ECOLOGY OF TWO GEOGRAPHICALLY DISTINCT GREATER SAGE-GROUSE POPULATIONS INHABITING UTAH'S WEST DESERT

by

Jason Douglas Robinson

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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

Ecology of Two Geographically Distinct Greater Sage-grouse Populations

Inhabiting Utah's West Desert

by

Jason D. Robinson, Master of Science

Utah State University, 2007

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

Sage-grouse (*Centrocercus*) have suffered declines throughout Utah. In response to the declines the West Desert Adaptive Resource Management (WDARM) local working group began meeting in 2004 to develop a greater sage-grouse (*C. urophasianus*) local conservation plan. However, little was known about the sage-grouse population inhabiting the area for application to management. To obtain this ecological information, I radio collared and monitored 49 greater sage-grouse between March 2005 and February 2007.

My research documented the existence of two distinct sage-grouse populations inhabiting the West Desert of Tooele and Juab counties: the Sheeprock and the Deep Creek Watershed populations. The two populations are geographically separated by the Great Salt Lake Desert. The specific objectives of my research were to describe seasonal habitat use patterns and relationships to vegetation, lekking areas, reproductive chronology, productivity, and population dynamics, and to provide a better estimate of the populations.

I identified 6 new leks, and confirmed that 2 historic leks, previously thought inactive, were being used. I counted 283 strutting males in 2006 and estimated the 2 populations together consisted of 1,132 individuals. I contribute this historic high to counting leks during peak male attendance and finding new strutting areas. The Sheeprock Watershed population is a 1-stage migratory population. The Deep Creek Watershed population is a non-migratory population.

Nesting success was higher in 2005 than 2006. Brood success was similar for the two years. The ratios of chicks per successful brood were higher in 2005 than 2006, for both sites. Ants (Formicidae) were the most abundant arthropod available to sage-grouse within the Sheeprock Watershed. I attribute these differences to precipitation. The spring of 2005 had twice the 30-year average spring precipitation, coming after a 5-year drought. However, there were no differences in vegetation at brood and random sites between years for either population. Chick recruitment in both populations was lower than reported in the literature. Sage-grouse survival rates for the Sheeprock and Deep Creek Watershed populations are lower and higher, respectively, than most published reports. Sage-grouse conservation strategies in both areas should emphasize enhancing existing brood-rearing habitat and protecting critical seasonal winter habitat.

(144 pages)

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CHAPTER 1

INTRODUCTION

The status of sage-grouse (*Centrocercus* spp.) populations has been a concern for several decades (Patterson 1952). Greater sage-grouse (*C. urophasianus*) occupy an estimated 56% of the pre-settlement distribution of potential habitat, and Gunnison sage-grouse (*C. minimus*) occupy an estimated 10% of pre-settlement distribution of potential habitat (Schroeder et al. 2004). Both species are being considered for federal listing under the Endangered Species Act. The continued decline of sage-grouse throughout the western United States has caused great concern. Many biologists attribute the decline of sage-grouse to several factors, but habitat loss and alteration seem to be the most significant factors. The general distribution of sage-grouse is very closely associated with the distribution of sagebrush (*Artemisia* spp.) (Patterson 1952). Factors responsible for habitat alteration have included, but are not limited to: alterations in fire regime, excessive livestock grazing, proliferation of non-native plants, conversion of rangelands to pastures seeded to crested wheatgrass (*Agropyron desertorum*), croplands, roads, gas development, and other land alterations (Crawford et al. 2004).

Species Description

The greater sage-grouse is the largest grouse species. The males are larger than females. The average size of a male is 1.7-2.9 kg and 65-75 cm long, the average size for a female is 1-1.8 kg and 50-60 cm long. Adult males have a whitish breast and under belly forming a ruff; the chin and throat are blackish. The tail is long and pointed, brownish in color with dark banding; primary wing feathers are plain brown; belly and undertail-coverts are brownish with large white tips on the undertail-coverts. There is a large black patch on the belly; they have a yellow fleshy comb above each eye; and long filoplumes stand from the back of the neck and head. During lekking times the males display on the lek by fanning their tails and expanding their white chests. Two yellow patches of bare skin (cervical apteria) are inflated for a brief moment to expose the yellow patches, appearing like yellow balloons (Schroeder et al. 1999).

Females are similar to males but also vary in several ways. The female is smaller and more cryptically colored. The head and neck are brown and gray, with no black. The females don't have the whitish breast of the males and they lack the bare yellow patches on the chest (Schroeder et al. 1999). Females also lack the yellow comb over each eye. Females have a black patch on the belly. Juvenile grouse resemble adults of their sex. Juveniles may be distinguished from adults for up to 17 months by the retention of the outer most 2 juvenile primaries, which are more pointed and often more frayed and worn (Gill 1967).

Greater sage-grouse males can be distinguished from other grouse species by their larger size, pointed tail, and distinctive color pattern. The female greater sage-grouse could be confused with several species of grouse, including blue grouse (*Dendragapus obscurus*) and sharp-tailed grouse (*Tympanchus phasianellus*). The blue grouse has a smaller, rounder tail and a more uniform coloration. The sharp-tailed grouse is smaller in size, and has a shorter tail, plainer underparts without a black patch on the belly, and dark V-shaped markings on the feathers (Schroeder et al. 1999). Sage-grouse will sometimes hybridize with blue and sharp-tailed grouse where they occur together (Kohn and

Kobriger 1986, Rensel and White 1988). The greater sage-grouse differs from Gunnison sage-grouse in several ways. The Gunnison sage-grouse is smaller in overall size, the banding on the tail of the male has broader whitish bars, and the filoplumes at the base of the neck are more prominent (Young et al. 2000).

Distribution

During pre-settlement, prior to 1800, greater sage-grouse occurred in Washington, Oregon, eastern California, Nevada, southern Idaho, Montana, southern British Columbia, southeast Alberta, southwest Saskatchewan, Wyoming, Utah, Colorado, northern Arizona, western North and South Dakota, and western Nebraska, with potential habitat estimated at 1,200,483 km^2 (Schroeder et al. 2004). Prior to 1800, Gunnison sage-grouse occurred in southeastern Utah, Colorado, northeastern Arizona and northwestern New Mexico with potential habitat estimated at 46,521 km^2 (Young et al. 2000).

Current distribution of greater sage-grouse includes patches in Washington, southeastern Oregon, eastern California, Nevada, southern Idaho, patches in Utah, eastern Montana, a small patch in southeastern Alberta, southern Saskatchewan, Wyoming, southwestern North Dakota, northwestern South Dakota, and northwestern Colorado, with an estimated area of current occupation to be 668,412 km^2, or approximately 56% of pre-settlement distribution (Schroeder et al. 2004). The greater sage-grouse has been extirpated from Arizona, New Mexico, Nebraska, and British Columbia (Schroeder et al. 2004). Current distribution of Gunnison sage-grouse includes patches in Colorado and Utah with an estimated area of current occupation to be 4787 km^2, or approximately 10%

of potential pre-settlement habitat (Schroeder et al. 2004). This species are believed to have been extirpated from Arizona and New Mexico.

Life History

Sage-grouse lack a muscular gizzard containing stones, so they are entirely dependent on soft materials for food (Patterson 1952). Sage-grouse are solely dependant upon sagebrush from October through April, but in May they shift to a diet dominated by forbs and some insects (Braun et al. 1977). Sage-grouse chicks have been shown to be very dependent on insects for the first several weeks after hatching (Johnson and Boyce 1990). Sage-grouse can have a variety of seasonal and annual migratory patterns (Wallestad 1975, Connelly et al. 1988). Sage-grouse have high fidelity to seasonal ranges; males often display on the same leks and females will return to the same area to nest each year (Fischer et al. 1993). Juvenile mortality has been estimated at 63% during the first few weeks after hatching (Wallestad 1975). Annual survival rates for adult females range from 68-85%, and for males from 46-54% (Connelly et al. 1994).

Males display for females in open areas termed leks. The males return to leks each year, and are often very site specific. The largest, most dominant males occupy the best positions in the lek area, often near the center of the lek. Most hens initiate a nest each year (Gregg 1991, Connelly et al. 1993), with as high as 99% nest initiation (Schroeder 1997). Sage-grouse nest success varies greatly throughout the species range, from 12 to 86% (Gregg 1991, Schroeder et al. 1999). Most hens have an incubation period of 27 days, following a period of laying one egg per day (Schroeder 1997). Average clutch size for sage-grouse varies from 6.3 to 9.1 eggs (Connelly et al. 1993, Gregg et al. 1994, Schroeder 1997, Connelly et al. 2004). Re-nesting attempts range from <20% (Patterson 1952) to >80% (Schroeder 1997). Connelly et al. (2000) suggest a ratio of ≥ 2.25 juveniles per hen in the fall to assure a stable to increasing sage-grouse population. Primary predators of sage-grouse include golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*B. swainsoni*), ferruginous hawk (*B. regalis*), northern harrier (*Circus cyaneus*), common raven (*Corvus corax*), weasel (*Mustelia* spp.), red fox (*Vulpes vulpes*), badger (*Taxidea taxus*), and coyote (*Canis latrans*) (Patterson 1952).

General Habitat Requirements

Pre-laying Females

Pre-laying period is the 5-week period preceding incubation (Barnett 1992). Habitats used by pre-laying females are often considered part of the breeding habitat (Connelly et al. 2000). A pre-laying female's diet contains 50 to 80% sagebrush leaves, with the remainder being various available forbs (Barnett and Crawford 1994). The nutritional component of the pre-laying hen's diet, which should be high in calcium, phosphorus, and protein, generally comes from the forb component, and may greatly affect nest initiation rate, clutch size, and subsequent reproductive success (Barnett and Crawford 1994).

Lekking

During early spring males gather at lek sites. Lek sites are the centers for male displays and breeding. Males appear to look for open areas adjacent to sagebrush habitat that would be acceptable for nesting habitat (Connelly et al. 2000). Leks are often formed in sparsely vegetated areas with little or no shrub cover (Patterson 1952). Leks are often formed in openings in sagebrush, ridgetops, landing strips, old lakebeds, roads, and burned areas adjacent to large expanses of sagebrush (Connelly et al. 1981). Leks can be the center of activities for non-migratory sage-grouse populations (Wallestad and Pyrah 1974, Wallestad and Schladweiller 1974). Lek sites are characterized by having high female traffic (Gibson 1992). There is little or no evidence that lek habitat is limiting (Schroeder et al. 1999) and additional lek habitat can be created if needed.

Nesting

Sage-grouse generally nest under sagebrush (Patterson 1952, Wallestad and Pyrah 1974), but will nest under other shrub species (Connelly et al. 1991). Often, a nest will be located under the tallest sagebrush in a stand (Apa 1998). Nests are often located near lek sites, but can be long distances from leks (Hanf et al. 1994). Sage-grouse often select areas with tall shrubs and much canopy cover in which to nest, with added cover from grasses (Gregg et al. 1994). Successful nests have been shown to occur in stands with greater shrub cover than unsuccessful nests (Holloran et al. 2005, Wallestad and Pyrah 1974). The proximity of the nest to water, or vegetation associated with water, may be an important determinant (Patterson 1952). Vegetation diversity may be important for horizontal and vertical concealment of the nest (Connelly et al. 1991). Grass height is also an important determinant of nest site selection, with taller and denser grass at nest sites than at random sites (Connelly et al. 2000, Holloran et al. 2005). Connelly et al. (2000, Table 3) suggested that guidelines for breeding habitat in mesic sites include 15-

25% sagebrush canopy cover with a height of 40-80 cm, and ≥ 25% grass-forb cover with a height >18 cm; and in arid sites 15-25% sagebrush canopy cover with a height of 30-80 cm, and ≥15% grass-forb canopy cover with a height >18 cm.

The most common reason for nest failure is predation by both mammalian and avian species (Ritchie et al. 1994, Schroeder and Baydack 2001). Common nest predators include ground squirrels, badgers, coyotes, and common ravens (Schroeder and Baydack 2001). Ample vegetation structure and cover can help mitigate predation (Schroeder and Baydack 2001). Ritchie et al. (1994) hypothesized that thicker sagebrush densities attracted more prey species, such as lagomorphs, which in turn attracted more predators that are more likely to use olfaction to locate nests. Predation rates were shown to be higher in untreated sagebrush stands, treatments reduced sagebrush cover (Ritchie et al. 1994). In some cases, domestic livestock can cause nest abandonment (Danvir 2002, Holloran and Anderson 2003).

Brood-rearing

Important dietary and structural components for brood-rearing include key forbs such as legumes and composites, insects, succulent mesic vegetation and sagebrush (Crawford et al. 2004). Hens with broods often seek out places where forb abundance is greatest (Drut et al. 1994b). They prefer habitat comprised of big and low sagebrush (*A. tridentata, A. arbuscula*) or riparian habitat. Hens will often seek out mesic sites as forbs desiccate on dryer sites (Wallestad 1971). Desiccation of forbs may occur earlier in drought years (Danvir 2002). Home range sizes can vary from < 1 km^2 (Wallestad 1971) to 5 km^2 (Drut et al. 1994b). Early brood-rearing habitat is often comprised of relatively open stands of sagebrush, exhibiting about 14% canopy cover (Wallestad 1971). Apa (1998) showed brood sites had twice as much forb cover as independent sites. Connelly et al. (2000, Table 3) suggested guidelines for brood-rearing habitat is the same for arid and mesic sites; 10-25% sagebrush canopy cover with 40-80 cm height, and >15% grass-forb canopy cover with variable height.

Insects are a vital component of early brood rearing habitat (Patterson 1952, Johnson and Boyce 1990). Sage-grouse chicks must have insects to survive for the first 3 weeks after hatching; they can survive with no insects after 3 weeks, however, growth rates are significantly lowered (Johnson and Boyce 1990). Drut et al. (1994a) showed sage-grouse chicks consumed 122 different foods, which included 34 genera of forbs, 2 genera of shrubs, 1 genus of grass, and 41 families of invertebrates. Of those foods consumed, 10 genera of forbs, 3 families of insects, and sagebrush were classified as primary foods; the majority of foods were eaten based on availability. The major insect groups eaten by sage-grouse chicks are beetles, ants, and grasshoppers (Patterson 1952, Drut et al. 1994a). Data suggest that the availability of forbs and invertebrates is positively associated with survival and recruitment of sage-grouse chicks. This relationship may be even more important in dry areas or drought years where forb availability is low and sagebrush becomes a greater component of the chick's diet (Drut et al. 1994a, Drut et al. 1994b). Arthropod abundance has been shown to generally increase with forb abundance (Potts 1986). Danvir (2002) showed arthropod biomass was generally greater in habitats having greater herbaceous plant cover.

Winter

During the winter months sage-grouse feed almost exclusively on sagebrush leaves (Patterson 1952), usually on big sagebrush, but also on other sagebrush species. Canopy coverage amounts range from 15-43% and height ranges from 20-56 cm (Connelly et al. 2000). Sagebrush not only provides food for sage-grouse but also thermal and escape cover (Connelly et al. 2000). Suggested sagebrush height is 25-35 cm above snow, and 10-30% canopy cover for mesic and arid sites (Connelly et al. 2000, Table 3). Unless snow completely covers up sagebrush, sever weather has little negative effect on sage-grouse populations, and in some instances sage-grouse can even gain weight during winter (Crawford et al. 2004). Areas that meet the above requirements should be given high priority for wildfire suppression, and sagebrush control should be avoided (Connelly et al. 2000).

Broodless Hens and Males

Often, sage-grouse nesting and brood-rearing success is low. A large proportion of the population can be composed of broodless hens, and survival of these hens may be important to population maintenance (Crawford et al. 2004). Habitat used by broodless hens is very similar to habitat used by brood hens, but broodless hens will generally move to riparian areas earlier in the season (Crawford et al. 2004). Broodless hens will form small flocks in May, which may increase in size to up to 25 hens in June and July (Gregg et al. 1993). Males follow a similar pattern of habitat use, but remain in large flocks separate from the females (Crawford et al. 2004).

Seasonal Movements

Sage-grouse populations may have 4 different types of annual migration patterns: 1) distinct winter, breeding, and summer areas; 2) distinct summer areas and integrated winter and breeding areas; 3) distinct winter areas and integrated breeding and summer areas; or 4) well-integrated seasonal habitats (non-migratory) (Connelly et al. 2000). Furthermore, sage-grouse populations can be classified as 3 types: 1) non-migratory; 2) 1-stage migratory: grouse move between 2 distinct seasonal ranges; and 3) 2-stage migratory: grouse move between 3 distinct seasonal ranges (Connelly et al. 2000).

Sage-grouse Conservation

Greater sage-grouse are declining throughout their historic range; breeding populations of this species have declined by 17-47% throughout much of its historic range (Connelly and Braun 1997). Historically, sage-grouse were found in 16 U.S. states and 3 Canadian providences, but they have been extirpated in Arizona, British Columbia, Kansas, Nebraska, New Mexico, and Oklahoma (Johnson and Braun 1999). Connelly et al. (2004) developed a range wide conservation assessment to address greater sage-grouse issues. The continued regional and statewide declines have prompted some organizations to petition the U.S. Fish and Wildlife Service (USFWS) to list the species as endangered or threatened. In January 2005, the USFWS concluded there was no need to list greater sage-grouse for protection under the Endangered Species Act at that time. The announcement encouraged state and federal agencies to continue research, and increase population size and improve habitat quality. The greater sage-grouse is still under pressure from several organizations to be listed as either threatened or endangered. Future petitions for listing are anticipated.

Sage-grouse in Utah

Sage-grouse originally occurred in all of Utah's 29 counties wherever sagebrush communities existed (Beck et al. 2003). Sage-grouse in Utah currently occupy 40.9% of their historical range. There has been a 60-70% decline in potential habitat, and 49% of known leks throughout Utah are no longer used by sage-grouse (Beck et al. 2003). To address these declines, the Utah Wildlife Board approved Utah's Strategic Management Plan for Sage-grouse in 2002. The plan identified regional issues and actions that needed to be implemented to reverse declining sage-grouse populations in Utah (UDWR 2002). The plan provided a framework for local working groups to develop area specific management plans to aid in the recovery of sage-grouse populations. The plan outlined statewide management issues including: population management issues, habitat issues, planning issues, and others. The plan also outlined the importance of continued research to aid local working groups with decision making and planning.

The West Desert Adaptive Resource Management (WDARM) local working group began meeting in 2004 to develop a management plan for Utah's West Desert, a physiographic region that includes part of Tooele and Juab counties. The area has two distinct conservation sites: the Sheeprock Watershed site and the Deep Creek Watershed site. Both of these areas are inhabited by greater sage-grouse.

Some local issues identified in the Utah Strategic Management Plan included: expansive areas of crested wheatgrass; loss of sagebrush habitat to fire, followed by cheatgrass (*Bromus tectorum*) invasion; degraded sagebrush habitat; small, isolated sage-grouse populations; lack of data; land ownership; and difficulty in habitat rehabilitation due to low rainfall. Some issues the WDARM has identified in its meetings include: spring grazing of cattle, Mormon cricket (*Anabrus simplex*) outbreaks and control with insecticides, recreational hunting (especially rabbit hunting) and poaching, mammalian and avian predation, trespassing, and human disturbance of sage-grouse. The WDARM has expressed a desire to have more and better baseline information and data. This group would like to have information on population numbers, lek attendance and locations, survival rates, habitat use, nest initiation dates, effects of insecticide spraying, and possible conflicts of grazing with sage-grouse recovery. The West Desert sage-grouse conservation plan will be completed in spring of 2007.

Purpose

The purpose of this thesis research is to determine factors affecting greater sage-grouse reproductive ecology and habitat use patterns in the West Desert study area. This information will be used by the WDARM to identify and implement management actions to benefit sage-grouse and local communities. Objectives are listed below:

1) To estimate greater sage-grouse population numbers.

2) To determine greater sage-grouse breeding, nesting, brood-rearing, and wintering habitat.

3) To determine greater sage-grouse hen nesting dates and success, nest site vegetation characteristics, brood success, brood site vegetation characteristics, and survival rates for adults.

4) To determine the relative abundance of arthropod populations exploited by grouse within the Sheeprock Watershed, and the direct or indirect effects of arthropod abundance on greater sage-grouse.

5) To provide the WDARM and Deep Creek Coordinated Resource Management Planning group with information to guide management actions designed to enhance habitat conditions for greater sage-grouse.

Style

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CHAPTER 2

ECOLOGY OF THE GREATER SAGE-GROUSE POPULATION INHABITING THE SHEEPROCK WATERSHED IN UTAH'S WEST DESERT

Abstract: Although the literature contains information about sage-grouse (*Centrocercus* spp.) biology, little is known about the ecology of sub or meta-populations which occur throughout the historic range of the species. Many of these populations are geographically separated as result of habitat fragmentation. Such is the case for a greater-sage-grouse (*C. urophasianus*) population inhabiting the Sheeprock Watershed in Utah's West Desert. From March 2005 through February 2007, I monitored 37 greater sage-grouse that had been fitted with radio transmitters to determine seasonal habitat uses, movement patterns, population dynamics, and reproductive ecology. The estimated population during the study, based on lek attendance, was the highest ever recorded, but this is largely attributed to increased survey efforts. This population is 1-stage migratory, and when compared to published reports for other populations it had lower survival, average nest initiation and nest success, lower chick recruitment, and smaller clutch sizes. I attribute these findings to highly variable seasonal precipitation patterns which affect vegetation structure and composition, and associated arthropod abundance. Conservation actions implemented to benefit this population should emphasize improvement of brood-rearing habitat and protection of critical seasonal habitats.

Introduction

The status of sage-grouse (*Centrocercus* spp.) populations has been a concern for several decades (Patterson 1952). Greater sage-grouse (*C. urophasianus*) occupy an estimated 56% of the pre-settlement distribution of potential habitat (Schroeder et al. 2004). Long-term studies suggest sage-grouse populations are on the steady decline (Schroeder et al. 2004), and the West Desert of Utah is no exception (Beck et al. 2003).

The general distribution of sage-grouse is very closely associated with the distribution of sagebrush (*Artemisia* spp.) (Patterson 1952). Factors responsible for habitat alteration have included, but are not limited to: alterations in fire regime, excessive livestock grazing, proliferation of non-native plants, conversion of rangelands to pastures seeded with crested wheatgrass (*Agropyron desertorum*), croplands, roads, gas development, and other land alterations (Crawford et al. 2004).

Much information has been gathered about food requirements, predation, and reproductive ecology. Studies have shown that insects are a critical component for egg-laying females and the early survival of chicks (Johnson and Boyce 1990, Barnett and Crawford 1994, Drut et al. 1994). Predators are often a large concern for sage-grouse populations, for predation of both adult grouse and eggs and chicks (Ritchie et al. 1994, DeLong et al. 1995, Schroeder and Baydack 2001, Holloran and Anderson 2003, Mezquida et al. 2006). Several studies have investigated the reproductive ecology of sage-grouse (Connelly et al. 1991, Connelly et al. 1993, Gregg et al. 1993, Schroeder 1997, Holloran et al. 2005).

Several guidelines have been published for managers to aid in management of sage-grouse and sage-grouse habitats (Braun et al. 1977, Connelly et al. 2000, Danvir 2002, Connelly et al. 2004, Crawford et al. 2004). The guidelines were developed based largely on studies conducted in southern Idaho. These areas have vast expanses of Wyoming big sagebrush (*A. tridentata wyomingensis*). Many of the habitats that are currently occupied by greater sage-grouse throughout their range do not exhibit the desired vegetation characteristics published in the guidelines. Little is known about the ecology of many of these populations for application to management. This information, when viewed in concert with ecological site conditions, will be essential to conserving and restoring fragmented populations and their habitats.

The West Desert Adaptive Resource Management (WDARM) local working group was organized in 2004 to develop and implement a sage-grouse conservation plan for the area. Concomitantly, it was recognized that better information about the ecology of the sage-grouse population in the area will be needed to guide this effort.

I used radio telemetry techniques to assess breeding ecology and habitat use of a greater sage-grouse population inhabiting the Sheeprock Watershed of Utah's West Desert. There is little information available on sage-grouse in Utah's West Desert to guide conservation efforts. The Utah Division of Wildlife Resources (UDWR) has been conducting lek surveys in the area since 1968. No other information on sage-grouse in the West Desert has been published.

The specific objectives of my research were to describe seasonal habitat-use patterns and relationships to vegetation, lekking areas and reproductive chronology, productivity, and population dynamics, and provide a current estimate of the population.

I compared my results to published reports in the literature and recommended guidelines. The information obtained will be used by WDARM to guide the development and implementation of their conservation plan.

Study Area

The West Desert study area is divided into two study site subunits, the Deep Creek and the Sheeprock Watershed sites (Figure 2.1). The study area encompasses 2,079,294 ha and follows the conservation area boundaries identified by WDARM. The study area is bounded to the south by the Juab/Millard County line, on the east by the Tooele/Utah County line and Highway 6, on the north by I-80, and on the west by the Utah/Nevada state line, excluding land managed by the U.S. Department of Defense (DOD). Both subunits are within Tooele and Juab Counties. The Sheeprock Watershed study site is located on the eastern side of Utah's West Desert, approximately 120 km east of the Deep Creek Watershed site and the Utah/Nevada border, around the Sheeprock Mountains and near the town of Vernon on Highway 36. The 2 study sites are separated by the southern end of the Great Salt Lake Desert. As expected due to lack of suitable habitat, there is no evidence that sage-grouse currently inhabit the desert salt flats or can cross the flats. The study area encompasses a variety of land ownerships, including: Bureau of Land Management (BLM), U.S. Forest Service (USFS), state, and private lands. The BLM manages 50% of the study area, DOD manages 27%, private ownership is 11%, state 6%, USFS 3%, Bureau of Indian Affairs, U.S. Fish and Wildlife Service (USFWS), and water make up <1% each (WDARM 2007). The main areas of focus within the Sheeprock Watershed site are the Little Valley, Government Valley, Harker Canyon, and Horse Canyon.

