*Centrocercus urophasianus*) population in western Box Elder County, Utah, in 2005 and 2006. Fifty sage-grouse were radio-collared and monitored during the study. Nest initiation rates in 2005 and 2006 were 83% and 71%, respectively. Nest sites exhibited 22.8% shrub canopy cover, and 18.5% forb and 21.5% grass cover. Females selected nest sites with taller shrub and perennial grass cover than adjacent random sites. Mayfield nest success was 38%. Females with broods selected areas exhibiting 27.1% shrub canopy cover, and 21.4% forb and 14.3% grass cover. These brood-rearing areas had greater visual obstruction, shrub cover, shrub height, forb cover, and forb height than adjacent random sites. Brood success was 44%. Successful broods selected habitats with more shrub cover, less perennial grass cover, and higher total arthropod volumes than habitats used by unsuccessful broods. Females without broods used areas with greater visual obstruction, shrub height, and perennial grass cover than those used by brooding hens. Additionally, single females and males used areas with greater shrub height, forb cover, and forb height than random sites. Spring and summer mortality rates (2005 = 16.7%, 2006 = 18.9%) were lower than winter rates (2005 = 35.3%, 2006 = 21.4%). Sage-grouse moved an average of 13.1 km to summer range, 22.6 km to winter range, and 25.4 km to return to spring range. Some birds engaged in long-distance movements to summer and winter ranges in southern Idaho and eastern Nevada. Adult birds moved farther than yearlings, and males moved farther than females to reach late-summer habitat. One adult male visited 2 leks in spring 2006. Additionally, 2 adult males moved from different leks to the same location in southern Idaho in April 2006. The data collected in this study will provide the Box Elder County Adaptive Resource Management local working group (BARM) with the baseline information needed to create a sage-grouse conservation plan for the area.

(125 pages)

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CHAPTER 1

INTRODUCTION

Historical Distribution

The greater sage-grouse (*Centrocercus urophasianus*) was historically one of the most abundant and widely distributed indigenous upland game birds in the western United States (Dalke et al. 1963). Although greater sage-grouse were once found in portions of at least 12 states and 3 three Canadian provinces, populations have been diminishing in the past 25 years (Connelly et al. 2004, Schroeder et al. 2004). Regional population declines have been estimated between 17 – 47% across the sage-grouse range (Connelly and Braun 1997).

The decline in sage-grouse numbers is mainly due to settlement of western North America and the subsequent alteration of sagebrush (*Artemisia* spp.) dominated lands for agricultural purposes (Dalke et al. 1963, Braun et al. 1976, Braun 1998, Schroeder et al. 1999). The main causes of sage-grouse population declines are: 1) habitat loss due to agriculture and other developments associated with western settlement; 2) habitat fragmentation due to the construction of roads, fences, and powerlines; and 3) habitat degradation due to biological, chemical, and mechanical treatments of sagebrush (Braun 1998). These manipulations of sagebrush habitats began on a large scale in the 1930s, and the vast majority of the projects were implemented for agriculture, ranching, or urban development (Braun et al. 1976, Braun 1998). More recently, sagebrush habitats have also been threatened by the expansion of juniper (*Juniperus* spp.) woodlands and the increased risk of wildfires associated with cheatgrass (*Bromus tectorum*) invasion (Connelly et al. 2004).

Due to continued downward population trends, several organizations have petitioned the U.S. Fish and Wildlife Service to list greater sage-grouse for protection under the Endangered Species Act of 1973 (Connelly et al. 2004). In 1996, the Western Association of Fish and Wildlife Agencies (WAFWA) recommended the formation of local working groups in each state that the birds occupy (Connelly et al. 2004). One of the main goals of these working groups is to research and focus on local sage-grouse population concerns, ultimately to create a local conservation plan using an adaptive management approach. There are currently 63 sage-grouse local working groups meeting in 11 states and 2 Canadian provinces (Stiver et al. 2006).

Greater Sage-grouse Ecology

Description

The greater sage-grouse is the largest species of grouse in North America (Griner 1939, Schroeder et al. 1999). This species belongs to the order *Galliformes*, along with the turkey, partridge, quail, pheasant, and domestic chicken (Patterson 1952). Gallinaceous birds all possess a specialized stomach. This type of digestive system allows the birds to consume herbs and browse (Patterson 1952).

Adult male and female sage-grouse are distinguishable by size and coloration, unlike any other North American grouse species (Patterson 1952, Dalke et al. 1963). Females are approximately half the size of males and are cryptically colored with gray and white markings (Dalke et al. 1963, Schroeder et al. 1999). During breeding, males have a black chin, black and white bands on the throat, and stiff, white breast feathers (Dalke et al. 1963). They also possess long filoplumes that stand up on the back of the neck and 2 yellow cervical apteria that are visible on the breast during display (Schroeder et al. 1999, Connelly et al. 2004). After breeding, males molt and replace chin and throat feathers with gray feathers comparable to those of females (Dalke et al. 1963).

Sage-grouse use a lek mating system (Schroeder et al. 1999). As soon as the snow begins to clear (usually late February to early March), male sage-grouse begin to congregate on lek sites, or strutting grounds (Johnsgard 1983). They continue to visit leks for up to 3 months throughout the spring (Vehrencamp et al. 1989). Males arrive at a lek approximately 1 hour before sunrise and perform a strutting display for up to 2.5 hours after sunrise, depending on hen attendance (Jenni and Hartzler 1978). The strutting display of the male sage-grouse consists of fanning the tail and standing erect, exposing the cervical apteria (Johnsgard 1983, Schroeder et al. 1999). The male heaves his esophageal sac upward and lets it fall twice, filling the sac with air (Wiley 1978). He then contracts the muscles of his chest and compresses the inflated sac, releasing the air with a popping sound that can be heard from several kilometers (Wiley 1978, Johnsgard 1983).

Adult males are usually the first to begin visiting leks in the spring (Jenni and Hartzler 1978). Females visit leks for a much shorter period than males, approximately 3 weeks in April (Jenni and Hartzler 1978, Wiley 1978). Male attendance peaks 1 - 3 weeks after female attendance peaks, when more juvenile males attend (Dalke et al. 1960, Jenni and Hartzler 1978, Emmons and Braun 1984).

Habitat Use and Diet

Greater sage-grouse are considered sagebrush obligates because of their dependence on sagebrush throughout the year for food, breeding, and cover (Patterson 1952, Braun et al. 1976). While some populations are believed to be resident, seasonal movements have been observed in many populations (Griner 1939, Dalke et al. 1963, Dunn and Braun 1986, Connelly et al. 1988). Sage-grouse population movements can be placed into 3 categories: non-migratory (no long distance movements), 1-stage migratory (movements between 2 seasonal ranges - winter/breeding and summer), and 2-stage migratory (movements between 3 seasonal ranges - breeding, summer, and winter) (Connelly et al. 2000, Connelly et al. 2004).

Breeding Habitat. Most sage-grouse breeding occurs on or near leks, or strutting grounds (Wiley 1978, Schroeder et al. 1999). Leks are typically open, sparsely vegetated areas surrounded by prospective nesting habitat (Patterson 1952, Wakkinen et al. 1992, Connelly et al. 2000). These areas may include grassy meadows, sheep bedding grounds, plowed fields, ridges, burned areas, and roads (Patterson 1952, Dalke et al. 1963, Connelly et al. 1981).

Ideal nesting habitat consists of both vertical and horizontal vegetation diversity (Wakkinen 1990, Connelly et al. 1991, Schroeder et al. 1999). Sage-grouse hens tend to nest in areas with dense shrub cover, under the tallest shrub within a stand (Patterson 1952, Wakkinen 1990). Nesting habitat should also include an understory of tall grasses and forbs for cover and herbaceous forage (Schroeder et al. 1999, Connelly et al. 2000). Forbs are especially important to pre-laying hens because they provide calcium, phosphorus, and protein that are essential to reproductive success (Barnett and

Crawford 1994).

Brood-rearing/Summer Habitat. Early brood-rearing habitats are generally close to nest sites but may have less shrub canopy cover and more herbaceous ground cover than nest sites (Martin 1970, Wallestad 1971, Sveum et al. 1998, Lyon 2000). Insects are essential to the survival and growth of sage-grouse chicks less than 3 weeks old (Patterson 1952, Klebenow and Gray 1968, Peterson 1970, Johnson and Boyce 1990). Ants (Hymenoptera) and beetles (Coleoptera) are especially common (Griner 1939, Drut et al. 1994, Fischer et al. 1996*a*). As the chicks age, insects become less important in the diet and forbs become more significant (Johnson and Boyce 1990, Drut et al. 1994, Pyle and Crawford 1996).

As sagebrush habitats begin to dry later in the summer, greater sage-grouse tend to move to areas with more succulent vegetation (Autenrieth 1981, Connelly et al. 1988, Fischer et al. 1996*b*). They may continue to use sagebrush habitat but select for areas with greater forb availability (Connelly et al. 2004). Other late-summer habitats may include small burned areas within sagebrush habitat, wet meadows, agricultural lands, and irrigated lawns (Connelly et al. 1988, Pyle and Crawford 1996).

Fall Habitat. Greater sage-grouse use a wide variety of habitats in the fall (Connelly et al. 2000). This is mainly a transitional stage between summer and winter habitats, and movements are slow and indirect (Connelly et al. 1988). Fall habitat may include sagebrush, meadows, riparian areas, and irrigated fields (Patterson 1952, Wallestad 1971). Sage-grouse move as vegetation desiccates or as frost sets in, forming flocks (Griner 1939, Patterson 1952, Fischer et al. 1996*b*). Diets change from sagebrush, forbs, and insects to primarily sagebrush (Griner 1939, Patterson 1952).

Winter Habitat. Sagebrush is the dominant vegetation type of winter habitat range, which provides both food and shelter for sage-grouse (Patterson 1952, Dalke et al. 1963). Winter habitat selection may depend on sagebrush height and density, topography, and snow depth (Robertson 1991, Schroeder et al. 1999). Sage-grouse may move to ridge tops where the wind has kept the sagebrush relatively free of snow accumulation (Griner 1939).

Seasonal Movements

Long distance migratory movements have been documented in many sage-grouse populations when seasonal habitats are not contiguous. Fischer et al. (1996*b*) found that movements from breeding habitat to summer range are initiated when vegetal moisture content drops below 60%. These movements usually occur between early June and July (Patterson 1952, Fischer et al. 1996*b*). Males and hens without broods tend to move earlier and faster than brooding hens (Patterson 1952, Connelly et al. 1988, Fischer et al. 1996*b*). Sage-grouse movements to summer ranges have been documented between 5 and 82 km (Dalke et al. 1960, Connelly et al. 1988, Fischer et al. 1997). Hens may move an average of 0.8 km/day to reach summer range (Wallestad 1971, Connelly et al. 1988).

The timing and distance of winter movements may be influenced by annual snowfall (Patterson 1952, Dalke et al. 1960). Sage-grouse may travel between 8 and 160 km to reach wintering habitat (Patterson 1952, Dalke et al. 1960, Beck 1977, Connelly and Markham 1983, Berry and Eng 1985, Dunn and Braun 1986, Connelly et al. 1988). Connelly et al. (1988) noted that juvenile sage-grouse moved an average of 0.3 km/day, while Eng and Schladweiler (1972) observed minimum daily movements of <1.2 km in winter. Schoenberg (1982) documented 28 - 30 km movements of sage-grouse returning from winter range to breeding habitat. Male sage-grouse in Idaho were more likely to return to the same lek than females (Dalke et al. 1960).

Interlek Movements. The movements of greater sage-grouse between leks sites throughout the breeding season have been documented in many populations (Dalke et al. 1963, Wallestad and Schladweiler 1974, Emmons and Braun 1984, Bradbury et al. 1989, Schroeder and Robb 2003). Juvenile males are more likely to participate in interlek movements than adults (Dalke et al. 1963, Emmons and Braun 1984, Dunn and Braun 1985, Schroeder and Robb 2003). Adult male sage-grouse tend to visit the same lek throughout the strutting season (Schroeder and Robb 2003).

Dalke et al. (1963) documented that in Idaho, 22 - 53% of banded males were involved in interlek movements of up to 7 km. In one study in central Montana, Wallestad and Schladweiler (1974) found that although interlek movements by males were uncommon, 1 out of 15 radio-marked males was observed strutting on an adjacent lek. Emmons and Braun (1984) reported interlek movements to be common in a sage-grouse population in North Park, Colorado. All radio-marked juvenile male sage-grouse visited 2 - 4 leks throughout the breeding season, remaining on the same lek an average of 4.3 days. The average interlek movement for juveniles was 4.0 km. One juvenile was observed visiting 2 leks (4.5 km apart) in the same morning. Interlek movements of adult males were less common and were observed in 3 of 11 adult males.

Dunn and Braun (1985) found that the amount of male interlek movements on Cold Spring Mountain, Colorado, varied from year to year. No movements were observed in 1982, and in 1983, 33% and 16% of juvenile and adult males, respectively, visited 2 or more leks. The average distance of interlek movements was 10.9 km.

Bradbury et al. (1989) observed 2 marked males displaying on an early season lek and moving later in the breeding season to a more permanent lek site. Schroeder and Robb (2003) documented 44% of radio-marked juvenile males visiting more than one lek, and the average distance between visited leks was 10.6 km. They also noted that juveniles were more likely to move between leks than adults.

Population Monitoring

Greater sage-grouse population trends are typically monitored by lek counts (Connelly et al. 2003). All males present on a lek are counted, at least 3 times a season if time and weather permit, and the highest of these counts is used to estimate population trends (Jenni and Hartzler 1978, Emmons and Braun 1984, Connelly et al. 2003). Population estimates are calculated from the lek count data assuming that: 1) 75% of all males in a population are present on leks during the peak counts; 2) the female to male ratio in sage-grouse populations is 2:1; and 3) each male displays on only one lek throughout the breeding season (UDWR 2002). Lek counts may be an inaccurate means of estimating the number of birds in a breeding population due to possible changes in lek attendance patterns, variance in sex ratio, and lack of precision in counting procedures (Emmons and Braun 1984, Swenson 1986, Connelly et al. 2003).

Sage-grouse populations may also be monitored by brood surveys, hunter harvest wing surveys, and radio-telemetry studies (Connelly et al. 2003). All of these methods are useful in the assessment of sage-grouse production. Brood surveys provide information on the number of birds inhabiting an area, brood size, and chick:adult hen ratio (Connelly et al. 2003). An examination of harvested sage-grouse wings offers information on the age, gender, and female reproductive status of birds in the population Dalke et al. 1963, Connelly et al. 2003). Radio-telemetry techniques allow the collection of detailed information on nesting initiation and success, habitat use, movement patterns, and survival.

Sage-grouse population dynamics may be influenced by predation, disease, hunting, and environmental stresses, such as severe temperatures, drought, and above-average snowfall (Patterson 1952, Beck 1977, Autenreith 1981, Connelly et al. 2004). The extent to which each of these factors affects sage-grouse populations is poorly understood, and may vary among individual populations (Connelly et al. 2004).

Greater Sage-grouse in Utah

The Utah Division of Wildlife Resources (UDWR) has monitored sage-grouse since the 1950s (Beck et al. 2003). It is estimated that sage-grouse once occupied all 29 counties in Utah, but currently are found in 26 counties and inhabit 50% of their historical distribution (UDWR 2002, Beck et al. 2003). Western Box Elder County supports one of the largest greater sage-grouse populations in the state (UDWR 2002, Beck et al. 2003).

The ecology of greater sage-grouse in several Utah populations has been studied extensively. In Strawberry Valley, habitat loss and degradation, along with the introduction of red foxes (*Vulpes vulpes*) have threatened sage-grouse since the 1930s (Rasmussen and Griner 1938, Bunnell 2000). Recent habitat rehabilitation, predator control, and sage-grouse transplants have been successful in increasing population size in the area (Bunnell 2000, R. Baxter, Brigham Young University, unpublished data).

The sage-grouse population on Parker Mountain in south-central Utah is among the largest in the state, and has been monitored since 1967 (UDWR 2002, PARM 2006). The ecology of the birds in this area has been studied by radio-telemetry continuously since 1998 (Chi 2004, Dahlgren 2006, PARM 2006). The low amount of herbaceous groundcover, particularly forbs, on Parker Mountain has been identified as a possible limiting factor to the sage-grouse population (PARM 2006). A series of Dixie harrow, Lawson aerator, and tebuthiuron sagebrush treatments, along with seedings, were implemented to increase herbaceous groundcover in brood-rearing habitats (Chi 2004, Dahlgren 2006). Additionally, sage-grouse chicks have been radio-marked to monitor juvenile survival in this population (PARM 2006, D. Dahlgren, Utah State University, unpublished data).

A recent study examined greater sage-grouse ecology in two distinct areas of Utah's West Desert (Robinson 2007). These sage-grouse populations inhabit the Deep Creek and Sheeprock Watersheds of Tooele and Juab counties. Because these populations are separated by the Great Salt Lake Desert, gene flow does not occur between them, although it is believed that both populations interbreed with other nearby populations (Robinson 2007). The main factors of concern for these two populations include low juvenile recruitment, the lack of effort put into lek searches, and habitat loss due to wildfire, exotic species invasion, and agricultural alterations (Robinson 2007).

Purpose

The purpose of this project was: 1) to collect baseline data regarding greater sage-grouse ecology in western Box Elder County, including information on general habitat use, nesting initiation and success, nesting and brood-rearing habitat, survival, and seasonal movement patterns; and 2) to document interlek movements of male sage-grouse in the study area. The Box Elder County Adaptive Resource Management local working group (BARM) was organized in 2002 to address stakeholder concerns about declining sage-grouse populations in the west. The major impetus in the formation of this group was to implement a 10-year adaptive resource management plan that would focus on greater sage-grouse conservation, local economic sustainability, and restoration of sagebrush communities. To create this management plan, baseline information on sage-grouse ecology in Box Elder County was needed.

Biologists also questioned the occurrence of interlek movements in western Box Elder County. There was a local belief that males began strutting on the southernmost leks at the lowest elevations, and moved to the northern leks as the snow cleared in the spring. If some sage-grouse males do, in fact, attend more than one lek in a breeding season, the possibility exists that numerous individuals are included in the lek count data more than once, augmenting the population estimate. To ensure more accurate population estimates, more information was needed on lek attendance and interlek movements of the sage-grouse population in Box Elder County. This thesis is written in a multiple-paper format according to the unified style guidelines for *The Wildlife Society* publications (Messmer and Morrison 2006).

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CHAPTER 2

ECOLOGY OF GREATER SAGE-GROUSE IN NORTHWESTERN UTAH

Abstract: Although the greater sage-grouse population in western Box Elder County is one of the largest in the state, little is known about the ecology of the birds for management purposes. In 2005-2006, I monitored 50 radio-collared sage-grouse (21 females and 29 males) to provide this information. Vegetation at bird use sites and random locations was measured using line-intercept, Daubenmire, and visual obstruction reading techniques. Pitfall traps were used to collect arthropods at these sites. I compared vegetation parameters between bird use and random sites, successful and unsuccessful nest and brood use sites, and brooding and non-brooding female use sites. Mayfield nest success throughout the study was 38%. Nest sites exhibited greater vegetation visual obstruction, nest bush height and diameter, and perennial grass height than adjacent randomly-selected sites. Broods selected areas with greater visual obstruction, shrub cover and height, and forb cover and height than randomly chosen sites. Forty-four percent of brooding females were successful in rearing juveniles past 50 days of age. Successful broods used areas with greater shrub canopy cover and less perennial grass cover than unsuccessful broods. Successful broods used areas with greater Coleoptera, Orthoptera, and overall arthropod volume than unsuccessful broods. Single females frequented areas exhibiting greater vegetation visual obstruction, shrub height, and perennial grass cover than females with broods. Single females and males used sites with greater shrub height, and forb cover and height than random sites. Females had higher mortality rates than males in combined years. Spring and summer mortality rates were lower than winter rates. Current grazing regimes should be

maintained, while chemical and mechanical techniques should be used to reduce juniper encroachment and dense sagebrush stands. Additionally, the effects of Mormon cricket and predator control programs on the local sage-grouse population should be evaluated.

Introduction

The decline of greater sage-grouse (*Centrocercus urophasianus*) populations throughout western North America has intensified effort to learn more about the ecology of geographically isolated meta-populations for application to management. Sage-grouse population declines have been largely attributed to the settlement of western North America and the subsequent alteration of sagebrush (*Artemisia* spp.) dominated lands for agriculture and other purposes (Dalke et al. 1963, Braun et al. 1976, Braun 1998, Schroeder et al. 1999). Current threats to sagebrush habitats include the expansion of juniper (*Juniperus* spp.) woodlands and the increased risk of wildfires associated with cheatgrass (*Bromus tectorum*) invasion (Connelly et al. 2004).

