GREATER SAGE-GROUSE RESPONSE TO SAGEBRUSH REDUCTION TREATMENTS IN RICH COUNTY, UTAH

by

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ABSTRACT

Greater Sage-grouse Response to Sagebrush Manipulations in Rich County, Utah

by

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Management of greater sage-grouse (*Centrocercus urophasianus*) in the west has changed over the last several decades in response to environmental and anthropogenic causes. Many land and wildlife management agencies have begun manipulating sagebrush with herbicides, machinery, and fire. The intent of these manipulations (treatments) is to reduce sagebrush canopy cover and increase the density of grass and forb species, thus providing higher quality sage-grouse brood-rearing habitat. However, monitoring of sage-grouse response to such manipulations has often been lacking or non-existent. The objective of our study was to determine the response of sage-grouse to sagebrush reduction treatments that have occurred recently in Rich County, Utah. Our study areas were treated with a pasture aerator with the intent of creating sage-grouse brood-rearing habitat. We used pellet transects, occupancy sampling, and GPS radio telemetry to quantify sage-grouse habitat use in treated and untreated areas. Pellet transect, occupancy, and GPS radio telemetry methods all showed a strong pattern of sage-grouse use of treated sites during the breeding and early brood-rearing periods.

Sage-grouse use of treated sites was greatest in lower elevation habitat (1950 to 2110 m), and use was highest during the breeding and early brood-rearing periods. We found very little use of higher elevation (2120 to 2250 m) treated or untreated sites. Our results suggest that sagebrush reduction treatments can have positive impacts on sage-grouse use at lower elevations and can be successful in creating brood-rearing habitat. Elevation differences and period of sage-grouse use were significant factors in our study in determining how beneficial sagebrush reduction treatments were for sage-grouse.

(108 pages)

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CHAPTER 1

INTRODUCTION

The greater sage-grouse (*Centrocercus urophasianus*) is the largest bodied grouse species in North America. The species historical presence, along with its unique physiological and behavioral displays, have made it a symbol of the American west. Many early explorers and settlers documented the presence of sage-grouse in large numbers. Sage-grouse populations have declined since their historical highs, largely due to changes in land management. These changes have occurred in the form of alteration of fire regimes, excessive livestock grazing, introduction of non-native plants, planting of large tracts of crested wheatgrass (*Agropyron cristatum*), farming, energy development, and other land alterations (Crawford et al. 2004). However, in areas of intact sagebrush and low disturbance, sage-grouse populations persist.

Providing quality shrubsteppe habitat is the focus of many management agencies. Managers have begun treating degraded areas to restore habitat components necessary to maintain productive sage-grouse populations. This requires knowledge of sage-grouse habitat needs, as well as the species response to these manipulations. It requires monitoring methods that provide an accurate assessment of sage-grouse habitat use. Adequate monitoring of treated areas can provide critical feedback to whether these areas are benefiting sage-grouse, and how and when sage-grouse are responding to shrubsteppe reduction treatments.

SPECIES DESCRIPTION

Greater sage-grouse are of the order Galiformes and the family Phasianidae. They are the largest native grouse species in North America. Male sage-grouse can weigh up to

3.2 kg and are 65-75 cm in length; females weigh up to 1.5 kg and are 50-60 cm in length (Autenrieth 1981). Males have a white breast and belly, long tail, dark back and head, with a yellow eye comb and filoplumes rising from the neck. They have 2 large yellow skin patches on their chest that are inflated during courtship displays (Schroeder et al. 1999). Females are smaller than males and are more cryptically colored. They lack the dark head and tail, yellow patches on the chest, and have a smaller eye comb (Schroeder et al. 1999). Males and females both have a black patch on their belly.

Sage-grouse are most recognized for their elaborate breeding displays which occur each spring. Males and females congregate on lek sites during the early morning hours. Males defend areas from 5–100 m^2 (Gibson and Bradbury 1987). Yearling males do not hold territories, but their attendance at leks increases as female attendance increases (Eng 1963, Gibson and Bradbury 1987). Females frequently visit the lek to breed with the dominant male (Gibson et al. 1991).