The Sheeprock Watershed site is characterized by hot dry summers and cold winters. According to the Western Regional Climate Center (2007) the 50-year average maximum summer temperature is 32.3° C (90.2° F) in July and the average minimum winter temperature is -10.3° C (13.4° F) in January. Average total precipitation is 7.9 cm (3.1 in) for spring, 6.4 cm (2.5 in) for summer, 7.1 cm (2.7 in) for autumn, and 5.4 cm (2.1 in) for winter, for an annual average of 26.9 cm (10.6 in). Average total snowfall is 95.0 cm (37.4 in) per year, with November-March receiving the majority of the snowfall, with most falling in January (20.3 cm, 8.0 in). The spring of 2005 was exceptionally wet with 16.9 cm (6.7 in) of precipitation falling from 1 March – 31 May, which is more than twice the 30 year average (Figure 2.2). The wet spring of 2005 came after 5 years of below average precipitation statewide (Figure 2.3)

Members of The Church of Jesus Christ of Latter-day Saints herded livestock into Tooele County prior to the establishment of permanent settlements which arrived in 1849. Early settlers of Tooele and Juab valleys relied on sheep and cattle herds and hay and grain crops. Mining came later and was an important industry for the area (WDARM 2007). Livestock, especially sheep and cattle, are still grazed on the study area. Ranching is a major industry for private landowners, and both the USFS and BLM have grazing allotments on the lands they manage. The Sheeprock Watershed site also has a large population of wild mustangs.

Vegetation

The lowest elevations are often areas of crested wheatgrass, with areas of Wyoming big sagebrush interspersed. The Sheeprock Watershed site has areas dominated by saltbush (*Atriplex* spp.) and greasewood (*Sarcobatus* spp.), in the lowest elevations. At mid-elevations the dominant shrub species is Wyoming big sagebrush with silver sagebrush (*A. cana*) in the wetter drainages. As elevation continues to increase, the vegetation includes a variety of shrubs such as: serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos albus*), antelope bitterbrush (*Purshia tridentata*), chokecherry (*Prunus virginiana*), and juniper (*Juniperus* spp.) stands. At the highest elevations there is mountain big sagebrush (*A. tridentata vaseyana*), with quaking aspen (*Populus tremuloides*) in the higher elevation drainages. Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) and rubber rabbitbrush (*C. nauseosus*) are found in varying densities throughout the site at all elevations. The Sheeprock Watershed site has had extensive fires in recent years. Often with cheatgrass and rabbitbrush replacing the sagebrush stands. Some of the more abundant and associated grasses and forbs include: cheatgrass, onion grass (*Melica bulbosa*), crested wheatgrass, sandberg bluegrass (*Poa secunda*), bulbous bluegrass (*P. bulbosa*), bluebunch wheatgrass (*Elymus spicatus*), western wheatgrass (*E. smithii*), squirreltail (*E. elymoides*), Indian ricegrass (*Stipa hymenoides*), basin wildrye (*Leymus cinereus*), acuminate onion (*Allium acuminatum*), lupine (*Lupinus* spp.), mountain dandelion (*Agoseris* spp.), milkvetch (*Astagalus* spp.), hawksbeard (*Crepis* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), phlox (*Phlox* spp.), blue-eyed Mary (*Collinsia parviflora*), and clover (*Trifolium* spp.).

Wildlife

Some of the more common mammalian species include: mule deer (*Odocoileus hemionus*), pronghorn (*Antilocapra americana*), wild horses, coyote (*Canis latrans*), red fox (*Vulpes vulpes*), badger (*Taxidea taxus*), weasel (*Mustela* spp.), black-tail jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus auduboni*), mountain lion (*Felis concolor*), elk (*Cervus elaphus*), and yellow-bellied marmot (*Marmota flaviventris*). Some common avian species include: western meadowlark (*Sturnella neglecta*), horned lark (*Eremophila alpestris*), common raven (*Corvus corax*), black-billed magpie (*Pica pica*), golden eagle (*Aquila chrysaetos*), sage sparrow (*Amphispiza belli*), sage thrasher (*Oreoscoptes montanus*), Brewer's sparrow (*Spezella breweri*), northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), burrowing owl (*Athene cunicularia*), short-ear owl (*Asio flammeus*), vesper sparrow (*Pooecetes gramineus*), Brewer's blackbird (*Euphagus cyanocephalus*), loggerhead shrike (*Lanius ludovicianus*), chukar (*Alectoris chukar*), turkey vulture (*Cathartes* aura), mourning dove (*Zenaida macroura*), and red-tailed hawk (*Buteo jamaicensis*).

Predator Control

Predator control was conducted within the research area during both years of this study by the U. S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS), Wildlife Services (WS). The work was conducted as part of a mule deer protection contract with the UDWR. No funds were available specifically for targeting sage-grouse predators. Additionally, many of the man hours devoted to this effort were for livestock protection. The area covered by WS encompassed about 68,152 ha (168,406 acres). In 2005, WS removed 80 coyotes and 3 coyote dens. No non-target species, such as badgers, were reported during the work. The time spent on predator control was 508.5 man hours by 4 specialists, 10 hours of helicopter, and 24.6 hours fixed wing aircraft work. In 2006, WS removed 103 coyotes, 5 coyote dens, and 12 red foxes. The time spent on predator control was 20.1 hours in fixed wing, 7 hours in helicopter, and 610.5 hours of ground time by 4 specialists.

Tooele County has offered bounties for coyotes since 2001, paid for by the county and in part by the Utah Department of Agriculture. The county keeps records of the number of coyotes brought in for bounty. The average number of coyotes taken for bounty in 2001-2004 was 397 coyotes per year; during 2005 and 2006, 700 and 750 coyotes, respectively, were taken for bounty (M. Jensen, Tooele County Auditors Office, personal communication). The county stipulates the coyotes should be taken by county residents in Tooele County. In addition, many recreational predator hunters hunt and trap within the research area and surrounding areas. They contribute some removal of predators in the area, but no records are kept of animals taken. Statewide estimates of the number of coyotes taken by hunters can be as much as twice the number taken by WS (Mezquida et al. 2006).

In addition to mammalian control, WS has also begun common raven control. Red foxes and common ravens have been implicated in affecting nest success and the annual survival of breeding age birds in the Strawberry Valley area of Utah (Bunnell et al. 2000). Common ravens have been shown to be substantial nest predators on sage-grouse (Willis et al. 1993, Coates and Delehanty 2004). In artificial nest studies conducted in Strawberry Valley, ravens depredated 98% of artificial nests within 48 hours of their placement; remote cameras were used to verify the identity of artificial nest predators (R. Baxter and J. Flinders, Brigham Young University, unpublished report). During 2005, an estimated 430 DRC-1339 eggs were placed by WS, removing approximately 95 ravens and 2 raven nests. During 2006, an estimated 400 DRC-1339 eggs were placed by WS at strategic sites based on information obtained from 2005 telemetry data in an effort to reduce nest predation caused by common ravens. An estimated 85 ravens were taken by the eggs. Raven control only took place during sage-grouse nesting periods.

Methods

Captures

To determine current habitat use and movement patterns of greater sage-grouse hens, we proposed to capture up to 20 hens and 10 cocks (30 birds total) each year over a 2-year period and fit each of them with a radio-collar. The collars were programmed (mortality signal cycle: 5 hours off, 19 hours on) 16.5 g Advanced Telemetry Solutions™ (PO Box 398, 470 First Avenue North, Isanti, MN 55040) necklace collars with a frequency range from 151.000-151.999 Mhz. Radio-collared birds were located using Telonics, Inc.™ (932 East Impala Avenue, Mesa, AZ 85204) and ICOM America Inc.™ (2380 116th Avenue northeast, Bellevue, WA 98004) receivers, handheld 3-element Yagi folding antennas, and vehicle mounted Omni antennas (RA-2A).

The capture methods consisted of going to the lek areas at night during lekking months (March-May). Sage-grouse could be captured at night with a spotlight and long dip net while they roosted near the leks (Giesen et al. 1982, Connelly et al. 2003). Sage-grouse prefer to roost on the ground in open areas within or near sagebrush. With the aid of binoculars, the spot light caused an eye shine on the roosting grouse and could be seen from up to 100 m. The grouse would then be approached by 2 individuals, 1 holding the spotlight and the other holding the long handled dip net. The spotlight and the noise from the vehicles would distract the roosting birds. The grouse was netted with the handheld dip net by a second person while it was distracted. Several grouse can be caught each night using this technique. The overall health of the grouse was visually ascertained before attaching the collar. The radio-transmitter was then attached to the grouse around the neck, with adequate space as to not impede the grouse's daily activities (Connelly et al. 2003). In addition, the grouse were weighed using a Pesola AG™ (Rebmattli 19, CH-6340 Baar, Switzerland) 2500 g spring scale, and each bird was aged according to Gill (1967) and Dalke et al. (1963). We recorded a location (Universal Transverse Mercator, NAD27) at each capture site using a Global Positioning System (GPS). Each grouse was released after information had been recorded. All sage-grouse were handled according to protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University, protocol file # 1195, and with a Certificate of Registration (COR) from the UDWR, COR # 2BAND6892.

Population Estimates

Methods used to obtain sage-grouse population data follow UDWR standard protocols and those of Connelly et al. (2003). Lek counts began in 1968, conducted by the UDWR, and in the last 2 years I was assisted by WDARM participants.

We conducted lek counts once a week from the first week in March to the first part of May. Lek counts were conducted 1/2 hour before sunrise to 1 hour after sunrise in reasonably good weather (i.e. light or no wind, and partly cloudy to clear skies). A location was selected near the lek that allowed for good visibility but did not disturb the birds. The time the lek count began was recorded, and then the male birds were counted from right to left. We waited 5 minutes then counted the number of males on the lek from left to right; next we waited another 5 minutes, and then counted a third time from right to left. We recorded the highest number of males observed in a single count. This procedure was repeated at no more than 3 lek sites per morning. The areas that were suitable sage-grouse lekking areas were searched for additional unknown leks and satellite leks. The highest numbers of males seen during the season are the reported totals.

Population estimates were based on the assumption that 75% of all males were counted on the strutting grounds and the male:female ratio in the population is 1:2 (UDWR 2002).

Nesting Ecology

Monitoring began 1 week after the birds were captured, to allow the birds to resume normal activities free of disturbance. Hens were located every 4 to 5 days until they initiated nesting activity. Hens were monitored to determine nest initiation rates, dates, distance between lek and nests, nesting success rates, nest predation rates, clutch size, and vegetation structure at nests. During the nesting period, hens were located every 2 to 3 days to try to account for all nesting attempts. Once a hen was in the same general location 2 days in a row during the nest initiation period, we would cautiously approach to within 10 m of the hen. At this point we were able to visually obtain the location of the hen with the aid of binoculars. Hens located under the same bush 2 days in a row were considered to be nesting. Nests were marked (flagging was never used, only discreet natural materials were used), and GPS readings and surrounding vegetation recorded. The nests were observed from a distance of 10 m every 2-3 days, so that their fates could be determined. For depredated nests, I tried to identify the type of predator by the state of any present eggshells, scat, tracks, and/or hairs (Patterson 1952). A successfully hatched nest was determined by the presence of 1 or more eggshells with loose membranes (Griner 1939). Nest initiation dates were estimated using a 27-day incubation period with 1 day added for each egg in the nest (Schroeder 1997).

Nest Site Vegetation

Nest site vegetation measurements were taken once nesting activities ceased. Vegetation visual obstruction readings (VOR) are a measure of concealment. These are taken by placing a Robel pole (Robel et al. 1970) in the center of the nest, and marked the center point for the vegetation measurements. We recorded vegetation measurements in 4 directions, at every 90° starting with a randomly chosen direction, from the center Robel pole. We measured shrub canopy coverage for 15 m from the center along each of the 4 transects using a modified line-intercept method (Canfield 1941). Gaps in the foliage < 5 cm were counted as continuous, gaps ≥ 5 cm were not counted. Heights were recorded for the tallest part of each shrub along each transect. We recorded VORs, to the nearest cm, between the nest and 4 m from the nest using a Robel pole. We recorded 2 measurements, Robel In (a measure of concealment) and Robel Out (a measure of hen's obstruction). The pole was placed in the location of interest (i.e., nest or location 4 m from nest) and the observer, standing at the opposite location, recorded the height on the pole, in cm, the vegetation appears to covers. The observer's eye level was at 1 m above the ground for both measurements.

A 20 by 50 cm Daubenmire (1959) frame was used to estimate percentage of forbs, grass, bare ground, rock, and litter cover to the nearest percent. A Daubenmire frame measurement was taken every 3 m (n = 5) along each of the 4 transects. The tallest height of each species of forb and grass (droop height) in each Daubenmire frame was recorded. Nest bush species, maximum height, maximum diameter, date of vegetation measurements, hatch date, clutch size, whether or not nest was predated, predator type, GPS position, aspect, slope, and general habitat were recorded for all nests.

Brood Monitoring

Following the nesting season, at least 2 times per week we located each bird that had successfully nested. Hens without broods were relocated once a week, until September. Brood hens were approached cautiously, and generally could be seen without flushing the hen. Most hens would flush when the chicks became older and could also fly. At each collared hen location a GPS coordinate, major vegetation, number of chicks seen, and total number of grouse flushed were recorded. Broods were considered successful if 1 or more chicks survived to ≥ 50 days and unsuccessful if no chicks survived to ≥ 50 days.

Brood Site Vegetation

The vegetation at brood site locations was measured 3-5 days after the brood location was recorded, which allowed time for the brood to leave the area. A Robel pole was placed in the center of the brood location, and marked the center point for the vegetation measurements. We recorded vegetation measurements in 4 directions, every 90° starting with a randomly chosen direction, from the center Robel pole. We measured shrub canopy coverage for 10 m from the center along each of the 4 transects using a modified line-intercept method (Canfield 1941). Gaps in the foliage < 5 cm were counted as continuous, and gaps ≥ 5 cm were not counted. Heights were recorded for the tallest part of each shrub along each transect. We recorded a VOR for each brood site using a Robel pole. We recorded a Robel In (a measure of concealment) measurement from 4 m from the center on each of the 4 transects, using the same technique as for nest sites.

A 20 by 50 cm Daubenmire (1959) frames was used to estimate percentage of forbs, grass, bare ground, rock, and litter cover to the nearest percent. A Daubenmire frame measurement was taken every 2.5 m (n = 4) along each of the 4 transects. The tallest height of each species of forb and grass (droop height) in each Daubenmire frame was recorded. At each brood site we recorded the date of vegetation measurement, date the brood was located, aspect, slope, GPS position, and general habitat. Vegetation parameters at random sites were recorded in the exact same manner on the same day within 500 m of 3 randomly chosen brood sites per week. Vegetation measurements were only made if the hen was suspected to still have a brood at the time of flush.

Arthropod Sampling

Arthropods are an important component of early brood-rearing habitat (Patterson 1952). Ants (Hymenoptera) and beetles (Coleoptera) are often the most important groups of arthropods for young sage-grouse chicks (Johnson and Boyce 1990), and their abundance can be assessed using pitfall traps. Sampling of arthropods via pitfall traps was conducted at nest sites, brood sites, and random sites. We placed pitfall traps so they were flush with the ground in a grid arrangement (Nelle 1998). The opening of each pitfall trap was 8 cm. Four 10 m transects were established at all locations, and 8 pitfall traps, 2 per each of the 4 transects, were placed at each location to capture ground-dwelling arthropods. A trap was placed at 5 m and 10 m from center on each transect. Arthropods were trapped by pitfalls at all nest sites. Each week for 7 weeks following hatching, 3 randomly chosen brood sites and 3 random sites associated with those brood sites (within 500 m of brood site) were sampled. Traps were opened for a maximum of 48 hours and insects were collected and preserved at the end of that time. Arthropods were placed in separate containers for each site, with 70% ethyl alcohol solution (Pedigo and Buntin 1993) for future quantification and identification. Arthropods were classified to order and families. Each individual was counted, and the volume of different groups of arthropods collected at each site was measured.

Movements

Movements of grouse were determined by locating birds at least once per week during spring and summer, and once per month in fall and winter. A combination of ground surveillance and aerial surveillance was used to locate birds. GPS locations, number of birds seen, and general habitat were recorded for all bird locations. If a bird was in the same area for an extended period of time a general description of the location was used instead of an exact GPS location.

Mortalities

When a radio collared bird mortality occurred, we examined the carcass and remains and feathers for signs of talon, claw, or teeth marks, and searched the surrounding area for remains, hair, feathers, tracks, and scat in an attempt to identify predators. We recorded the location, general habitat, and possible signs of the predator. In most cases it was difficult to assign a predator type to the birds because of heavy scavenging. Scavenger activity increased if it had been more than a couple of days since the mortality occurred. In most cases only the collar and a few feathers were located, and often predators were not identified.

Raven Monitoring

In 2005 and 2006, we conducted a 20-minute weekly raven survey, beginning 1 May and ending 1 August, to determine the effect of control efforts on the number of ravens near nesting areas. We traveled at speeds ranging from 24-40 km/h, for 12.8 km with no scheduled stops. We would only stop for positive identification, counting multiple ravens, and if necessary. The survey was conducted from 0630-0900. We recorded the number of ravens observed with our eyes only; we only used binoculars for positive identification. Double counting was avoided, but may have occurred on a limited basis.

Data Analysis

I used SAS Institute Inc.™ (100 SAS Campus Drive, Cary, NC 27513), SAS 9.1 (2002) software to run one-way analysis of variance (ANOVA) to compare female capture weights, nest and brood vegetation parameters within and between years, nest and brood arthropod abundance within and between years; values for degrees of freedom (DF) and sum of squares (SS) are reported as corrected totals. Paired t-test for means were used to compare nest bush height (measured) to surround shrub height (average height of all shrubs along each of 4 transects). All tests had a P-value set at 0.05 level of significance. Descriptive statistics were used to describe population estimates, nest initiation rates, nest initiation dates, clutch size, nest success, brood success, annual survival, and movements. The data for 2005 and 2006 were kept separate, except for winter data, due to the unusually wet spring of 2005, which had an impact on the parameters measured. I used ArcGIS 9 Geographic Information System (GIS) software to analyze movement data. Aspects of nests and broods were divided into 8 categories: north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W), and northwest (NW), each cover 45° (e.g. east (E) covers 67.5 – 112.5°).

Results

Captures

Thirty-seven birds total were captured and collared in 2005 and 2006. No birds were injured during capture activities. In 2005, 24 birds were captured and collared. Captures started on 1 April and ended 14 May. Three adult males were captured and collared from each of the 3 known lek areas. Twenty-one females were captured and collared. Four females were captured on the Benmore flats, 5 in Little Valley, and 12 on the McIntyre lek. The mean elevation for captures was 2,041.8 m (SD = 121.4, range = 1,788-2,161).

In 2006, 13 birds were captured and collared. Captures started on 8 April and ended 23 April. Once captures were all complete and with birds still collared from 2005, the site had 6 males and 21 females with radio collars. An adult male and an adult female were captured and collared on the Benmore strutting area. An adult male and an adult female were captured and collared on the Lookout Pass strutting area, and 2 adult males and 2 females, 1 adult and 1 juvenile, from the Simpson strutting area. Four females, 3 adults and 1 juvenile, were captured and collared from the McIntyre lek. An adult female was captured and collared from the Little Valley lek. The mean elevation for captures was 1,838.7 m (SD = 225.3, range = 1,594-2,108). The average weight for adult and juvenile females, both years combined, differed (P = 0.0053, DF = 28, SS = 390,467) and were: juveniles 1,310 g (SE = 37.5, range = 1,160-1,440 g); adults 1,454 g (SE = 22.2, range = 1,270-1,685 g).

Population Estimates

In 2005, lek attendance for males began in late February, and lek counts began 3 March. Peak male attendance was the first week in April, and peak female attendance occurred during the second and third weeks in April. There were 2 known active leks within the Sheeprock Watershed: McIntyre and Little Valley. A third strutting area, Benmore, was found 2 April 2005 by the researchers. The area will be deemed an active lek if $\geq$ 2 males are seen strutting in 3 of the next 5 years. Season high male lek attendance was 87 males on 6 April for the McIntyre lek, 32 males on 15 March for the Little Valley lek, and 24 males on 2 April for the Benmore strutting area. Lek counts concluded on 1 May 2005, but some males continued to strut until the second week in May. With a total of 143 strutting males observed, the population of the Sheeprock Watershed site was estimated to be 572 birds, using UDWR protocols.

In 2006, lek attendance for males began in late February, and lek counts began 3 March. Peak male attendance during the last week in March, was earlier for lower elevation leks. Peak male attendance for higher elevation leks was the third week in April. Peak female attendance was generally two weeks later than peak male attendance. We monitored 2 active leks (McIntyre and Little Valley), a historic lek (Benmore Historic), and a strutting area found in spring of 2005 (Benmore). Two additional strutting areas were discovered by the researchers and volunteers, one on 3 March 2006 (Lookout Pass), and one on 7 April 2006 (Simpson). The areas will be deemed active leks if $\geq$ 2 males strut there for 3 or more of the next 5 years. The season high male lek attendance was 77 males on 12 April for the McIntyre lek, 37 males on May 2 for the Little Valley lek, 15 males on 22 March for the Benmore lek, 17 males on 3 March for the Lookout Pass strutting area, and 37 males on 8 April for the Simpson strutting area. Seven strutting males were observed on the Benmore Historic lek only once on 8 March 2006. Lek counts concluded on 5 May 2006, but some males continued to strut until the second week in May. One hundred ninety males were seen strutting in the Sheeprock Watershed site, which is the highest number ever recorded for the area (Figure 2.4). With 190 strutting males observed, the population was estimated to be 760 total birds.

Nesting Ecology

Nesting ecology varied between 2005 and 2006 (Table 2.1). In 2005, 10 of 19 hens monitored initiated nests. Of the 10 nests initiated, 2 were predated, 1 nest was predated while hatching, and 7 hatched successfully. Although it was difficult to determine the type of predator that predated the nests, I suspect one of the predation events was mammalian due to buried egg shells. No re-nesting attempts were documented. A hen was accidentally flushed from her nest by the researchers; she flew a short distance and returned to her nest the following day. The nest hatched successfully.

Average clutch size for all nests was 6.0 eggs/nest, (range = 4 - 7). Average nest initiation date was 7 May (range = 26 April – 16 May). Of the 47 eggs observed, 37 hatched, 5 did not hatch and were at various stages of development, and ≥ 5 were predated. Average hatch date was 9 June (range = 30 May – 18 June). Eight of 10 nests were within 3.2 km of a lek (Figure 2.5). The mean distance a hen traveled from a lek to a nest was 1.95 km (range = 0.4 ─ 4.3 km).

In 2006, nests were initiated by 18 of 22 hens. Of the 18 nest initiated, 8 were predated and 10 hatched successfully. It was extremely difficult to determine the type of predator that predated the nests. I suspect a variety of predators which include: common ravens, red foxes, coyotes, badgers, and weasels. No re-nesting attempts were documented. A hen was accidentally flushed from her nest by the researchers; she flew a short distance and returned to her nest 2 days later. The nest hatched successfully.

Average clutch size for all nests was 6.3 eggs/nest, (range = 5 - 8). Average nest initiation date was 19 April (range = 2 April – 7 May). Nest initiation dates were two weeks later in 2005 than in 2006 (Figure 2.6). Sixty-seven eggs were observed. Of those, 59 hatched successfully, and 8 did not hatch and were at various stages of development. Many additional eggs were suspected to be in the predated nests, but usually an egg count was impossible. Average hatch date was 23 May (range = 4 May – 8 June). Sixteen of 18 nests were within 3.2 km of a lek (Figure 2.7). The mean distance a hen traveled from a lek to a nest was 1.6 km (range = 0.3 ─ 5.5 km)

Six hens nested in both 2005 and 2006. Three of those hens had successful nests both years, 2 had unsuccessful nests both years, and 1 had a successful nest in 2005 and an unsuccessful nest in 2006. The average distance a hen nested in 2006 compared to her nest in 2005 was 449.3 m (range = 63 – 880 m). Three hens did not nest in 2005 or 2006.

Nest Site Vegetation

During both years, 22 of 28 hens nested under sagebrush. Nest sites in 2005 showed some difference in characteristics than those of 2006 (Table 2.2). In 2005, 7 of 10 hens nested under sagebrush. One hen nested under rubber rabbitbrush, and 2 hens nested under snowberry/sagebrush. The mean elevation for nests was 2,055 m (SD = 104.3, range = 1,896 – 2,160 m). Nest bush diameter (P = 0.047, DF = 26, SS = 139,425), forb cover (P = 0.002, DF = 26, SS = 7,824), forb height (P = 0.0014, DF = 26, SS = 924), grass cover (P < 0.0001, DF = 26, SS = 3,803), grass height (P = 0.0025, DF = 26, SS = 2,496), rock cover (P = 0.007, DF = 26, SS = 467) differed between 2005 and 2006. Forb cover and height, and grass cover and height were all higher in 2005.