Sage-grouse are largely dependent on sagebrush habitats throughout the year for food, reproduction, and cover (Patterson 1952, Braun et al. 1976). Concerns over the loss, fragmentation, and degradation of these habitats have caused several organizations to petition the U.S. Fish and Wildlife Service (USFWS) to list greater sage-grouse for protection under the Endangered Species Act of 1973 (Connelly et al. 2004). The USFWS has denied these petitions, acknowledging the role of vigorous conservation and management efforts rangewide.

In 1996, the Western Association of Fish and Wildlife Agencies (WAFWA) promoted rangewide efforts to form sage-grouse working groups to address conservation issues on the local level (Connelly et al. 2004). The main goal of these working groups was to develop conservation plans that embrace adaptive management approaches. There are currently 63 sage-grouse local working groups meeting in 11 states and 2 Canadian provinces (Stiver et al. 2006).

Greater sage-grouse in Utah are believed to have inhabited all 29 counties in the state. Populations currently occupy 26 counties and about 50% of their historical range (UDWR 2002, Beck et al. 2003). These populations are geographically isolated, inhabiting distinct physiographic areas. Little is known about these populations for management purposes. Western Box Elder County supports one of the largest greater sage-grouse populations in Utah (UDWR 2002, Beck et al. 2003).

Sage-grouse population monitoring began in western Box Elder County in 1959. The estimated population size has fluctuated since this time. The causes of these population changes were poorly understood. More consistent monitoring efforts and precise information were needed before management actions could be implemented to maintain a viable population.

The Western Box Elder County Adaptive Resource Management local working group (BARM) was established in 2002 with the intention of developing and implementing a sage-grouse conservation plan. Historical lek counts, hunter harvest surveys, and brood surveys were the only data available to the group at the time of formation. Due to the members' interest in implementing habitat improvement projects, baseline data on sage-grouse ecology were needed. The purpose of this research was to collect the baseline data to guide the development and implementation of a BARM conservation plan. This radio-telemetry study was initiated in spring 2005 to gather information on general habitat use, nesting initiation and success, nesting and brood-rearing habitat, and survival.

Study Area

The study area is in the Grouse Creek subunit of the BARM management area, in the extreme northwestern corner of Utah (Figure 2.1). It is bounded by the Idaho border on the north, Nevada border on the west, Route 30 on the south, and the Grouse Creek mountain range on the east. The area ranges from approximately 1,500 – 2,500 m in elevation and is characterized by varied topography, from sagebrush flats to steep, rocky drainages. Soils in the study area range from deep, clay loam to fine, sandy loam.

The area encompasses approximately 1,570 km^2 and exhibits a checkerboard pattern of land ownership, particularly at its southern end. Forty-seven percent of the land is privately owned, 46% is administered by the Bureau of Land Management (BLM), and 7% is owned by the Utah School and Institutional Trust Lands Administration (SITLA). The majority of the lands in the study area are managed for cattle production. Thus, grazing allotments consist of a patchwork of public and private lands.

In addition, there are several rock quarries at the northern end of the area. Quartzite, flagstone, and boulders are mined from these quarries and shipped throughout the country for building and landscaping purposes. Workers use large flatbed and dump trucks to travel frequently to and from the quarry sites throughout the summer months. The areas surrounding these quarries are also used by sage-grouse as late-summering habitat.

Climate

The average annual precipitation in the study area is 29 cm (WRCC 2007) (Table 2.1). In both 2005 and 2006, more precipitation was recorded in April than any other month. Long-term averages over 47 years indicate that precipitation was generally lowest in August and greatest in May. The spring of 2005 was especially rainy, and followed several years of below-average precipitation. Average snowfall in the study area is 95.5 cm. Total snowfall was greater in winter 2005-2006 than the previous winter. The average temperature in the study area is 7.2°C. January is typically the coldest month, while July is typically the warmest. The minimum average temperature for 2005 and 2006 is -12°C and the maximum average temperature is 32°C.

Vegetation

The vegetation type in the study area consists mainly of sagebrush shrubland intermixed with grassy meadows, juniper woodlands, and aspen stands. Common shrubs and trees include basin big sagebrush (*A. tridentata* ssp. *tridentata*), mountain big sagebrush (*A. t.* ssp. *vaseyana*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), rabbitbrush (*Chrysothamnus* spp.), serviceberry (*Amelanchier utahensis*), snowberry (*Symphoricarpos oreophilus*), bitterbrush (*Purshia tridentata*), Utah juniper (*J. osteosperma*), quaking aspen (*Populus tremuloides*), and chokecherry (*Prunus virginiana*). Common grasses include wheatgrasses (*Agropyron* spp., *Elymus* spp.), bluegrasses (*Poa* spp.), Great Basin wildrye (*Elymus cinereus*), and cheatgrass. Common forbs include blue-eyed mary (*Collinsia parviflora*), phlox (*Phlox* spp.), astragalus (*Astragalus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus* *argenteus*), western yarrow (*Achillea millefolium*), prickly pear (*Opuntia* sp.), wild onion (*Allium* spp.), fleabane (*Erigeron* spp.), and buckwheat (*Eriogonum* spp.).

The lower-elevation, southern end of the valley also supports irrigated alfalfa (*Medicago sativa*) fields used for cattle production. These fields are surrounded largely by greasewood (*Sarcobatus vermiculatus*), hopsage (*Grayia spinosa*), gray rabbitbrush (*C. nauseosus*), Wyoming big sagebrush (*A. t.* ssp. *wyomingensis*), and black sagebrush.

Wildlife

The study area exhibits a diversity of other wildlife species. Common avian species include the greater sage-grouse, red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), 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*), mourning dove (*Zenaidura macroura*), killdeer (*Charadrius vociferous*), common nighthawk (*Chordeiles minor*), and chukar (*Alectoris chukar*). Common mammalian species include the mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), coyote (*Canis latrans*), mountain lion (*Felis concolor*), bobcat (*Felis rufus*), yellow-bellied marmot (*Marmota flaviventris*), badger (*Taxidea taxus*), Columbian ground squirrel (*Spermophilus columbianus*), black-tailed jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus audubonii*), and pygmy rabbit (*Brachylagus idahoensis*).

Land Use

The primary land use in the study area is cattle grazing. Cotton Thomas Basin, property owned by the J. R. Simplot Company, and Kimbell Creek are areas that are both grazed and used heavily by sage-grouse in the summer months. Cattle are moved into these areas in May or June and remain until mid-October (Jay Tanner and Milt Omen, private landowners, personal communications). Stocking rates are approximately 1 animal/8 ha. Portions of the Simplot property are treated with 2,4-D every few years. Additionally, managers attempt to minimize cattle use of riparian areas by herding and by placing supplements in upland areas.

Mormon Cricket Control

Mormon cricket (*Anabrus simplex*) outbreaks are common in the study area in the summer months. The BLM controls these pests using 2 different methods (Ed Bianco, BLM, personal communication). Crickets are baited using 5% carbaryl at a rate of 11.3 kg/ha. Areas dense with crickets are also sprayed with Demolin at 111 mL/ha.

Sage-grouse Monitoring

The Utah Division of Wildlife Resources (UDWR) has documented greater sage-grouse lek counts in the study area since 1959 (Figure 2.2). The number of males present on leks has been counted annually over the same period of time (Figure 2.3). There are currently 35 known, active leks in the area, ranging from approximately 1,500 – 2,100 m in elevation (Figure 2.4). Sixty-three percent of the active leks are on private land, and 37% are on lands administered by the BLM.

This sage-grouse population has been hunted since the late 1950s. Hunter harvest surveys have been conducted during this time. Brood surveys were also conducted from the early 1960s to the late 1990s (UDWR 1951-2005). This project is the first radio-telemetry study that has been done in the area.

Methods

Population Status and Trends

The methods used to establish area sage-grouse population estimates followed UDWR standard protocols and those of Connelly et al. (2003). Population estimates were calculated from the lek count data assuming that: 1) 75% of all males in the population were present on leks during the peak counts; 2) the female to male ratio in the sage-grouse population was 2:1; and 2) each male displayed on only 1 lek throughout the breeding season (UDWR 2002). These population estimates were useful in comparing relative changes from year to year (Beck and Braun 1980).

Lek sites within the study area were counted once a week from the last week in March to the end of April. The lek counts were conducted using a combination of the techniques described by Patterson (1952), and Beck and Braun (1980). Lek counts were conducted beginning 0.5 hours before sunrise in reasonably good weather, light or no wind and partly cloudy to clear skies (Emmons and Braun 1984). A location was selected near the lek that allowed for good visibility of the lek but did not disturb the birds. The time that the count began was recorded, and the male birds present on the lek were counted from right to left. The observer then waited 5 - 10 minutes before counting the males from left to right; waited 5 - 10 minutes, and counted a third time from right to left. The highest number of males observed in 1 of the 3 counts was recorded. This process was repeated to obtain lek counts for a maximum of 4 lek sites per morning.

Captures

Greater sage-grouse hens and males were captured in spring 2005 and 2006. Birds were located on or near leks during the night using a spotlight and binoculars. Grouse were captured from a truck or an ATV using a long-handled net, following the techniques described by Giesen et al. (1982) and Connelly et al. (2003). In 2005, I fitted the birds with a programmed (19 hours on, 5 hours off), 16.5-g Advanced Telemetry Systems™ (Advanced Telemetry Systems, Isanti, MN, USA) radio-collar (150.000 – 151.000 MHz). In 2006, I used 19-g collars from Holohil Systems™ (Holohil Systems, Carp, Ontario, Canada) that remained on at all times (151.000 – 152.000 MHz).

I determined if each bird was a yearling or an adult based on primary feather characteristics (Dalke et al. 1963). Each bird was weighed using a cotton bag and a Pesola™ (Pesola, Zug, Baar, Switzerland) 2,500-g spring scale. At the site of each capture, I used a Garmin™ (Garmin, Olathe, KS, USA) global positioning system (GPS) unit set to Universal Transverse Mercator (UTM) NAD27 to record the location to the nearest 5 m. I handled each bird in accordance with protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University, protocol file #1194, and UDWR Certificate of Registration (COR) #2BAND6891. Radio-marked birds were located using Communications Specialists™ (Communications Specialists, Orange, CA, USA) and Telonics™ (Telonics, Mesa, AZ, USA) receivers, handheld 3-element Yagi antennas, and vehicle-mounted omni antennas.

Nesting Ecology

Hens were relocated every 2 days during the month of May in 2005 and 2006 to determine nesting status. Once I confirmed a nesting location, I marked the best viewing location with a rock cairn or other natural materials. I obtained a visual of the hen on the nest at least 3 times a week until the eggs successfully hatched, were predated, or were abandoned. I considered a nest successfully hatched if the eggshells were neatly broken and remained in the nest, or if 1 or more of the eggshells had loose membranes (Griner 1939). Predated nests were evaluated to identify potential nest predators from any eggshells, scat, tracks, or hairs remaining at the site.

Once the hen left the nesting location, I recorded a GPS location (within 5 m accuracy) along with the bush species, bush height and diameter, clutch size, slope, and aspect. I defined aspect direction (north, northeast, east, southeast, south, southwest, west, or northwest) by dividing the 360° range into increments of 45° (Chi 2004). For example, a north-facing slope would have an aspect of 338 – 22°.

Vegetation measurements were taken in 4 directions (every 90° starting with a randomly chosen direction) from the nest. I placed a 2-m Robel pole (Robel et al. 1970) in the center of the nest and extended a 15-m tape in each direction from the nest to determine vegetation visual obstruction readings (VOR). I knelt 4 m from the nest so eye-level was 1 m from the ground and recorded the height at which the pole became visible above the vegetation. If the vegetation surpassed the 2-m pole, I recorded an estimate.

Shrub canopy coverage was sampled using a modified line-intercept method along the 15-m tape (Canfield 1941). I measured the amount and height of live shrub canopy intersecting an imaginary vertical plane on the tape, counting gaps in the foliage smaller than 5 cm as continuous and excluding gaps larger than 5 cm. Total shrub canopy coverage was calculated by summing the amount of total shrub intersecting the line and dividing by the length of the line (Connelly et al. 2003).

The composition of the understory at the site was calculated by placing a 20x50 cm Daubenmire (1959) frame every 3 m along the 15-m tape. I estimated the percentage of each forb and grass species within the frame, as well as the percentage of litter, rock, and bare ground (Daubenmire 1959). I also measured the height of each forb and grass species. For each nest site, I moved 80 m along a randomly chosen compass bearing and took vegetation measurements using identical techniques to compare the habitat at chosen nesting sites to that at non-nesting sites.

Habitat Use Patterns

Broods. A female was assumed to have a brood if she successfully hatched a nest, until determined otherwise. I obtained a visual location on each female with a brood approximately 3 times a week until the juveniles were lost or until the brood was successful. Locations were obtained at different times of day to determine the full range of habitat use by each female. A brood was considered successful if at least one juvenile survived to 50 days. I did not intentionally flush females with broods until the juveniles were at least 3 weeks old to avoid brood abandonment.

At brooding female locations, I recorded a GPS location (within 5 m accuracy), slope, aspect, and the number of visible juveniles. Within 24 hours of locating the bird, I measured the vegetation using the same techniques as for the nest sites described above. At brood sites, however, I used a 10-m tape instead of a 15-m tape, and placed the

Daubenmire frame every 2.5 m along the tape. I only took these measurements if the female had or was suspected to have a brood. I also took vegetation measurements at a random location 80 m from each brood site to compare known brood-rearing habitat to randomly chosen habitat.

Single Females and Males. Females without broods and males were located once a week through mid-August. Each week through the brood-rearing season, I randomly chose single female and male habitat use sites by their collar frequencies and took vegetation measurements at these sites and correlated random sites. I used exactly the same techniques at these sites as I did at brood use sites to compare brooding female habitat use to non-brooding female habitat use.

Mortality. Collars that switched to a mortality signal were located as soon as possible. I recorded a location and inspected the remains, if any, for sign of predation. I also examined the site for clues to the cause of death, such as signs of a struggle or the mark of a predator.

Arthropod Abundance

Numerous studies have shown that arthropods, particularly insects, are an essential element of sage-grouse brood-rearing habitat (Patterson 1952, Klebenow and Gray 1968, Peterson 1970, Johnson and Boyce 1990, Drut et al. 1994*b*). To determine what insect foods are available to the juvenile sage-grouse in the study area, I used pitfall traps to collect arthropods at brood use sites through the 50-day brood-rearing period (Southwood and Henderson 2000, Connelly et al. 2003). Starting with the nest site, I placed traps at one vegetation measurement site per week for each brood that I tracked. I also collected arthropods at the correlated random site for each use site to compare abundance between brood-rearing sites and random sites.

Eight aluminum cans, 11 cm deep and 8 cm in diameter, were placed at each site. I used the vegetation measurement transects and positioned a can at the halfway point and at the end of each transect. I dug the cans into the ground until they were flush and filled them with approximately 4 cm of a 50/50 water and antifreeze solution. The cans were left open for approximately 48 hours before collection.

The arthropods were filtered from the antifreeze solution and rinsed thoroughly before being placed in vials filled with a 75% ethanol solution. Arthropods were identified to order and family, and each individual was counted. Because I collected the arthropods with antifreeze, I could not measure insect biomass accurately (Leonard 1939). Instead, water displacement was used to obtain a volume reading of the individuals in each family (Southwood and Henderson 2000).

Data Analysis

I determined nest initiation dates by assuming an incubation period of 27 days and adding 1 day for each egg in the nest (Peterson 1980, Schroeder et al. 1999). Nest success was calculated using a Mayfield estimate (Mayfield 1961) and an incubation period of 27 days. The Mayfield estimate is a calculation of nest success based on the number of days that each nest is observed before hatching or failing. Nests that were abandoned due to the observer were not included in the success calculation. Descriptive statistics were computed for nesting and brood success, habitat use, arthropod data, and mortality.

Case-control conditional logistic regression was used for the paired-point data to compare habitat characteristics (visual obstruction, shrub canopy, shrub height, forb cover, forb height, grass cover, and grass height) between sage-grouse use sites and random sites (Hosmer and Lemeshow 1989). Separate analyses were conducted for each habitat characteristic individually. To assure that the assumption of linearity in the logit was adequately met, I determined an appropriate scale for each continuous habitat characteristic following procedures recommended by Hosmer and Lemeshow (1989). I assessed habitat characteristic data on the original and log normal scales, and in certain combinations with additional terms: x with $x \ln(x)$ (Box and Tidwell 1962), x with x^2 or $\ln(x)$ with $[\ln(x)]^2$ (hereafter, the quadratic model), and x with $\ln(x)$ (hereafter, the gamma model), where x was the habitat variable.

I used standard logistic regression to compare habitat characteristics between successful and unsuccessful nest and brood sites, and between brooding and non-brooding female sites. All reported chi-square and *P*-values for conditional and standard logistic regression were based on likelihood ratio tests. Relationships were considered significant if $P \leq 0.05$. Model fit was assessed graphically and using *P*-values. Outliers were determined by plotting deviance residuals against estimated probabilities, using an influence diagnostic to indicate individual point leverage on the outcome of the model. Influential outliers were reviewed and removed from the analysis if they were found to exhibit unusual characteristics.

Data analyses were conducted using the SAS/STAT software (SAS Version 9.1, 2002-2003). The LOGISTIC procedure was used for both conditional and standard logistic regression. The MEANS procedure was used to obtain descriptive statistics.

Results

Population Status and Trends

Peak lek counts occurred from the last week of March through the second week of April in 2005, and from the last week of March through the last week of April in 2006 (UDWR, unpublished data). The timing of peak male attendance was dependent on lek elevation. Male attendance on leks <1,600 m in elevation peaked the last week of March, and attendance on leks >1,600 m in elevation peaked through April. High elevation leks peaked 1-2 weeks later in 2006 than in 2005, most likely due to higher snowpack in 2006.

Thirty-four leks were counted in the study area in 2005, and 35 leks were counted in 2006 (Figure 2.2). The highest numbers of male sage-grouse counted on leks in these years were 443 and 373, respectively (Table 2.2) (UDWR, unpublished data). These results demonstrated a steady decline from the peak count of 479 males in 2004 (Figure 2.3).

Captures

I captured and radio-marked 50 greater sage-grouse through the course of the study. Captures occurred between the hours of 2300 – 0545 in mid-March to early May of both years. Twenty-one of the captured birds were female; 16 of these were yearlings and 5 were adults. The mean weight of yearling females was 1,307 g (SE = 21.7), and the mean weight of adult females was 1,574 g (SE = 40.2). Females were captured within 0.4 – 1.6 km of the Dry Canyon Mountain, Red Bank Springs, Kimbell Creek, Ray Kimber Ranch, and Meadow Creek Pass leks (Figure 2.4). Capture locations of females ranged between 1,596 – 2,115 m in elevation.

Twenty-nine of the captured birds were male; 3 of these were yearlings and 26 were adults. Only a few males were weighed due to my weighing bags being too small for the majority of the birds. Males were captured on or within 1.4 km of the Dry Canyon Mountain, Hardister Creek, Red Bank Springs, and Badger Flat leks. Capture locations of males ranged between 1,583 – 2,144 m in elevation.

Nesting Ecology

I monitored 20 greater sage-grouse nests in 2005 and 2006. Nests were initiated from the last week of April through the second week of May. In 2005, the nest initiation rate was 83% (100% for adults, 78% for yearlings). In 2006, the nest initiation rate was 71% (89% for adults, 40% for yearlings).

Hens nested at elevations between 1,580 – 2,170 m. Nests were located on slopes up to 32°, but 80% of the nests were located on slopes <20° (Figure 2.5). Sixty percent of nesting locations were on slopes with westerly or southwesterly aspects, while other nest sites were located on northerly (15%), easterly (15%), northwesterly (5%), and southeasterly (5%) slopes (Figure 2.6). There was no evidence of habitat differences related to slope aspect. Nest sites were located 0.4 – 3.3 km ($\bar{x}$ = 1.7, SE = 0.8) from active leks.

Eleven (55%) nests were located under sagebrush, 5 (25%) under juniper trees, 2 (10%) in bunches of wildrye, 1 (5%) under rabbitbrush, and 1 (5%) under hopsage. The habitat surrounding nest sites had a mean shrub canopy cover of 22.8% (range = 6.6 – 36.5, SE = 1.9) (Figure 2.7). Heights of big sagebrush, low-growing sagebrush, and low rabbitbrush (*Chrysothamnus viscidiflorus*) are summarized in Table 2.3. Mean understory cover surrounding nest sites was 18.5% for forbs (range = 0.3 – 37.2, SE = 2.2) and 21.5% for grass (range = 8.9 – 50.6, SE = 2.4). The mean forb height was 13.1 cm (range = 0.5 – 22.5, SE = 1.1), and the mean grass height was 30 cm (range = 16.8 – 44.3, SE = 1.6).