SPECIES DISTRIBUTION

Greater sage-grouse are considered shrubsteppe-obligate species due to their dependence on sagebrush communities for most of their life cycle (Braun et al. 1977). Greater sage-grouse ranges occur in portions of western North America that support sagebrush (*Artemisia* spp.) species. Sage-grouse range encompasses 2 Canadian provinces and twelve U.S. states, including Alberta, Saskatchewan, North Dakota, South Dakota, Wyoming, Montana, Colorado, Idaho, Utah, Nevada, California, Oregon, and Washington (Schroeder et al. 2004). Historical sage-grouse populations also existed in Arizona, New Mexico, Oklahoma, Nebraska, Kansas, and British Columbia (Patterson 1952, Schroeder et al. 2004). In Utah, sage-grouse once occupied all 29 counties.

However, their distribution has been reduced to 26 counties and only 50% of their historical distribution in the state (UDWR 2002, Beck et al. 2003).

GENERAL HABITAT REQUIREMENTS

Sagebrush is the dominant component of sage-grouse habitat. Sagebrush steppe habitat used by sage-grouse can vary by sagebrush species, grass and forb composition, and structure. Sage-grouse utilize sagebrush communities for wintering, pre-laying, lekking, nesting, early brood rearing, and summer-late brood rearing habitat. Sagebrush communities follow a grassland to shrubland continuum, where communities along the continuum range in grass, forb, and shrub cover and height, and provide specific habitat components necessary for sustaining sage-grouse during different times of the year. Maintaining heterogeneous sagebrush habitats at different stages within this sagebrush state is critical for adequate sage-grouse habitat (Westoby et al. 1989, West 1999).

Winter Habitat

Sagebrush in winter habitat is tall, relatively dense, and provides food and cover for sage-grouse. These areas usually have denser, taller sagebrush than nesting sites. Wintering sites are selected based on topography and snow depth, depending on environmental conditions (Robertson 1991). Sage-grouse frequently utilize south-facing slopes where snow depths are shallower and more vegetation is exposed due to melting. Winter sagebrush habitat typically has a canopy cover of 10-40% and heights of ≥25 cm (Connelly et al. 2000a) Tall sagebrush provide sage-grouse access to forage and cover above the snow. Sage-grouse feed almost exclusively on sagebrush leaves during the winter (Patterson 1952). Big sagebrush (*A. tridentata*) is the preferred sagebrush species consumed by greater sage-grouse (Patterson 1952, Wallested 1975, Remington and Braun 1985, Welch et al. 1988, Robertson 1991), although low sagebrush (*A. arbuscula*), black sagebrush (*A. nova*, Dalke et al 1963, Beck 1977, Dahlgren 2006), fringed sagebrush (*A. frigida*, Wallestad 1975), and silver sagebrush (*A. cana*, Aldridge 1998) are also consumed by sage-grouse.

Pre-laying Habitat

Pre-laying habitats are important areas for hens preparing to nest. They are areas in winter and nesting habitat where sage-grouse hens feed to prepare for nesting. Pre-laying is approximately 5 weeks before incubation occurs (Barnett 1992). At that time hen sage-grouse diets consists of 50 to 80% sagebrush leaves (Barnett and Crawford 1994). However, many of the nutrients needed for egg laying come from forbs that are high in calcium, phosphorus, and protein. Areas lacking forbs can greatly inhibit sage-grouse reproductive success and nest initiation rates (Barnett and Crawford 1994, Coggins 1998).

Lekking Habitat

Lekking sites occur in areas with sparse vegetative cover, such as short sagebrush flats, ridge tops, roads, abandoned mining sites, and old lake beds (Connelly et al. 1981). Lekking sites are typically adjacent to sagebrush habitat that would be considered productive nesting habitat (Connelly et al. 2000a). These sites become important congregating areas for sage-grouse. Males use these sites for mating displays; females visit these sites to select mates. These sites are often formed opportunistically (Connelly et al. 2000a) in areas with high numbers of females (Gibson 1992).