Fifteen of 18 (83%) hens monitored in 2006 nested under sagebrush. One hen nested under a juniper tree, another hen in Indian rice grass, and another hen nested under basin wildrye. The mean elevation for nests was 2,022.1 m (SD = 173.7, range = 1,605-

2,210 m). The bush nests were located under taller than surrounding shrubs ($P < 0.0001$, DF = 26, t-stat = 4.98). Percent of nest sites in each aspect category, for 2005 and 2006 combined, were: N-4%, NE-19%, E-19%, SE-30%, S-0%, SW-7%, W-0%, and NW-22%.

Nest Site Arthropods

There were 22 families of arthropods available to hens and chicks, as estimated from pitfall trapping. Five families (Formicidae, Carabidae, Tenebrionidae, Cicadellidae, Araneida) were most abundant. Ants (Formicidae) were the most important of all arthropods based on availability, making up 99% of arthropods caught based on the number of individuals, and 77% based on volume (Table 2.3). There were more ants available in both number and volume in 2005 than in 2006, but differences between the two years were not significant ($P = 0.16$, DF = 16, SS = 8,269,631; $P = 0.13$, DF = 16, SS = 1,360, respectively). There were no differences in the number or volume of all other families of arthropods between 2005 and 2006 (Table 2.3).

Brood Success

In 2005, 2 of 7 broods were successful with 4 and 3 juveniles per hen. For 19 total collared hens, there were 7 chicks we know reached an age of ≥ 50 days, which is a ratio of 0.37 juveniles/collared hen. In 2006, 3 of 10 broods were successful, with 2, 2, and 1 juveniles per hen. For 22 total collared hens, there were 5 chicks we know reached an age of ≥ 50 days, which is a ratio of 0.23 juveniles/collared hen.

Three hens had broods in both 2005 and 2006. One hen had unsuccessful broods in both years, 2 hens had unsuccessful broods in 2005, but had successful broods in 2006. No hen had a successful brood in both 2005 and 2006.

Brood Site Vegetation

Brood site vegetation parameters varied between 2005 and 2006 (Table 2.4). In 2005, the vegetation parameters at brood sites did not differ from those at random sites, except for forb height (P = 0.013, DF = 56, SS = 1,317). The average elevation for brood sites was 2,139.5 m (SD = 167.9, range = 1,895 - 2,252 m). In 2006, the vegetation parameters at brood sites did not differ from random sites, except for rock cover (P = 0.016, DF = 96, SS = 2,791) and bare ground (P = 0.033, DF = 96, SS = 7,330). The average elevation for brood sites was 2,079.5 m (SD = 96.83, range = 1,707 - 2,208 m). The Robel In measurements were 25.8 (SE = 3.2) and 40.1 cm (SE = 4.2) for 2005 and 2006, respectively. Rock cover was 8.5 (SE = 1.6) and 4.5 % (SE = 0.6) for 2005 and 2006, respectively. Slope was 11.9 (SE = 1.2) and 9.2 degrees (SE = 1.0) for 2005 and 2006, respectively. There was a difference in Robel In (P = 0.023, DF = 116, SS = 123,276), shrub cover (P = 0.002, DF = 116, SS = 39,977), shrub height (P = 0.032, DF = 116, SS = 52,963), forb cover (P < 0.0001, DF = 116, SS = 16,229), forb height (P < 0.0001, DF = 115, SS = 2,560), grass cover (P <0.0001, DF = 116, SS = 16,332), grass height (P < 0.0001, DF = 116, SS = 8,094) rock cover (P = 0.004, DF = 116, SS = 6,242), and bare ground (P = 0.0005, DF = 116, SS = 13,082) between 2005 and 2006 at brood locations. Forb cover and height, and grass cover and height were higher in 2005. Shrub cover and height, and Robel In were all higher in 2006. Percent of brood sites in each aspect category, for 2005 and 2006 combined, were: N-17%, NE-30%, E-21%, SE-9%, S-9%, SW-0%, W-4%, and NW-9%.

Brood Site Arthropods

Arthropod abundance varied between 2005 and 2006 (Table 2.5). In 2005, there were 22 families of insects available to hens and young chicks at brood sites. Five families (Formicidae, Carabidae, Tenebrionidae, Cicadellidae, Araneida) were most abundant. There was no difference in the number or volume of arthropods at brood and random sites, or between 2005 and 2006.

In 2006, there were 22 families of insects available to hens and young chicks at brood and random sites. Five families (Formicidae, Carabidae, Tenebrionidae, Cicadellidae, Araneida) were most abundant. The number and volume of ants were greater at brood sites than at random sites, but the differences were not significant ($P = 0.12$, $DF = 41$, $SS = 70,785,014$; $P = 0.086$, $DF = 41$, $SS = 12,327$, respectively). The number of all other arthropods did not differ between brood and random sites ($P = 0.242$, $DF = 41$, $SS = 4,258$), but the volume of other arthropods did differ ($P = 0.0077$, $DF = 41$, $SS = 33$). Neither the number nor volume of arthropods captured differed between 2005 and 2006 at brood locations. We captured 25 families (2 unknown families) total, with varying numbers of individuals (Appendix Table A.1). Ants made up 99% of arthropods caught based on number of individuals, and 77% based on volume.

Movements

In 2005, most hens (80%) nested within 3.2 km of a lek. Of the hens that had successful nests, most had broods that stayed close to the nest site. All 60 documented brood locations were within 1.6 km of the nest site, with the exception of bird 474 (Figure 2.8). She had 2 locations that were 2.2 km and 2.7 km away from the nest site. This bird had an unsuccessful brood and these 2 points may have been recorded after she had lost her brood. Some birds had small areas of use while others had larger areas of use. The female bird with the smallest area of use traveled 740 m from place of capture to nest site, and then 2.3 km from her nest to the farthest summer point recorded. The female bird with the largest area of use traveled 10.5 km from place of capture to nest site, and then 6.7 km from nest to the farthest summer point recorded. The male with the largest area of use traveled 6.7 km from the capture site to the farthest recorded summer point.

In 2006, most hens (89%) nested within 3.2 km of a lek. Of the hens that had successful nests, most had broods that stayed close to the nest site. Of 76 brood locations, 74 were within 3.2 km of the hatch nest. Bird 515 went 4.0 km from her nest, and then came back within 3.2 km of the nest. She died as soon as she came back towards the nest. The other location recorded outside the 3.2 km buffer was for bird 536. She only ventured outside the buffer once, to a distance of 3.4 km from her nest. Another interesting bird was 416. She took her brood 1.6 km from the nest site within 3 days of hatching. She then never ventured closer than 1.6 km to her nest and never farther then 3.2 km of her nest (Figure 2.9). Some birds had small areas of use while others had larger areas of use. The female bird with the smallest area of use traveled 0.460 km from place of capture to nest site, and then 0.9 km from her nest to the farthest summer point recorded. The female bird with the largest area of use traveled 5.4 km from place of capture to nest site, and then 10.7 km from her nest to the farthest summer point recorded. The male with the largest area of use traveled 23.5 km from the capture site to the farthest recorded summer point.

Winter Habitat Use

Winter data were grouped for 2005 and 2006 because both winters were close to average and differed little from each other. Nine of 27 winter locations were within 9.6 km of a lek site. However, 3 of the birds for these 9 locations ended up on winter ranges outside the 9.6 km buffer sometime later. There are 2 wintering areas within the site, one area to the north and another to the south of the Sheeprock Range. Both winter ranges were lower in elevation in Wyoming big sagebrush dominated areas. We had 4 winter locations within the north winter range. Bird 474 traveled 16.4 km from the capture site to get to the north winter range, but died upon arriving at the range. Bird 175 traveled 15.6 km from the site of capture to get to the north winter range. The other 2 birds did not travel far from the capture site to the north winter range. Most birds (20 of 24, 83.3%) traveled to the south winter range. The average distance a bird traveled to reach the south winter range was 14.6 km (range = 10.3 – 16.6 km) from the site of capture (Figure 2.10).

In January 2007, sagebrush heights were measured at winter bird locations to get a general idea of sagebrush height. We also visually estimated shrub cover. The mean sagebrush height for 5 bird locations during winter was 47.98 cm (n = 83) with little snow coverage, and estimated sagebrush shrub cover was 20-30 %.

Mortalities

During the study we documented 24 mortalities in radio-collared birds. In 2005, 10 of the 24 collared grouse were mortalities. Annual survival rates varied by sex, age, and year (Table 2.1). Two birds that died were juvenile females and 2 were adult females from the McIntyre lek. The cause of mortality was undetermined, but a golden eagle is suspected in 2 of the cases. Three birds that died were adult females from Little Valley. Again the cause of mortality was hard to determine. We suspect either a red fox or coyote for 2 of the Little Valley birds. Red fox, coyote, badger, weasels, and eagles have all been observed by the researchers in the sage-grouse areas. Three birds died in January, 2 in April, 1 in May, 1 in August, 1 in October, and 2 in November.

In 2006, 14 of the 27 collared grouse were recorded mortalities. One adult male was found dead in May on the McIntyre lek. Two adult males were found dead in September on the south side of the Sheeprock Mountains. Another adult male was found dead in February on the west slope of the Sheeprock Mountains. Three females were found dead in May, 1 of which was killed while on her nest. A coyote is suspected to be the predator based on evidence at the nest site. A female was found dead in June, 2 more in August, 3 more in September, and another in February. Most predators could not be identified due to heavy scavenging and the time it took to locate dead birds.

Raven Monitoring

The average number of ravens seen per week in 2005 was 7.3 (range = 0 - 22). However, the 2005 average number of ravens during, and soon after, raven control (1 May - 14 June) was 2.6 (range = 0 - 4). After raven control ended (15 June - 1 August) the average number was 11.8 ravens (range = 3 - 22). The average number of ravens seen per week in 2006 was 7.5 (range = 1 - 25). However, the 2006 average number of ravens during, and soon after, raven control (1 May - 14 June) was 3.3 ravens (range = 1 - 7). After raven control ended (15 June - 1 August) the average number was 12.6 ravens (range = 5 - 25). Raven control seems to have an effect on the number of ravens, but the population recovers to pre-treatment levels once control ceases and the remaining chicks are fledged (Figure 2.11).

Discussion

Predator Control

Anecdotal evidence suggests that red fox numbers in the research area might be on the increase. Mezquida et al. (2006) suggested the removal of coyotes may have a mesopredator release effect. With the removal of coyotes, more predators like red fox, badgers, common ravens, and sometimes golden eagles, can increase in number due to the lack of suppression from the coyotes. Predators can have significant impacts on sage-grouse nesting success (Mezquida et al. 2006 and references therein). We observed red foxes on a regular basis near sage-grouse areas. In both 2005 and 2006, red fox dens were located with piles of sage-grouse feathers around the opening. We often saw coyotes and red fox in the same areas. I suspect their home ranges may overlap. Mesopredator release probably occurs in the Sheeprock Watershed (M. Tamllos, USDA APHIS Wildlife Services, personal communication).

Nesting Ecology

The nesting ecology for the Sheeprock Watershed population is comparable to published reports (Connelly et al. 2004, and reference therein) in terms of the number of hens initiating nests (63.1-100%). Nest successes, 56-70%, were within published ranges (14.5-86.1%) (Connelly et al. 2004). The average clutch size for both years is slightly below the published range (6.3-9.1) (Connelly et al. 2004). Patterson (1952) had re-nesting attempts <20%, while we never documented a re-nesting attempt. Nest initiation dates vary greatly between populations. This population falls within the range, but we documented a large variance between years due to precipitation. Nests are usually located near leks (Wakkinen et al. 1992), and this population is no different. Sage-grouse have been shown to have high fidelity to seasonal areas (Keister and Willis 1986, Fischer et al. 1993); this population shows high fidelity to lek and nest areas.

Nest Site Vegetation

Most of the hens (78.6%) I monitored selected nest sites under sagebrush, but did not have higher nesting success. Connelly et al. (2004) reported similar observations in a review of published literature. Often hens will nest under taller shrubs (Apa 1998), as was the case with this population. The recommended sagebrush canopy cover for nesting cover is 15-25% (Connelly et al. 2000). This population is on the upper end of the guidelines. The recommended sagebrush height in nesting areas is 20-80 cm (Connelly et al. 2000). The sagebrush height at the Sheeprock study site falls within this range. The recommended grass-forb canopy cover is ≥ 15% with a height of >18 cm (Connelly et al. 2000). In 2005, forb and grass cover exceeded the guidelines, but in 2006 forb and grass cover were below the guidelines. In both years the heights were below the guidelines. However, in 2005 grass heights were above the guidelines. This area is extremely arid, and with above average precipitation in spring 2005, the forb and grass parameters responded within the same season. In most years the forb and grass components will probably be below the recommended guidelines. Thinning of shrub cover may allow for greater forb and grass cover.

Nest Site Arthropods

Ants were the most abundant arthropods in pitfall traps, and there were more ants in 2005 then in 2006. The number and volume of all other arthropods was low in comparison to ants (Table 2.2). Drut et al. (1994) showed beetles, ants, and grasshoppers to be primary foods of sage-grouse in Oregon; the majority of foods were eaten based on availability. We captured very few grasshoppers at nest sites. In 2005, there was greater forb and grass cover than in 2006, which may have been a factor in the greater number of arthropods in 2005. Arthropod abundance generally increases with forb abundance (Potts 1986). Danvir (2002) showed that arthropod biomass was generally greater in habitats having greater herbaceous plant cover. The study area previously had tremendous Mormon cricket (*Anabrus simplex*) outbreaks which ended in 2004, and which were controlled with insecticides. The extremely wet spring of 2005 probably killed most Mormon crickets and grasshoppers in the research area, and allowed for ants to prosper from more forbs and less competition.

Brood Success

In general, brood success was very low. Connelly et al. (2000) suggest ≥ 2.25 juveniles per hen are required for a steady to increasing population; this population is below that number in both years. The ratios for the Sheeprock population may be underestimated, but more research needs to be done to address the problem.

We were unable to determine the fates of the chicks in unsuccessful broods, because we could only track the brood hen. Broods were previously considered unsuccessful if a hen had no chicks. This was thought to be due to mortality of the chicks. However, current research (D. Dahlgren, Utah State University, personal communication) suggests that lost broods may be due to brood-hopping. Brood-hopping occurs when chicks from 1 brood leave their birth mother and join the brood of another hen.

Brood-hopping might be occurring in the West Desert study area. On one occasion we had a hen with 3 chicks. After some time with another brood, the collared hen had 4 chicks once the 2 broods separated. If brood-hopping does occur frequently, our successful brood estimates may be lower than the actual number of chicks that survived. Field observations suggest that more chicks may have survived than reported, since many un-collared hens with chicks were observed in the study area. As reported, this population of sage-grouse does not measure up to the guidelines of ≥ 2.25 juveniles per hen (Connelly et al. 2000) in either 2005 or 2006. Low brood success may be limiting the population growth; however, these data are not firm enough to draw broad conclusions. We need more accurate data on brood success for this population.

Brood Site Vegetation

Connelly et al. (2000) suggest that brood sites have 10-25% sagebrush cover with 20-80 cm height, and >15% grass-forb cover with variable height. Sage-grouse within this population selected sites within the upper range of sagebrush cover within the suggested guidelines, and heights in the middle of the range for sagebrush. Forb and grass cover were higher than the guidelines in 2005, and forb cover was lower than the guidelines, and grass cover within the guidelines in 2006. Broods select areas with a certain amount of hiding cover. The wet spring of 2005 produced more forb and grass cover with taller plants, and broods were found in areas with less shrub cover and shorter shrubs. The drier spring of 2006 produced less forb and grass cover with shorter plants, and broods selected areas with higher shrub cover and height.

Brood Site Arthropods

We captured 25 families of arthropods during the study. We captured 22 families of arthropods at brood locations. Drut et al. (1994) reported 41 families of invertebrates consumed by chicks, based on availability; beetles, ants, and grasshoppers were considered primary foods. Ants (Formicidae) made up the vast majority of the arthropods captured in the Sheeprock study site, accounting for 77% based on volume (Appendix Table A.1). Ants and beetles were the most available groups of arthropods; we captured few grasshoppers. In west Box Elder County, Utah, using the same capture methods grasshoppers and Mormon crickets made up the majority of arthropods available, and ants only made up 20% of arthropod volume (J. Knerr, Utah State University, unpublished report). Ants might be the first groups of arthropods to recover from the Mormon cricket control efforts, and possibly benefited from higher forb cover and lowered competition.

Movements

Movements for 2006 were very similar to movements in 2005. Most hens nested within 3.2 km of a lek, and most broods stayed near the nest site. Movements by this population were very similar to movements described by Connelly et al. (2000). Individuals in this population appear to migrate from their summer brood-rearing habitat to their wintering habitat, and most likely this is driven by snow accumulation in the summer range. This population of sage-grouse would best be described as a type 3, one-stage migratory population, according to Connelly et al. (2000). The birds select the higher elevation sites in the summer to benefit from the forb and insect abundance that result from higher levels of precipitation, but as winter approaches the snow accumulates to a depth too high for grouse, which forces them to lower elevations to winter.

This population showed high fidelity to seasonal ranges. The average sagebrush height above snow was 47.98 cm, with 20-30% sagebrush cover. Both aspects of winter range sagebrush cover and height are within the suggested guidelines of Connelly et al. (2000).

Mortalities

No grouse mortalities occurred from human structures, including fences. No known mortalities have occurred from West Nile Virus. Several un-collared grouse were found dead, but had been heavily scavenged, and cause of mortality could not be determined. We encountered many sportsmen in the field looking for sage-grouse to hunt in the fall. Hunting sage-grouse in Tooele and Juab counties was banned in 1990 and 1988, respectively. An interesting note is that hunters in annual mail surveys reported taking sage-grouse in these counties as late as 2001, even though it was unlawful. All sportsmen we encountered were informed it was unlawful to harvest sage-grouse in the counties. Poaching of sage-grouse most likely occurs at the research site; however, no collared grouse were killed by poachers.

The survival rate for adult females is at or below the mean for published ranges (Crawford et al. 2004) (Table 2.1). Male survival rates are near the average for published ranges (48.9%) (Crawford et al. 2004); however, this is based on a small sample size. The population suffers high rates of predation. The biggest contributing factors are: golden eagles taking sage-grouse on and near the leks, red fox and coyote predation, and added physical stress from migratory movements. Most mortality occurs in early spring and late fall.

Management Implications

One of the most important factors in the Sheeprock Watershed is locating areas used by sage-grouse. The best way to find new areas of use is to find leks. Additional leks are suspected to exist. The area should continue to have counts conducted during peak male attendance, and extensive searches for new lek sites. Lek attendance is used for population estimates. Most female grouse in the study site nest within 3.2 km of a lek. Most brood-rearing takes place near leks. If additional leks are located, additional areas of nesting and brood-rearing habitat will be identified. Having more and accurate information regarding leks will aid in the recoveries of the populations of sage-grouse in the Sheeprock Watershed study site.

Chick recruitment is also very important to the Sheeprock Watershed population. Our estimates of recruitment are very low. More and better brood-rearing habitat needs to be identified and or created. Dahlgren et al. (2006) showed an increase in brood use by creating small openings in large expanses of identified brood rearing habitat; with most sage-grouse using areas within 30 m of an edge. I believe more and better brood-rearing habitat could be created in the study site. The area is moisture limited; thus, a reduction in shrubs should result in an increase in forbs. An increase in forbs may mean an increase in arthropods as well. Also, I suggest more research on chick survival and recruitment.

Currently, the winter ranges for this population are in good condition; however, the study site has recently been devastated by wildfires. The winter ranges consist mostly of Wyoming big sagebrush with a cheatgrass understory. They are very susceptible to a catastrophic wildfire. I recommend both winter ranges receive top priority for wildfire suppression.

There is currently a lot of predator control in the study site, mostly for pronghorn and mule deer benefit. Anecdotal evidence suggests coyote removal may be allowing red fox to increase in number. Red fox have been shown to be major predators of sage-grouse (Bunnell et al. 2000). Red fox are being taken by WS on a more frequent basis. The control efforts of WS seem to be reducing the number of common ravens during critical nesting and early brood rearing times. I suggest continued predator control efforts, especially targeting red fox and common ravens.

Hunting of this population should not occur at this time. The population is small, with limited or no interaction with other populations. If more areas of use are identified and more leks are located, and subsequently a higher population number is estimated, the population may be able to withstand some limited fall hunting. Unlawful hunting of sage-grouse in the study site may be a contributing factor to mortalities. A more extensive outreach program on sage-grouse poaching will benefit this population.

The Sheeprock Watershed population of sage-grouse occurs on a variety of land ownerships. A critical component of maintaining this population is working with government agencies and private land owners. Habitat improvement projects must be monitored, and set up in a way to show the benefits to the project. The most critical sage-grouse use areas are on private lands. Relationships have been formed through the working group process, and those relationships must remain intact and on good terms. The WDARM has been instrumental in creating relationships. This work must continue.

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Table 2.1. Population dynamics of greater sage-grouse monitored, Sheeprock Watershed, Utah, 2005-2006.

	2005			2006		
Parameter	N	n	%	N	n	%
Nest Initiation	19	10	52.6	22	18	81.8
$\bar{x}$ Nest Initiation Date		7 MAY			19 APR	
Successful Nests	10	7	70	18	10	55.6
Nests Under Sagebrush	10	7	70	18	15	83.3
$\bar{x}$ Distance, Lek to Nest		1.95 km			1.6 km	
$\bar{x}$ Clutch size		6.0			6.3	
Brood Success	7	2	28.6	10	3	30
Chicks/successful brood		3.5			1.7	
Annual Survival						
Adults	19	12	63.2	25	12	48
Males	3	2	66.7	6	2	33.3
Females	16	10	62.5	19	10	52.6
Juveniles	5	2	40	2	1	50
Males	0	N/A	N/A	0	N/A	N/A
Females	5	2	40	2	1	50

Table 2.2. Vegetation parameters measured at greater sage-grouse nest sites; Sheeprock Watershed, Utah, 2005-2006. An asterisk (*) denotes a significant difference.

	2005		2006	
Parameter	Mean (SE)	Range	Mean (SE)	Range
Nest Bush Height (cm)	91.2 (7.4)	75-141	96.2 (8.2)	56-218
Nest Bush Diameter (cm)	230.3 (30.1)*	125-365	171.4 (13.2)*	97-289
Shrub Cover (%)	33.5 (3.1)	13.8-44.8	34.2 (3.6)	1-57.7
Shrub Height (cm)	55.2 (12.3)	19-142.4	61 (7.0)	19-141
Sagebrush Cover (%)[a]	62.6 (11.7)	3.2-96.7	83.5 (3.9)	45.9-100
Sagebrush Height (cm)	55.5 (8.9)	15.5-108.7	64.3 (4.2)	22-95.1
Forb Cover (%)	34.5 (7.4)*	6.3-71.3	13.9 (2.1)*	0.8-27.8
Forb Height (cm)	18 (2.3)*	10.4-33.3	10.4 (0.8)*	4.7-17.3
Grass Cover (%)	33.9 (3.5)*	21.7-54	14.7 (1.5)*	2.1-26
Grass Height (cm)	34 (4.2)*	18.6-54.3	22.6 (1.2)*	15.7-34
Rock Cover (%)	7.8 (1.6)*	0.5-16.8	3.4 (0.8)*	0-10.1
Bare Ground (%)	24.1 (3.1)	7.7-39.9	17.7 (2.5)	1.7-36.8
Litter Cover (%)	41.2 (5.0)	16.8-60.2	41.5 (2.5)	27.6-72
Robel In (cm)	65.8 (6.0)	49-92	71 (6.1)	27-133
Robel Out (cm)	40 (8.6)	16-100.8	42.3 (5.6)	13-96.5
Slope (degrees)	7.4 (1.9)	2-18	5 (0.7)	1-12

[a] Represents the percent of total shrub cover that is sagebrush

Table 2.3. Arthropod diversity, abundance, and volume at greater sage-grouse nest sites, means per site averaged over 7 week, Sheeprock Watershed, Utah, 2005-2006.

	2005		2006	
Parameter	Mean (SE)	Range	Mean (SE)	Range
Number of Families	22		22	
Number of ants	697.6 (391)	7-2920	188.5 (93.3)	8-980
Volume of ants (mL)	8.7 (5.1)	0.04-37	1.7 (0.9)	0.01-9.2
Number of all others	17.1 (4.7)	0-32	24.3 (3.3)	7-41
Volume of all others (mL)	2.1 (1.2)	0-8.9	2.7 (1.1)	0.02-10.6

Table 2.4. Vegetation measured at greater sage-grouse brood and random sites, Sheeprock Watershed, Utah, 2005-2006.

	2005				2006			
	Brood		Random		Brood		Random	
Parameter	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Shrub Cover (%)	23.6 (2.9)*	1.5-62.5	18.4 (3.1)	0-45.4	34.4 (2.0)*	1.6-81.2	31.4 (4.0)	0.7-70
Shrub Height (cm)	42.2 (2.3)*	14-68.2	48.3 (3.5)	33-80.7	51.1 (2.7)*	17-138.4	49.2 (3.5)	13-73
Sagebrush Cover (%)[a]	73.6 (3.8)	6.5-100	72.9 (6.0)	19.6-100	72.7 (3.4)	2.1-100	69.6 (7.4)	2.3-100
Sagebrush Height (cm)	49 (3.1)	11-88.9	52 (5.0)	13.9-88.4	58.7 (2.8)	11-113.2	57.9 (5.3)	20-111
Forb Cover (%)	24.1 (2.1)*	2.8-54.8	24.5 (3.6)	4.4-48.9	9.9 (0.8)*	0-33.1	10 (2.0)	0.1-39
Forb Height (cm)	17.3 (0.7)*	7-26.4	13.8 (1.0)*	8.3-24	11.6 (0.4)*	4-22	11.7 (0.7)	3-16.9
Grass Cover (%)	28.6 (2.2)*	11.1-67.5	33.1 (4.8)	6.4-80.9	18.3 (1.0)*	3.1-43.3	14.5 (1.5)	4.1-28
Grass Height (cm)	34 (1.1)*	18.1-50	36.4 (2.0)	20.5-48.9	24.6 (0.8)*	11.2-60.7	24.4 (1.0)	18-34
Litter Cover (%)	35.3 (2.5)	10.3-75.9	36 (4.4)	11.5-68.6	38.3 (1.1)	21.6-66.6	35 (2.2)	14.8-61
Bare Ground (%)	26 (2.0)*	6.6-54.1	28.5 (2.8)	9.4-53.8	19 (1.0)*	3-39.1	23.5 (2.0)*	5.9-41

[a] Represents the percent of total shrub cover that is sagebrush

* denotes a significant difference

Table 2.5. Arthropod abundance and volume measured at brood and random sites, means per site averaged over 7 weeks, Sheeprock Watershed, Utah, 2005-2006.