Nesting locations had greater visual obstruction readings ($\chi^2 = 15.03$, df = 1, $P \leq 0.001$), bush height ($\chi^2 = 10.86$, df = 1, $P = 0.001$), bush diameter ($\chi^2 = 9.24$, df = 1, $P = 0.002$), and perennial grass height ($\chi^2 = 9.02$, df = 1, $P = 0.003$) than randomly chosen sites (Table 2.4). I analyzed each of these variables on the original scale.

Clutch size ranged from 2 – 10 eggs ($\bar{x} = 5.7$, SE = 1.9) (Table 2.5). The clutch size of 4 nests could not be determined due to predation. The mean clutch size of yearling nests ($\bar{x} = 5.2$, SE = 2.4) was comparable to that of adult nests ($\bar{x} = 6$, SE = 1.5). Three nests (1 yearling and 2 adult) contained a total of 4 infertile eggs.

The Mayfield estimate of total nest success throughout the study was 38%. Ten nests were predated, and 1 nest was abandoned due to the observer (Table 2.5). Adult nest success ($n = 7$, 55%) was greater than yearling nest success ($n = 2$, 19%). Nest success in 2005 ($n = 2$, 17%) was lower than in 2006 ($n = 7$, 74%). Fifty percent of the nests under sagebrush, 60% of the nests under juniper, 50% of the nests in wildrye, and the only nest under rabbitbrush were predated. There were no renesting attempts by unsuccessful hens.

One hen that was successful and 4 hens that were unsuccessful in 2005 nested again in spring 2006. The successful hen nested within 90 m of her previous nest the second year, while the unsuccessful hens nested 0.7 – 16.7 km from their previous nests. There was no evidence of habitat differences between successful nest sites and unsuccessful nest sites.

It was difficult to determine the primary predator of most nests, but I assumed both avian and mammalian predators from the eggshell remains. Some eggshells had holes punched in them, and others had bites taken out of them (Figure 2.8). Most likely nest predators included ravens, magpies, coyotes, badgers, and ground squirrels.

Habitat Use Patterns

Broods. I monitored 9 greater sage-grouse broods throughout the study. Broods used areas 1,550 – 2,400 m in elevation. Ninety-eight percent (n = 102) of brood locations were on slopes <20° (Figure 2.9), and 66% of the locations were on southwesterly, westerly, or northwesterly slopes (Figure 2.10).

The mean number of juveniles that hatched from each successful nest was 5.1 (Table 2.5), and brooding hens were observed with 1 – 6 juveniles throughout the 50-day rearing period. Broods used several types of habitats in the study area, including sagebrush stands, aspen and chokecherry stands, riparian areas, and irrigated alfalfa fields. Most of the areas where I observed frequent brood use were seasonally grazed. The mean shrub canopy cover at brood use sites was 27.1% (range = 0 – 54.2, SE = 1.2), mean forb cover was 21.4% (range = 1.4 – 55, SE = 1.1), and mean grass cover was 14.3% (range = 4.4 – 53.3, SE = 0.7) (Table 2.6).

Broods used areas with greater visual obstruction (χ^2 = 24.71, df = 2, $P \leq 0.001$), shrub cover (χ^2 = 10.55, df = 2, P = 0.005), shrub height (χ^2 = 11.49, df = 2, P = 0.003), forb cover (χ^2 = 5.15, df = 1, P = 0.02), and forb height (χ^2 = 10.57, df = 2, P = 0.005) than randomly chosen sites. I analyzed forb cover on the lognormal scale. A gamma model was used to analyze visual obstruction, shrub height, and forb height due to nonlinearity in the logit. A quadratic model was used to analyze shrub cover, also due to nonlinearity.

In addition, I removed two outlier points from the shrub cover data. These sites were directly next to a stream and had no shrubs. Although many brooding hens were found in moist habitats and riparian areas, these two points were unusual because of their close proximity to areas with dense shrub cover. These outliers had a strong influence on the outcome of the model and were therefore omitted from the analysis.

Four females (44%) were successful in rearing juveniles past 50 days of age in 2005 and 2006 (Table 2.5). Approximately 24% of the juveniles that hatched were recruited into the population. Successful broods moved 1.4 – 9.4 km ($\bar{x}$ = 4.6, SE = 3.5) from their nesting locations, and used areas 1,790 – 2,400 m in elevation. Successful broods used areas with greater shrub canopy cover ($\chi^2 = 24.1$, df = 1, $P \leq 0.001$) and less perennial grass cover ($\chi^2 = 20.95$, df = 2, $P \leq 0.001$) than unsuccessful broods. I analyzed shrub cover data on the original linear scale, and I used a gamma model on the grass cover data due to detected nonlinearity.

Arthropods in 12 orders were collected at brood use sites (Table 2.7). Fifty-six percent of the arthropod volume collected at brood sites was Orthoptera (crickets and grasshoppers), 20% was Hymenoptera (ants), and 17% was Coleoptera (beetles). There were Mormon cricket outbreaks both years of the study, and numerous sage-grouse broods (with both collared and uncollared hens) were observed in areas where crickets were abundant. On one occasion a juvenile sage-grouse was observed chasing, pecking, and eventually eating a Mormon cricket. There was no evidence of differences in insect abundance or volume between brood use and randomly chosen sites, however, successful broods used areas with greater Coleoptera ($\chi^2 = 8.29$, df = 1, $P = 0.004$), Orthoptera ($\chi^2 = 8.46$, df = 1, $P = 0.004$), and overall arthropod ($\chi^2 = 12.17$, df = 1, $P \leq 0.001$) volume than unsuccessful broods. I analyzed these variables on the lognormal scale.

Single Females and Males. Females without broods used habitat with a mean shrub canopy cover of 26.5% (range = 6 – 51.7, SE = 2.2), a mean forb cover of 22.3% (range = 5.5 – 38, SE = 1.5), and a mean grass cover of 19.7% (range = 11.6 – 35.3, SE = 1.1) (Table 2.6). Single females were found in areas with greater visual obstruction readings ($\chi^2 = 9.74$, df = 2, $P = 0.008$), shrub height ($\chi^2 = 7.24$, df = 1, $P = 0.007$), and perennial grass cover ($\chi^2 = 14.39$, df = 1, $P \leq 0.001$) than females with broods. I used a quadratic model on the log normal scale to analyze visual obstruction. I analyzed shrub height and perennial grass cover on the lognormal scale, eliminating one outlier point from the perennial grass cover data. This site had an unusually high cover of perennial grass because it was in an open, wet meadow.

While single females were usually found alone or in groups of 2 – 3, males tended to flock in large groups, sometimes of up to 30 birds. Males were located in habitat with a mean shrub canopy cover of 30% (range = 11.3 – 50.7, SE = 2.1), mean forb cover of 23.9% (range = 1.3 – 51.3, SE = 2.8), and mean grass cover of 15.8% (range = 5.7 – 36.3, SE = 1.6) (Table 2.8).

Single females and males used habitats similar to those used by brooding hens, but were also occasionally found in juniper stands. Single hens and males used areas with greater shrub height ($\chi^2 = 5.34$, df = 1, $P = 0.02$), forb cover ($\chi^2 = 4.59$, df = 1, *P* = 0.03), and forb height (χ^2 = 4.79, df = 1, *P* = 0.03) than randomly selected sites. I analyzed these habitat variables on the lognormal scale.

Mortality. I retrieved a total of 28 collars throughout the study. Five of these collars fell off of birds due to loose fastening. The deaths of 23 birds were confirmed, although in most cases it was difficult to specify the predator or other cause of death. I assumed that 8 (35%) of the confirmed deaths were caused by mammalian predators due to tooth marks on the rubber neckpiece or heads buried under sagebrush. Although this population is open to hunting in the fall season, no birds were harvested by hunters. Two hens were found dead but completely intact. These birds were swabbed and tested for disease, but the results were negative. Females had a greater mortality rate than males in combined years (Table 2.5). Spring and summer mortality rates (2005 = 16.7%, 2006 = 18.9%) were less than winter rates (2005 = 35.3%, 2006 = 21.4%).

Discussion

Population Status and Trends

It is difficult to interpret long-term sage-grouse population trends in the study area due to fluctuations in the number of leks counted each year. These fluctuations reflected the amount of time and staff effort that could be allocated to performing lek counts by the UDWR (K. Enright, UDWR, personal communication). The decline in males counted on leks between 2005 and 2006 may be a sign of increased winter mortality due to heavy snowfall in winter 2005-2006.

Nesting Ecology

The majority (60%) of the nest sites that I monitored were on westerly or southwesterly slopes. Slopes with these aspects receive afternoon sun, which would cause snow to melt faster and understory vegetation to grow more readily in the spring. Although the data I collected did not reflect any differences in habitat related to aspect, it appears that sage-grouse hens prefer westerly slopes when choosing nest sites.

Greater sage-grouse generally select nesting sites under shrubs that provide more cover (both canopy and lateral) than random sites (Wakkinen 1990, Sveum et al. 1998*b*, Lane 2005). Sage-grouse may nest under plant species other than sagebrush (Connelly et al. 1991, Gregg 1991, Sveum et al. 1998*b*, Chi 2004, Lane 2005). However, sage-grouse rarely nest under junipers.

The nesting hens monitored in this study exhibited similar preferences, although the nesting shrubs used by hens in western Box Elder County were considerably taller than those described in the sage-grouse management guidelines (Connelly et al. 2000). Many of the monitored hens nested under basin big sagebrush, which is the tallest growing subspecies of sagebrush (Winward 2004). Additionally, some hens nested in stands of juniper under trees that were >2 m tall. Connelly et al. (1991) suggested that hens nesting under sagebrush had greater success than those nesting under other species. Nest success for the hens I monitored did not differ by shrub species.

Another major factor shown to influence female nest site selection is the height of perennial grasses (Wakkinen 1990, Connelly et al. 1991, Gregg 1991, Sveum et al. 1998*b*). The combination of large shrub size and grass height also affected female nest site choice in my study area. This preference reinforces the importance of canopy cover and understory as critical components of sage-grouse nesting habitat (Wakkinen 1990, Connelly et al. 1991, Schroeder et al. 1999).

Connelly et al. (2000) recommend maintaining 15 – 25% sagebrush canopy cover, ≥10% forb cover, and ≥15% grass cover in breeding habitats. On average, the nest sites analyzed were within these guidelines. While most nest locations did not meet all of the guidelines for shrub, forb, and grass cover, all were within the guidelines for at least one of these parameters. Most nest sites were in locations with shrub canopy coverage >25%. All sites exhibited some perennial ground cover >18 cm, as recommended by Connelly et al. (2000).

Nest initiation dates in western Box Elder County were similar to most sage-grouse populations across the range (Connelly et al. 2004). Initiation rates decreased approximately 12% from 2005-2006, which may be a reflection of the greater snowpack in spring 2006. Connelly et al. (1993) noted that adult nest initiation rates were greater than yearling initiation rates. My data supported this observation.

Sage-grouse nest success rates have been calculated ranging from 14.5 – 86.1% (Trueblood 1954, Gregg et al. 1994, Schroeder et al. 1999, Connelly et al. 2004). Nest success rates in western Box Elder County were at the lower end of this range. Success in 2005 may have been so low because I was checking the nests too often (≥5 times a week) and therefore drawing in predators. In 2006, I only checked the nests 3 times a week, and had much greater success.

My calculated success rate was comparable to several studies in Oregon, Wyoming, Washington (Patterson 1952, Schroeder 1997, Coggins 1998, Holloran et al. 2005), although different methodologies were used in the calculations among studies.

Nest success in the western Box Elder County population was lower than observed in other sage-grouse populations in Utah (Rasmussen and Griner 1938, Trueblood 1954, Bunnell 2000, Chi 2004, Dahlgren 2006, Robinson 2007). My data support reports by Schroeder and Robb (2003) and Chi (2004) that indicate that nest site fidelity is stronger in successfully nesting hens than those that are unsuccessful.

Habitat Use Patterns

Connelly et al. (2000) recommended maintaining 10 – 25% sagebrush canopy cover in summer – late brood-rearing sage-grouse habitats. Mean shrub canopy cover in areas used by brooding hens, non-brooding hens, and males all exceeded this guideline. Broods in the study area used habitat with similar shrub canopy cover to studies in south-central Utah (Chi 2004) and Oregon (Drut et al. 1994*a*), and more shrub canopy cover than studies in Montana, Washington, and Wyoming (Wallestad 1971, Sveum et al. 1998*a*, Lane 2005). Shrub height at brood use sites was greater than in studies in Montana, Oregon, and Washington (Martin 1970, Drut et al. 1994*a*, Sveum et al. 1998*a*). There was more forb and grass understory coverage in western Box Elder County than in most studies (Drut et al. 1994*a*, Chi 2004, Lane 2005, Dahlgren 2006), however, forb cover was comparable to that found by Wallestad (1971) in Montana and Sveum et al. (1998*a*) in Washington.

The brooding hens I studied preferred areas with greater herbaceous ground cover, particularly forbs. My analysis predicted that brood use of an area was likely if forb cover was ≥10%. My data were consistent with studies that documented sage-grouse brood preferences for areas exhibiting greater forb cover (Klebenow 1969, Schoenberg 1982, Dunn and Braun 1986, Sveum et al. 1998*a*).

Johnson and Boyce (1990) in Wyoming reported that as the amount of insects in juvenile sage-grouse diets increased, survival increased. This observation is consistent with my findings that arthropod volume was greater at successful brood sites than unsuccessful brood sites. Peterson (1970) determined that insects in the order Orthoptera comprised the greatest percentage of animal food in juvenile sage-grouse diets, while Orthoptera provided the most insect volume in brood use sites in my study.

The average brood size that I observed in 2005 and 2006 was consistent with brood surveys conducted in the area 1963-1997 (UDWR 1951-2005). Juvenile recruitment in my study area seems low, but my calculations may not be entirely accurate because I did not radio-mark juveniles through the brood-rearing period. Therefore, if a brooding hen no longer was observed with juveniles, I had to assume that they had died. Current research in south-central Utah suggests that juvenile survival may be higher than previously recorded (D. Dahlgren, Utah State University, unpublished data). Juveniles may leave the mother hen to join another brood early in life. In my study area, numerous broods tended to use the same areas, so it would be easy and likely for juveniles to "brood-hop." It is a good possibility that juveniles that I assumed to be dead were actually recruited into the population.

Management Implications

Maintaining adequate herbaceous ground cover is crucial to the success of sage-grouse populations. Many of the areas preferred by sage-grouse in the late summer are used for cattle grazing. In these areas, the birds preferred riparian areas and wet meadows. Currently, these areas are being managed by the landowners to minimize the impacts frequently cited in the literature as being detrimental to sage-grouse. The current management regimes should be maintained.

The fact that sage-grouse hens nested under juniper trees indicates that juniper encroachment on sagebrush habitats should be addressed in the study area. The increase of juniper in these habitats may lead to reduction in water availability and herbaceous cover for wildlife and livestock (Miller et al. 1987). To restore sagebrush habitats and particularly nesting areas, BARM should consider implementing projects to remove juniper trees. Any treatments conducted to address juniper encroachment should be monitored to determine their impacts.

Dense, tall stands of basin big sagebrush may be reducing the amount of herbaceous ground cover in potential brood-rearing areas. Mechanical and chemical sagebrush treatments should be conducted to evaluate the effects on vegetation composition and sage-grouse use of these sites. If these treatment areas are managed to maintain adequate sagebrush canopy and herbaceous ground cover, they could serve as important nesting and brood-rearing habitat for sage-grouse.

Managing for adequate water availability and herbaceous ground cover will also help to maintain or increase insect quantity and diversity. This area has a history of Mormon cricket outbreaks. The typical control methods are spraying and the use of baits. The effect of spraying for Mormon crickets on sage-grouse and arthropod availability is largely unknown. If Mormon cricket outbreaks continue to occur, the effect of the control activities on overall insect abundance should be evaluated.

Nest success in my study was within the range reported in the literature. Nest success in other areas in Utah where potential avian and mammalian predators are being managed consistently exceeds 60%. This suggests that predator management may be a viable tool to address persistently low nest success. Ravens are abundant in the area, and controlling them, using poison such as DRC-1339, could be helpful in increasing nest success. Using culling techniques to decrease mammalian predator populations, such as coyotes, may help more juveniles to survive. However, prior to initiating a predator control program, BARM should consider implementing a program to measure the effect of such an effort on sage-grouse nest success and mortality.

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Table 2.1. Climate data for western Box Elder County, Utah, 2005-2006.

	2005		2006		47 year average	
	$\bar{x}$	**Range**	$\bar{x}$	**Range**	$\bar{x}$ **(SD)**	**Range**
Temperature						
°C	6.7	(-11.7 – 32.1)	8.0	(-12.2 – 33.2)	7.2	(-12.1 – 31.2)
°F	44.1	(11.0 – 89.7)	46.4	(10.0 – 91.8)	45.0 (1.5)	(10.3 – 88.1)
Precipitation						
cm	45.2		25.4		29.0	(14.7 – 45.5)
in	17.8		10.0		11.4 (2.9)	(5.8 – 17.9)
Snowfall						
cm	71.1		129.8		95.5	(5.1 – 246.4)
in	28.0		51.1		37.6 (22.8)	(2.0 – 97.0)

Table 2.2. No. males counted on leks in western Box Elder County, Utah, 2005-2006.

	Maximum no. males	
Lek	**2005**	**2006**
Dakes Pass	15	8
Tom's Cabin Creek	11	13
Kimber Ranch Spring	18	28
Badger Flat	43	35
Dairy Valley Wash	25	16
Ray Kimber Ranch	31	24
Kimbell Creek South	30[a]	6
Kimbell Creek East	30[a]	17
Kimbell Creek Saddle	30[a]	11
Kimbell Creek North	30[a]	0
Kimbell Creek Turnoff	13	11
Dry Canyon Mountain 1	11	24
Dry Canyon Mountain 2	13	4
Quaking Aspen	24	52
Meadow Creek	N/A	0
Meadow Creek Pass	17	16
Hardister Creek Lower Meadow	0	0
Hardister Creek Upper Meadow	18	30
Hardister Creek Mud Springs	0	1
Hardister Creek Ridge	1	2
Hardister Creek Saddle	31	16
Devil's Gate	17	3
Red Bank Springs 1	81[b]	3
Red Bank Springs 2	81[b]	0
Red Bank Springs 3	81[b]	1
Red Bank Springs 4	81[b]	1
Red Bank Springs 5	81[b]	37
Cotton Thomas 1	0[c]	0
Cotton Thomas 2	0[c]	0
First Creek	0[c]	0
Lynn - Cotton Thomas Divide 1	0	0
Lynn - Cotton Thomas Divide 2	12	12
Goose Creek 1	32[d]	2[d]
Goose Creek 2	32[d]	2[d]
Goose Creek - Nevada Line	0	0
Totals	443	373

[a,b,c,d] Represent combined data for a lek complex.

Table 2.3. Height (cm) of most commonly occurring shrubs at vegetation measurement sites in western Box Elder County, Utah, 2005-2006.

	Nest sites		**Brood sites**		**Single female sites**		**Male sites**	
	$\bar{x}$ **(SE)**	**Range**	$\bar{x}$ **(SE)**	**Range**	$\bar{x}$ **(SE)**	**Range**	$\bar{x}$ **(SE)**	**Range**
Big Sagebrush[a]	59.6 (16.6)	28.6 – 86.9	58.2 (15.4)	30.0 – 103.6	71.1 (19.3)	29.3 – 111.5	58.6 (15.1)	26.9 – 96.2
Low Sagebrush[b]	21.1 (7.5)	7.0 – 27.3	25.4 (8.7)	13.3 – 57.0	39.4 (12.6)	16.3 – 59.0	32.2 (9.4)	17.8 – 41.0
Low Rabbitbrush[c]	27.6 (6.3)	14.6 – 37.1	28.0 (6.9)	10.0 – 44.8	30.1 (5.2)	18.9 – 44.0	30.3 (5.9)	20.0 – 42.3

[a] Represents *Artemisia tridentata* ssp. *tridentata*, *A. t.* ssp. *vaseyana*, and *A. cana*.
[b] Represents *A. nova* and *A. arbuscula.*
[c] *Chrysothamnus viscidiflorus.*

Table 2.4. Vegetation characteristics at greater sage-grouse nests and randomly selected sites in western Box Elder County, Utah, 2005-2006.