Nesting Habitat

Most sage-grouse initiate nests under sagebrush plants (Wallestad and Pyrah 1974). In southeastern Idaho, Connelly et al. (1991) found that 79% of sage-grouse nests were located under sagebrush. Sage-grouse that nest under sagebrush have greater nest success than grouse nesting under any other plant species because of the canopy cover sagebrush provides (Connelly et al. 1991). Mean sagebrush height used by nesting grouse ranges from 29 to 80 cm (Apa 1998). Most nests are placed under shrubs having large canopy cover (Wakkinen 1990, Sveum et al. 1998). Nesting habitat typically has a sage-brush canopy cover between 15-30% (Connelly et al. 2000a).

Grass and native forb cover are also important components of nesting habitat. Grass heights at nest sites were taller and denser than grass heights at random sites (Wakkinen 1990, Sveum et a. 1998). Herbaceous cover in nesting habitat can vary from 3-51% (Connelly et al. 2000a). Gregg et al. (1994) showed that nests in stands of sagebrush 40-80 cm in height experienced less nest predation if grass heights exceeded 18 cm. Herbaceous cover may provide scent, visual, and physical obstructions for potential predators (DeLong et a. 1995). Having vegetation diversity is critical to provide horizontal and vertical concealment of nests (Connelly et al. 1991).

Early Brood-Rearing Habitat

Brood rearing habitat occurs in areas close to nesting sites. This habitat typically has less sage canopy cover than nesting habitat, with relatively dense (≥15%) grass and forb cover (Sveum et al. 1998, Lyon 2000). Areas with high plant species richness and abundant insects and forbs are ideal brood rearing areas (Apa 1998). Drut et al. (1994a) showed that hens with broods sought out areas where forb abundance was greatest. Brood sites in southeastern Idaho had twice as much forb cover as random sites (Apa 1998). Insect abundance plays a critical role in brood rearing habitat (Drut et al. 1994b, Fischer et al. 1996a). Sage-grouse chicks depend on insects, primarily beetles, ants, and grasshoppers, for survival and growth (Patterson 1952, Johnson and Boyce 1990).

Summer-Late Brood-Rearing Habitat

Sage-grouse move to summer habitat in June and July. These areas are typically more mesic and/or often at higher elevations than nesting habitat (Gill 1965, Klebenow 1969, Savage 1969, Connelly and Markham 1983, Gates 1983, Connelly et al. 1988, Fischer et al. 1996b). They frequently contain succulent forbs such as dandelion (*Taraxacum officinale*), salsify (*Tragopon dubius*), lettuce (*Lactuca* spp.), and hawksbeard (*Crepis acuminate*) (Connelly et al. 2003). Burned areas (Pyle and Crawford 1996), wet meadows (Savage 1969), sagebrush (Martin 1970), farmland, and irrigated areas near sagebrush characterize summer habitat (Connelly et al. 1988). These areas provide green forbs and are abundant with insects. Apa (1998) found habitat used by broods during this period had twice as much forb cover as random sites.

SAGE-GROUSE HABITAT MANAGEMENT

Sage-grouse population declines and range contractions have been attributed to alteration of sagebrush ecosystems through agricultural conversion, drought, fire, invasive species, and urban and commercial development (Braun 1995, Connelly and Braun 1997, Knick et al. 2003). Habitat loss occurs when sagebrush structure (vertical height and horizontal cover) and the diversity of plant species in the understory is greatly reduced (Winward 1991). Habitat fragmentation can occur when productive sage-grouse habitat is interrupted or fragmented by roads, power lines, and buildings. Indirect effects from these disturbances, such as human activity and noise, can further disturb sage-grouse. Results of habitat degradation can result in increased competition for suitable nesting sites, reduced feeding and brood rearing areas, and an overall decline in sage-grouse populations (Connelly et al. 2000a). Vale (1974) predicted that eventually all sagebrush habitat would be manipulated in some way. This has been the case in many areas in the west, including Rich County, Utah.