	2005				2006			
	Brood		Random		Brood		Random	
Parameter	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Number of Families	22		21		22		22	
Number of ants	1112.5 (521.2)	10-6531	210.6 (160.6)[a]	15-2135	797.3 (392)	8-7304	170.5 (69)	2-1256
Volume of ants (mL)	15.1 (7.1)	0-75.5	2.7 (2.6)[a]	0.01-30.9	10.9 (5.2)	0.03-86	1.7 (0.8)	0-11
Number of all others	17.6 (2.7)	6-37	20.8 (3.7)	3-55	17.7 (2.3)	8-49	13.9 (2.1)	4-38
Volume of all others (mL)	8.2 (4.5)	0.2-66.5	3.2 (1.5)	0.02-23.1	1.2 (0.2)	0.1-3.4	0.5 (0.1)	0.1-1.8

[a] Excluding 2 outliers with 10,865 and 9,941 ants, and 104 and 143 mL, respectively

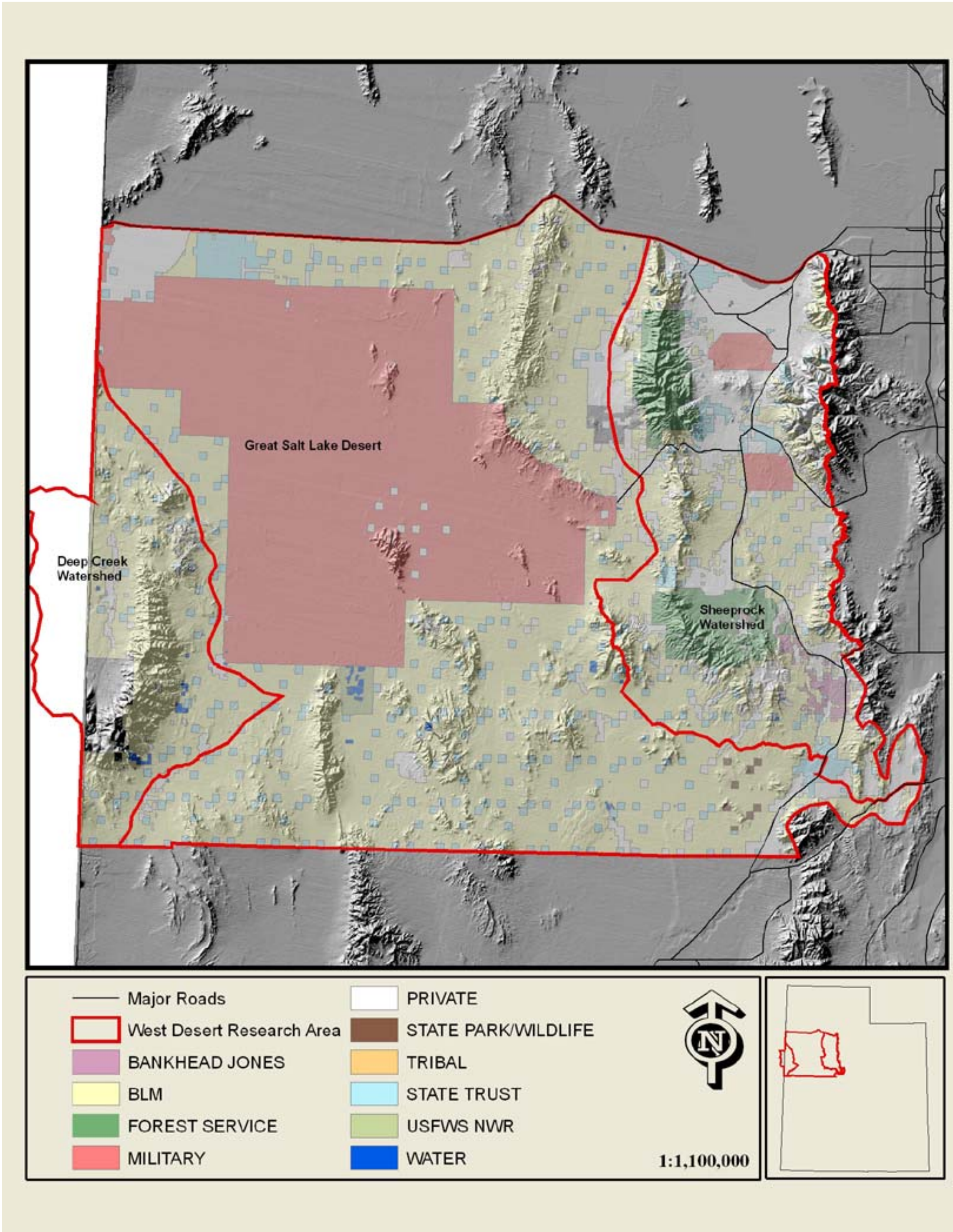

Figure 2.1. The West Desert Study Area showing the Sheeprock Watershed and the Deep Creek Watershed study sites, separated by the Great Salt Lake Desert, Utah.

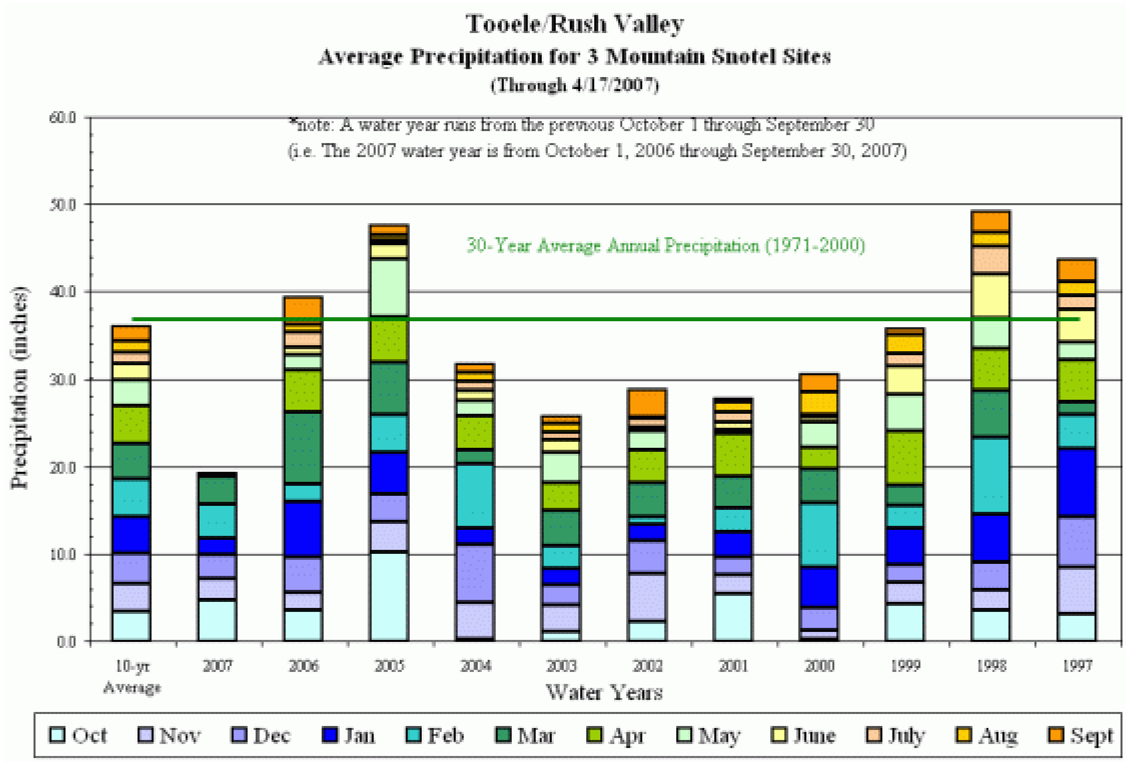

Figure 2.2. The average precipitation falling in Tooele/Rush Valley, Utah, 1997-April 2007.

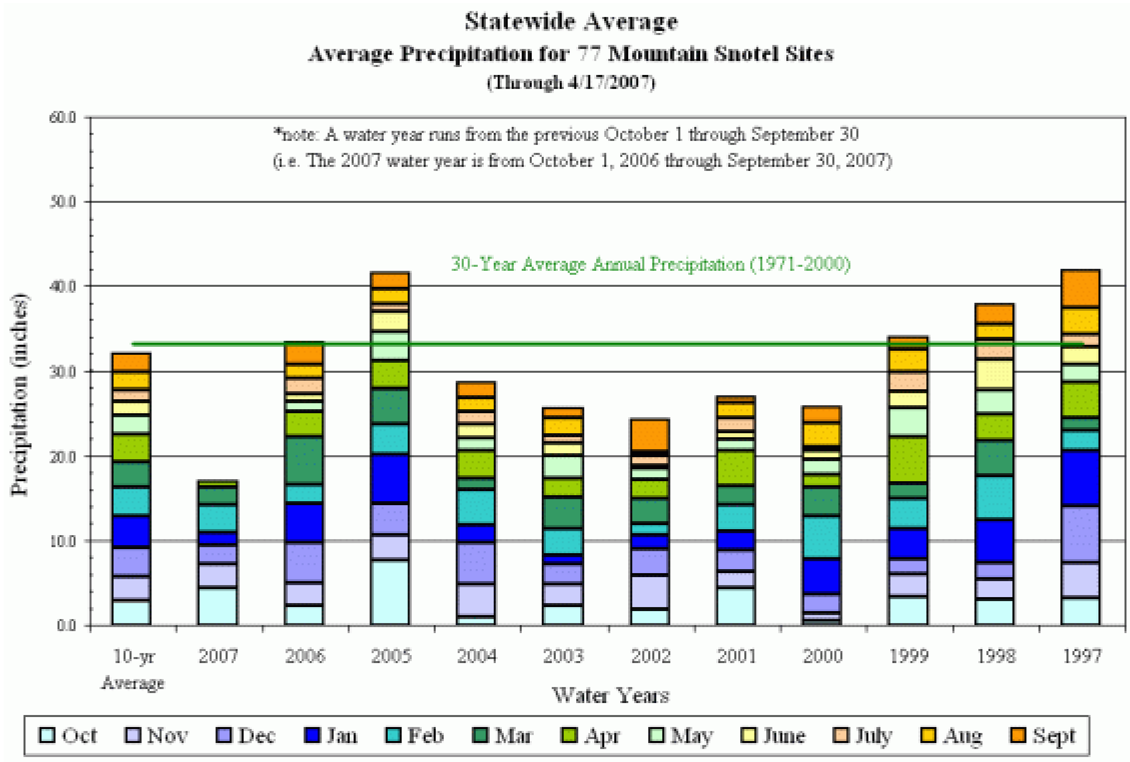

Figure 2.3. Average statewide precipitation falling in Utah, showing the 30-year average, 1997-April 2007.

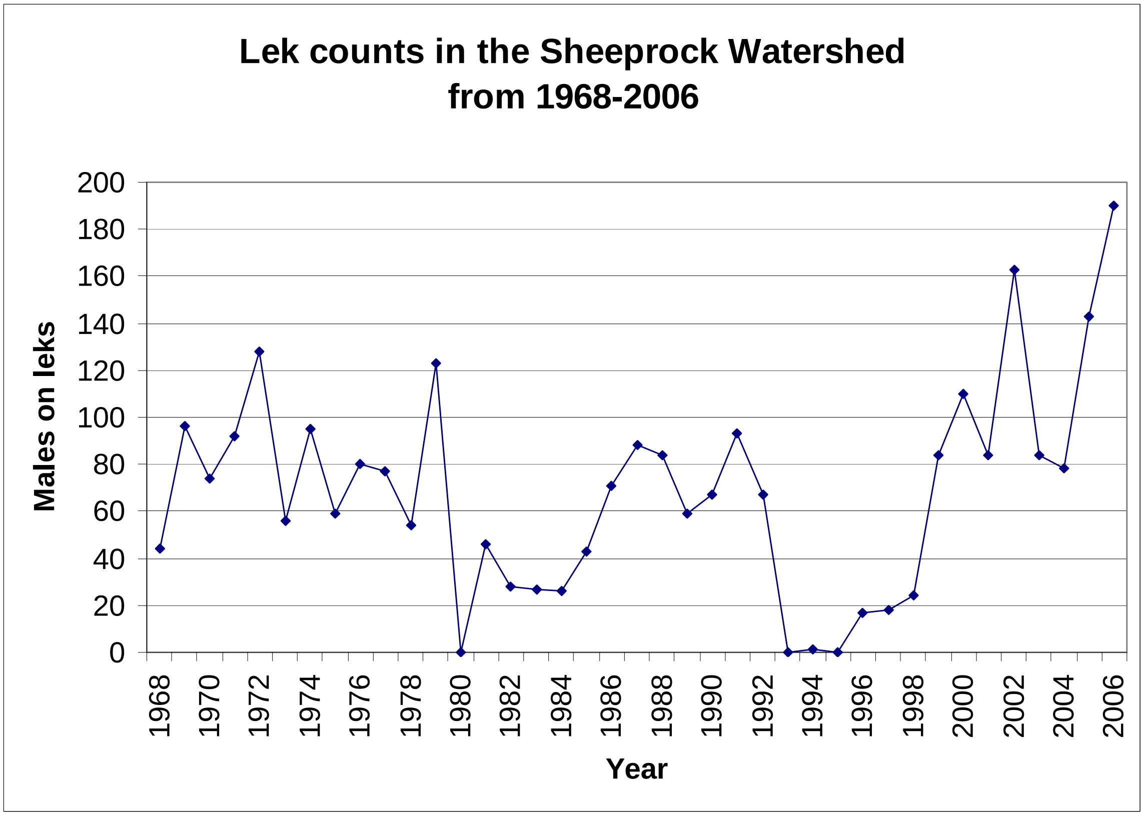

Figure 2.4. Lek surveys assessing male greater sage-grouse lek attendance, zeros indicate no counts were conducted, Sheeprock Watershed, Utah, 1968-2006.

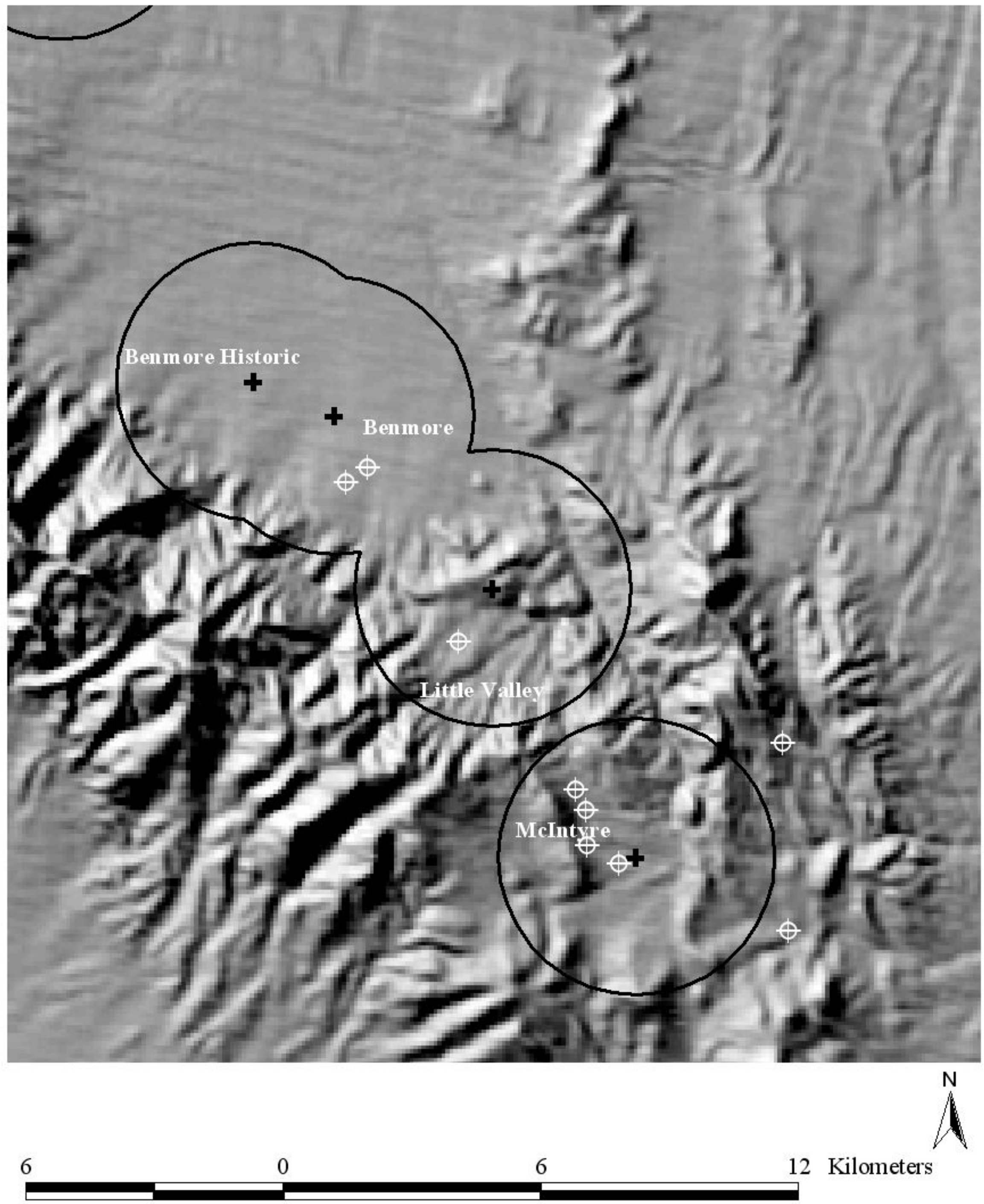

Figure 2.5. Greater sage-grouse nest site locations (crosshairs) in comparison to lek sites (bold cross) with a 3.2-km buffer around each lek, Sheeprock Watershed, Utah, 2005.

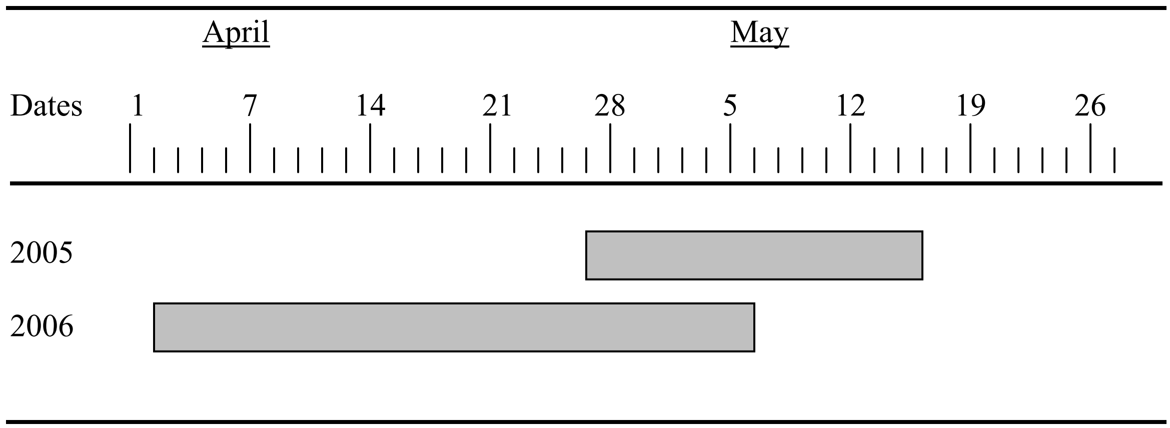

Figure 2.6. Greater sage-grouse successful nest initiation dates, Sheeprock Watershed, Utah, 2005-2006,

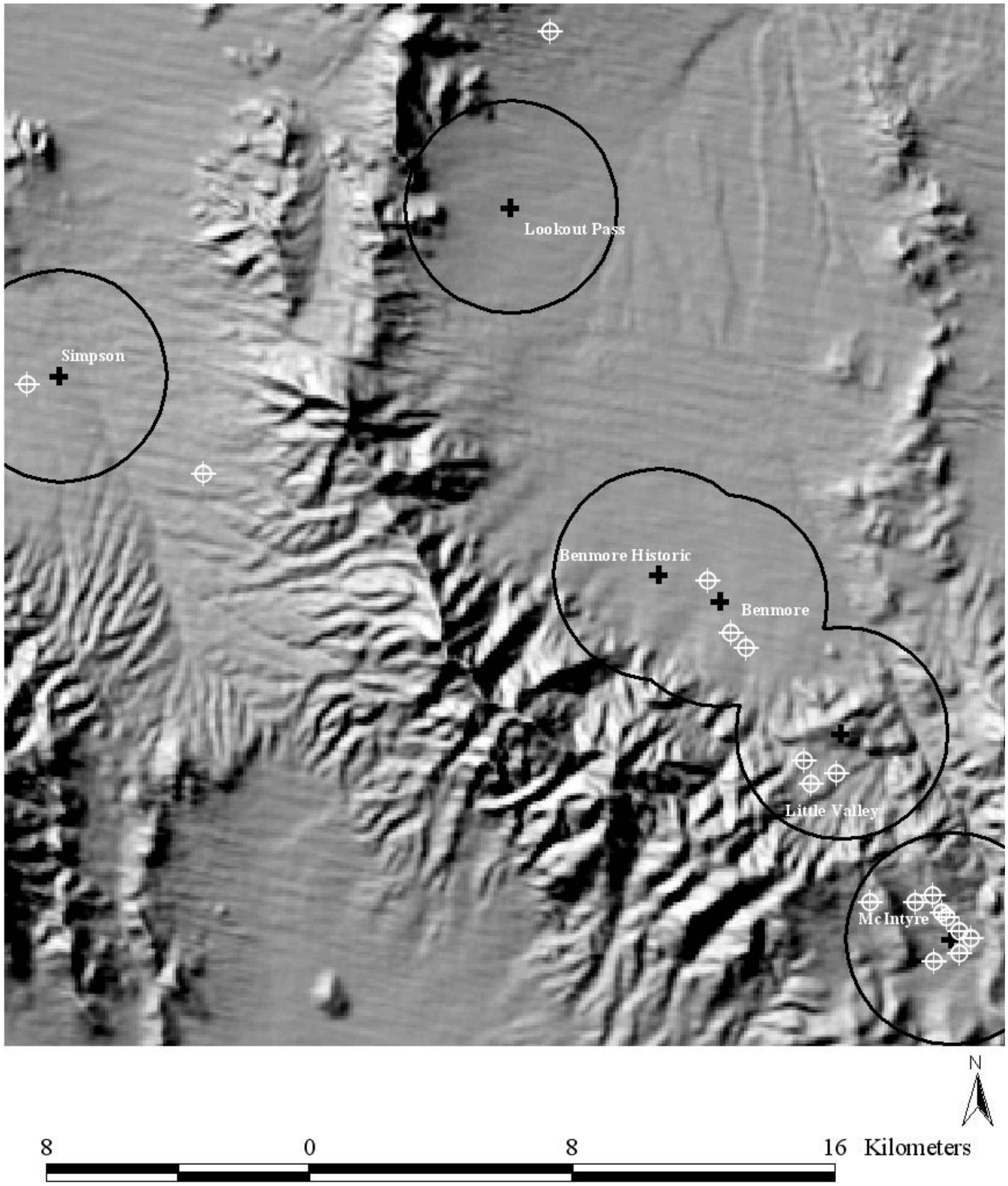

Figure 2.7. Greater sage-grouse nest site locations (crosshairs) in comparison to lek sites (bold cross) with a 3.2-km buffer around each lek, Sheeprock Watershed, Utah, 2006.