	Nest sites		**Random sites**	
	$\bar{x}$ **(SE)**	**Range**	$\bar{x}$ **(SE)**	**Range**
Bush height (cm)	125.4 (24.5)	45.0 – 410.0	61.2 (6.4)	16.0 – 117.0
Bush diameter (cm)	164.3 (24.9)	39.0 – 455.0	86.3 (10.1)	35.0 – 214.0
VOR (cm)	112.2 (23.6)[a]	40.8 – 419.3[a]	45.6 (5.6)[a]	12.8 – 110.3[a]
Shrub canopy (%)	22.8 (1.9)	6.6 – 36.5	19.6 (2.0)	3.0 – 36.2
Shrub height (cm)	55.5 (7.0)	24.6 – 145.6	47.4 (5.8)	11.5 – 125.2
Forb cover (%)	18.5 (2.2)	0.3 – 37.2	18.0 (1.6)	5.2 – 30.6
Forb height (cm)	13.1 (1.1)	1.0 – 22.5	13.1 (0.9)	5.0 – 22.1
Perennial grass cover (%)	15.8 (1.65)	1.4 – 30.8	13.9 (1.3)	1.0 – 22.9
Perennial grass height (cm)	34.5 (1.96)	19.9 – 51.6	28.2 (2.0)	15.5 – 46.8
Annual grass cover (%)	6.3 (2.6)	0 – 49.3	6.3 (2.8)	0 – 52.5
Annual grass height (cm)	17.7 (2.1)	9.3 – 36.8	15.8 (1.8)	6.9 – 31.9

[a]Values include estimated readings due to vegetation surpassing the 2-m Robel pole.

Table 2.5. Demographics, mortality, and productivity of greater sage-grouse monitored in western Box Elder County, Utah, 2005-2006.

	2005	**2006**	**Combined Years**
	n (%)	*n* (%)	*n* (%)
Total birds monitored	24	37	50
Female	13 (54.2)	16 (43.2)	21 (42.0)
Male	11 (45.8)	21 (56.8)	29 (58.0)
Total mortality	10 (41.7)	13 (35.1)	26 (52.0)
Female	5 (38.5)	6 (37.5)	11 (52.4)
Male	5 (45.5)	7 (33.3)	12 (41.4)
Nest initiation	10 (83.3[a])	10 (71.4[a])	20 (76.9[a])
Mean clutch size (range)	5.1 (2 – 8)	6.3 (5 – 10)	5.7 (2 – 10)
Successful nests	2 (20.0)	7 (70.0)	9 (45.0)
Predated nests	7 (70.0)	3 (30.0)	10 (50.0)
Abandoned nests	1 (10.0)	0	1 (5.0)
Successful broods	2 (100)	2 (28.6)	4 (44.4)
Juveniles monitored	9	37	46
Mean juveniles/brood (range)	4.5 (4 – 5)	5.3 (3 – 8)	5.1 (3 – 8)
Juveniles recruited	5 (55.6)	6 (16.2)	11 (23.9)

[a]Values corrected for signals that could not be located during the nesting period.

Table 2.6. Vegetation characteristics at female greater sage-grouse use and randomly selected sites in western Box Elder County, Utah, 2005-2006.

	Brood sites		**Non-brood sites**		**Random sites**	
	$\bar{x}$ (SE)	**Range**	**$\bar{x}$ (SE)**	**Range**	**$\bar{x}$ (SE)**	**Range**
VOR (cm)	47.0 (2.6)[a]	6.3 – 152.8[a]	66.3 (11.7)[a]	7.5 – 280.0[a]	45.4 (3.8)[a]	0 – 272.5[a]
Shrub canopy (%)	27.1 (1.2)	0 – 54.2	26.5 (2.2)	6.0 – 51.7	25.7 (1.1)	0 – 60.5
Shrub height (cm)	43.6 (1.7)	14.1 – 115.2	55.6 (5.4)	19.2 – 149.8	42.1 (1.8)	10.8 – 117.8
Forb cover (%)	21.4 (1.1)	1.4 - 55	22.3 (1.5)	5.5 – 38.0	18.8 (0.9)	1.3 – 44.2
Forb height (cm)	13.6 (0.5)	3.5 – 41.2	14.3 (0.7)	5.7 – 20.7	13.1 (0.4)	2.0 – 35.3
Perennial grass cover (%)	13.1 (0.7)	1.3 – 53.3	17.6 (1.3)	10.4 – 35.3	14.4 (0.7)	1.9 – 52.8
Perennial grass height (cm)	35.9 (1.3)	13.1 – 85.3	35.5 (1.8)	18.9 – 51.9	35.3 (1.0)	13.5 – 72.5
Annual grass cover (%)	1.2 (0.2)	0 – 12.2	2.1 (0.7)	0 – 14.7	1.6 (0.4)	0 – 26.9
Annual grass height (cm)	15.9 (0.8)	8.5 – 32.0	24.5 (2.5)	8.1 – 43.8	17.3 (0.9)	4.0 – 33.0

[a]Values include estimated readings due to vegetation surpassing the 2-m Robel pole.

Table 2.7. Arthropods collected at greater sage-grouse brood and randomly selected sites in western Box Elder County, Utah, 2005-2006.

		Brood sites			Random sites		
Order		**$\bar{x}$ (SE)**	**Range**	**%**	**$\bar{x}$ (SE)**	**Range**	**%**
Hymenoptera	No. individuals	364.6 (99.7)	27 – 4640	80.2	265.4 (32.9)	18 – 843	73.5
	Volume (mL)	3.8 (1.5)	0.1 – 69.2	19.8	2.3 (0.4)	0.1 – 12.4	12.5
Coleoptera	No. individuals	24.1 (6.6)	0 – 309	5.3	36.9 (20.5)	1 – 955	10.2
	Volume (mL)	3.4 (0.6)	0 – 23.0	17.6	3.1 (0.6)	0.01 – 24.7	16.9
Orthoptera	No. individuals	10.2 (2.0)	0 – 63	2.2	11.3 (3.0)	0 – 106	3.1
	Volume (mL)	10.9 (3.3)	0 – 82.5	55.9	10.7 (3.7)	0 – 106.7	58.5
Lepidoptera	No. individuals	0.8 (0.1)	0 – 3	0.2	1.4 (0.4)	0 – 11	0.4
	Volume (mL)	0.3 (0.1)	0 – 6.0	1.3	1.3 (0.5)	0 – 16.3	6.9
Hemiptera	No. individuals	19.7 (5.2)	0 – 236	4.3	20.3 (6.8)	0 – 315	5.6
	Volume (mL)	0.1 (0.03)	0 – 1.1	0.7	0.1 (0.04)	0 – 1.7	0.8
Dermaptera	No. individuals	0.4 (0.3)	0 – 15	<0.001	0.02 (0.02)	0 – 1	<0.001
	Volume (mL)	0.01 (0.007)	0 – 0.3	<0.001	<0.001	0 – 0.03	<0.001
Neuroptera	No. individuals	0.02 (0.02)	0 – 1	<0.001	N/A	N/A	N/A
	Volume (mL)	<0.001	0 – 0.01	<0.001	N/A	N/A	N/A
Diptera	No. individuals	6.4 (2.3)	0 – 88	1.4	5.5 (1.9)	0 – 63	1.5
	Volume (mL)	0.4 (0.1)	0 – 5.2	1.9	0.3 (0.1)	0 – 4.4	1.9
Thysanura	No. individuals	12.9 (6.4)	0 – 298	2.8	8.5 (2.3)	0 – 75	2.3
	Volume (mL)	0.06 (0.03)	0 – 1.5	0.3	0.04 (0.009)	0 – 0.25	0.2
Araneida	No. individuals	13 (9.6)	2 – 49	2.9	10.1 (5.7)	0 – 20	2.8
	Volume (mL)	0.4 (0.3)	0.01 – 1.9	1.9	0.3 (0.3)	0 – 1.4	1.8
Solpugida	No. individuals	0.2 (0.5)	0 – 2	<0.001	0.1 (0.4)	0 – 2	<0.001
	Volume (mL)	0.02 (0.06)	0 – 0.35	<0.001	0.01 (0.05)	0 – 0.3	<0.001
Phalangida	No. individuals	2.4 (6.6)	0 – 39	0.5	1.6 (5.8)	0 – 36	0.4
	Volume (mL)	0.09 (0.3)	0 – 1.6	0.5	0.09 (0.3)	0 – 1.7	0.5

Table 2.8. Vegetation characteristics at male greater sage-grouse use sites and randomly selected sites in western Box Elder County, Utah, 2005-2006.

	Use sites		**Random sites**	
	$\bar{x}$ (SE)	**Range**	**$\bar{x}$ (SE)**	**Range**
VOR (cm)	67.2 (9.7)[a]	17.0 – 200.0[a]	51.8 (7.2)[a]	3.8 – 138.0[a]
Shrub canopy (%)	30.2 (2.0)	11.3 – 50.7	27.3 (2.5)	8.0 – 52.5
Shrub height (cm)	46.0 (2.8)	25.9 – 86.0	39.7 (3.6)	12.6 – 88.7
Forb cover (%)	23.9 (2.8)	1.3 – 51.3	21.5 (2.5)	2.4 – 51.9
Forb height (cm)	17.5 (1.2)	5.8 – 28.7	14.3 (0.9)	3.6 – 19.9
Perennial grass cover (%)	14.2 (1.3)	5.7 – 36.3	15.4 (1.5)	4.0 – 30.8
Perennial grass height (cm)	40.2 (2.3)	16.3 – 70.3	38.8 (2.2)	26.7 – 62.0
Annual grass cover (%)	1.7 (0.8)	0 – 16.1	1.3 (0.8)	0 – 14.6
Annual grass height (cm)	20.0 (2.5)	8.0 – 28.3	25.6 (1.0)	22.8 – 27.5

[a]Values include estimated readings due to vegetation surpassing the 2-m Robel pole.

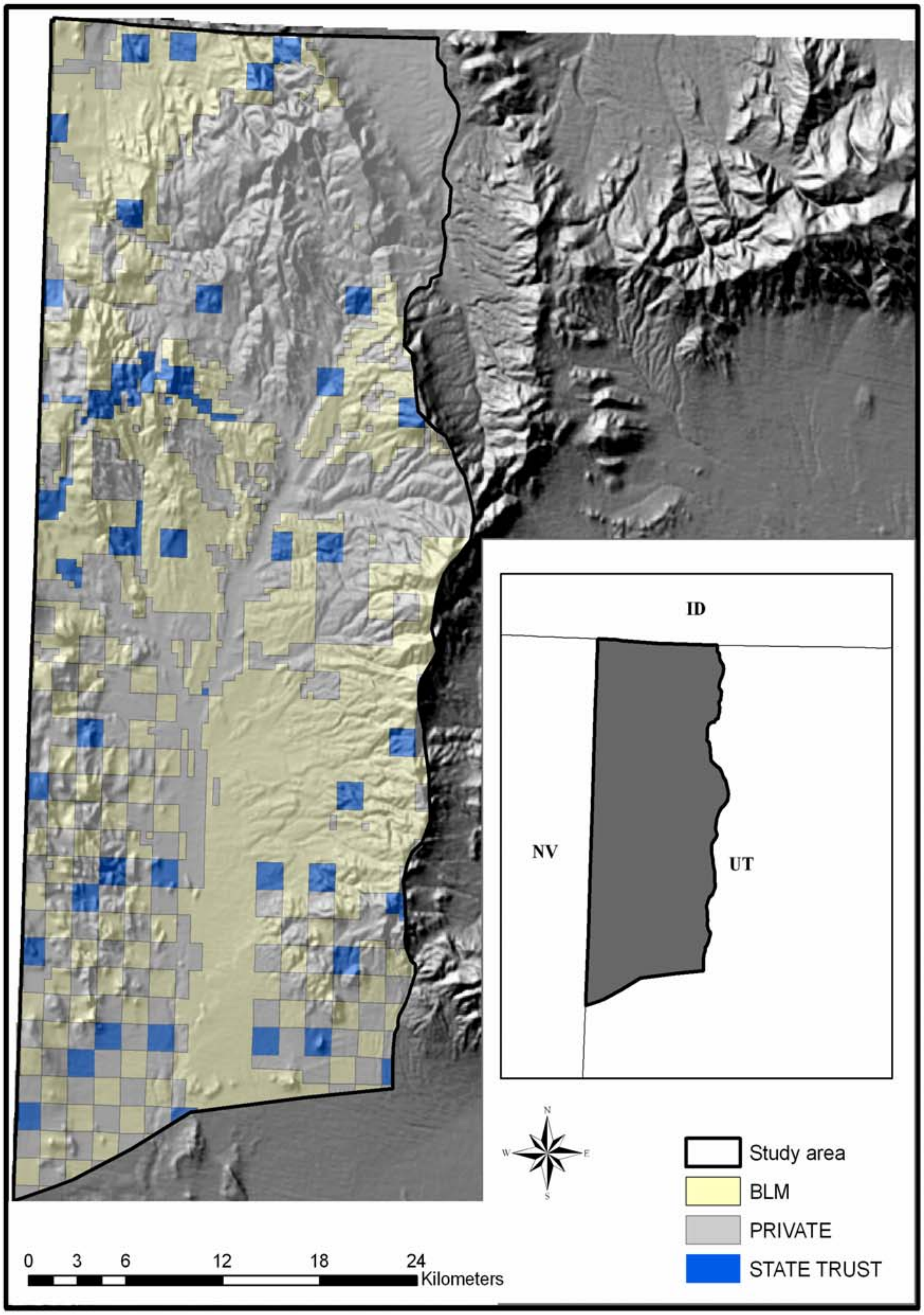

Figure 2.1. The study area in western Box Elder County, Utah.

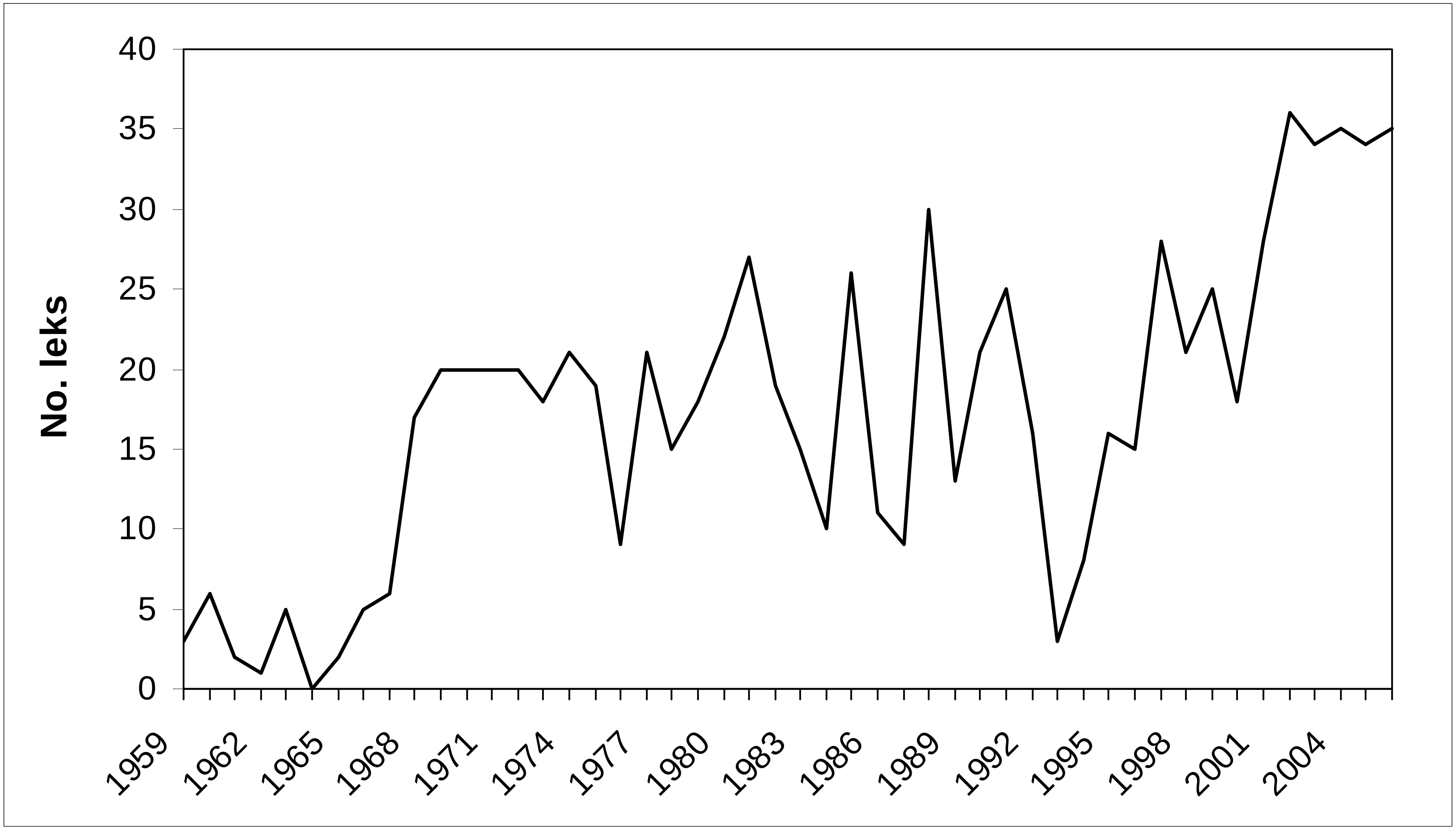

Figure 2.2. No. leks counted annually in western Box Elder County, Utah, 1959-2006.

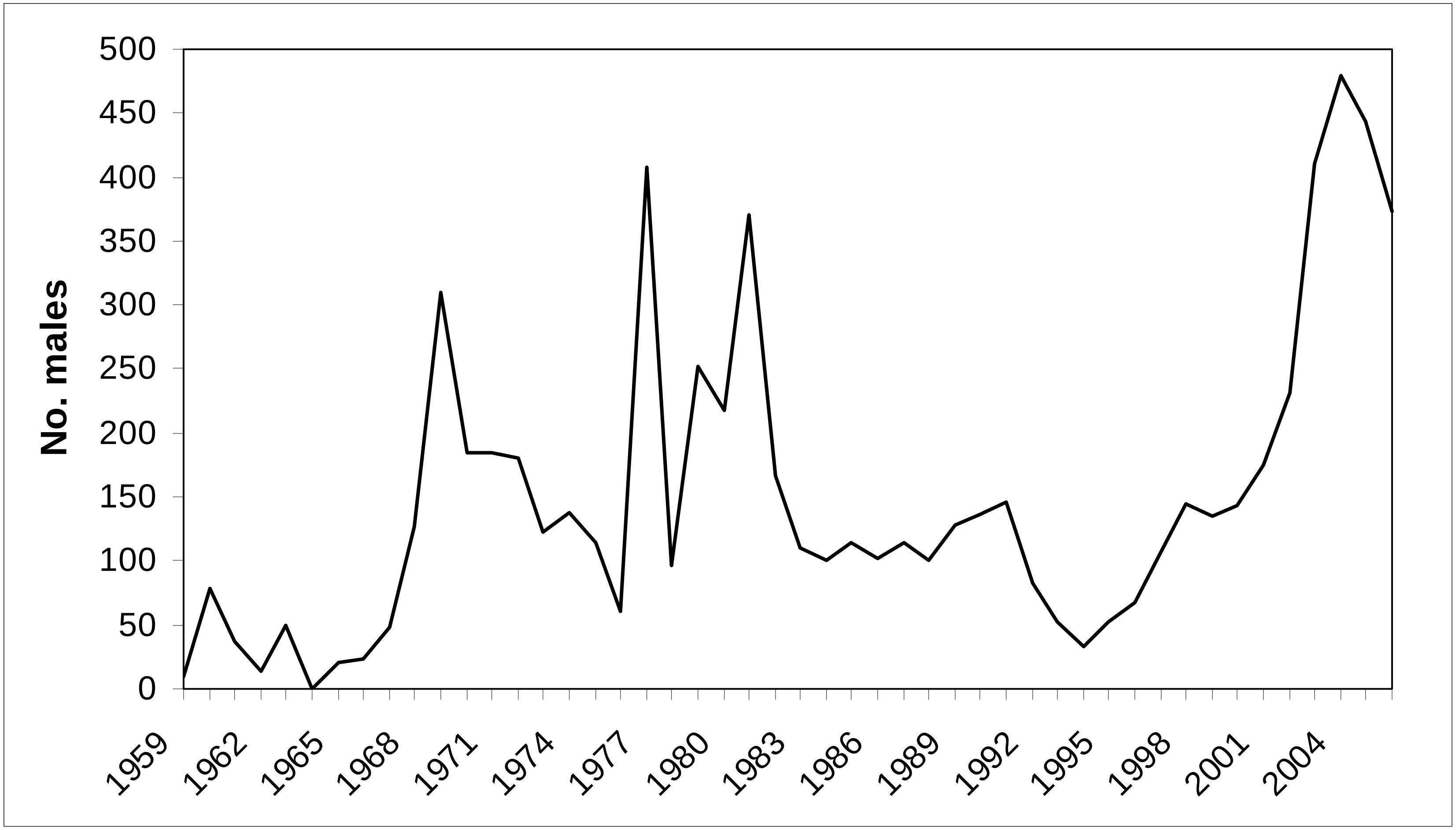

Figure 2.3. Historical lek counts in western Box Elder County, Utah, 1959-2006.