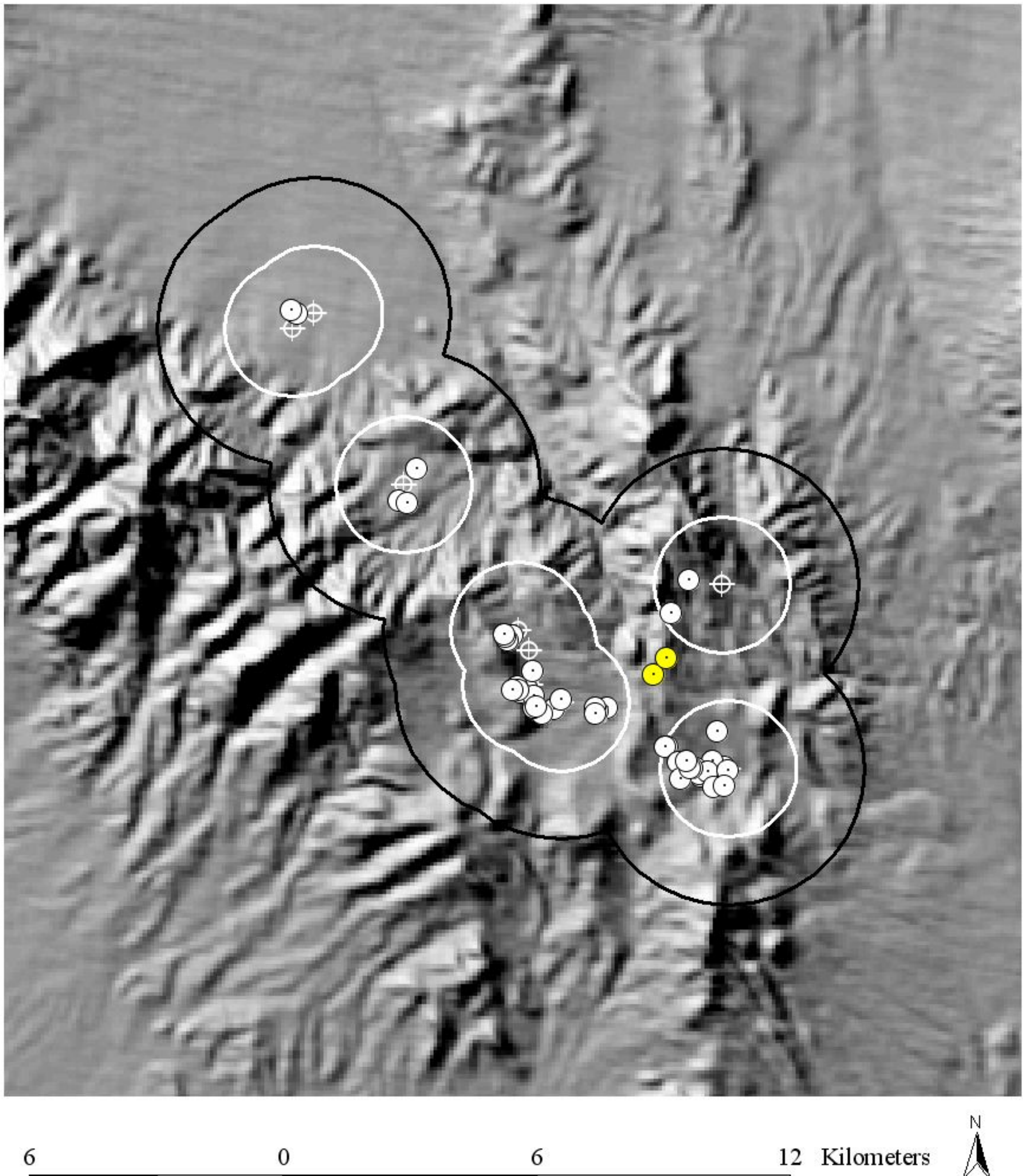

Figure 2.8. Greater sage-grouse brood site locations (dotted circles) in comparison to nest site (crosshairs) with a 1.6-km (white) and 3.2-km (black) buffer around each nest site, Sheeprock Watershed, Utah, 2005.

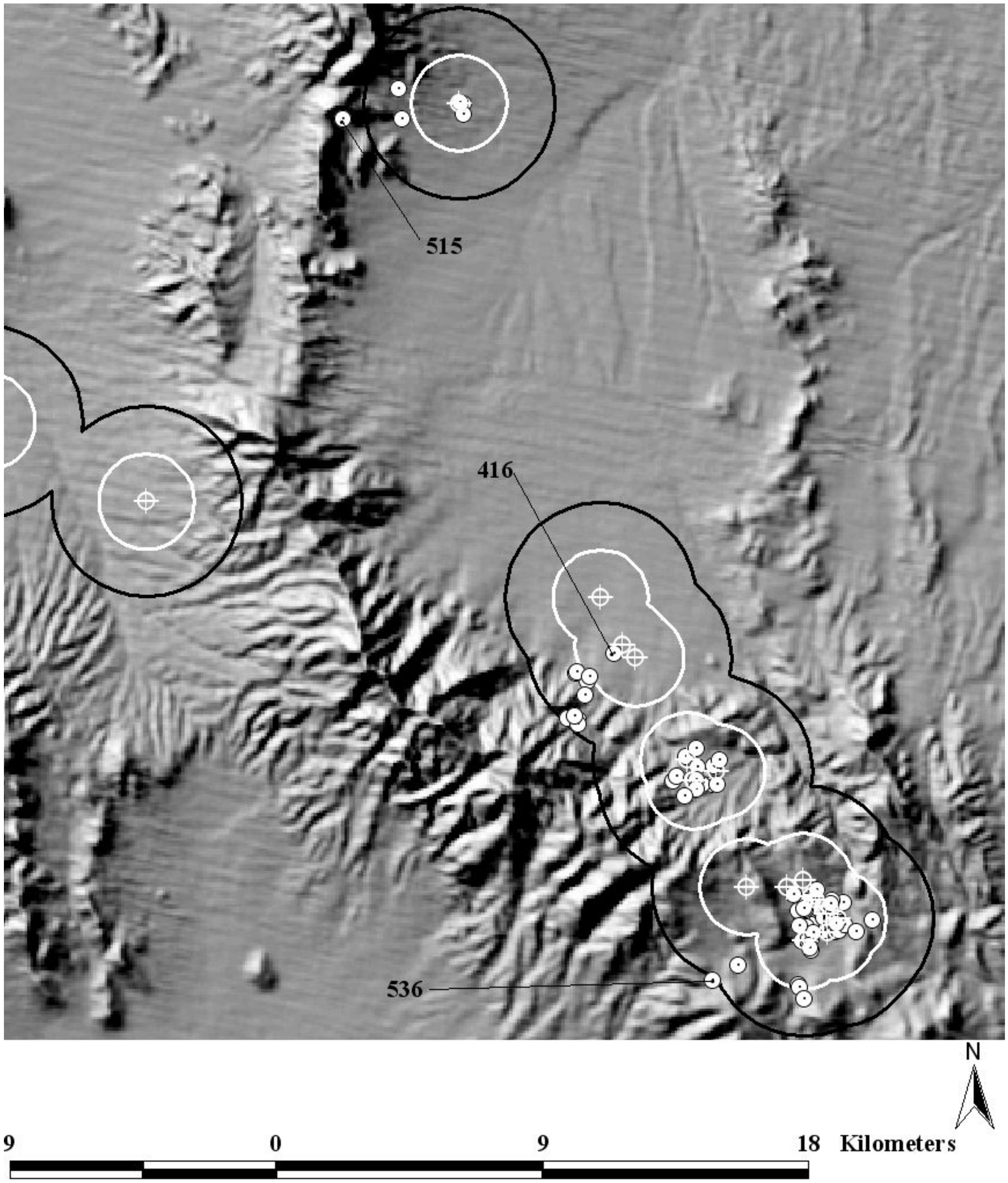

Figure 2.9. Greater sage-grouse brood site locations (dotted circles) in comparison to nest sites (crosshairs) with a 1.6-km (white) and 3.2-km (black) buffer around each nest site, Sheeprock Watershed, Utah, 2006.

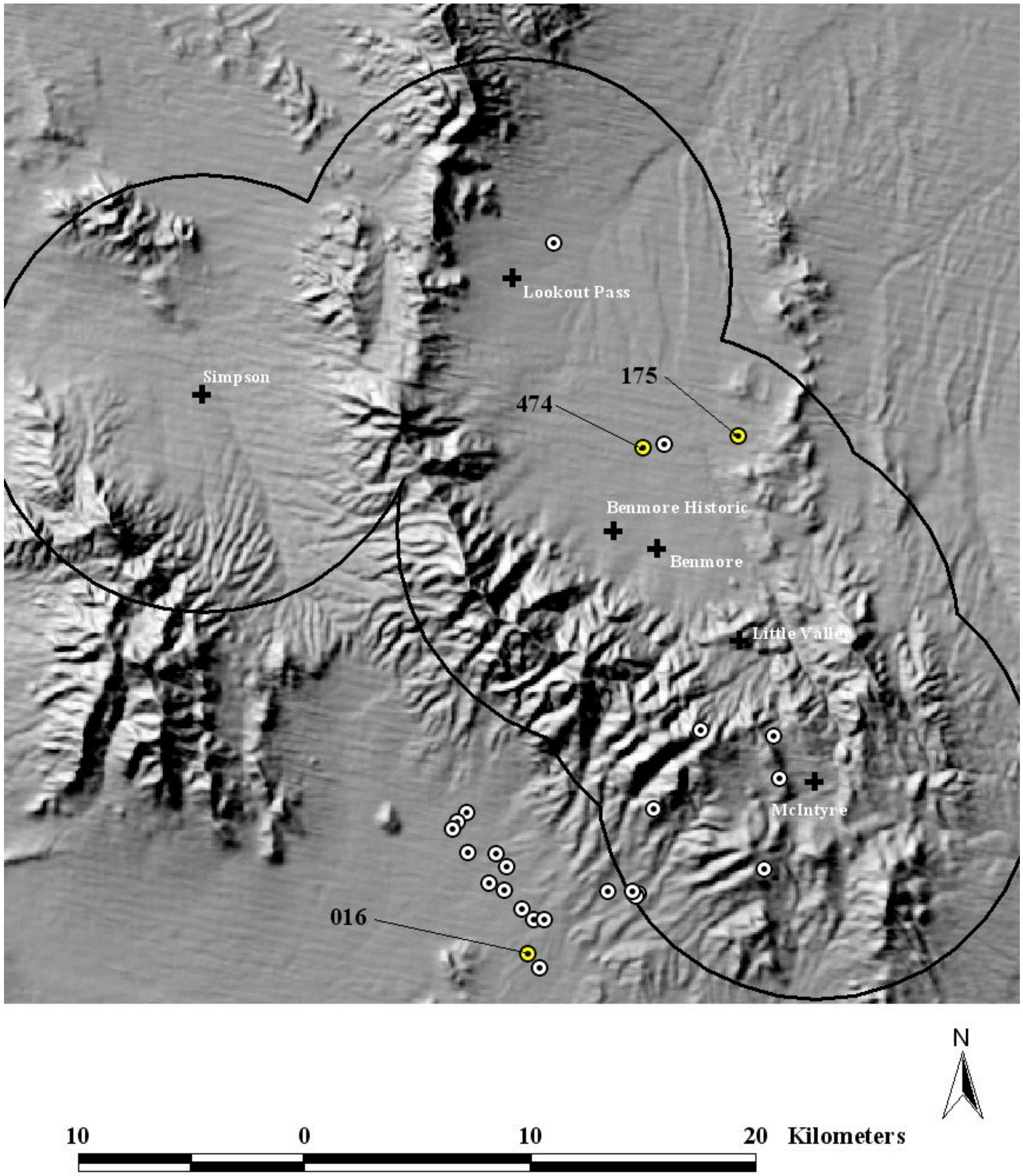

Figure 2.10. Greater sage-grouse winter locations (dotted circles) in comparison to lek sites (bold crosses) with a 9.6-km buffer around each lek, Sheeprock Watershed, Utah, 2005-2006.

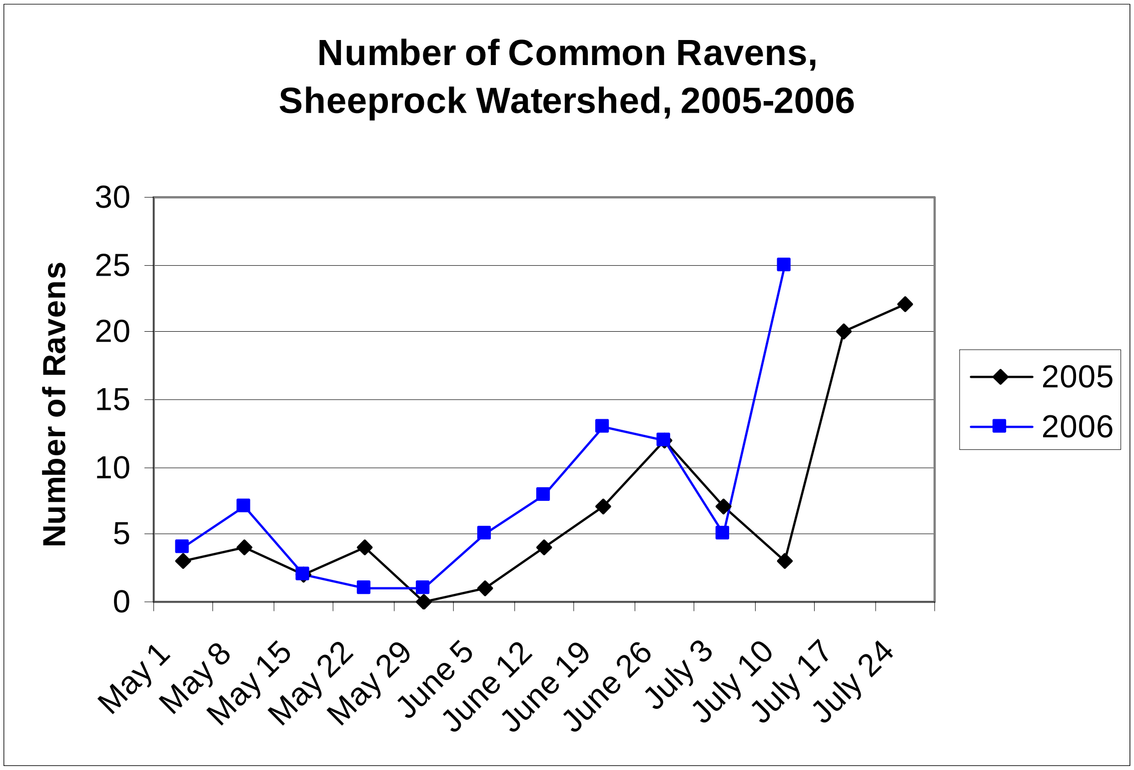

Figure 2.11. The number of common ravens observed on a weekly survey during nesting and early brood-rearing times, Sheeprock Watershed, Utah, 2005-2006.

CHAPTER 3

ECOLOGY OF THE GREATER SAGE-GROUSE POPULATION INHABITING THE DEEP CREEK WATERSHED IN UTAH'S WEST DESERT

Abstract: Little is known about the ecology of greater sage-grouse (*Centrocercus urophasianus*) sub or meta-populations which occur throughout the historic range of the species. Many of these populations are geographically separated as result of habitat fragmentation. The greater sage-grouse population inhabiting the Deep Creek Watershed in Utah's West Desert is believed to be isolated from other Utah populations. In 2004, the West Desert Adaptive Resource Management (WDARM) local working group was organized to develop and implement a local sage-grouse conservation plan for the area. Better information about the ecology of the sage-grouse population in the area will be needed to guide this effort.

I monitored 12 greater sage-grouse using radio telemetry techniques between March 2005-February 2007 to describe seasonal habitat use patterns and relationships to vegetation, lekking areas and reproductive chronology, productivity, population dynamics, and provide a better estimate of the population. I subsequently compared my results to published reports in the literature and recommended guidelines. The population in the Deep Creek Watershed was estimated to be at a historic high, with 372 individuals, but this was largely attributed to increased survey efforts. The Deep Creek population is non-migratory, and exhibiting a relatively high adult survival rate and large clutch sizes. Nest initiation and success were within ranges reported in the literature, but chick

recruitment was lower. Wide variation in seasonal precipitation affected vegetation structure and composition. Conservation actions designed to enhance and protect seasonal use areas may help mitigate the effects of variable precipitation on critical habitats.

Introduction

Greater sage-grouse (*Centrocercus urophasianus*) occupy an estimated 56% of the pre-settlement distribution of potential habitat, and populations are in steady decline (Schroeder et al. 2004). Beck et al. (2003) reported similar trends for sage-grouse in Utah. Sage-grouse distribution and populations throughout the range and in Utah are closely associated with sagebrush (*Artemisia* ssp.) occurrence (Patterson 1952). Factors frequently cited for declining sage-grouse populations include: alterations in fire regime, excessive livestock grazing, proliferation of non-native plants, conversion of rangelands to pastures seeded to crested wheatgrass (*Agropyron desertorum*), croplands, roads, gas development, and other land alterations (Crawford et al. 2004).

Connelly et al. (1991), Connelly et al. (1993), Gregg et al. (1993), Schroeder (1997), Holloran et al. (2005) and others have reported on the role of several habitat features in the nesting ecology of sage-grouse. Concomitantly, guidelines have been published to aid managers in managing for sage-grouse and their habitats (Braun et al. 1977, Connelly et al. 2000, Danvir 2002, Connelly et al. 2004, Crawford et al. 2004).

Additionally, the availability of arthropods has been reported as a critical component for egg-laying females and the early survival of chicks (Johnson and Boyce 1990, Barnett and Crawford 1994, Drut et al. 1994). Predators are also a concern for sage-grouse populations, both for predation of adult grouse, and eggs and chicks (Ritchie et al. 1994, DeLong et al. 1995, Schroeder and Baydack 2001, Holloran and Anderson 2003, Mezquida et al. 2006).

The Utah Division of Wildlife Resources (UDWR) began conducting lek surveys in the Deep Creek Watershed in 1982. However, because of the remoteness of the site, no other information was collected. Thus, the West Desert Adaptive Resource Management local working group (WDARM) was interested in learning more about the population to better guide their management efforts.

I used radio telemetry techniques to assess breeding ecology and habitat use by greater sage-grouse. The purpose of this research was to estimate population numbers, to determine breeding, nesting, brood-rearing, and wintering habitat, to determine hen nesting dates and success, nest site vegetation characteristics, brood success, brood site vegetation characteristics, and mortality rates for adults. I compared our results to the recommended guidelines for a self-sustaining population of greater sage-grouse. The information obtained will be used by the WDARM to develop and implement a local sage-grouse conservation plan.

Study Area

The West Desert Study Area is located in Utah's West Desert and within the boundaries of the conservation area delineated by WDARM. The conservation area encompasses 2,079,294 ha. It is bounded to the south by the Juab/Millard County line, on the east by the Tooele/Utah County line and Highway 6, on the north by I-80, and on the west by the Utah/Nevada state line, excluding land managed by the U.S. Department of Defense (DOD). The study area is divided into two study site subunits, the Deep Creek Watershed site and the Sheeprock Watershed site (Figure 3.1). The focus of the Deep Creek Watershed site is west of the Deep Creek Mountain range in Ibapah Valley. It encompasses the Goshute Indian Reservation, and is near the town of Ibapah, by the Utah/Nevada border. The Deep Creek Watershed study site is separated from the rest of the state by the southern end of the Great Salt Lake Desert. There is no evidence that sage-grouse currently inhabit the desert salt flats or can cross the flats due to lack of suitable habitat. The study area encompasses a variety of land ownerships, including: Bureau of Land Management (BLM), U.S. Forest Service (USFS), state, and private lands. The BLM manages 50% of the study area, DOD manages 27%, private ownership is 11%, state 6%, USFS 3%, and the Bureau of Indian Affairs, U.S. Fish and Wildlife Service, and water make up <1% each (WDARM 2007).

The Deep Creek Watershed site is characterized by hot dry summers and cold winters. According to the Western Regional Climate Center (2007), the 50-year average maximum summer temperature is 33.3° C (92.0° F) in July and the average minimum winter temperature is -11.8° C (10.8° F) in January. Average total precipitation is 8.4 cm (3.3 in) in spring, 6.5 cm (2.6 in) in summer, 5.5 cm (2.2 in) in autumn, and 4.5 cm (1.8 in) in winter, for an annual average of 24.8 cm (9.8 in). Average total snowfall is 76.7 cm (30.2 in) per year, with November-March receiving the majority of the snowfall, with the most falling in January (17 cm). The spring of 2005 was exceptionally wet with 15.4 cm (6.1 in) of precipitation falling from 1 March – 31 May, which is almost twice the 30 year average (Figure 3.2).

Members of The Church of Jesus Christ of Latter-day Saints herded livestock into Tooele County prior to the establishment of permanent settlements which arrived in 1849. Early settlers of Tooele and Juab valleys relied on sheep and cattle herds and hay and grain crops. Mining came later, and was an important industry for the area (WDARM 2007). Livestock, especially sheep and cattle, are still grazed on the study area. Ranching is a major industry for private landowners, and both the USFS and BLM have grazing allotments on the lands they manage. The Goshute Tribe leases out their property to cattle grazing, as well as pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), and elk (*Cervus elaphus*) hunting.

Vegetation

The lower elevations are often areas of crested wheatgrass, with areas of Wyoming big sagebrush (*A. tridentata wyomingensis*) interspersed. The site has areas dominated by saltbush (*Atriplex* spp.) and greasewood (*Sarcobatus* spp.), in the lowest elevations. At mid-elevations the dominant shrub species is Wyoming big sagebrush, with silver sagebrush (*A. cana*) in the wetter drainages. As elevation continues to increase, additional vegetation is comprised of a variety of shrubs, including: serviceberry (*Amelanchier alnifolia*), snowberry (*Symphoricarpos albus*), antelope bitterbrush (*Purshia tridentata*), chokecherry (*Prunus virginiana*), and juniper (*Juniperus* spp.) stands. At the highest elevations there is mountain big sagebrush (*A. t. vaseyana*), with quaking aspen (*Populus tremuloides*) in the higher elevation drainages. Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) and rubber rabbitbrush (*C. nauseosus*) are found in varying densities throughout the sites at all elevations. Some of the more abundant and associated grasses and forbs include: cheatgrass (*Bromus tectorum*), crested wheatgrass, sandberg bluegrass (*Poa secunda*), bulbous bluegrass (*P. bulbosa*), bluebunch wheatgrass (*Elymus spicatus*), western wheatgrass (*E. smithii*), squirreltail (*E. elymoides*), Indian ricegrass (*Stipa hymenoides*), basin wildrye (*Leymus cinereus*), lupine (*Lupinus* spp.), milkvetch (*Astagalus* spp.), hawksbeard (*Crepis* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), phlox (*Phlox* spp.), alfalfa (*Medicago* sp.), and clover (*Trifolium* spp.).

Wildlife

Some of the more common mammalian species include: mule deer, elk, pronghorn, wild horses, coyote (*Canis latrans*), badger (*Taxidea taxus*), weasel (*Mustela* spp.), black-tail jackrabbit (*Lepus californicus*), desert cottontail (*Sylvilagus auduboni*), pygmy rabbit (*Brachylagus idahoensis*) (recently rediscovered), mountain lion (*Felis concolor*), and yellow-bellied marmot (*Marmota flaviventris*). Some common avian species include: western meadowlark (*Sturnella neglecta*), horned lark (*Eremophila alpestris*), common raven (*Corvus corax*), black-billed magpie (*Pica pica*), golden eagle (*Aquila chrysaetos*), sage sparrow (*Amphispiza belli*), sage thrasher (*Oreoscoptes montanus*), Brewer's sparrow (*Spezella breweri*), northern harrier (*Circus cyaneus*), American kestrel (*Falco sparverius*), vesper sparrow (*Pooecetes gramineus*), Brewer's blackbird (*Euphagus cyanocephalus*), loggerhead shrike (*Lanius ludovicianus*), chukar (*Alectoris chukar*), turkey vulture (*Cathartes* aura), mourning dove (*Zenaida macroura*), and red-tailed hawk (*Buteo jamaicensis*).

Predator Control

The United States Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services (WS) conducted the predator control in the Deep Creek Watershed during the study. However, no records were kept of the number of predators removed because it was not considered a livestock or wildlife protection area (M. Tamllos, USDA APHIS WS, personal communication).

Tooele County has offered bounties for predators since 2001, paid for by the county and in part by the Utah Department of Agriculture. The county keeps records of the number of coyotes brought in for bounty. The average number of coyotes taken for bounty in 2001-2004 was 397 coyotes; during 2005 and 2006, 700 and 750 coyotes, respectively, were taken for bounty (M. Jensen, Tooele County Auditors Office, personal communication). The county stipulates the coyotes should be taken by county residents in Tooele County. In addition, many recreational predator hunters hunt and trap within the research area and surrounding areas. They contribute some removal of predators in the area, but no records are kept of animals taken. Statewide estimates of the number of coyotes taken by hunters can be as high as twice the number taken by WS (Mezquida et al. 2006).

Red foxes and common ravens have been implicated in affecting nest success and the annual survival of breeding age birds in the Strawberry Valley area of Utah (Bunnell et al. 2000). Common ravens have been shown to be substantial nest predators on sage-grouse (Willis et al. 1993, Coates and Delehanty 2004). In artificial nest studies conducted in Strawberry Valley, ravens depredated 98% of artificial nests within 48 hours of their placement; remote cameras were used to verify the identity of artificial nest predators (R. Baxter and J. Flinders, Brigham Young University, unpublished report). There was no raven removal conducted within the research site in 2005 or 2006 due to budget constraints. No red foxes were ever observed in the study site.

Methods

Captures

To determine current habitat use and movement patterns of greater sage-grouse hens, we proposed to capture up to 10 hens and 10 cocks, 20 birds total, each year over a 2-year period and fit each of them with a radio-collar. The collars were programmed (mortality signal cycle: 5 hours off, 19 hours on) 16.5 g Advanced Telemetry Solutions™ (PO Box 398, 470 First Avenue North, Isanti, MN 55040) necklace collars with a frequency range from 151.000-151.999 Mhz. Radio-collared birds were located using Telonics, Inc.™ (932 East Impala Avenue, Mesa, AZ 85204) and ICOM America Inc.™ (2380 116th Avenue northeast, Bellevue, WA 98004) receivers, handheld 3-element Yagi folding antennas, and vehicle mounted Omni antennas (RA-2A).