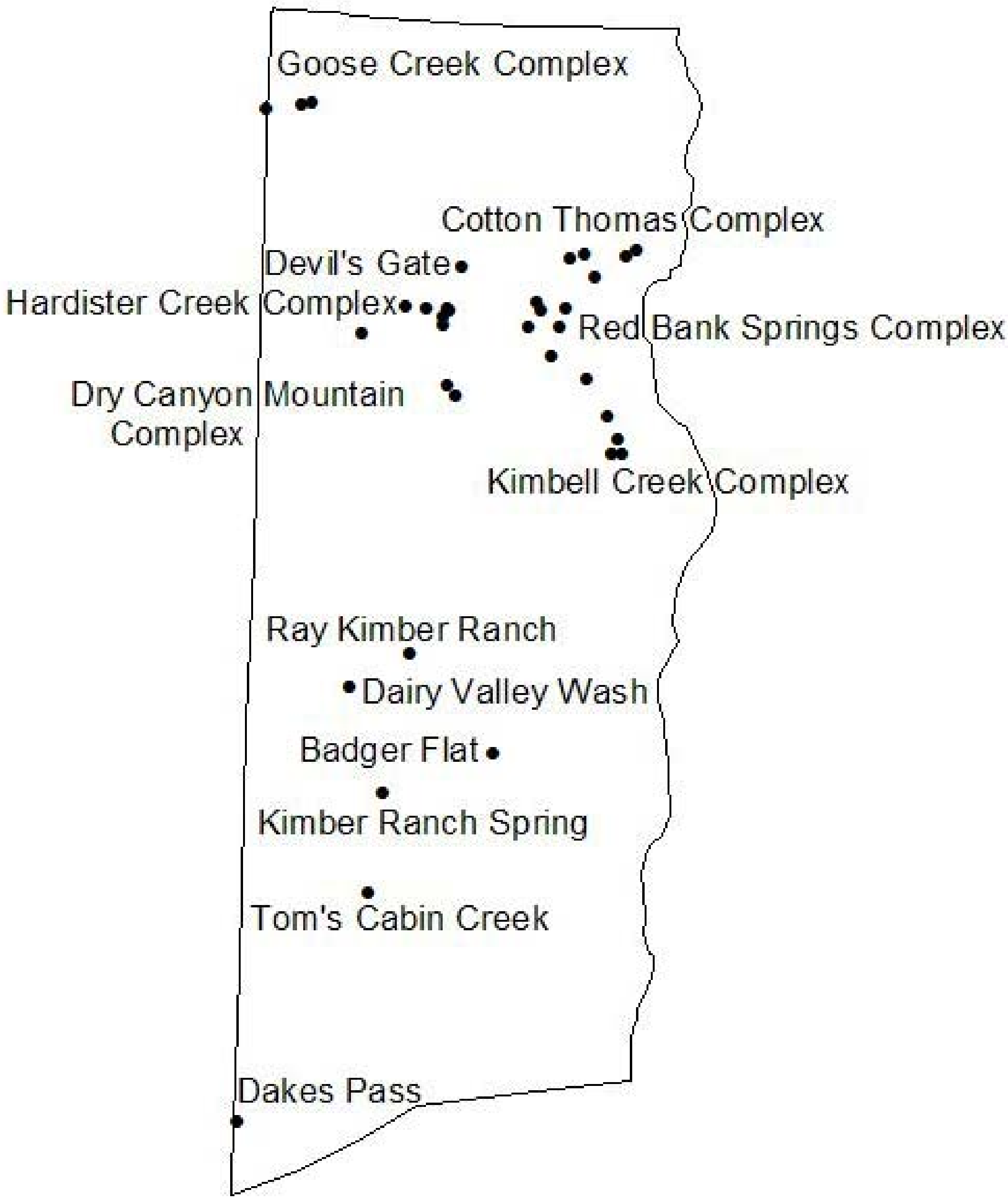

Figure 2.4. Active leks in the study area in western Box Elder County, Utah.

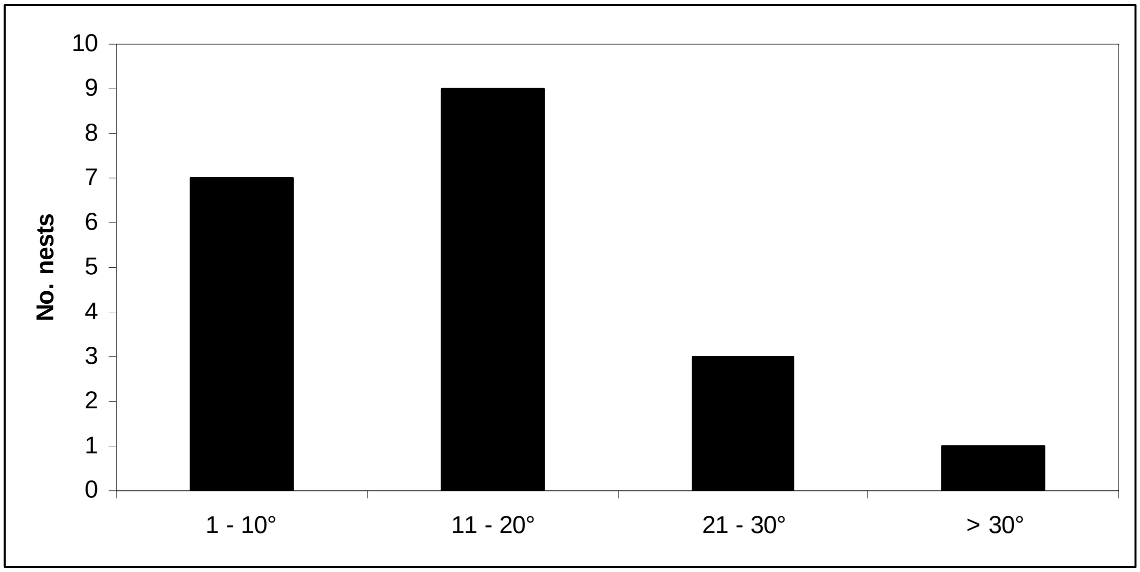

Figure 2.5. Slope measurements of greater sage-grouse nest sites in western Box Elder County, Utah, 2005-2006.

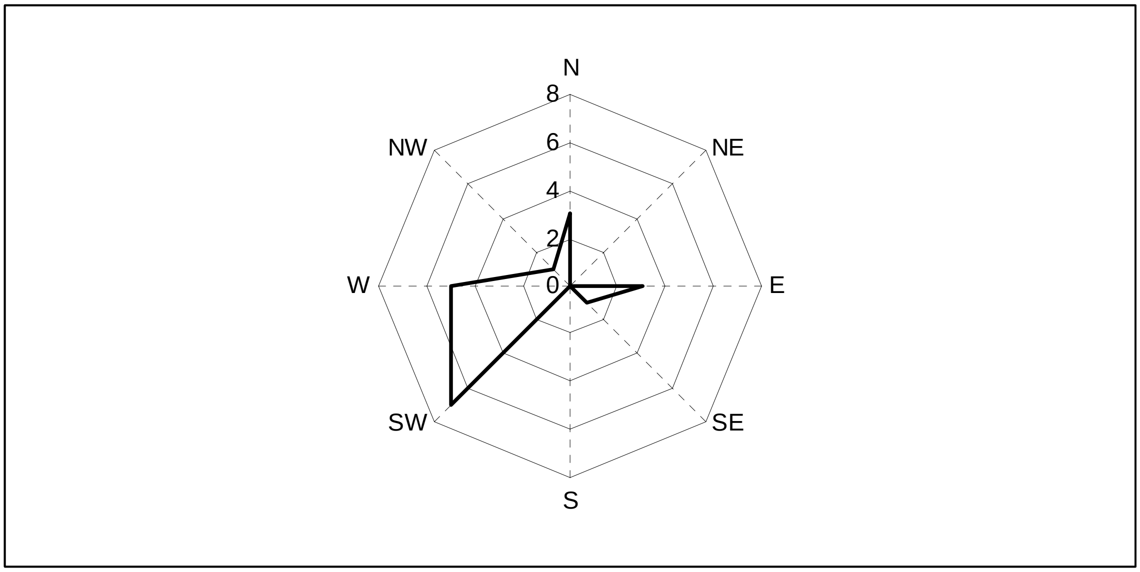

Figure 2.6. Slope aspects of greater sage-grouse nest sites in western Box Elder County, Utah, 2005-2006.

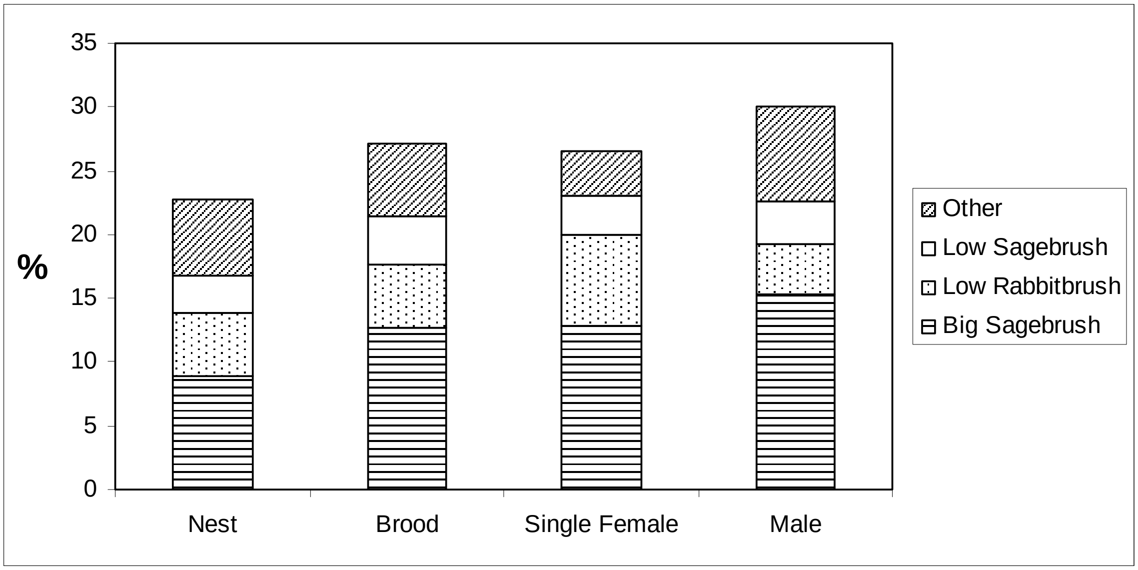

Figure 2.7. Percent shrub canopy cover of nest, brood, single female, and male use sites in western Box Elder County, Utah, 2005-2006. Big sagebrush represents *Artemisia tridentata* ssp. *tridentata*, *A. t.* ssp. *vaseyana*, and *A. cana*. Low rabbitbrush represents *Chrysothamnus viscidiflorus*. Low sagebrush represents *A. nova* and *A. arbuscula*.

Figure 2.8. Predated greater sage-grouse eggs in western Box Elder County, Utah, 2005.

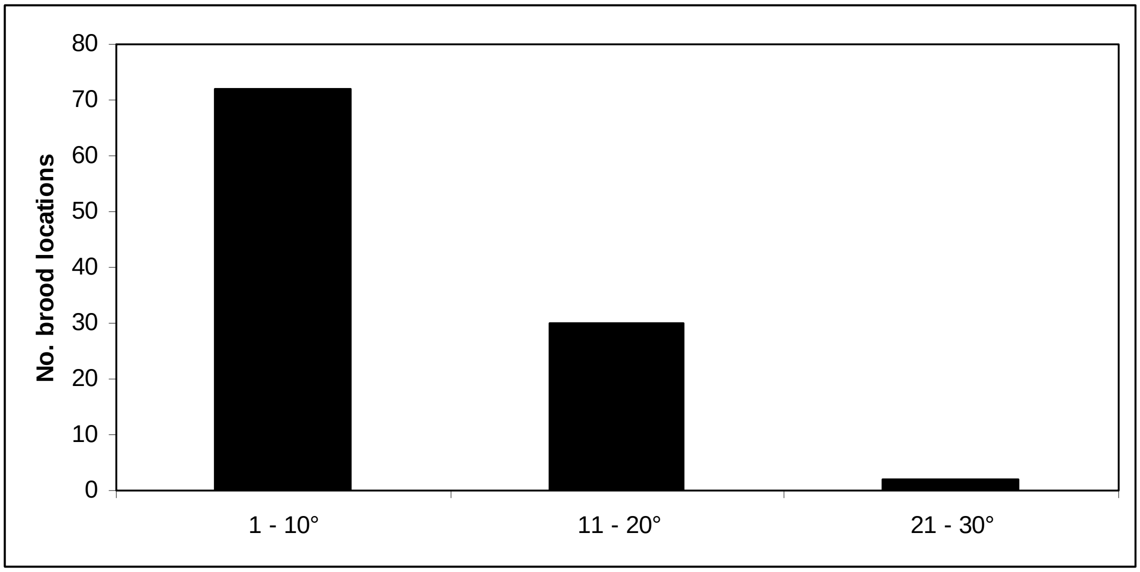

Figure 2.9. Slope measurements of greater sage-grouse brood-rearing sites in western Box Elder County, Utah, 2005-2006.

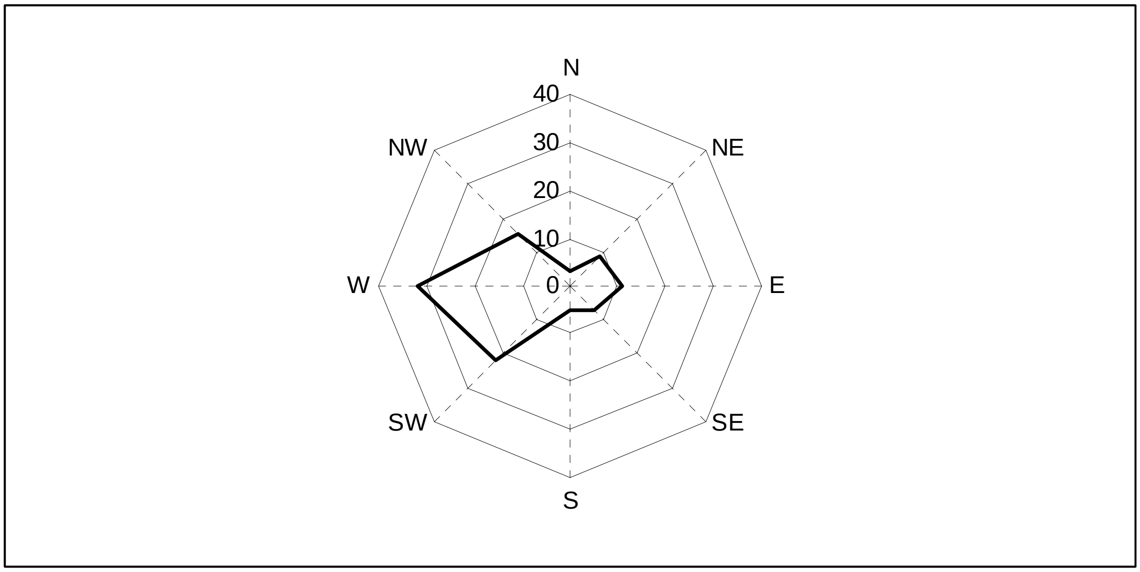

Figure 2.10. Slope aspects of greater sage-grouse brood-rearing sites in western Box Elder County, Utah, 2005-2006.

CHAPTER 3

MIGRATION PATTERNS OF GREATER SAGE-GROUSE IN NORTHWESTERN UTAH

Abstract: Little is known about geographical seasonal-use patterns of the greater sage-grouse population that inhabits northwestern Utah. To provide this information, I monitored 50 radio-collared sage-grouse in 2005 and 2006 to document their migration patterns. Eighteen males were captured on a single lek to determine the extent of interlek movements. Monitored sage-grouse migrated an average of 13.1 km (range = 0.2 – 69.3, SE = 14.4) to summer range, 22.6 km (range = 0.2 – 46.1, SE = 12.6) to winter range, and 25.4 km (range = 1.1 – 37.2, SE = 13.4) to return to spring range. Birds in this population used seasonal habitats in Idaho, Nevada, and Utah. One adult male visited 2 leks in spring 2006, moving 7.7 km from the capture lek. An additional two adult males captured on different leks in Utah traveled 53.3 and 75.6 km to the same location in Idaho during the lekking period. These birds were located 5.3 km from the nearest known lek. These observations support the need for increased coordination between Utah, Nevada, and Idaho, leading to the development of an interstate sage-grouse conservation plan. Additionally, the movements documented during the lekking season suggest that biologists should reconsider current protocols that use lek counts to estimate populations.

Introduction

Greater sage-grouse (*Centrocercus urophasianus*) are strongly dependent on sagebrush (*Artemisia* spp.) habitats throughout the year for food, breeding, and cover (Patterson 1952, Braun et al. 1976). Some populations are considered resident, however, seasonal movements have been observed in many populations (Griner 1939, Dalke et al. 1963, Dunn and Braun 1986, Connelly et al. 1988). Connelly et al. (2004) placed sage-grouse population movements into 3 categories: non-migratory (no long distance movements), 1-stage migratory (movements between 2 seasonal ranges - winter/breeding and summer), and 2-stage migratory (movements between 3 seasonal ranges - breeding, summer, and winter).

Breeding habitats typically consist of sparsely vegetated areas to serve as lekking grounds surrounded by potential nesting and early brood-rearing habitat (Patterson 1952, Wakkinen et al. 1992, Connelly et al. 2000). Nesting habitat should consist of both vertical and horizontal vegetation diversity (Wakkinen 1990, Connelly et al. 1991, Schroeder et al. 1999). It should include relatively dense shrub cover with an understory of tall grasses and forbs for cover and essential herbaceous forage (Patterson 1952, Wakkinen 1990, Schroeder et al. 1999, Connelly et al. 2000). Early brood-rearing habitat may have less shrub canopy cover and more herbaceous ground cover than nest sites (Martin 1970, Wallestad 1971, Sveum et al. 1998, Lyon 2000). Insects are a crucial component of these habitats because they are an important food source to juvenile sage-grouse less than 3 weeks old (Patterson 1952, Klebenow and Gray 1968, Peterson 1970, Johnson and Boyce 1990).

As sagebrush habitats begin to dry later in the summer, greater sage-grouse tend to move to areas with more succulent vegetation (Autenrieth 1981, Connelly et al. 1988, Fischer et al. 1996). They may continue to use sagebrush habitat but select for areas with greater forb availability (Connelly et al. 2004). Throughout the fall, sage-grouse may initiate slow, indirect movements toward wintering habitat (Connelly et al. 1988).

Sagebrush is the dominant vegetation type of winter habitat range. This shrub provides both food and shelter for sage-grouse (Patterson 1952, Dalke et al. 1963). Griner (1939) and Robertson (1991) reported that sage-grouse in Utah selected areas with dense, tall sagebrush or low snow accumulation as wintering sites.

Long distance migratory movements have been documented in many sage-grouse populations when seasonal habitats are not contiguous. Fischer et al. (1996) found that movements from breeding habitat to summer range are initiated when vegetal moisture content drops below 60%. These movements usually occur between early June and July (Patterson 1952, Fischer et al. 1996). Males and hens without broods tend to move earlier and faster than brooding hens (Patterson 1952, Connelly et al. 1988, Fischer et al. 1996). Sage-grouse movements to summer ranges have been documented between 5 and 82 km (Dalke et al. 1960, Connelly et al. 1988, Fischer et al. 1997). Hens may move an average of 0.8 km/day to reach summer range (Wallestad 1971, Connelly et al. 1988).