The capture methods consisted of going to the lek areas at night during lekking months (March-May). Sage-grouse could be captured at night with a spotlight and long dip net while they roosted near the leks (Giesen et al. 1982, Connelly et al. 2003). Sage-grouse prefer to roost on the ground in open areas within or near sagebrush. With the aid of binoculars, the spot light caused an eye shine on the roosting grouse and could be seen from up to 100 m. The grouse would then be approached by 2 individuals, 1 holding the spotlight and the other would have the long handled dip net. The spotlight and the noise from the vehicles would distract the roosting birds. The grouse was netted with the handheld dip net by a second person while it was distracted. Several grouse can be caught each night using this technique. The overall health of the grouse was visually ascertained before attaching the collar. The radio-transmitter was then attached to the grouse around the neck, with adequate space as to not impede the grouse's daily activities (Connelly et al. 2003). In addition, the grouse were weighed using a Pesola AG™ (Rebmattli 19, CH-6340 Baar, Switzerland) 2500 g spring scale, and each bird was aged according to Gill (1967) and Dalke et al. (1963). We recorded a location (Universal Transverse Mercator, NAD27) at each capture site using a Global Positioning System (GPS). Each grouse was released after information had been recorded. All sage-grouse were handled according to protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University, protocol file # 1195, and with a Certificate of Registration (COR) from the UDWR, COR # 2BAND6892.

Population Estimates

Methods used to obtain sage-grouse population data follow UDWR standard protocols and those of Connelly et al. (2003). Lek counts began in 1982 conducted by the UDWR. During 2005-2006, the UDWR was assisted by participants of WDARM.

We conducted lek counts once a week from the first week in March to the first part of May. Lek counts were conducted 1/2 hour before sunrise to 1 hour after sunrise in reasonably good weather (i.e. light or no wind, and partly cloudy to clear skies). A location was selected near the lek that allowed for good visibility but did not disturb the birds. The time the lek count began was recorded, and then the male birds were counted from right to left. We waited 5 minutes then counted the number of males on the lek from left to right; waited another 5 minutes, and then counted a third time from right to left. We recorded the highest number of males observed. This procedure was repeated at no more than 3 lek sites per morning. The areas that were suitable sage-grouse lekking areas were searched for additional unknown leks and satellite leks. The highest numbers of males seen during the season are the reported totals.

Population estimates were based on the assumption that 75% of all males were counted on the strutting grounds and the male:female ratio in the population is 1:2 (UDWR 2002).

Nesting Ecology

Monitoring of nesting activity began 1 week after the birds were captured to allow them to resume normal activities free of disturbance. Hens were located every 4 to 5 days until they initiated nesting activity. Hens were monitored to determine nest initiation rates, dates, distance between lek and nests, nesting success rates, nest predation rates, clutch size, and vegetation structure at nests. During the nesting period, hens were located every 2 to 3 days to try to account for all nesting attempts. Once a hen was in the same general location 2 days in a row during the nest initiation period, we would cautiously approach to within 10 m of the hen. At this point we were able to visual obtain the location of the hen with the aid of binoculars. Hens located under the same bush 2 days in a row were considered to be nesting. Nests were marked (flagging was never used, only discreet natural materials were used), GPS readings and surrounding vegetation recorded. The nests were observed from a distance of 10 m every 2-3 days, their fate could be determined. For depredated nests, I tried to identify the type of predator by the state of any present eggshells, scat, tracks, and/or hairs (Patterson 1952). A successfully hatched nest was determined by the presence of 1 or more eggshells with loose membranes (Griner 1939). Nest initiation dates were estimated using a 27-day incubation period with 1 day added for each egg in the nest (Schroeder 1997).

Nest Site Vegetation

Nest site vegetation measurements were taken once nesting activities had ceased. A Robel pole (Robel et al. 1970) was placed in the center of the nest, and marked the center point for the vegetation measurements. We recorded vegetation measurements in 4 directions, every 90° starting with a randomly chosen direction, from the center Robel pole. We measured shrub canopy coverage for 15 m from the center along each of the 4 transects using a modified line-intercept method (Canfield 1941). Gaps in the foliage < 5 cm were counted as continuous, gaps ≥ 5 cm were not counted. Heights were recorded for the tallest part of each shrub along each transect. Vegetation visual obstruction readings (VOR) are a measure of concealment. We recorded VORs between the nest and 4 m from the nest using a Robel pole. We recorded 2 different VOR measurements. The pole was placed in the location of interest (i.e., nest or location 4 m from nest) and the observer recorded the height on the pole, in cm, that the vegetation appears to covers. The observer’s eye level was 1 m above ground for both measurements.

A 20 by 50 cm Daubenmire (1959) frame was used to estimate percentage of forbs, grass, bare ground, rock, and litter cover to the nearest percent. A Daubenmire frame measurement was taken every 3 m (n = 5) along each of the 4 transects. The tallest height of each species of forb and grass (droop height) in each Daubenmire frame was recorded. Nest bush species, maximum height, maximum diameter, date of vegetation measurements, hatch date, clutch size, whether or not nest was predated, predator type, GPS position, aspect, slope, and general habitat were recorded for all nests.

Brood Monitoring

Following the nesting season, we located birds that successfully nested at least 2 times per week. Hens without broods were relocated once a week, until September. Brood hens were approached cautiously, and generally could been seen without flushing the hen. Most hens would flush when the chick became older and could also fly. At each collared hen location a GPS coordinate, major vegetation, number of chick seen, and total number of grouse flushed were recorded. Broods were considered successful if 1 or more chicks survived to ≥ 50 days and unsuccessful if no chicks survived to ≥ 50 days.

Brood Site Vegetation

Brood site locations were measured 3-5 days after the brood location was recorded, which allowed time for the brood to leave the area. A Robel pole was placed in the center of the brood location to measure VOR, and marked the center point for the subsequent vegetation measurements. We recorded vegetation measurements in 4 directions, every 90° starting with a randomly chosen direction, from the center Robel pole. We measured shrub canopy coverage for 10 m from the center along each of the 4 transects using a modified line-intercept method (Canfield 1941). Gaps in the foliage < 5 cm were counted as continuous, and gaps ≥ 5 cm were not counted. Heights were recorded for the tallest part of each shrub along each transect.

A 20 by 50 cm Daubenmire (1959) frame was used to estimate percentage of forbs, grass, bare ground, rock, and litter cover to the nearest percent. A Daubenmire frame measurement was taken every 2.5 m (n = 4) along each of the 4 transects. The tallest height of each species of forb and grass (droop height) in each Daubenmire frame was recorded. We recorded a VOR for each brood site using a Robel pole (Robel et al. 1970), to the nearest cm. We recorded a Robel In (a measure of concealment) measurement from 4 m from the center on each of the 4 transects using the same methods as for nest sites. At each brood site we recorded the date of vegetation measurement, date brood was located, aspect, slope, GPS position, and general habitat. Vegetation parameters were measured on randomly selected sites using the same techniques on the same day within 500 m of selected brood sites. Vegetation measurements were only made if the hen was suspected to still have a brood at the time of flush.

Movements

Movements of grouse were determined by locating birds at least once per week during spring and summer, and once per month in fall and winter. A combination of ground surveillance and aerial surveillance was used to locate birds. GPS locations, number of birds, and general habitat were recorded for all bird locations. If a bird was in the same area for an extended period of time a general description of the location was used instead of an exact GPS location.

Mortalities

When a radio collared hen died, we examined the carcass, remains, and feathers for signs of talon, claw, or teeth marks, and searched the surrounding area for remains, hair, feathers, tracks, and scat in an attempt to identify predators. We recorded the location, general habitat, and possible signs of the predator. In most cases it was difficult to assign a predator type to the birds because of heavy scavenging. Scavenger activity increased if it had been more than a couple of days since the mortality occurred. In most cases only the collar and a few feathers were located, and often predators were not identified.

Data Analysis

I used SAS Institute Inc.™ (100 SAS Campus Drive, Cary, NC 27513), SAS 9.1 (2002) software to run one-way analysis of variance (ANOVA) to compare female capture weights, nest and brood vegetation parameters within and between years, nest and brood arthropod abundance within and between years; values for degrees of freedom (DF) and sum of squares (SS) are reported as corrected totals. Paired t-test for means were used to compare nest bush height (measured) to surround shrub height (average height of all shrubs along each of 4 transects). All tests had a P-value set at 0.05 level of significance. Descriptive statistics were used to describe population estimates, nest initiation rates, nest initiation dates, clutch size, nest success, brood success, annual survival, and movements. The data for 2005 and 2006 were kept separate, except for winter data, due to the unusually wet spring of 2005, which had an impact on the parameters measured. I used ArcGIS 9 Geographic Information System (GIS) software to analyze movement data. Aspects of nests and broods were divided into 8 categories: north (N), northeast (NE), east (E), southeast (SE), south (S), southwest (SW), west (W), and northwest (NW), each cover 45° (e.g. east (E) covers 67.5 – 112.5°).

Results

Captures

In 2005, 3 males and 8 females were captured and collared near each of the known lek areas. Two females were captured east of the Deep Creek highway, and 6 females were captured west of the highway near the leks. We captured 3 adult males, 5 juvenile females, and 3 adult females. The mean elevation for captures was 1,804.6 m (SD = 35.9, range = 1,771 - 1,883 m).

In 2006, only 1 adult female was captured and collared near the Ibapah North strutting area at an elevation of 1,751 m. Once captures were complete and with the birds collared in 2005, the study site had a total sample size of 3 males and 8 females. All males and females were mature adults. The average weight for adult and juvenile females, both years combined, did not differed (P = 0.369, DF = 8, SS = 97,556) and were: juveniles 1,306 g (SE = 61.4, range = 1,080 – 1,410 g); adults 1,377 g (SE = 30.1, range = 1,300 – 1,430 g).

Population Estimates

In 2005, lek attendance for males began in mid-March; lek counts began 1 April. Peak male attendance occurred during the second week in April. Peak female attendance occurred during the third week in April. There was 1 known active lek in the Ibapah Valley. Two additional strutting areas, west of the known active lek, were discovered by the researchers on 20 April. The season high male lek attendance for the known active lek (Ibapah East) was 20 males on 12 April. The season high male lek attendance for the 2 discovered strutting areas, Ibapah West and Ibapah North strutting areas, was 15 and 24 males, respectively, on 20 April. Lek counts concluded on 1 May. With a total of 59 strutting males observed, the population estimate is 236 total birds, using UDWR standard protocols.

In 2006, lek attendance for males began in mid-March; lek counts began 31 March. Peak male attendance was the first week in April. Peak female attendance was the third week in April. We monitored 1 active lek (Ibapah East), 2 strutting areas discovered by the researchers spring of 2005 (Ibapah West, Ibapah North), a historic lek near the Nevada border (Spring Creek), and a strutting area discovered by the researchers in 2006 on the Goshute tribal lands (Goshute). The season high male lek attendance for the Ibapah East lek was 41 males on 31 March 2006. The season high male attendance was 2 on 31 March for the Ibapah West strutting area (observation was complicated by the large biomass of cheatgrass that made viewing strutting males extremely difficult), 11 on 31 March for the Ibapah North strutting area, 9 on 14 April for the Spring Creek historic lek, and 30 on 1 May for the Goshute strutting area. Lek counts concluded on 1 May 2006. The total number of males seen strutting was 93, which is a historic all time high (Figure 3.3). With 93 strutting males observed, the population estimate is 372 total birds.

Nesting Ecology

Nesting ecology varied between 2005 and 2006 (Table 3.1). In 2005, 4 of 8 hens monitored initiated nests. Eggs in all 4 of the nests hatched successfully. No nests were predated upon. No re-nesting attempts were documented. Average clutch size for all nests was 7.25 eggs per nest, (range = 6 - 9). Average nest initiation date was 5 May (range = 23 April – 23 May). A total of 29 eggs were observed: of those, all hatched successfully. Average hatch date was 8 June (range = 29 May – 25 June). Three of 4 nests were within 3.2 km of a lek (Figure 3.4). The mean distance a hen traveled from the closest lek to her nest was 2.1 km (range = 0.757 – 6.1 km).

In 2006, nests were initiated by 6 of 8 hens. Of the 6 nests, 3 were predated and 3 hatched successfully. Of the 3 predated nests, 1 predator could not be determined, nor the clutch size. Another nest had 4 eggs still intact and ≥ 2 had been eaten, but the predator could not be determined. The third nest was probably predated by an avian predator, possibly a common raven, with ≥ 8 eggs in the nest. No re-nesting attempts were documented.

Average clutch size for all successful nests was 8.67 eggs per nest (range = 8 - 9). Average nest initiation date was 13 April (range = 11 April – 15 April). Average nest initiation was later in 2005 than in 2006 (Figure 3.5). Of the 40 eggs observed, 27 hatched successfully, 4 did not hatch and were at various stages of development and ≥ 9 were predated. Average hatch date was 19 May (range = 17 May – 21 May). Four of 6 nests were within 3.2 km of a lek (Figure 3.6). The mean distance a hen traveled from the closest lek to her nest was 2.7 km (range = 0.728 – 6.4 km).

Three birds nested in both 2005 and 2006. Of those 3 birds, 2 had successful nests both years, and 1 had a successful nest in 2005 and an unsuccessful nest in 2006. The average distance a hen nested in 2006 compared to her nest in 2005 was 473 m (range = 194 – 881 m). One collared hen did not nest in either 2005 or 2006.

Nest Site Vegetation

During the study, 9 of the 10 hens that nested placed their nests under sagebrush. In 2005, all (n = 4) hens nested under sagebrush. The mean elevation for nests was 1,816 m (SD = 58.9, range = 1,782 - 1,884 m). In 2006, 5 of 6 hens nested under sagebrush, and 1 hen nested under sagebrush-Douglas rabbitbrush. The mean elevation for nests was 1,797.4 m (SD = 59.0, range = 1,756 – 1,900 m). Nests were located under shrubs taller than the surrounding shrubs (P = <0.0001, DF = 9, t-stat = 7.29). Nest site vegetation did not differ between 2005 and 2006, with the exception of grass height (P = <0.0001, DF = 9, SS = 1,084) (Table 3.2). Percent of nest sites in each aspect category, for 2005 and 2006 combined, were: N-30%, NE-20%, E-20%, SE-0%, S-10%, SW-10%, W-10%, and NW-0%.

Brood Success

In 2005, 2 of 4 broods were considered successful with 3 juveniles/hen. There were 6 chicks for 8 total collared hens that we know reached an age of ≥ 50 days, which is a ratio of 0.75 juveniles/collared hen. In 2006, 2 of 3 broods were considered successful, with 3 and 1 juveniles/hen. There were 4 chicks for 8 total collared hens that we know reached an age of ≥ 50 days, which is a ratio of 0.5 juveniles/collared hen (Table 3.1).

Two hens had broods in both 2005 and 2006. Both hens had unsuccessful broods in 2005, but had successful broods in 2006. No hens had successful broods in both 2005 and 2006.

Brood Site Vegetation

There was no difference in vegetation parameters at brood and random sites in 2005 ($P > 0.2$, DF = 31). The mean elevation for brood sites was 1,823.8 m (SD = 125.2, range = 1,687 - 2,047 m). There was no difference in brood and random sites in 2006 ($P > 0.05$, DF = 31). The mean elevation for brood sites was 1,801.4 m (SD = 69.7, range = 1,677 - 1,904 m).

Four of 11 vegetation parameters differed at brood locations between 2005 and 2006; specifically shrub cover (P = 0.008, DF = 51, SS = 9,291), grass cover (P = 0.005, DF = 51, SS = 9,435), and grass height (P = 0.0002, DF = 51, SS = 6,499) (Table 3.3). Visual obstruction reading measurements were 26.6 (SE = 7.4) and 30.9 cm (SE = 7.0) for 2005 and 2006, respectively. Rock cover was 12.5 (SE = 1.9) and 8.8 % (SE = 1.5) for 2005 and 2006, respectively. Slope was 6.7 (SE = 1.4) and 3.3 degrees (SE = 0.6) for 2005 and 2006, respectively, and differed (P = 0.03, DF = 51, SS = 1,677). Percent of brood site aspects falling within each category, for 2005 and 2006 combined, were: N-19%, NE-19%, E-6%, SE-4%, S-0%, SW-8%, W-13%, and NW-31%.

Movements

In 2005, most hens (75%) nested within 3.2 km of a lek. Of the hens that nested successfully, most stayed close to the nest site. Seven of 26 brood locations were within 1.6 km of the nest, and 18 of 26 locations were within 3.2 km of the nest. Hen 315 took her brood up in elevation as the summer progressed. Hen 907 traveled the farthest with her brood; she took her brood as far as 6.4 km from her nest. She and her brood headed towards a permanent water supply and stayed there after arriving (Figure 3.7). Some birds had small areas of use while others had larger areas of use. The female bird with the smallest area of use traveled 2.3 km from place of capture to nest site. The farthest summer documentation was only 862 m from her nest site. The female bird with the largest area of use traveled only 365 m from place of capture to nest site, but then moved her brood 6.4 km from nest to the farthest summer point recorded, and then moved 16.9 km from capture site to winter range. The male with the largest area of use traveled 5.7 km from the capture site to the farthest recorded summer point.

In 2006, most hens (67%) nested within 3.2 km of a lek. Of the hens that had successful nests, most had broods that stayed close to the nest site. Eight of 26 brood locations were within 1.6 km of the nest site. Twenty of 26 brood locations were within 3.2 km of the nest site. Hen 567 moved her brood the farthest, traveling 6.0 km from the nest to farthest summer location (Figure 3.8). Some birds had small areas of use while others had larger areas of use. The female bird with the smallest area of use traveled 725 m from place of capture to nest site, and then 3.6 km from her nest to the farthest summer point recorded. The female bird with the largest area of use traveled 746 m from place of capture to nest site, and then 7.8 km from nest to the farthest summer point recorded. The male with the largest area of use traveled 18.1 km from the capture site to the farthest recorded summer point. As soon as lekking activities commenced, this male would follow Johnson Canyon south. He summered in a high elevation sagebrush meadow in the Deep Creek Mountains at an elevation of over 2,200 m.

Winter Habitat Use

Winter data was grouped for 2005 and 2006 because both winters were close to average and differed little from each other. Nine of 11 winter locations were within 9.6 km of a lek site. Birds had a general movement to the northwest, into Nevada. The average distance a bird moved from its capture site to a winter location was 8.9 km (range = 1.7 – 16.9 km). If the two birds with the greatest movement are excluded, the average distance a bird traveled from capture to winter range is 5.5 km (range = 1.7 – 12.0 km). The two locations where birds were outside of the 9.6 km buffer were 16.9 km and 15.5 km from their capture site. Bird 907 had the greatest movement to her winter location (Figure 3.9). This population does not appear to migrate from its summer brood-rearing habitat to its wintering habitat. With the exception of a few individual birds, most stay close to the areas where breeding, nesting, and brood-rearing occurs. This population of sage-grouse would best be described as a non-migratory population with well-integrated, seasonal habitat (Connelly et al. 2000).

Mortalities

Only 2 confirmed collared grouse mortalities, both adult females, were documented during the study. In 2005, no male or female mortalities occurred. One collar ceased working (the fate of that female was undetermined).

In 2006, the annual survival rate for females was 75% (n = 8). Two collars on male sage-grouse detached from lekking activities; the fates of the two males were undetermined (Table 3.1). One male kept his collar throughout the study. One confirmed mortality was an adult female in December 2006, and the second was an adult female in

February 2007. The cause of mortality could not be determined, because the carcasses were both heavily scavenged and some time had passed since mortality.

Discussion

Nesting Ecology

Most hens in the Deep Creek Watershed population initiate nests, which is consistent with published studies (63.1-100%) (Connelly et al. 2004). Nest success is within the published ranges (14.5-86.1%) (Connelly et al. 2004). The average clutch size for both years is within the published range (6.3-9.1) (Connelly et al. 2004). Patterson (1952) had re-nesting attempts < 20%. I never documented a re-nesting attempt. Nest initiation dates vary greatly in other populations. This population's initiation dates are similar to other populations, but we documented a large difference between years. Nests are usually located near leks (Wakkinen et al. 1992), and this population is no different. Sage-grouse have been shown to have high fidelity to seasonal areas (Keister and Willis 1986, Fischer et al. 1993); this population shows high fidelity to lek and nest areas.

Nest Site Vegetation

Connelly et al. (2004) showed that most hens nest under sagebrush. Most hens (90%) in this population nested under sagebrush, although nests under sagebrush did not have higher success. Often hens will nest under taller shrubs (Apa 1998), as was the case with this population. The recommended sagebrush canopy cover for nesting is 15-25% (Connelly et al. 2000). Birds within this population selected sites with more sagebrush cover than other populations. The recommended sagebrush height is 20-80 cm, and this population selects sites that are in the middle of the guidelines. The recommended grass-forb canopy cover is ≥ 15% with a height of >18 cm. In both years, the forb cover was considerably lower than the suggested guidelines, and forb height was also lower than the recommended guidelines. Grass cover and height were higher than the guidelines in both years. This area is dominated by Wyoming big sagebrush with mostly cheatgrass in the understory.

Brood Success

In general, brood success in the Deep Creek Watershed population was very low. I was unable to determine the fates of the chicks in unsuccessful broods, because I could only track the brood hen. Broods were considered unsuccessful if a hen had no chicks. This was thought to be due to mortality of the chicks. However, current research (D. Dahlgren, Utah State University, personal communication) suggests lost broods may be due to brood-hopping. Brood-hopping occurs when chicks from one brood leave their birth mother and join the brood of another hen.

Brood-hopping was probably occurring in the West Desert study area. If this is the case, my successful brood estimates may be lower than the actual number of chicks that survived. Anecdotal evidence observed by us in the field suggests more chicks may have survived than reported, since many un-collared hens with chicks were observed in the study area.

Connelly et al. (2000) suggest ≥ 2.25 juveniles per hen for a steady to increasing population. This population does not meet that guideline. Utah has lower chick survival than other western states (Connelly et al. 2004), and the Deep Creek population is low for

Utah. However, the ratios for the Deep Creek Watershed population may be estimated low, because at the current level of chick recruitment the population would be plummeting, which it is not. More research directed at deriving better estimates of chick recruitment needs to be conducted to address the discrepancy.

Brood Site Vegetation

Connelly et al. (2000) suggest that brood sites have 10-25% sagebrush cover with 20-80 cm height, and >15% grass-forb cover with variable height. Sage-grouse within this population use sites within the mid to low range of the guidelines and heights in the middle of the range for sagebrush. Forb cover was well below the recommended guidelines in both years, and grass cover was within the guidelines in 2005, but not in 2006. Chicks and adults are likely subsisting largely on a diet of arthropods and shrubs. Some broods are able to find riparian areas and likely are able to incorporate some forbs into their diets.

Movements

Most birds nested within 3.2 km of a lek, and most brood locations were near nest sites. Birds tend to head towards permanent water sources as desiccation of vegetation occurs. This population is non-migratory; thus, all activities occur in the same general area. There is no evidence to suggest the population is connected to any others in Utah. Cooperation with Nevada Department of Wildlife and the Goshute Tribe should take place. The Ibapah Valley, including parts of Nevada and the Reservation, should be considered one population, which may or may not be connected to other populations in Nevada.

Mortalities

No grouse mortalities have occurred from human structures, including fences. No known mortalities have occurred from West Nile Virus. Several un-collared grouse were found dead, but had been heavily scavenged, and cause of mortality could not be determined. Hunting of sage-grouse can and does occur on the Goshute Indian Reservation by tribe members. The Reservation does not keep records of the number of birds taken, and has no regulations on season and bag limits. No collared birds were killed by hunters. Hunting was banned in 1990 outside of the Reservation boundaries. Annual survival rates for grouse in this study site are very high (Table 3.1), above or at the upper end of the published rates (Connelly et al. 2004). The high survival rate may be related to low predator numbers, low human disturbance, an adequate amount of sagebrush habitat, and lowered physical stress (no long distance migrations). An addition factor for consideration is the small sample size.

Management Implications

Knowing areas of use is a vital component for managing a sage-grouse population. Finding new lek areas is critical in identifying areas of use. Lek attendance is used for population estimates. Most female grouse in the Deep Creek Watershed population nest within 3.2 km of a lek. Most brood-rearing takes place near leks, and leks serve as the focal point for sage-grouse activities. If additional leks are located, additional areas of nesting and brood-rearing habitat will be identified. Having more and accurate information regarding leks will aid in the recoveries of the population of sage-grouse in the Deep Creek Watershed study site population. The focus should be on counting the known leks at peak male attendance, and locating additional unknown leks. Accurate lek information is very critical when preparing a conservation plan. Having good information on where the leks and use areas occur would mitigate the risk of a vegetation management project being initiated that destroys critical habitat. An example is a fuels reduction project conducted in 2003 near lekking areas. The project thinned sagebrush in a north to south fashion, and because of the wet spring of 2005 cheatgrass became exceedingly tall. The tall cheatgrass caused the area to become unused by sage-grouse. Our telemetry data showed most birds travel east to west. In fall 2005, a sagebrush thinning project was conducted in potential brood-rearing habitat in an east to west fashion that facilitated sage-grouse use and movements.

Recruitment of chicks to adults is vital for any population of sage-grouse. My research has shown that chick recruitment in this population is very low. These estimates might be lower than the actual value, but I believe the population is still under the suggested ≥ 2.25 juveniles/hen (Connelly et al. 2000). Forbs are all but non-existent in the Deep Creek Watershed. Chicks are probably surviving on insects and shrubs. Most of the areas of use have a cheatgrass understory. Additional brood-rearing habitat needs to be identified and/or created. Great care must be taken when doing habitat improvement projects. The cheatgrass understory can completely take over the area, and our research showed grouse will stop using areas if the cheatgrass cover becomes too great.

Catastrophic wildfires are a major concern in this study site. The area is dominated by Wyoming big sagebrush and cheatgrass, with some areas of created wheatgrass plantings. A large wildfire could remove most of the available habitat for sage-grouse. A fuels reduction treatment was conducted in November 2003 and another in November 2005 on BLM lands. The effects of the treatment on movements, nesting, brood-rearing, and roosting of sage-grouse should continue to be monitored. A juniper reduction project was conducted on the Goshute tribal lands in 2005. The area should be monitored to see the effects of the treatment.

Hunting should not occur on this population of sage-grouse. The population is small and isolated, and it is unclear how much, if any, immigration and emigration occurs with birds in Nevada. Hunting does not occur for state managed birds; however, hunting of sage-grouse can and does occur on Goshute tribal lands. A relationship has been formed with the Goshute tribe. I suggest that state agencies (Utah and Nevada) work with the Goshute tribe through the working group process to address the issue of hunting on tribal lands. If new areas of use and leks are identified, and subsequently a higher population estimate, this population could withstand some limited and strictly regulated fall hunting.

The Deep Creek Watershed population of sage-grouse occurs on a variety of land ownerships. Government and private landowners must work together in order to sustain the population. Habitat improvement projects must be monitored, and set up in a way to show the benefits of the project. This population occurs on the boundaries of two states, tribal land, and federal lands. The birds recognize none of these boundaries. The population must be addressed as one, which means WDARM must work with the state of Nevada and the Goshute tribe when addressing this population. Goshute tribal land is a major use area for this population, but access to land has been restricted. Relationships have become much better. A good relationship should continue to be maintained. The working group process is a great avenue to address very complex management problems, and WDARM must continue with adaptive resource management.

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Table 3.1. Population dynamics of greater sage-grouse monitored, Deep Creek Watershed, Utah, 2005-2006.

	2005			2006		
Parameter	N	n	%	N	n	%
Nest Initiation	8	4	50	8	6	75
$\bar{x}$ Nest Initiation Date		5 MAY			13 APR	
Successful Nests	4	4	100	6	3	50
Nests Under Sagebrush	4	4	100	6	5	83.3
$\bar{x}$ Distance, Lek to Nest		2.14 km			2.67 km	
$\bar{x}$ Clutch size		7.25			8.67	
Brood Success	4	2	50	3	2	66.7
Chicks/successful brood		3			2	
Annual Survival						
Adults	6	6	100	11	7	63.6
Males	3	3	100	3	1[a]	33.3
Females	3	3	100	8	6	75
Juveniles	5	5	100	0	N/A	N/A
Males	0	N/A	N/A	0	N/A	N/A
Females	5	5	100	0	N/A	N/A

[a] Unknown if mortality occurred, 2 of 3 males' collars disconnected after lekking activities.

Table 3.2. Greater sage-grouse nest site vegetation characteristics in the Deep Creek Watershed, Utah, 2005-2006. An asterisk (*) denotes a significant difference.

	2005		2006	
Parameter	Mean (SE)	Range	Mean (SE)	Range
Nest Bush Height (cm)	87.5 (6.4)	76-101	79.2 (10.9)	43-125
Nest Bush Diameter (cm)	185 (14.5)	156-223	125.2 (22.9)	48-206
Shrub Cover (%)	29.5 (2.0)	26.1-35.1	29.7 (4.0)	19.4-45.1
Shrub Height (cm)	40.6 (4.3)	30.9-51.8	46.9 (5.3)	30-60.8
Sagebrush Cover (%)[a]	91.5 (5.7)	74.4-98.7	86.5 (7.7)	49.8-100
Sagebrush Height (cm)	54.1 (6.9)	34.7-71.5	56.8 (7.8)	37.6-88.6
Forb Cover (%)	5.3 (3.4)	1.3-15.4	1.5 (1.0)	0-6.3
Forb Height (cm)	16.9 (3.6)	9.5-25	17.8 (4.3)	9.8-24.6
Grass Cover (%)	27.2 (3.6)	18-34.2	17.1 (3.1)	7.1-27.7
Grass Height (cm)	33.6 (2.1)*	29.6-38.4	13.2 (1.0)*	9.2-15.5
Rock Cover (%)	11.6 (4.4)	3.9-24.1	10.1 (4.3)	2-30.3
Bare Ground (%)	28.7 (3.6)	24.3-39.3	21.5 (4.0)	5-29.5
Litter Cover (%)	47.6 (4.3)	38.6-59.1	40.9 (3.1)	34.5-51.4
Robel In (cm)	54.5 (6.9)	40-69	56.7 (5.5)	35-75
Robel Out (cm)	34.5 (2.3)	31-41	43.8 (5.4)	25-63
Slope (degrees)	7 (1.2)	4-9	6.2 (1.2)	2-10

[a] Represents the percent that is sagebrush of total shrub cover

Table 3.3. Greater sage-grouse brood and random site vegetation parameters measured, Deep Creek Watershed, Utah, 2005-2006.

	2005				2006			
	Brood		Random		Brood		Random	
Parameter	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range	Mean (SE)	Range
Shrub Cover (%)	23.8 (3.0)*	0-61.6	21.5 (5.8)	0-34.4	14 (1.8)*	0-31.1	11.1 (4.1)	0-25.7
Shrub Height (cm)	41.4 (6.9)	0-193.7	36.8 (5.3)	26-56.3	51.4 (6.8)	19-155	34.3 (5.8)	23-54.7
Sagebrush Cover (%)[a]	78.1 (4.8)	26.8-100	64.8 (15.7)	18.7-91.8	74.7 (6.4)	13.6-100	72 (22.4)	28-100
Sagebrush Height (cm)	42.0 (2.9)	18.5-72	40.5 (5.5)	29.6-61	57.7 (5.3)	38.5-123	42.7 (6.1)	34-55
Forb Cover (%)	5.7 (1.1)	0-19.6	9.5 (4.7)	0.3-26	5.6 (1.9)	0-42.9	2.0 (1.0)	0-5.6
Forb Height (cm)	16.9 (2.1)	2.7-55	18.9 (4.8)	11-42.5	17.6 (2.2)	2-32.5	12.8 (0.6)	12-14
Grass Cover (%)	23.3 (2.9)*	2.3-60.3	24.7 (6.2)	4.8-41	12.9 (2.0)*	0.1-41.1	11.5 (3.2)	4.1-27
Grass Height (cm)	34.7 (2.2)*	17-67.5	36.7 (2.9)	30-50.1	23.6 (1.7)*	8-45.9	25.1 (4.0)	12-41
Bare Ground (%)	35 (3.3)	4.6-61.5	37.1 (6.3)	18.4-58.5	28.3 (2.9)	3.9-67.1	31 (6.9)	4.8-55
Litter Cover (%)	35.3 (2.9)	9.9-76.3	41.8 (7.0)	13.1-63.1	38.9 (2.7)	8.5-65.9	40.8 (3.0)	32-51

[a] Represents the percent of total shrub cover that is sagebrush

* denotes a significant difference

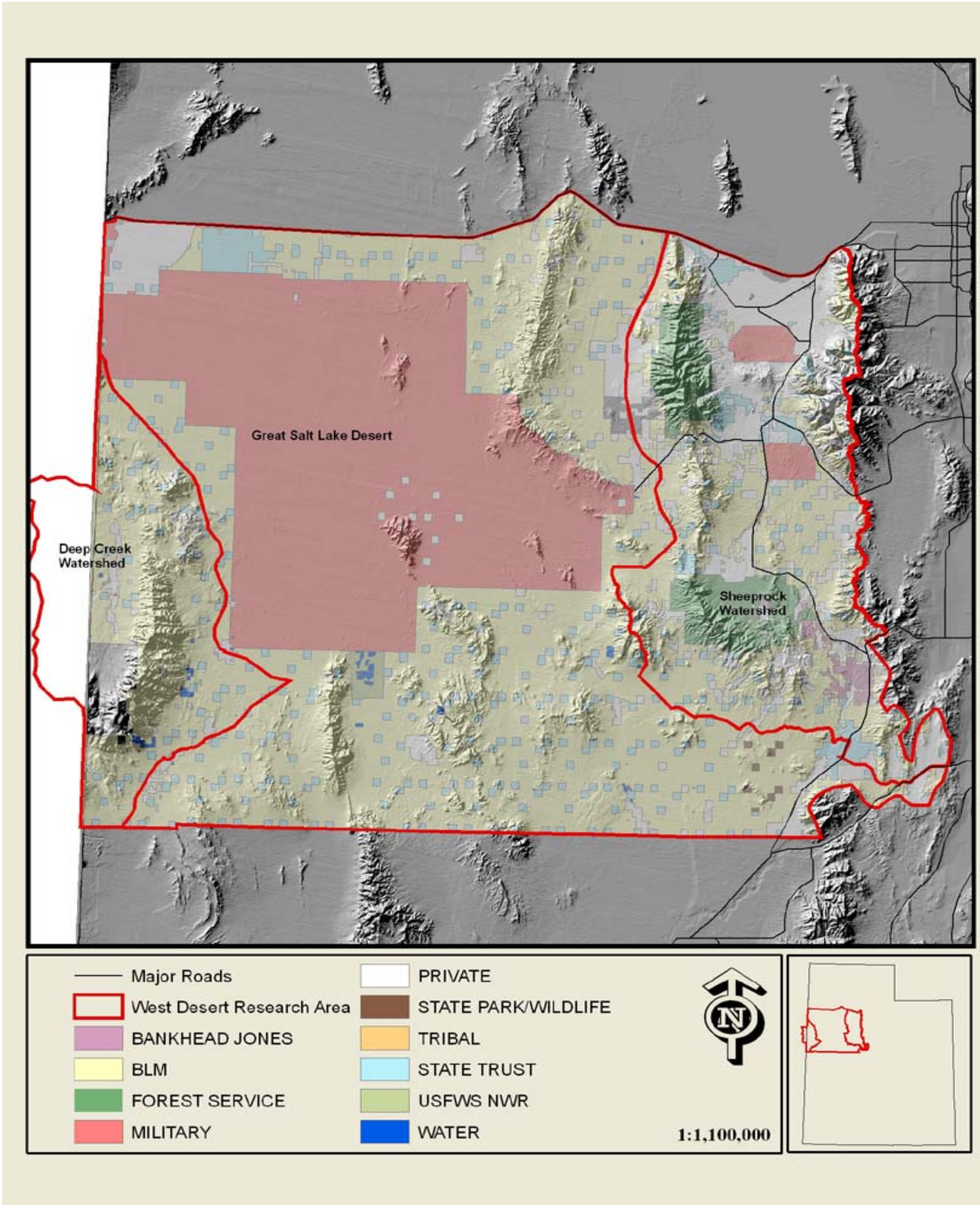


Figure 3.1. The West Desert Study Area showing the Deep Creek Watershed and Sheeprock Watershed study sites, separated by the Great Salt Lake Desert, Utah.

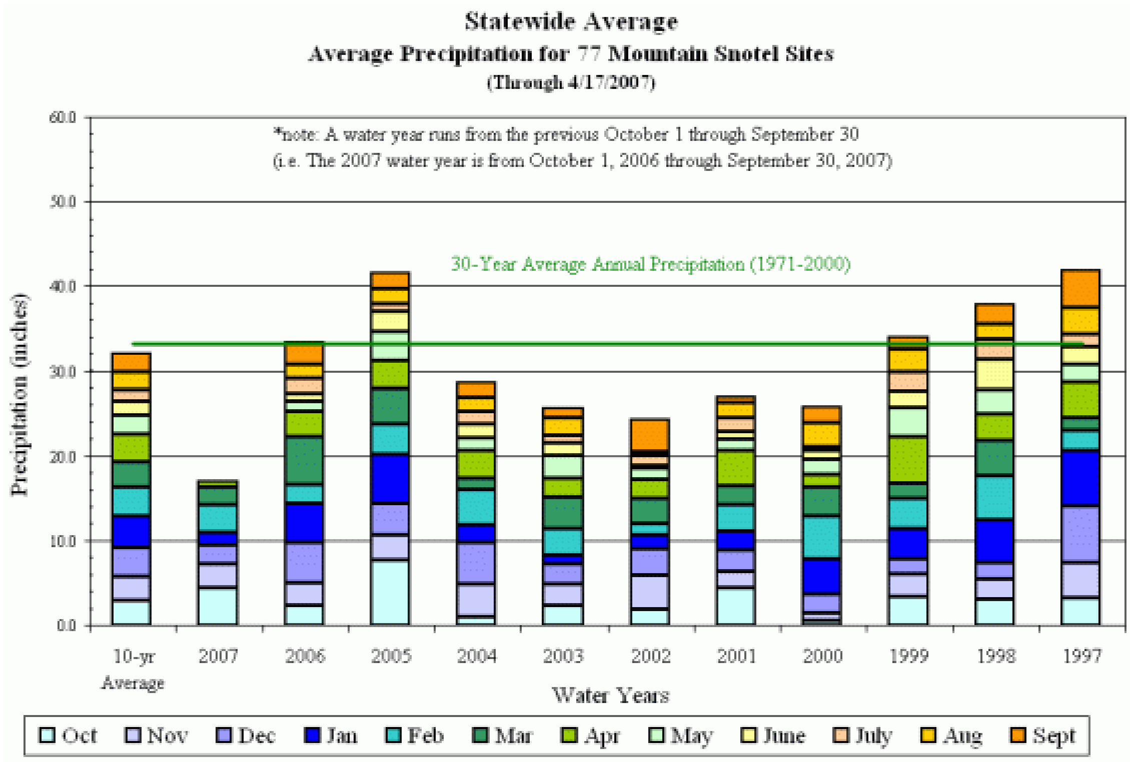


Figure 3.2. Statewide average precipitation, showing 30-year average, Utah, 1997-April 2007.

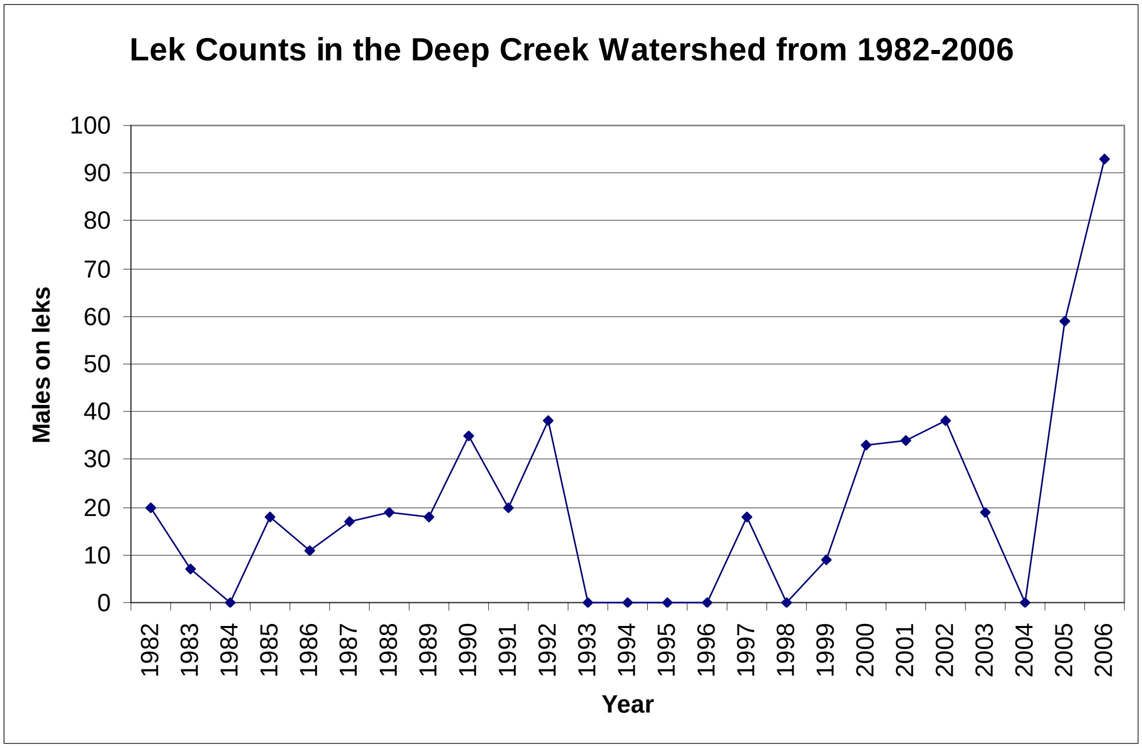


Figure 3.3. Lek summary of male greater sage-grouse counted on all known leks, zeros indicate no counts were conducted, Deep Creek Watershed, Utah, 1982-2006.

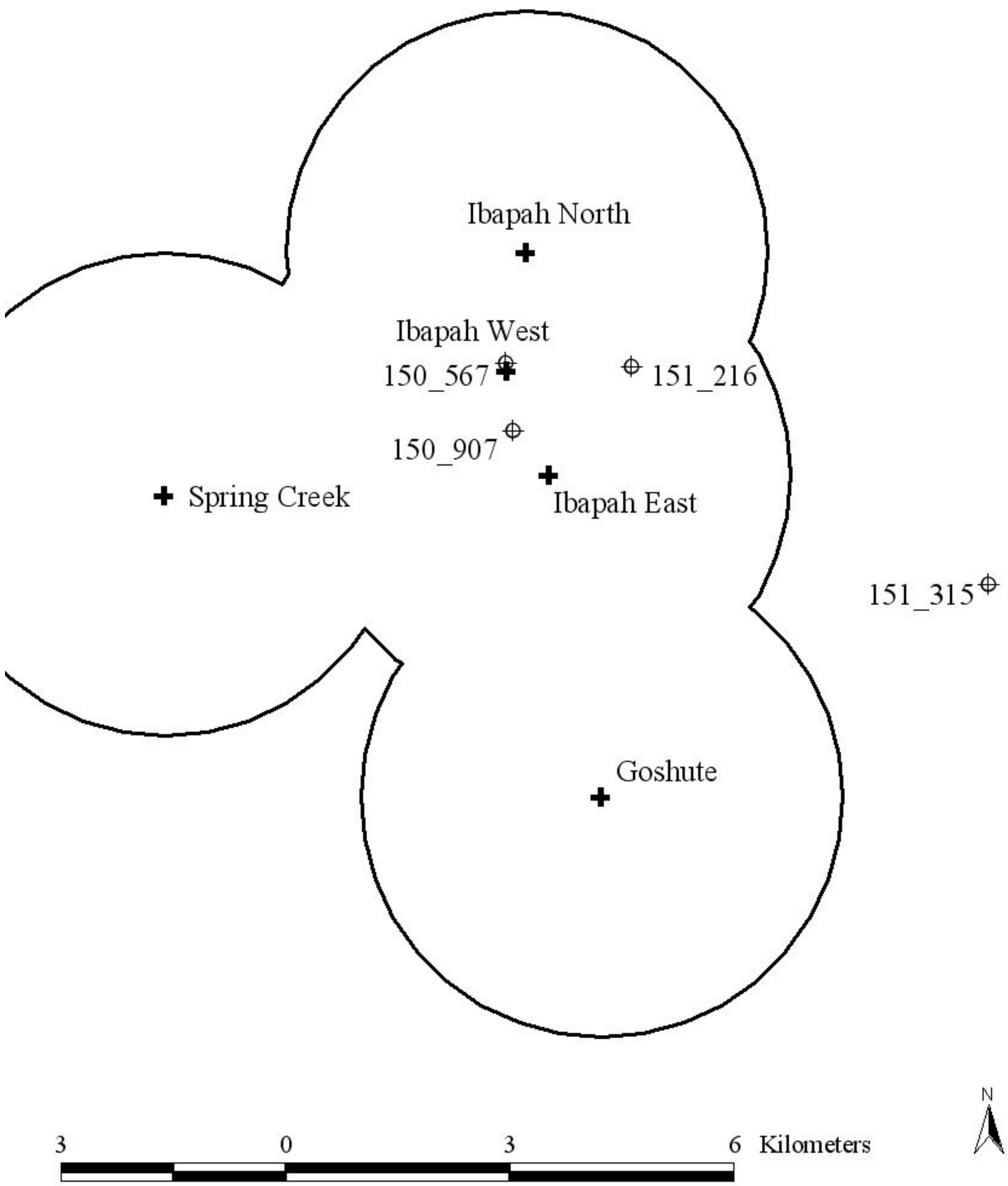
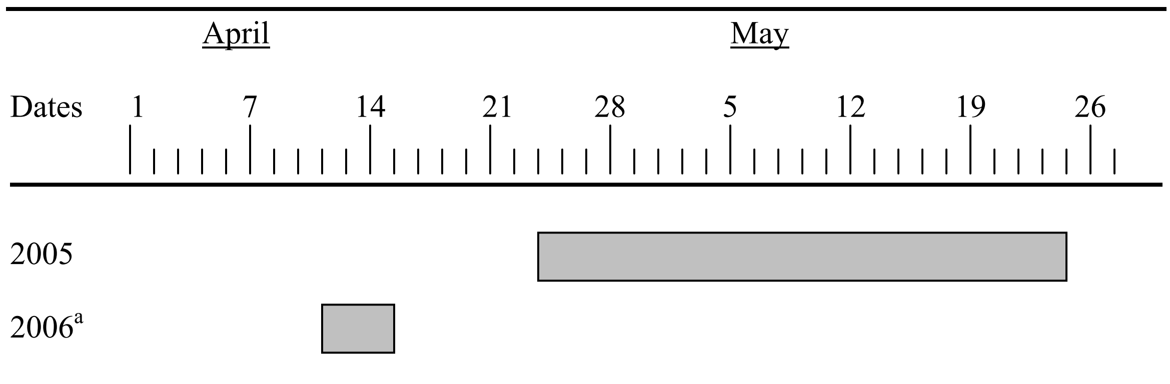


Figure 3.4. Greater sage-grouse nest site locations (crosshairs) in comparison to lek sites (bold cross) with a 3.2-km buffer around each lek, Deep Creek Watershed, Utah, 2005.



[a] Based on 3 successful nests.

Figure 3.5. Greater sage-grouse successful nest initiation dates, Deep Creek Watershed, Utah, 2005-2006.

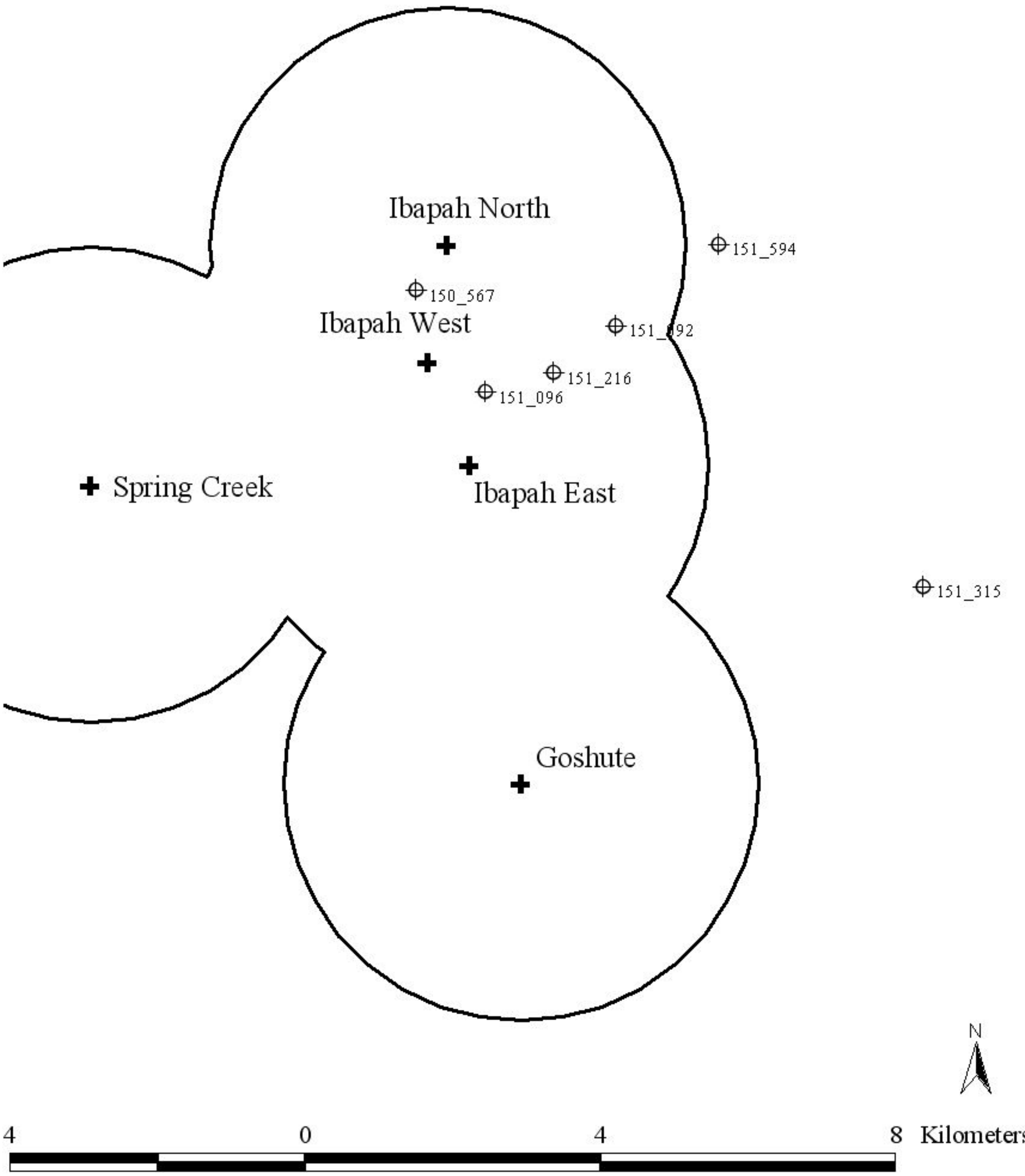


Figure 3.6. Greater sage-grouse nest site locations (crosshairs) in comparison to lek sites (bold cross) with a 3.2-km buffer around eack lek, Deep Creek Watershed, Utah, 2006.