The timing and distance of winter movements may be influenced by annual snowfall (Patterson 1952, Dalke et al. 1960). Sage-grouse may travel between 8 and 160 km to reach wintering habitat (Patterson 1952, Dalke et al. 1960, Beck 1977, Connelly and Markham 1983, Berry and Eng 1985, Dunn and Braun 1986, Connelly et al. 1988). Connelly et al. (1988) noted that yearling sage-grouse moved an average of 0.3 km/day, while Eng and Schladweiler (1972) observed minimum daily movements of <1.2 km in winter. Schoenberg (1982) documented 28 - 30 km movements of sage-grouse returning from winter range to breeding habitat. Male sage-grouse in Idaho were more likely to return to the same lek than females (Dalke et al. 1960).

In addition to long distance seasonal movements, interlek movements have been observed in several sage-grouse populations. Dalke et al. (1963) documented that in Idaho, 22 - 53% of banded males were involved in interlek movements of up to 7 km. In one study in central Montana, Wallestad and Schladweiler (1974) found that although interlek movements by males were uncommon, 1 out of 15 radio-marked males was observed strutting on an adjacent lek. Emmons and Braun (1984) reported interlek movements to be common in a sage-grouse population in North Park, Colorado. All radio-marked yearling male sage-grouse visited 2 - 4 leks throughout the breeding season, remaining on the same lek an average of 4.3 days. The average interlek movement for yearlings was 4.0 km. One yearling was observed visiting 2 leks (4.5 km apart) in the same morning. Interlek movements of adult males were less common and were observed in 3 of 11 adult males.

Dunn and Braun (1985) found that the amount of male interlek movements on Cold Spring Mountain, Colorado, varied from year to year. No movements were observed in 1982, and in 1983, 33% and 16% of yearling and adult males, respectively, visited 2 or more leks. The distance of interlek movements ranged from 7.5 – 13.1 km. Bradbury et al. (1989) observed 2 marked males displaying on an early season lek and moving later in the breeding season to a more permanent lek site. In a Wyoming study, 2 (1 yearling and 1 adult) of 10 collared birds were observed on 2 or more leks (Rothenmaier 1979). Schroeder and Robb (2003) documented 44% of radio-marked yearling males visiting more than one lek, and the average distance between visited leks was 10.6 km. They also noted that yearlings were more likely to move between leks than adults.

This project was the first radio-telemetry study conducted on greater sage-grouse in northwestern Utah. Until this point, little was known about the seasonal movements and habitat use of this sage-grouse population. Biologists were concerned that interlek movements in the area may be biasing population estimates. There was a local belief that males began strutting on the southernmost leks at the lowest elevations, and moved to the northern, higher-elevation leks as the snow cleared in the spring. If some sage-grouse males do, in fact, attend more than one lek in a breeding season, the possibility exists that numerous individuals could be included in the lek count data more than once.

The information gathered in this study will aid the Utah Division of Wildlife Resources (UDWR) in sage-grouse monitoring efforts into the future. It will also be used by the Western Box Elder County Adaptive Resource Management local working group (BARM) as they continue to develop and implement a local sage-grouse conservation plan.

Study Area

The study area is in the Grouse Creek subunit of the BARM management area, in the extreme northwestern corner of Utah (Figure 3.1). It is bounded by the Idaho border on the north, Nevada border on the west, Route 30 on the south, and the Grouse Creek mountain range on the east. The area ranges from approximately 1,500 – 2,500 m in elevation and is characterized by varied topography, from sagebrush flats to steep, rocky drainages. Soils in the study area range from deep, clay loam to fine, sandy loam.

The area encompasses approximately 1,570 km^2 and exhibits a checkerboard pattern of land ownership, particularly at its southern end. Forty-seven percent of the land is privately owned, 46% is administered by the Bureau of Land Management (BLM), and 7% is owned by the Utah School and Institutional Trust Lands Administration (SITLA). The majority of the lands in the study area are managed for cattle production. Thus, grazing allotments consist of a patchwork of public and private lands.

In addition, there are several rock quarries at the northern end of the area. Quartzite, flagstone, and boulders are mined from these quarries and shipped throughout the country for building and landscaping purposes. Workers use large flatbed and dump trucks to travel frequently to and from the quarry sites throughout the summer months. The areas surrounding these quarries are also used by sage-grouse as late-summering habitat.

Climate

The average annual precipitation in the study area is 29 cm (WRCC 2007) (Table 3.1). In both 2005 and 2006, more precipitation was recorded in April than any other month. Long-term averages over 47 years indicate that precipitation was generally lowest in August and greatest in May. The spring of 2005 was especially rainy, and followed several years of below-average precipitation. Average snowfall in the study area is 95.5 cm. Total snowfall was greater in winter 2005-2006 than the previous winter. The average temperature in the study area is 7.2°C. January is typically the coldest month, while July is typically the warmest. The minimum average temperature for 2005 and 2006 is -12°C and the maximum average temperature is 32°C.

Vegetation

The vegetation type in the study area consists mainly of sagebrush shrubland intermixed with grassy meadows, juniper woodlands, and aspen stands. Common shrubs and trees include basin big sagebrush (*A. tridentata* ssp. *tridentata*), mountain big sagebrush (*A. t.* ssp. *vaseyana*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), rabbitbrush (*Chrysothamnus* spp.), serviceberry (*Amelanchier utahensis*), snowberry (*Symphoricarpos oreophilus*), bitterbrush (*Purshia tridentata*), Utah juniper (*Juniperus osteosperma*), quaking aspen (*Populus tremuloides*), and chokecherry (*Prunus virginiana*). Common grasses include wheatgrasses (*Agropyron* spp., *Elymus* spp.), bluegrasses (*Poa* spp.), cheatgrass (*Bromus tectorum*), and Great Basin wildrye (*Elymus cinereus*). Common forbs include blue-eyed mary (*Collinsia parviflora*), phlox (*Phlox* spp.), astragalus (*Astragalus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus argenteus*), western yarrow (*Achillea millefolium*), prickly pear (*Opuntia* sp.), wild onion (*Allium* spp.), fleabane (*Erigeron* spp.), and buckwheat (*Eriogonum* spp.).

The lower-elevation, southern end of the valley also supports irrigated alfalfa (*Medicago sativa*) fields used for cattle production. These fields are surrounded largely by greasewood (*Sarcobatus vermiculatus*), hopsage (*Grayia spinosa*), gray rabbitbrush (*C. nauseosus*), Wyoming big sagebrush (*A. t.* ssp. *wyomingensis*), and black sagebrush.

Wildlife

The study area exhibits a diversity of other wildlife species. Common avian species include the greater sage-grouse, red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), 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*), mourning dove (*Zenaidura macroura*), killdeer (*Charadrius vociferous*), common nighthawk (*Chordeiles minor*), and chukar (*Alectoris chukar*). Common mammalian species include the mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), coyote (*Canis latrans*), mountain lion (*Felis concolor*), bobcat (*Felis rufus*), yellow-bellied marmot (*Marmota flaviventris*), badger (*Taxidea taxus*), Columbian ground squirrel (*Spermophilus columbianus*), black-tailed jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus audubonii*), and pygmy rabbit (*Brachylagus idahoensis*).

Land Use

The primary land use in the study area is cattle grazing. Cotton Thomas Basin, property owned by the J. R. Simplot Company, and Kimbell Creek are areas that are both grazed and used heavily by sage-grouse in the summer months. Cattle are moved into these areas in May or June and remain until mid-October (Jay Tanner and Milt Omen, private landowners, personal communications). Stocking rates are approximately 1 animal/8 ha. Portions of the Simplot property are treated with 2,4-D every few years to reduce sagebrush canopy. Additionally, managers limit cattle use of riparian areas by herding and by placing supplements in upland areas.

Sage-grouse Monitoring

The UDWR has been conducting greater sage-grouse lek counts in the study area since 1959. There are currently 35 known, active leks in the area, ranging from approximately 1,500 – 2,100 m in elevation (Figure 3.2). Sixty-three percent of the active leks are on private land, and 37% are on lands administered by the BLM.

This sage-grouse population has been hunted since the late 1950s. Hunter harvest surveys have been conducted during this time. Brood surveys were also conducted from the early 1960s to the late 1990s (UDWR 1951-2005). This project is the first radio-telemetry study that has been done in the area.

Methods

Seasonal Movements

In the spring of 2005 and 2006, greater sage-grouse hens (n = 21) and males (n = 29) were captured near leks and fitted with radio-collars. Birds were located on or near leks during the night using a spotlight and binoculars. Grouse were captured by study personnel riding in the back of pick-up trucks or on ATVs and using a long-handled net (Giesen et al. 1982, Connelly et al. 2003). In 2005, captured birds were fitted with a programmed (19 hours on, 5 hours off), 16.5-g ATS™ (Advanced Telemetry Systems, Isanti, MN, USA) radio-collar (150.000 – 151.000 MHz). In 2006, I used 19-g collars (Holohil Systems, Carp, Ontario, Canada) that remained on at all times (151.000 – 152.000 MHz).

The age of each bird (yearling or adult) was determined based on primary feather characteristics (Dalke et al. 1963). Each bird was weighed using a cotton bag and a Pesola™ (Pesola, Zug, Baar, Switzerland) 2,500-g spring scale. A Garmin™ (Garmin, Olathe, KS, USA) Global Positioning System (GPS) unit set to Universal Transverse Mercator (UTM) NAD27 was used to record the location to the nearest 5 m. Birds were handled in accordance with protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University, protocol file #1194, and with a UDWR Certificate of Registration (COR) #2BAND6891.

Radio-marked birds were relocated using Communications Specialists™ (Communications Specialists, Orange, CA, USA) and Telonics™ (Telonics, Mesa, AZ, USA) receivers, handheld 3-element Yagi antennas, and vehicle-mounted omni antennas. Visual locations on females that were nesting or rearing broods were acquired approximately 3 times a week, and non-brooding females and males once a week between April and September. Non-brooding females, males, and brooding females with juveniles older than 3 weeks were flushed to determine flock size or brood size. Sage-grouse wintering areas were determined from a fixed-wing aircraft by flying at least 3 times between December and April.

Collars that switched to a mortality signal were located as soon as possible. For each mortality, the location was recorded and remains, if any, were inspected to determine signs of predation. The surrounding site and collars were also examined for clues to the cause of death, such as signs of a struggle, tooth marks, or predator scat and tracks.

Interlek Movements

To conduct this study, 18 male sage-grouse were captured and radio-collared on the Badger Flat lek, one of the southernmost low-elevation leks in the study area, in the last 2 weeks of March after strutting had commenced. The number of males attending these leks was counted 3 times and the highest number recorded (Jenni and Hartzler 1978). Counts were conducted approximately one half-hour before sunrise at least 3 days a week in reasonably good weather, light or no wind and partly cloudy to clear skies (Emmons and Braun 1984).

All radio-marked males on the lek were located and monitored each day the lek was visited. This monitoring was done far enough away from the lek to avoid disturbing the birds yet to allow acquisition of at least 2 directional signals to determine if each bird was present on the lek. The Badger Flat lek is not a typical, sparsely-vegetated strutting ground. It is characterized by black sagebrush and tall perennial grasses such as crested wheatgrass (*Agropyron desertorum*), so it was nearly impossible to obtain a visual of the radio-collared males, even using binoculars.

If a male was determined to not be on the Badger Flat lek, I searched the nearest known leks to document any interlek movements. In addition, flights in a fixed-wing aircraft were conducted in the last week of April to locate birds whose signals were lost. The Badger Flat lek was counted and radio-marked males monitored until lek attendance ended.

Data Analysis

Summer movements were defined between breeding areas and summer habitat from April to September. Winter movements were defined as travel from summer to wintering habitat between October and February. Spring movements were defined between wintering areas and breeding areas in March and April. Geographic Information System (ArcView GIS 3.3) software was used to analyze movement data. Movement distance was calculated as a minimum, straight-line distance between 2 locations. I used a one-way analysis of variance to determine differences between the seasonal movements of females and males, yearlings and adults, and brooding females and non-brooding females. Residuals were assessed for normality and homogeneity of variances using graphical methods. Square root transformations of the distance data were used to meet the assumptions of the analysis where needed. I used descriptive statistics to summarize movement patterns and interlek movements.

Data analyses were conducted using the SAS/STAT software (SAS Version 9.1, 2002-2003). The GLM procedure was used for ANOVA. The MEANS procedure was used to obtain descriptive statistics.

Results

Seasonal Movements

Captures. A total of 50 greater sage-grouse were captured and radio-marked through the course of the study. Captures occurred between the hours of 2300 – 0545 in mid-March to early May of both years. Twenty-one of the captured birds were female; 16 of these were yearlings and 5 were adults. The mean weight of yearling females was 1,307 g (SE = 21.7), and the mean weight of adult females was 1,574 g (SE = 40.2). Females were captured on the Dry Canyon Mountain, Red Bank Springs, Kimbell Creek, Ray Kimber Ranch, and Meadow Creek leks. Capture locations of females ranged between 1,596 – 2,115 m in elevation.

Twenty-nine of the captured birds were male; 3 of these were yearlings and 26 were adults. Only a few males were weighed due to the weighing bags being too small for the majority of the birds. Males were captured on the Dry Canyon Mountain, Devil's Gate, Red Bank Springs, and Badger Flat leks. Capture locations of males ranged between 1,583 – 2,144 m in elevation.

Summer Movements. I tracked 47 greater sage-grouse summer movements in 2005 and 2006 (Figure 3.3). Movements of radio-collared birds ranged from 0.2 – 69.3 km, with a mean distance of 13.1 km (SE = 14.4) (Table 3.2). Adult sage-grouse traveled a greater distance than yearling birds throughout the summers of this study ($F_{1,45} = 9.47$, MSE = 2.84, $P = 0.004$). Male sage-grouse moved farther than females ($F_{1,45} = 16.67$, MSE = 2.51, $P \leq 0.001$). I used a square root transformation on these distance data to meet the assumptions of the analysis of variance. Movement distances for yearling and adult females were not shown to differ. I did not have enough data on yearling males to make this comparison with adult males.

The birds that used the Badger Flat lek in spring 2006 tended to move north into the Grouse Creek Mountains throughout the summer. Seven males were located in the Kimbell Creek area in August, traveling a mean distance of 22.3 km. Three males moved 11.6 km into the alfalfa fields in Grouse Creek, while another male moved 6.6 km to use agricultural areas south of the town. One male traveled 21 km northwest from Badger Flat into eastern Nevada, where his collar was found on mortality. A female originally captured in Dry Canyon visited the Badger Flat lek in the second spring that I tracked her. After visiting the lek and nesting nearby, her nest was predated and she traveled 18.9 km north to return to Dry Canyon.

Two females captured on a ridgeline overlooking the Ray Kimber Ranch lek moved 0.9 and 1.9 km off the ridge into the surrounding alfalfa fields. Birds collared on the Dry Canyon Mountain leks tended to remain within 1 – 3 km of their capture locations, sometimes crossing Goose Creek Road. One female trapped here traveled up to 12.7 km northeast into Cotton Thomas Basin in both summers of the study. Two females, one with a brood, moved 9.4 and 15.3 km north from Dry Canyon onto lands owned by Simplot, surrounding the Twin Peaks. These females were captured within 50 m of each other.

The only bird, a male, captured on the Devil's Gate lek moved onto Simplot property (up to 14.3 km) both summers that I tracked him. Birds trapped in Kimbell Creek stayed within 2.5 km of their trapping locations. Two birds captured near Red Bank Springs leks crossed the road soon after being collared to reside in Kimbell Creek.

Sage-grouse captured in the Red Bank Springs lekking complex scattered throughout the summer. Three females stayed in this area until the end of August. The second summer I tracked her, one of these females traveled 26.5 km into southern Idaho after losing her brood. Three birds (2 females and 1 male) moved a mean distance of 7 km north into Cotton Thomas Basin. Three males moved northwest 12.8 – 17.4 km onto Simplot property. One male traveled 8.6 km west into the Meadow Creek area.

The most extensive summer movements came from 3 birds (1 female and 2 males) that had moved north into the Jim Sage Mountains of Idaho in the spring. The female traveled 48.9 km in May and June to return to her original capture location in Dry Canyon. One male moved 54.3 km south from Idaho to a drainage near to his trapping location in Red Bank Springs, where his collar was found on mortality. The second male traveled 69.3 km southwest from Idaho into eastern Nevada between May and August.

Successfully brooding females moved a maximum distance of 1.4 – 9.8 km from their nest sites during the 50 days of brood-rearing. The mean elevation gain of these movements was 270 m (SE = 59.7). Movement distances of brooding and non-brooding females were not shown to differ.

Winter Movements. I tracked 30 greater sage-grouse movements from summer habitat to wintering areas (Figure 3.4). Winter movements ranged from 0.2 – 46.1 km, with a mean distance of 22.6 km (SE = 12.6). Movement distances of yearlings and adults, males and females, or yearling females and adult females were not shown to differ. I did not collect enough data on yearling males to make a comparison with adult males.

One female that summered in the alfalfa fields south of Grouse Creek did not move from the area to winter. The area surrounding the Badger Flat lek provided wintering habitat to a large number of birds. All located birds captured on this lek returned to the area to winter, traveling 8 – 24.6 km from the alfalfa fields in Grouse Creek, Kimbell Creek, and eastern Nevada. In addition, 2 females that summered south of Grouse Creek and in Dry Canyon moved 3.7 and 20 km to winter in this area.

Three females traveled a mean distance of 34.4 km (SE = 3.0) from Cotton Thomas Basin and Kimbell Creek into the sagebrush flats south of Etna. One female and 1 male moved southwest from Simplot property to the mountains just west of Dry Canyon Mountain, traveling 17.4 and 21 km, respectively. Another male followed the same path, but continued into eastern Nevada, moving a total of 44 km.

Two females wintered in the Red Bank Springs area, traveling southeast 2.7 and 24 km to reach this destination. Two females and 1 male moved 19.6 – 27.8 km from Kimbell Creek, Red Bank Springs, and Dry Canyon to winter in Dry Basin, crossing the Grouse Creek Mountains. One female and 1 male traveled 42.1 – 46.1 km into the Jim Sage Mountains of Idaho over the course of 2 winters.

Spring Movements. I tracked the movements of 6 female and 3 male sage-grouse returning from their wintering locations to breeding areas in spring 2006 (Figure 3.5). All of these birds, with the exception of 1 female, returned to the lekking areas where they were captured. One yearling female that was captured on the Dry Canyon Mountain lek complex wintered near the Badger Flat lek, then visited this lek in the spring and stayed in the area to nest. Another female traveled 45.9 km from her wintering location in southern Idaho back to the area of her capture. Two weeks later, she had moved 47.9 km north, returning to Idaho.

Spring movements ranged from 1.1 – 45.9 km, with a mean distance of 25.4 km (SE = 13.4). Spring movements of yearlings and adults, or males and females were not shown to differ. I had too few data to make comparisons between yearling and adult females, and I had no spring movement data on yearling males.

Interlek Movements

Eighteen male sage-grouse (3 yearlings and 15 adults) were captured and radio-collared on the Badger Flat lek between 23 March and 30 March 2006. Captures occurred between the hours of 2300 – 0207. Elevations of capture locations ranged from 1,583 – 1,617 m. The peak lek count was 35 males and was taken in the last week of March (UDWR, unpublished data). The males on the lek began to disperse by 5 May, and strutting had completely stopped by 19 May.

The collars fell off of 1 yearling and 1 adult bird during the course of this study due to failed crimps. Thirteen (81.3%) of the remaining radio-collared males were located on the lek or in the vicinity of the lek each morning that the area was monitored.

I could not obtain a signal on 1 yearling male for the first week of April, and could not locate him on any of the adjacent leks. By the next week, he had returned to Badger Flat.

One adult male was triangulated onto the Ray Kimber Ranch lek on the morning of 25 March (Figure 3.6). This lek is located 7.7 km northwest of Badger Flat. One week later the bird had returned to Badger Flat and remained there for the rest of spring.

Another adult male left Badger Flat on 14 April, and I could not regain the signal from the ground. From a fixed-wing aircraft on 25 April, I located this male 75.6 km northeast of Badger Flat in the Jim Sage Mountains of Idaho. Another collared adult male that had been captured in spring 2005 was found in the same location. This male was collared in the Red Bank Springs lek complex, and had been located there on 1 April 2006. This bird had traveled 53.3 km into Idaho.

In addition to the males I collared specifically for this lek study, I observed several females on strutting grounds other than the leks where they were captured. One yearling female that was captured on the Dry Canyon Mountain lek complex in 2005 used Badger Flat in 2006. The distance between these leks is 21 km. One yearling female and 1 adult female that were captured on the Red Bank Springs and Kimbell Creek leks, respectively, were located out of the study area on the Dry Basin lek on 14 March, as approximately 250 males displayed. Both females had returned to their original capture locations by 25 April and nested near these locations, traveling 24.2 and 20.9 km. It is assumed that because these females nested near their capture locations, they copulated on these leks and simply used the Dry Basin area as wintering habitat.

Discussion

Connelly et al. (2000) described sage-grouse populations as non-migratory (no long distance movements), 1-stage migratory (movements between 2 seasonal ranges - winter/breeding and summer), or 2-stage migratory (movements between 3 seasonal ranges - breeding, summer, and winter). Based on my data, it would be difficult to assign the population in western Box Elder County to one of these categories. Of the birds monitored for at least 1 full year, I found that the majority of the females moved between 2 seasonal ranges and the majority of the males moved between 3 ranges. However, other females captured near the same leks were non-migratory or 2-stage migratory, and some males were only 1-stage migratory. These movement patterns suggest that local resource availability had a major influence on bird movements.

Seasonal Movements

The scale of the movements made by monitored grouse was dependent on the resources that were available to them. Resource availability in my study area reflects contemporary land uses. This land use is the result of a historical checkerboard pattern of public and private landownership. The northern portion of the study area consisted mainly of higher elevation sections of public and private rangelands. These areas were seasonally grazed by domestic cattle from summer to early fall. The southern portion of the study area consisted of sections of irrigated private hayfields interspersed with public rangelands that could be described as sagebrush flats. This unique combination provided some of the sage-grouse I monitored with year-round access to suitable resources.

For example, hens captured near the Ray Kimber Ranch lek used the surrounding sagebrush flats for both nesting and wintering habitats. The lek was on private land and the sagebrush flats were on public rangelands. After the nesting season, these birds, both hens with and without broods, moved to spend the summer in alfalfa fields on private lands that were within 2 km of their capture sites. These fields remained succulent throughout the summer and exhibited high arthropod abundance. Because of their close proximity to these resources, the birds spent their entire life cycle within approximately 7 km^2 of the lek on which they were captured.

However, this relationship was not as clear for birds captured on the higher elevation, northern leks. Although some of these birds remained within 5 km of their capture sites throughout the summer, more engaged in long-distance seasonal movements. The birds that remained closer to their capture sites were frequently found in close association with riparian areas, including wet meadows and semi-permanent streams. These areas exhibited greater juniper encroachment than the southern sites.

The range of movement distances I recorded was similar to those reported of sage-grouse populations in Idaho (Dalke et al. 1960, Connelly et al. 1988, Fischer et al. 1997). In these studies, as in mine, bird movements were initiated when vegetation began to desiccate in response to increasing ambient temperatures.

Patterson (1952) and Klebenow (1969) observed that sage-grouse tended to move higher in elevation throughout the summer in search of adequate resources. Some of the birds I monitored used higher elevation aspen and chokecherry stands later in the season. These areas exhibited more succulent herbaceous understory. Patterson (1952) and Connelly et al. (1988) also reported that grouse did not seek higher elevation in the summer months because they found adequate habitat in irrigated agricultural fields. The population in western Box Elder County exhibited similar patterns. The timing and distance traveled for the birds I studied were predicated on their ability to find suitable resources.

The male grouse I monitored traveled the farthest. Connelly et al. (1988) also noted that males in Idaho moved farther to summer range than females. Additionally, adult birds moved farther than yearlings. However, the movement differences between adults and yearlings may be questionable because most of the yearling birds tracked were female. More movement data should be collected on yearling males to validate this observation.

Movement distances of brooding and non-brooding females did not differ. Three (75%) of the successfully brooding hens stayed within 2.7 km of their nests, making small movements each day. The other hen stayed within 1.2 km of her nest before moving 9.2 km in the first week of July. She stayed within 0.8 km of this new location for the rest of the summer. Most non-brooding females stayed in the same area throughout the summer months, while others made one major movement, usually in late June or early July. All of the areas these birds used tended to be moister than the site they originally used or the surrounding landscape.

Sage-grouse that were trapped on different leks and used different areas in the summer moved to use the same areas in the winter. These wintering areas differed, both in proximity and in habitat type, from summer areas. The majority of the birds I monitored moved to lower elevations in the winter, using areas dominated by black sagebrush. A few birds used more mountainous areas as wintering habitat, but the exact habitat type they used is unknown. Sage-grouse that I tracked for 2 consecutive winters tended to move to the same general areas both years.

The winter movements of the birds I monitored appeared to be similar to those of sage-grouse populations in southeastern Idaho (Connelly and Markham 1983), southwestern Wyoming (Berry and Eng 1985), and on Cold Spring Mountain, Colorado (Dunn and Braun 1986). The movements of yearling birds were comparable to those of adults, as was observed by Connelly et al. (1988).

The distances of movements from winter habitat to breeding areas in this population were greater than those noted by Schoenberg (1982) in North Park, Colorado. With the exception of 1 female that wintered 1 km from the lek she used in the spring, sage-grouse moved 11.4 – 45.9 km to return to breeding areas. The above-mentioned female was the only bird I tracked for 2 breeding seasons that did not return to the same lek complex the second spring. Dalke et al. (1960) noted that 70% of marked grouse returned to the same strutting ground each spring for 3 consecutive years, and that females were less likely to return to the same lek due to a lack of territoriality.

One female returned from southern Idaho to her original capture location the second spring, traveled back into Idaho 2 weeks later, and then moved back to her original location in mid-June. The round-trip distance on this hen’s travels was 142.7 km between February and June. Berry and Eng (1985) noted a winter movement of similar nature by a hen in Wyoming, and associated this anomaly with weather. The only detectable difference between the first and second springs that I tracked this hen was a greater snowpack the second year. This difference may have influenced her return to Idaho.

Interlek Movements

Long-distance interlek movements exceeding 50 km are rare in the sage-grouse literature. In my study, 2 adult males moved 53.3 and 75.6 km into Idaho at the peak of the lekking season. These birds had been trapped on leks approximately 27 km apart. There is no known active lek at the location where these 2 males were found in Idaho. The nearest active lek to their location was 5.3 km, and there were 6 additional leks that were within 8 km.

The fact that 2 adult males captured on different leks traveled such long distances in mid-April to be found in the exact same location seems to be more than a coincidence. It is possible that these males were using an unknown lek, or had used a known lek on another day. Without the use of GPS collars, it is impossible to know exactly where these males had been.

I documented 1 (6%) adult male moving to a known lek throughout the course of my lek study. One yearling male left the Badger Flat lek, but could not be located on another lek. The one interlek movement that I can be sure occurred was similar in distance to those in Idaho (Dalke et al. 1963). The proportion of birds that made interlek movements was comparable to that noted in a study in central Montana (Wallestad and Schladweiler 1974). Many sage-grouse lek studies indicate that yearlings are more likely than adults to make interlek movements (Emmons and Braun 1984, Dunn and Braun 1985, Schroeder and Robb 2003). In my case, 3 males (1 yearling and 2 adults) left the lek for at least a week, but the known interlek movement was made by an adult.

Management Implications

Kimbell Creek, Cotton Thomas Basin, and Simplot property are critical brood-rearing and summer habitats for the sage-grouse monitored. All of these areas are currently managed for cattle grazing and are ≥2,000 m in elevation. Each exhibits riparian habitats, with ample streams and wet meadows, and scattered aspen stands. Current grazing management appears to be compatible with sage-grouse.

Managing for increased water availability will help to maintain adequate summer habitats for sage-grouse. Cattle grazing should continue to be managed to protect riparian areas. Additionally, treatments should be considered to reduce juniper encroachment in brood-rearing and summering areas. Juniper species cause significant water losses to ecosystems by transpiration (Miller et al. 1987). The resulting increase in moisture from juniper removal will provide the succulent herbaceous groundcover that is essential for sage-grouse in the late spring and summer.

Important wintering areas of this population are the sagebrush flats south of the towns of Grouse Creek and Etna, Dry Basin, the Jim Sage Mountain range in Idaho, and the mountains to the east of Grouse Creek on the Utah-Nevada border. These areas need to be protected to ensure adequate sagebrush cover for sage-grouse wintering habitat. Some areas of the sagebrush flats were determined to have groundcover of up to 50% cheatgrass. This species could quickly dominate the landscape if not considered in management regimes.

More information needs to be collected on interlek movements of this sage-grouse population to ensure more accurate lek counts and population monitoring. The lek study on Badger Flat was initiated with the notion that males may be double counted if these birds are visiting more than one lek in the study area throughout the spring. While 6% of the males that I collared on Badger Flat visited more than one lek in Utah, approximately 10% of the total number of collared males that I monitored in spring 2006 moved into Idaho. If this proportion of males is, in fact, also using leks in Idaho, we may be double counting these birds in 2 different states.

Connelly et al. (1988) mentioned that sage-grouse populations should be defined on a temporal and geographic basis, and this is true of the population in northwestern Utah. There were numerous movements not only into southern Idaho, but also into eastern Nevada. Because some of the these birds inhabit portions of 3 states, the future of the sage-grouse in this area may depend upon local working groups from Utah, Idaho, and Nevada joining forces and striving to attain common goals.

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Table 3.1. Climate data for western Box Elder County, Utah, 2005-2006.

	2005		2006		47 year average	
	$\bar{x}$	**Range**	$\bar{x}$	**Range**	$\bar{x}$ **(SD)**	**Range**
Temperature						
°C	6.7	(-11.7 – 32.1)	8.0	(-12.2 – 33.2)	7.2	(-12.1 – 31.2)
°F	44.1	(11.0 – 89.7)	46.4	(10.0 – 91.8)	45.0 (1.5)	(10.3 – 88.1)
Precipitation						
cm	45.2		25.4		29.0	(14.7 – 45.5)
in	17.8		10.0		11.4 (2.9)	(5.8 – 17.9)
Snowfall						
cm	71.1		129.8		95.5	(5.1 – 246.4)
in	28.0		51.1		37.6 (22.8)	(2.0 – 97.0)

Table 3.2. Seasonal movements of greater sage-grouse captured in western Box Elder County, Utah, 2005-2006.

	n	**Distance (km)**	
		$\bar{x}$ (SE)	**Range**
Summer			
Females	24	7.4 (2.3)	0.2 – 48.9
Males	23	19.0 (3.2)	2.1 – 69.3
Yearlings	14	5.4 (1.7)	0.2 – 21.4
Adults	33	16.3 (2.7)	0.9 – 69.3
Winter			
Females	15	24.1 (3.7)	0.2 – 46.1
Males	15	21.2 (2.8)	8.0 – 44.0
Yearlings	10	23.6 (4.4)	2.7 – 46.1
Adults	20	22.1 (2.7)	0.2 – 45.0
Spring			
Females	5	22.4 (6.0)	1.1 – 37.2
Males	3	23.6 (6.3)	11.4 – 32.3
Yearlings	4	22.8 (7.7)	1.1 – 37.2
Adults	4	22.9 (4.5)	11.4 – 32.3

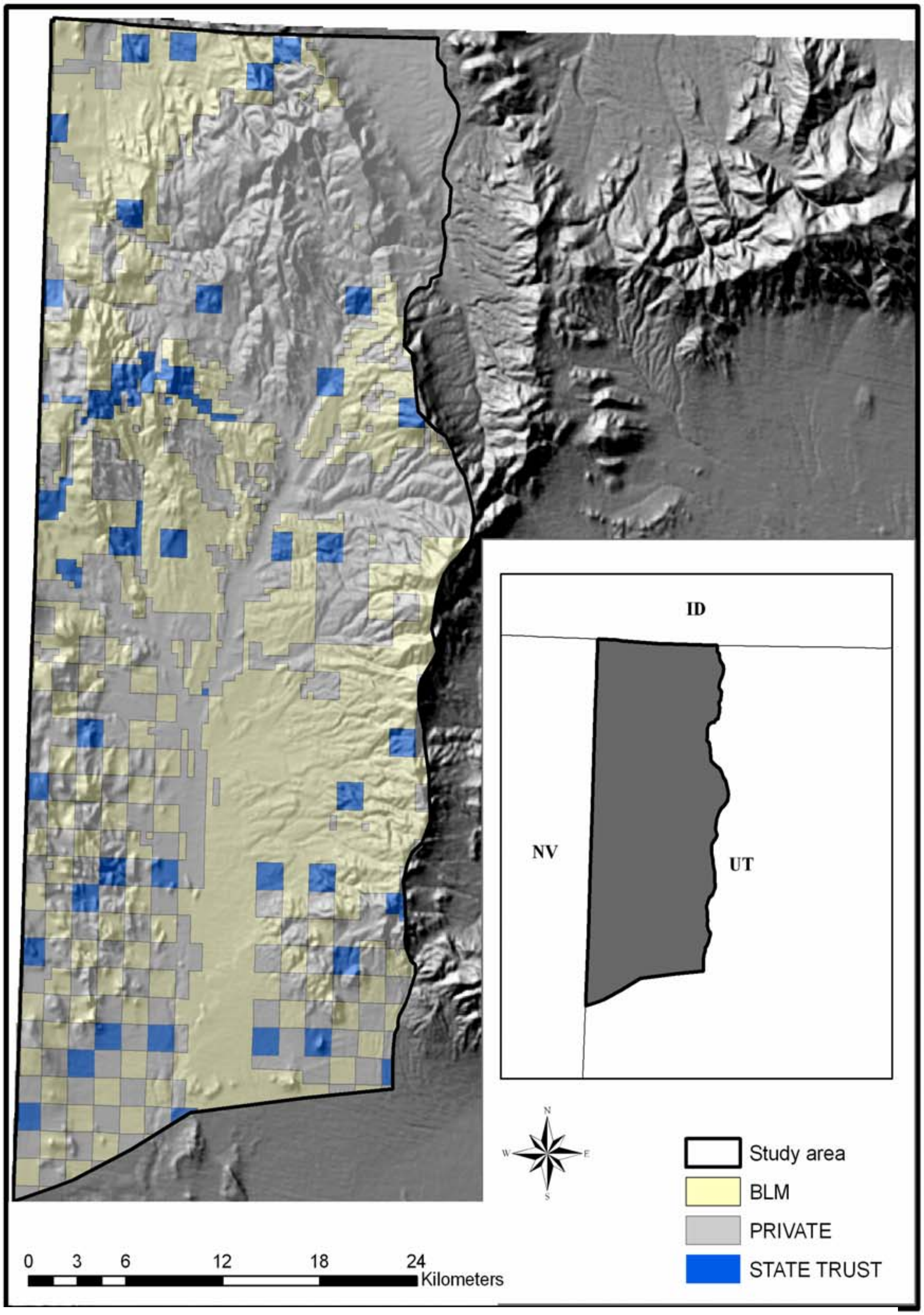

Figure 3.1. The study area in western Box Elder County, Utah.

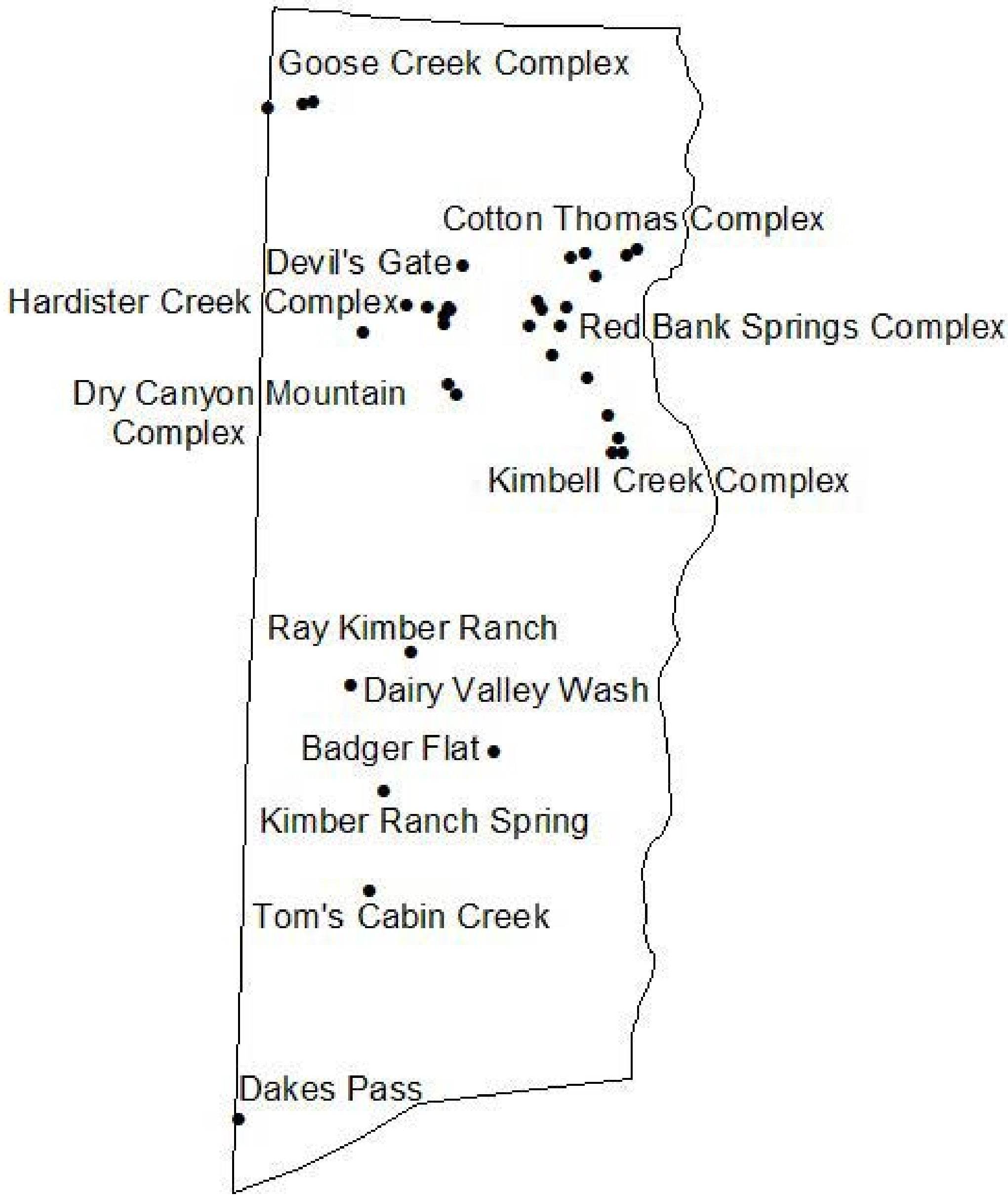

Figure 3.2. Active leks in the study area in western Box Elder County, Utah.

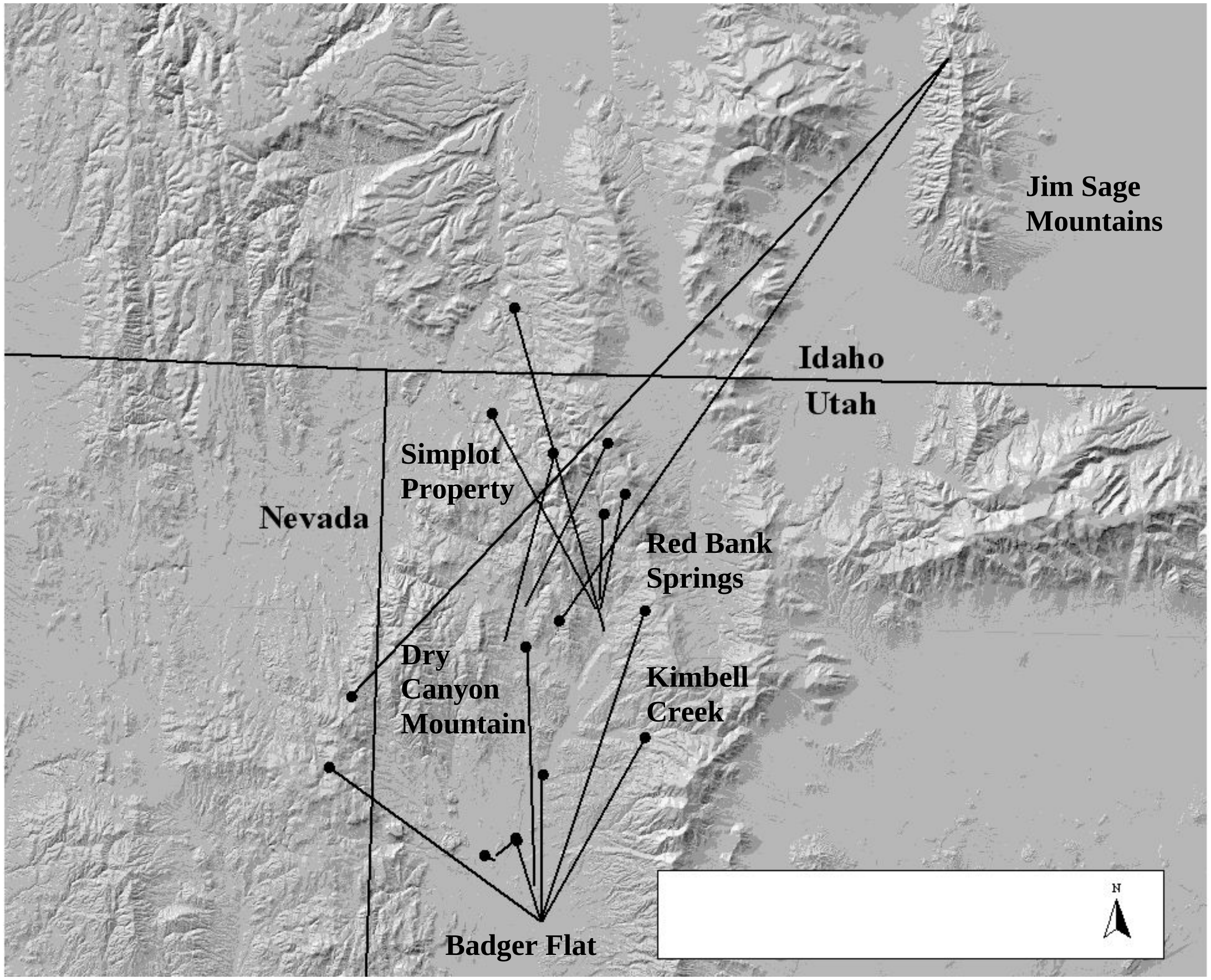

Figure 3.3. Representative summer movements of greater sage-grouse in western Box Elder County, Utah, 2005-2006. Circles represent ending bird locations.