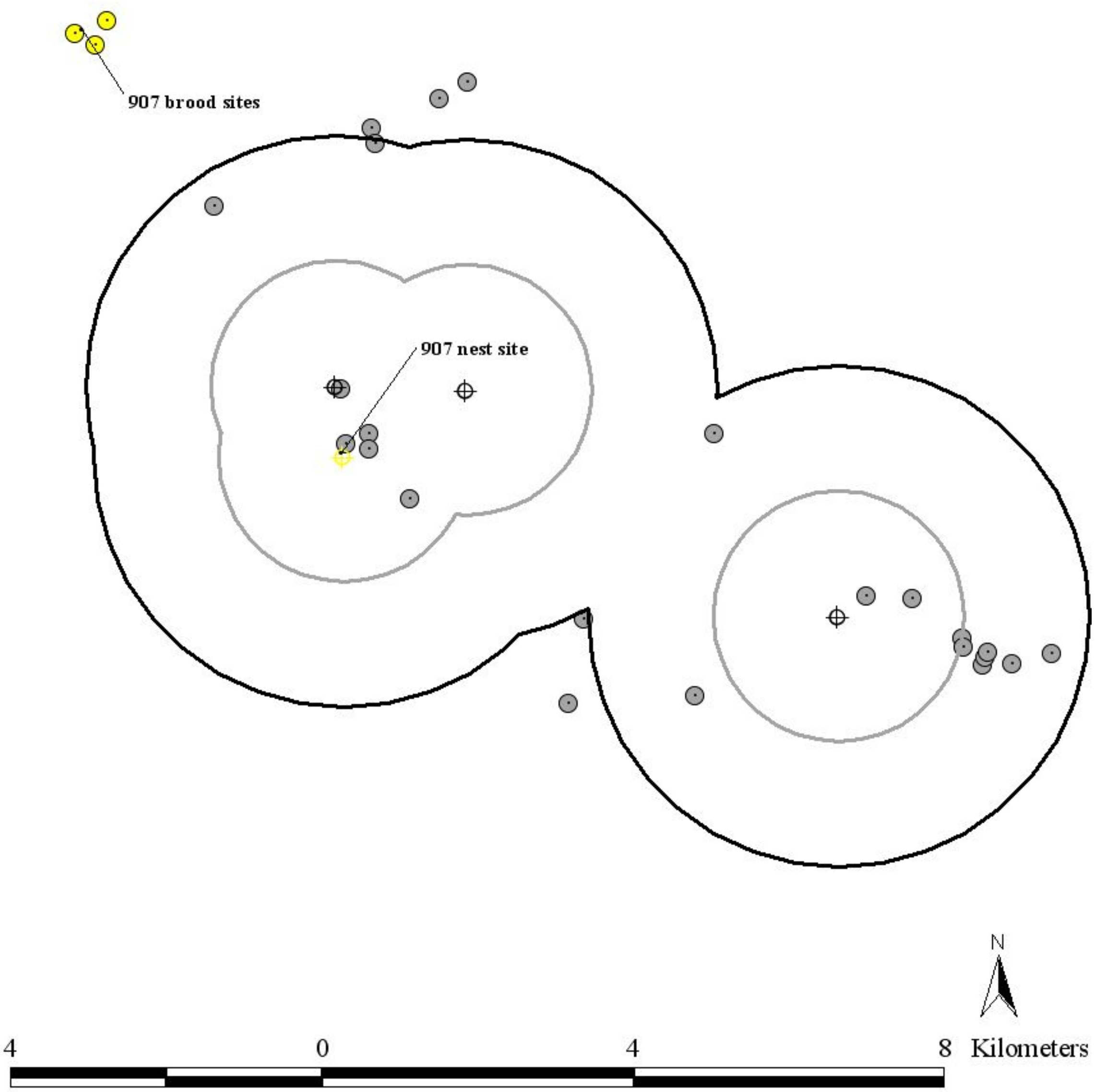


Figure 3.7. Greater sage-grouse brood site locations (dotted circle) in comparison to nest site locations (crosshairs) with a 1.6-km (gray) and 3.2-km (black) buffer around each nest, Deep Creek Watershed, Utah, 2005.

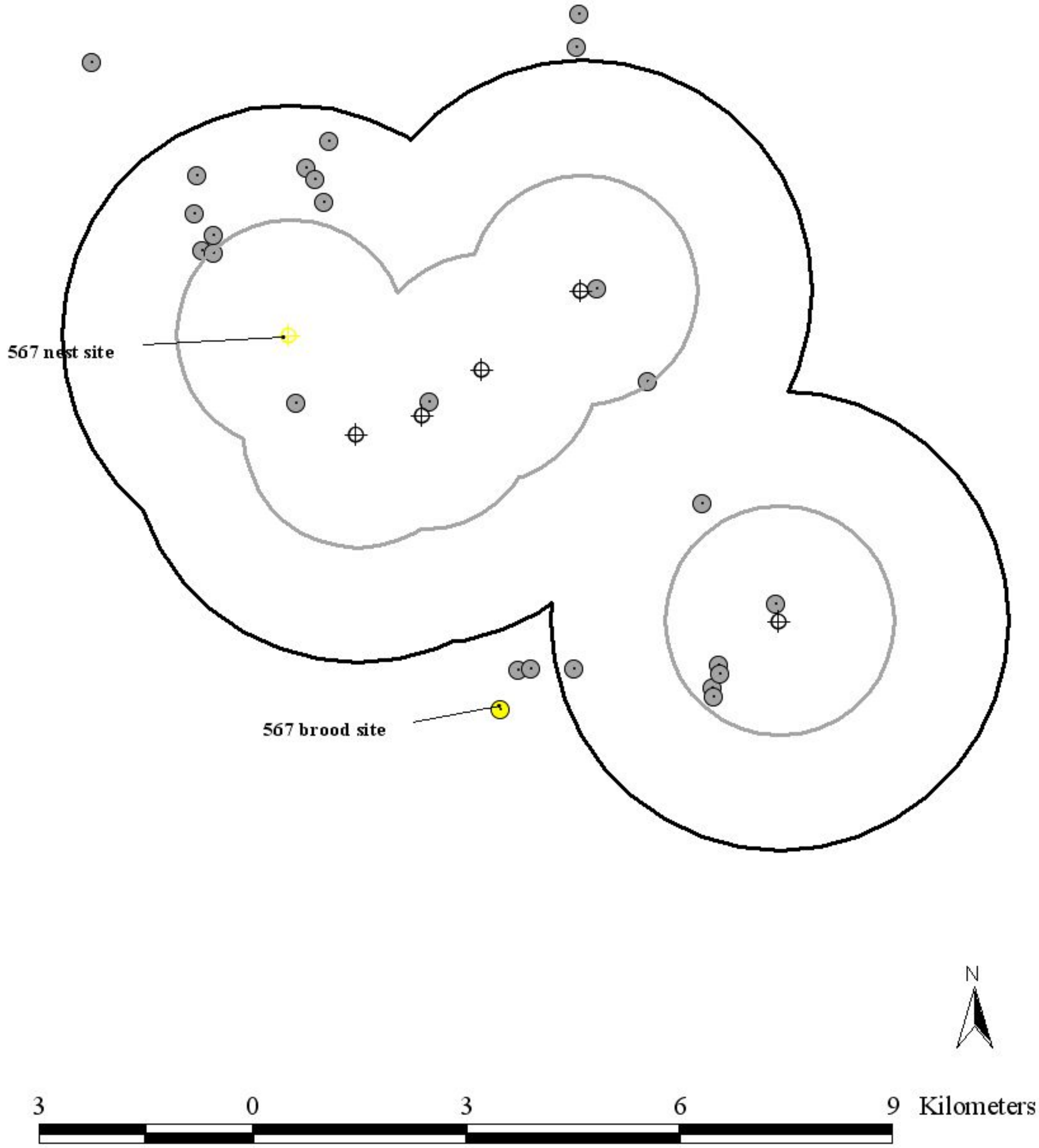


Figure 3.8. Greater sage-grouse brood site locations (dotted circle) in comparison to nest site locations (crosshair) with a 1.6-km (gray) and 3.2-km (black) buffer around each nest, Deep Creek Watershed, Utah, 2006.

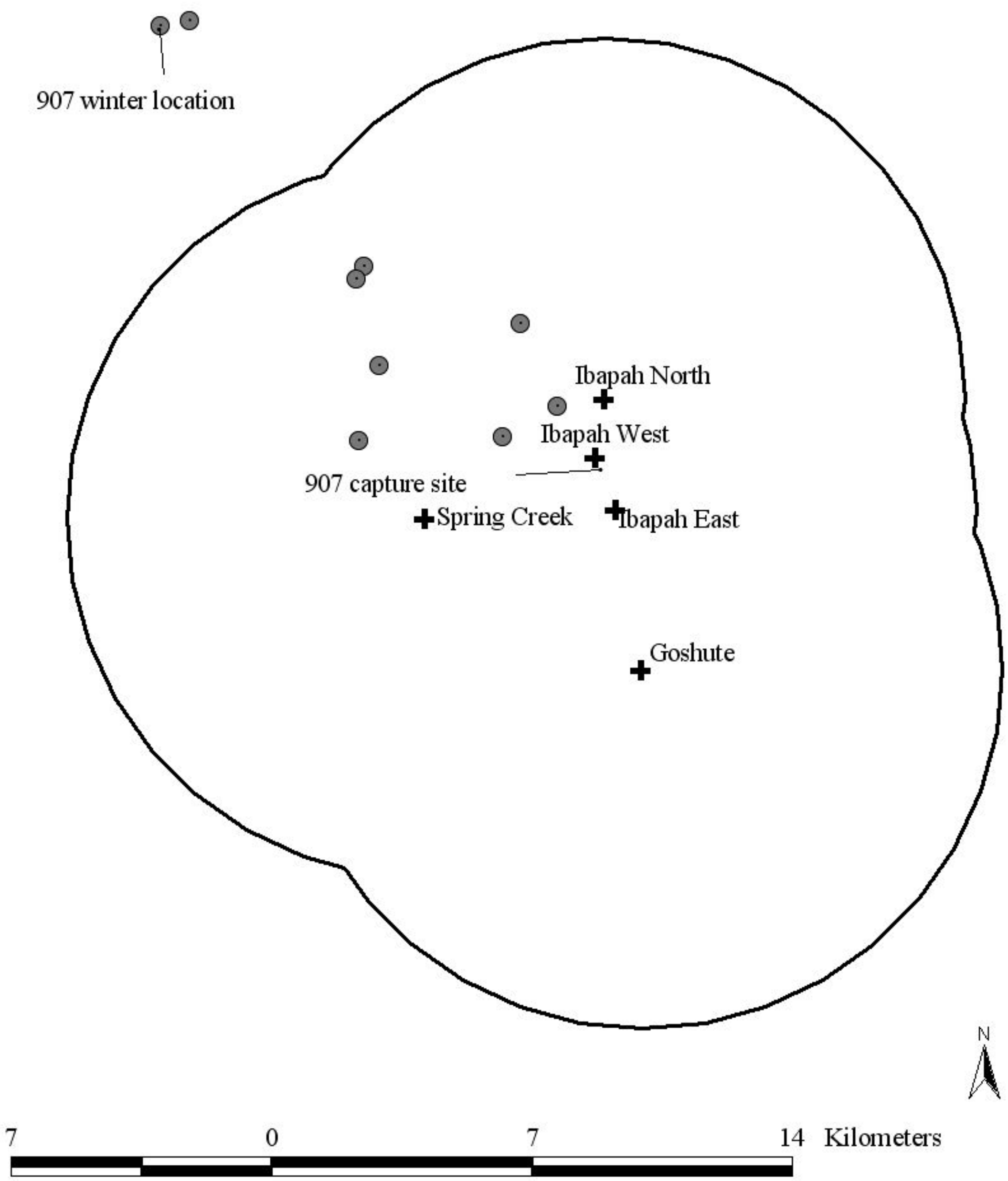


Figure 3.9. Greater sage-grouse winter locations (dotted circle) in comparison to lek sites (bold cross) with a 9.6-km buffer around each lek, Deep Creek Watershed, Utah, 2005-2006.

CHAPTER 4

CONCLUSIONS

Long-term declines in greater sage-grouse (*Centrocercus urophasianus*) populations and their distributions have prompted several environmental groups to petition the U. S. Fish and Wildlife Service (USFWS) to list the species as a threatened or endangered species under the Endangered Species Act. These petitions were denied in 2005, but further litigation is anticipated (L. Romin, USFWS, personal communication). The continued decline prompted the state of Utah to develop a Strategic Management Plan.

The Utah Division of Wildlife Resources (UDWR) prepared a Strategic Management Plan for sage-grouse in 2002 (UDWR 2002). The plan encouraged the formation of local working groups to address the declining numbers of sage-grouse. The plan was designed to be: "a framework for local working groups to develop area-specific management programs to maintain, improve and restore local sage-grouse populations and their habitat" (UDWR 2002).

To date, 12 local working groups have been organized and charged with the responsibility to develop and implement local sage-grouse conservation plans. The West Desert Adaptive Resource Management (WDARM) local working group began meeting in 2004. The mission of WDARM is: "to develop a greater sage-grouse conservation plan that will outline strategies to maintain, improve and restore local greater sage-grouse populations and their habitats while taking into consideration historical land uses and long-term social and economic issues of the West Desert community" (WDARM 2007).

Two geographically distinct greater sage-grouse populations inhabit the West Desert of Utah within the WDARM boundaries. The two populations are separated by the Great Salt Lake (GSL) Desert. There is no evidence to suggest the two populations have contact with one another: however, they may or may not have limited interactions with other populations in Utah and Nevada. The GSL Desert is a harsh environment with little vegetation, specifically sagebrush, and few water sources. The West Desert receives very little annual precipitation, and most precipitation comes in the form of snow. The area is large, vast, and has few cities or towns.

Very little information was known about either of the two populations of sage-grouse within the WDARM boundaries. The UDWR has been conducting lek counts in both areas for several decades. However, the lek counts were conducted sporadically on only the 3 known active leks in the entire West Desert. To complete their plan, WDARM needed information on sage-grouse ecology, in particular, habitat use and movements.

The goal of my thesis research was to determine factors affecting greater sage-grouse reproductive ecology and habitat use patterns in the WDARM conservation area. This information will be used by the WDARM to identify and implement management actions to benefit sage-grouse and local communities, and aid in the writing of a local sage-grouse conservation plan. The specific objectives of this study were to: 1) estimate greater sage-grouse population numbers, 2) determine greater sage-grouse breeding, nesting, brood-rearing, and wintering habitat, 3) determine greater sage-grouse hen nesting dates and success, nest site vegetation characteristics, brood success, brood site vegetation characteristics, and annual survival rates for adults, 4) determine the relative abundance of arthropod populations within the Sheeprock Watershed, and 5) provide the

WDARM and Deep Creek Coordinated Resource Management Planning group with information to guide management actions designed to enhance habitat conditions for greater sage-grouse.

The Sheeprock Watershed population is migratory. The birds use the Sheeprock Mountains for breeding, nesting, and brood-rearing, then migrate to lower elevations to the north and south of the range during winter. The Deep Creek Watershed population is non-migratory; the birds use the Ibapah valley for all seasonal uses. Small segments of the population, mostly males, travel to the high elevations of the Deep Creek Mountains during the summer. Most birds move to the northwest into Nevada during winter, but I don't consider this a migration because of the short distance traveled and relatively similar habitat in both areas.

Gene flow does not occur between the Deep Creek and Sheeprock Watershed populations. However, gene flow may occur with other nearby populations. The Sheeprock Watershed population possibly has gene flow from the southeast. Known leks occur in Juab County along Highway 6; however, there may not be flow beyond those leks. The Deep Creek Watershed population may have gene flow with birds in Nevada. However, my research did not document any interactions of collared birds with any other populations. I do not believe translocating grouse into either population is needed or warranted at this time. Both populations are large enough that a genetic bottle neck is not occurring, and gene flow is taking place. Research in Strawberry Valley, Utah, has shown that translocated grouse do quite well (R. Baxter, Brigham Young University, unpublished report). If these populations become totally isolated, and their population numbers drop drastically, translocation can be used as a "last ditch effort."

The area had a 5-year drought in the early 2000s, but 2005 was a very wet year, with twice the annual spring precipitation. The wet spring of 2005 had effects on the nesting times and vegetation in both populations. Nest initiation dates were 2 weeks later in 2005 than in 2006 in both populations (Figure 4.1). In general, the forb and grass cover was greater in 2005 than in 2006. Grass height was also greater in 2005 than 2006. The higher percent of forb and grass cover, and increased grass heights may have been a contributing factor to the higher nest successes in both populations in 2005 (Table 4.1). The increase in precipitation in 2005, and subsequently an increase in forb production, may have caused an increase in arthropod production. Arthropod abundance generally increases with forb abundance (Potts 1986). Danvir (2002) showed arthropod biomass was generally greater in habitats having greater herbaceous plant cover. This increase in forbs and arthropods may be a contributing factor in the higher number of chicks per successful brood in 2005, compared to 2006 (Table 4.1).

Annual survival rates were generally higher in the Deep Creek Watershed than in the Sheeprock Watershed. At first thought this is surprising because the Sheeprock Watershed receives more predator control work, while the Deep Creek Watershed receives very little predator control work in comparison. A possible explanation for this is the relatively lower production of the Deep Creek Watershed site. There are fewer prey items for predators, which in turn would mean a lower number of predators in general to prey on sage-grouse. The reason the Sheeprock Watershed site receives a lot of predator control is because there are a lot of predators in the area. The control efforts do not kill all predators, and even with intensive control efforts, there are more predators in the Sheeprock Watershed site than in the Deep Creek Watershed. No red foxes were ever observed in the Deep Creek Watershed site, but were frequently seen in the Sheeprock Watershed site.

There are 3 factors that should be of greatest concern for the 2 populations of sage-grouse within the West Desert: 1) recruitment of sage-grouse chicks into the adult populations; 2) locating active leks; and 3) habitat loss and alteration. The ratio of chicks reaching adulthood is very low for both populations. This should be of great concern to managers, and should also be the focus of continued research. I suggest conducting telemetry studies to determine actual chick survival and determine if brood hopping is occurring. Current telemetry research in Utah has shown chick survival to be higher than any published survival rates (D. Dahlgren, Utah State University, personal communication). There is research being conducted throughout the West to determine if juvenile survival has been underestimated. Based on my research, these populations should be declining very quickly, but they are not. This suggests that my data may be underestimating population abundance. Dahlgren et al. (2006) showed an increase in brood use in small mosaic (maximize edge) treated (sagebrush thinning) areas in larger expanses of sagebrush, with most brood use within 30 m of an edge. I suggest treatments in known brood rearing habitats to remove sagebrush canopy cover to create edge effect, and then plant with forbs. The area is extremely arid, and research to address which forbs will be successful within the treatments should be considered. Creating more and better brood rearing habitat will be beneficial to both populations.

Locating leks is vital in recovering the populations of sage-grouse in the West Desert. My research has shown that finding new leks is possible with increased effort. Heavy monitoring of known leks is also extremely important for identifying trends.

Locating new unknown leks is also very critical. Leks in the West Desert are the focal points for breeding, nesting, and brood-rearing. They may not be the focal point for winter habitat (as in the Sheeprock Watershed). Lek counts also serve as the basis for population estimates.

Habitat loss and alteration has been, and will continue to be a large concern for sage-grouse, and the West Desert is no different. Fires have burned large areas of habitat in both study sites, often being replaced by cheatgrass. Wildfire suppression in critical habitats should receive the highest priority. Green stripping should be implemented in areas to slow or stop wildfires from burning critical habitats. Intensive rehabilitation should take place after wildfires. Knowledge of which forbs do well in the arid environments of the study area would aid in rehabilitation efforts. Cheatgrass is a serious threat to both populations of sage-grouse, and research should be conducted to see if cheatgrass can be controlled in the West Desert.

Areas of sagebrush have been converted to large areas of crested wheatgrass, dry farms, or irrigated pastures. Fire suppression and livestock grazing have changed the distribution and age-class of dominant vegetation types. Effort needs to be placed on converting some areas to a mosaic of differing age-classes of dominant vegetation. Treatments need to be conducted and monitored into the future to determine if they met habitat improvement objective. Sage-grouse are a good management indicator species because of the wide varieties of habitat they use. Management projects cannot focus on only one species, while others may be “slipping through the cracks.” All species that use the landscape must be considered.

The WDARM has been very successful thus far in the process. The local sage-grouse conservation plan will be completed in spring of 2007. A local adaptive resource management plan is the best current method we have of address the complex world of natural resource management, and specifically sage-grouse recovery (Braun 1998). Involvement of all stake holders is vital in creating an atmosphere where everyone can be heard and have a chance to state their own goals and objectives. WDARM should continue to meet into the future to address new problems as they arise, and also to address new species of concern as they too arise.

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Table 4.1. Greater sage-grouse nesting, brood-rearing, and annual survival data, Sheeprock and Deep Creek Watersheds, Utah, 2005-2006.

	Sheeprock Watershed		Deep Creek Watershed	
Parameter	2005	2006	2005	2006
Population Estimate	572	760	236	372
Nest Success	70%	55.6%	100%	50%
$\bar{x}$ clutch size	6.0	6.3	7.25	8.7
$\bar{x}$ nest initiation date	7 May	19 Apr	5 May	15 Apr
Brood Success[a]	28.6%	30%	50%	66.7%
$\bar{x}$ chicks/successful brood	3.5	1.7	3	2
Female survival rate	57%	52%	100%	75%
Male survival rate	67%	33%	100%	33%[b]

[a] Represents the % of hens that successfully nested that had successful broods. A brood was considered successful if ≥ 1 chicks lived to an age of 50 days.

[b] Unknown if mortality occurred, 2 of 3 males' collars disconnected during lekking activities.

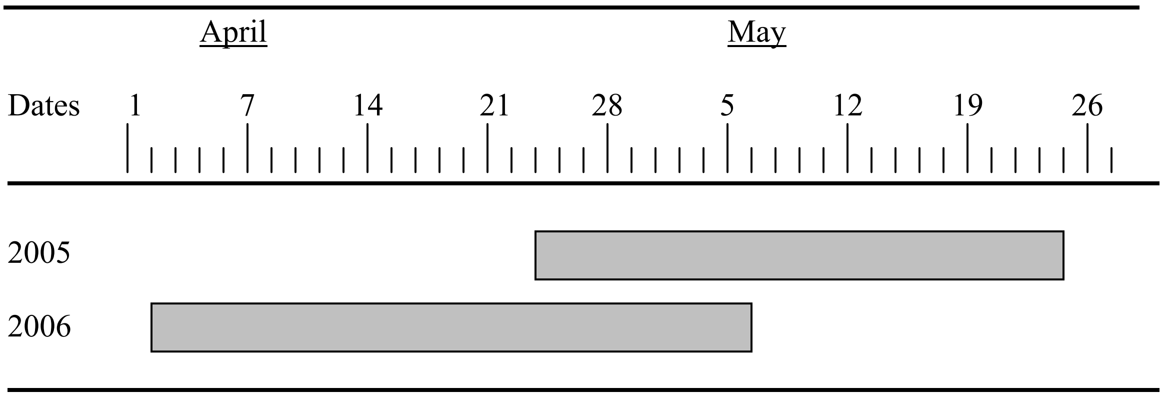

Figure 4.1. Greater sage-grouse successful nest initiation dates for all nests, both populations combined, West Desert Study Area, Utah, 2005-2006.

APPENDIX

Arthropod Collection

Table A.1. Arthropod families, number of individuals, and volume for all arthropods captured in pitfall traps, Sheeprock Watershed, Utah, 2005-2006.

Family	# of Individuals	Volume (ml)
Formicidae (Ants)	67,412	851.19
Carabidae (Ground Beetles)	167	125.25
Tenebrionidae (Darking Beetles)	86	14.82
Histeridae (Carion Beetles)	47	11.73
Nabidae (Damsel Bug)	2	0.04
Scarabaeidae (Scarab Beetles)	13	2.12
Elateridae (Click Beetles)	7	0.35
Curculionidae (Weevils)	2	0.44
Coccinellidae (Ladybird Beetles)	2	0.06
Cicadellidae (Leafhoppers)	421	1.74
Cercopidae (Spittlebugs)	8	0.05
Lygaidae (Seed Bugs)	153	1.73
Gryllacrididae (Camel Cricket)	22	2.79
Acrididae (Grasshoppers)	7	6.54
Tettigonidae (Mormon Cricket)	8	4.24
Forficulidae (Earwig)	2	0.11
Tipulidae (Craneflies)	53	5.28
Machilidae (Jumping Bristletails)	66	0.64
Araneida (Spiders)	484	21.52
Solpugida (Windscorpians)	1	0.08
Isopoda (Pillbugs)	16	0.7
Phalangida (Harvestmen)	9	0.4
Unknown Coleoptera larvae	13	0.32
Saturniidae (Moth larvae)	32	48.43
Unknown Lepidoptera larvae	54	7.02