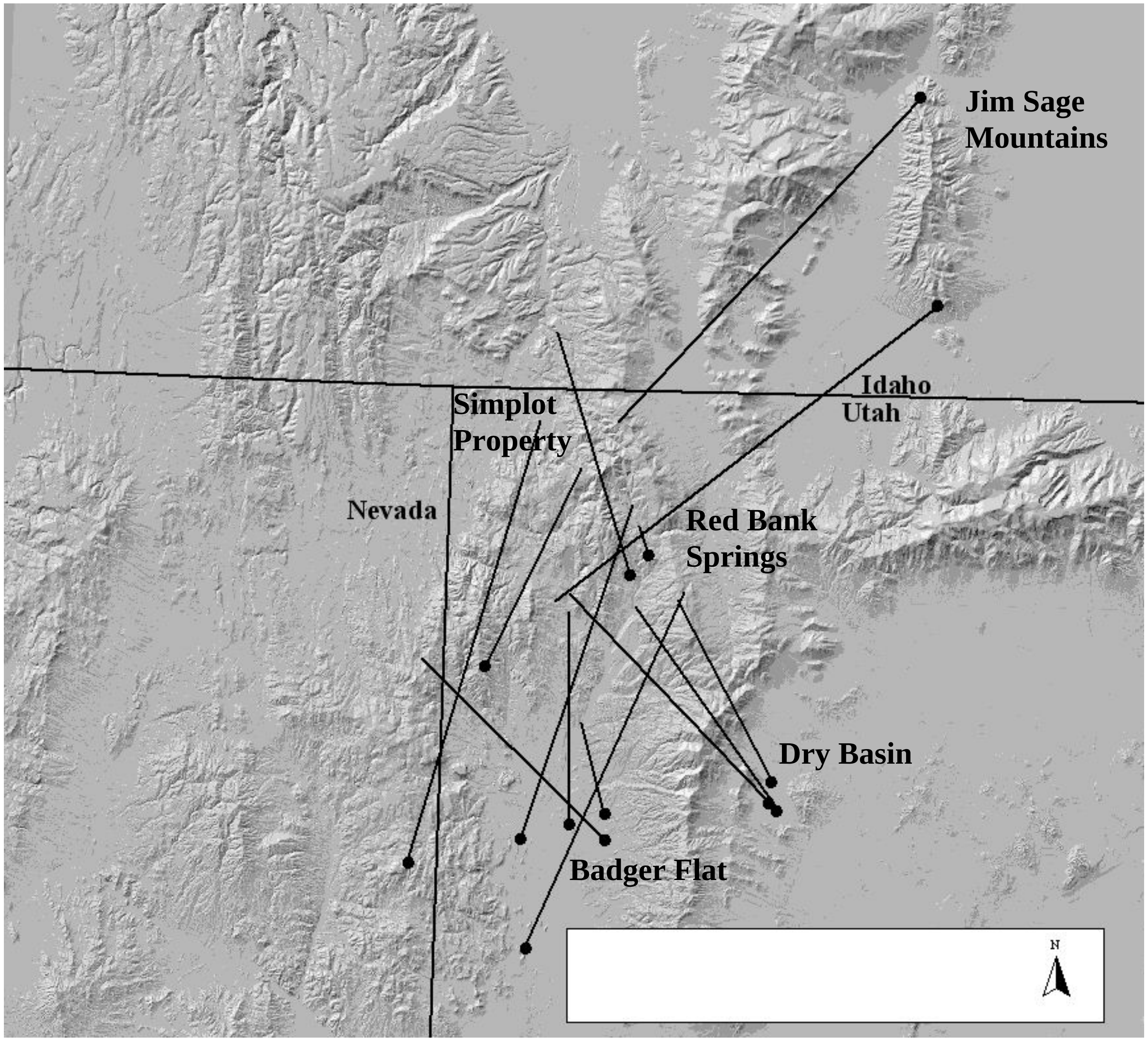

Figure 3.4. Representative winter movements of greater sage-grouse in western Box Elder County, Utah, 2005-2006. Circles represent ending bird locations.

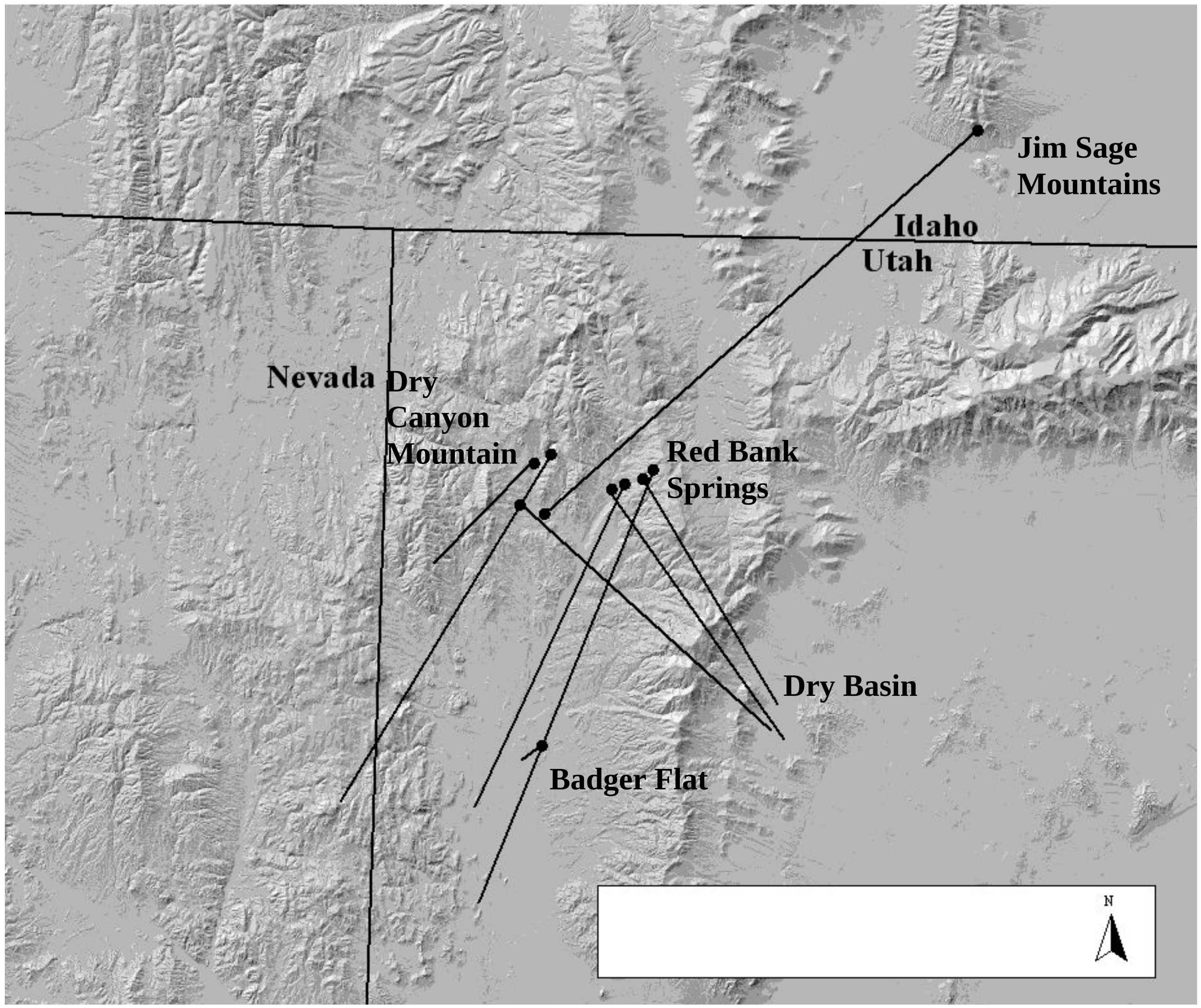

Figure 3.5. Spring movements of greater sage-grouse in western Box Elder County, Utah, 2005-2006. Circles represent ending locations. A line with circles at both ends represents a bird traveling back and forth in a short period of time.

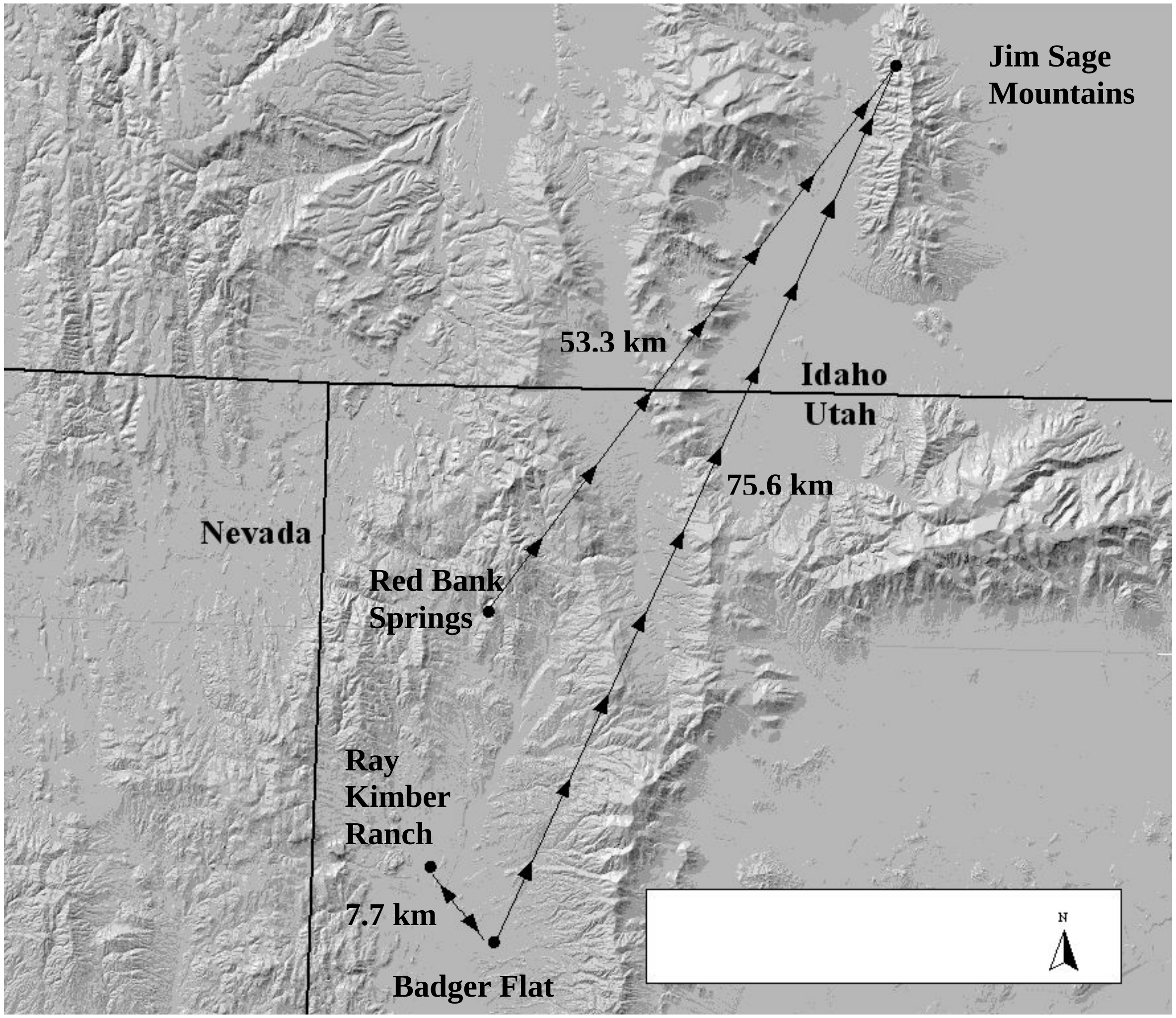

Figure 3.6. Movements of male greater sage-grouse during the lekking period in western Box Elder County, Utah, 2006.

CHAPTER 4

CONCLUSIONS

The decline of greater sage-grouse (*Centrocercus urophasianus*) in the past several decades has renewed rangewide efforts to gather information on the ecology of individual populations for application to management. Habitat loss, degradation, and fragmentation have been identified as the main causes of the decrease in sage-grouse numbers (Braun et al. 1976, Braun 1998, Schroeder et al. 1999). Because sage-grouse occupy a wide range, it is crucial to identify the quality and quantity of critical habitat types used by individual sage-grouse populations within specific physiographical areas.

The western Box Elder County Adaptive Resource Management local working group (BARM) was formed in 2002 as part of a rangewide effort to research and focus on local sage-grouse population issues (Connelly et al. 2004). Except for hunter harvest, lek count, and brood survey data, BARM had no information on the local sage-grouse population ecology to build a regional conservation plan. To address this problem, I initiated a sage-grouse ecology study in 2005 using radio-telemetry techniques.

I monitored the demographics, habitat use patterns, and seasonal movements of 50 sage-grouse over the course of 2 years. The major factors that influenced hen nest site choice were nest shrub size (height and diameter) and perennial grass height surrounding the nest location. Nest shrubs were considerably taller than recommended by Connelly et al. (2000); however, tall-growing basin big sagebrush (*Artemisia tridentata* spp. *tridentata*) and juniper (*Juniperus osteosperma*) were abundant in sage-grouse breeding areas. Shrub canopy, forb and grass cover at nest sites were within the guidelines recommended by Connelly et al. (2000). Nest initiation rates were similar to those documented in most other sage-grouse populations (Connelly et al. 2004), while success rates were at the low end of the observed range (Trueblood 1954, Gregg et al. 1994, Schroeder et al. 1999, Connelly et al. 2004).

Brood success rates were low, but may be inaccurate because I did not radio-mark individual juveniles. Hens with broods used several habitat types, including sagebrush stands, aspen and chokecherry stands, riparian areas, and irrigated alfalfa fields. Shrub canopy cover, shrub height, and herbaceous ground cover at brood use sites were greater than in numerous studies throughout the range (Wallestad 1971, Drut et al. 1994, Sveum et al. 1998, Chi 2004, Lane 2005, Dahlgren 2006). Shrub canopy cover was similar to studies in south-central Utah (Chi 2004) and Oregon (Drut et al. 1994), and forb cover was comparable to studies in Montana and Washington (Wallestad 1971, Sveum et al. 1998).

Hens with broods preferred areas with greater visual obstruction, shrub canopy, shrub height, forb cover, and forb height than randomly chosen sites. Additionally, successful broods were found in areas with greater shrub canopy, less perennial grass cover, and greater overall arthropod abundance than areas used by unsuccessful broods.

Single hens used sites with greater visual obstruction, shrub height, and perennial grass cover than sites used by broods. Males and single females also used sites with greater shrub height, forb cover, and forb height than randomly chosen sites. Shrub canopy cover at locations used by all birds throughout the summer exceeded the guideline recommended by Connelly et al. (2000). Spring and summer mortality rates for both years were less than winter mortality rates.

The scale of the movements that sage-grouse made throughout the year was dependent on the resources that were available to the birds. A few individual birds spent an entire year within approximately 7 km^2, because they could find adequate breeding, summer, and winter habitats in close proximity. Other birds traveled up to 70 km between seasons.

Sage-grouse breeding sites are spread throughout the study area and occur within a broad range of elevations. I identified key summering areas as Kimbell Creek, Cotton Thomas Basin, and property owned by Simplot. All of these areas are currently managed for cattle grazing and are ≥2,000 m in elevation. Each exhibits riparian habitats, with ample streams and wet meadows, and scattered aspen stands. Irrigated alfalfa fields <1,600 m in elevation also provided adequate moisture and cover for the sage-grouse to survive the summer months.

The majority of the monitored birds moved to the sagebrush flats south of the towns of Grouse Creek and Etna, Dry Basin, the Jim Sage Mountain range in Idaho, and the mountains to the east of Grouse Creek on the Utah-Nevada border in the winter. The sagebrush flats in the southern end of the valley and Dry Basin both exhibit low elevation (approximately 1,500 m), black sagebrush (*A. nova*) habitats. I did not collect information on the winter habitat types used in Idaho or on the Utah-Nevada border. All birds except for 1 hen returned to use the same breeding areas in the spring.

Biologists were concerned that interlek movements in the area may be biasing population estimates. There was a local belief that males began strutting on the southernmost leks at the lowest elevations, and moved to the northern, higher-elevation leks as the snow cleared in the spring. To address this issue, I radio-collared 18 males on the Badger Flat lek, one of the southernmost low elevation leks in the valley, and monitored them throughout spring 2006. Although the majority of the males remained on Badger Flat until the lek was no longer active, 1 adult male (6%) was documented visiting another active lek. Two adult males (10% of all monitored males) captured on 2 different leks moved into Idaho during the lekking period. If males from the study area are also visiting leks in Idaho, the possibility exists that biologists are not only double-counting males in the study area, but may also be double-counting males in 2 different states.

Management Recommendations

Sage-grouse summer habitat use in western Box Elder County is strongly associated with grazed areas. The current grazing regimes appear to be suitable for sage-grouse management and should be continued. Additionally, riparian areas should be monitored to help prevent detrimental effects of continued grazing.

Juniper removal in areas threatened by encroachment may increase water availability and help to improve sage-grouse summer habitat. A study in Colorado indicated that sage-grouse use increased in areas where juniper was removed (Commons et al. 1999). Trees should be removed beginning in areas where the juniper meets sagebrush habitat, leaving scattered trees to create edges for wildlife. Mechanical methods such as chaining and rollerchopping can be effective means of selective control (Sorensen 1999, Stevens 1999). Herbicides such as tebuthiuron can also be applied as a primary control method, or to extend the life of a previous mechanical treatment (McDaniel and WhiteTrifaro 1987).

The checkerboard pattern of public and private land ownership is important in providing adequate, year-round habitats for sage-grouse. Private landowners should consider taking part in habitat improvements such as chemical and mechanical sagebrush treatments. Methods such as aerial application of tebuthiuron and sagebrush thinning using a Dixie harrow or Lawson aerator can be effective ways to improve sage-grouse brood-rearing habitats (Dahlgren 2006). Sagebrush should be thinned to approximately 15 – 20% canopy cover, in a mosaic pattern that creates habitat edges.

Public lands should be monitored for cheatgrass (*Bromus tectorum*) invasion, and the proper measures should be taken to protect essential wintering habitats. Early spring grazing and herbicide application may help to prevent cheatgrass invasion, while green stripping in areas where encroachment has already occurred will aid in the prevention of large scale fires. In the future, BARM may need to join with other local working groups in both Idaho and Nevada to manage the entire spectrum of areas that these birds use throughout the year.

The results of my study have raised several issues that should be addressed in the future. Although I identified some key wintering areas, more information is needed on the specific habitats that are used by sage-grouse during these months. A more detailed lek study involving more birds would also provide important information to biologists who conduct lek counts every spring.

The effects of treatments such as sagebrush thinning and juniper removal should be researched as means to improve sage-grouse habitats and increase water availability. Because Mormon cricket (*Anabrus simplex*) outbreaks are a common occurrence in the study area, the effects of cricket control measures on arthropod abundance in brood-rearing areas should be investigated. Populations of predators such as ravens (*Corvus corax*) and coyotes (*Canis latrans*) should be monitored and controlled, if necessary.

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