Sagebrush removal has been occurring for many decades. Demands for cattle and sheep in the mid 1900s led to the conversion of many sagebrush rangelands to grasslands (Rummell 1981). In many areas, sagebrush was removed and large monocultures of grass, such as crested wheatgrass, were introduced to increase livestock forage (Shown et al. 1969, Vale 1974, Beck and Mitchell 2000). For example, an estimated 2-6 million ha of shrublands were treated in the 1970s (Vale 1974). Herbicides (mostly 2, 4-D and tebuthiron) were a common chemical treatment method used to reduce sagebrush on rangelands until the 1980s (Braun 1987). Fire has become a more common form of treatment since the use of 2, 4-D on public lands was prohibited (Braun 1987). Mechanical manipulations of sagebrush have occurred for decades, but in recent years there has been a major movement to improve wildlife habitat on rangelands using less disruptive mechanical techniques. As a result, mechanical treatments have become the most frequently used method to reduce shrub cover.

Currently, many land and wildlife management agencies and private ranches are reducing sagebrush with herbicides, various machinery, and prescribed fire. This reduction in shrub cover is designed to increase grass and forb cover and return the system to an earlier successional stage. This approach follows the state-and-transition model concept (Westoby 1989, West 1999), that stable plant communities can potentially occupy individual ecological sites. This concept is not limited to a single pathway of vegetation change or a single climax plant community. It is founded on the idea that continuous and reversible vegetation dynamics will exist within a stable vegetation state. Discontinuous and nonreversible dynamics will occur when thresholds are surpassed and one stable state replaces another (Briske et al. 2005). An example of this is the invasion of cheatgrass (*Bromus tectorum*) throughout the west. As cheatgrass densities increase, fire return intervals become shorter, resulting in fewer native shrub, grass, and forb species, and large monocultures of cheatgrass.

The intent of sagebrush reduction treatments for sage-grouse habitat management is to reduce sagebrush canopy cover and increase the density and diversity of grass and forb species, thus providing higher quality sage-grouse foraging areas and brood rearing habitat (Sveum et al. 1998, Lyon 2000, Connelly et al. 2000a). A wide range of fire, chemical, and mechanical methods exists for managing sage-grouse habitat. Each manipulation scheme varies in percent of sagebrush reduction, amount of ecological disturbance, and system recovery time.

Fire Management

Fire has played an important role in the disturbance regime of sagebrush communities. Historic fire return intervals for sagebrush ecosystems varied depending on the sagebrush community. Fire return intervals were 325-450 years in low sagebrush systems (*A. arbuscula*); 100-240 years in Wyoming big sagebrush; 70-200 in mountain big sagebrush; and 35-100 years in mountain grasslands with little sagebrush (Baker 2006).

As settlement began in the Intermountain West, time between wildfires increased dramatically. This was primarily due to a loss of fine fuels by overuse of livestock, land fragmentation, and intentional fire suppression (Wrobleski and Kauffman 2003). The suppression of fire can alter the balance between sagebrush and herbaceous cover by increasing shrub species and reducing grasses and forbs in sagebrush understory (Burkhardt and Tisdale 1976). Fire suppression also promotes pinyon-juniper expansion, which has reduced sage-grouse habitat in some areas (Commons et al. 1999).

Intense and frequent fires can also increase harmful invasive plant species, such as cheatgrass (Valentine 1989). Cheatgrass is an annual grass that flowers in late spring or early summer. It is very aggressive and can completely replace native vegetation. It produces large amounts of seed and biomass which become highly flammable, fine-textured fuels. Cheatgrass can increase the fire return intervals to 5 years or less (Whisenant 1990); sagebrush cannot re-establish under such short intervals. This creates a cheatgrass-fire feedback loop that is difficult to break. It results in monocultures of cheatgrass, loss of sagebrush, and increased soil and nutrient loss due to erosion (Swanson 1981, Walker 1999). Reversing this cycle and moving these monocultures over a threshold to another more natural state has proved to be very difficult (Pellent 1990, D'Antonio and Vitousek 1992, Knick and Rotenberry 1995, Knick 1999, Briske et al. 2005).

Public perception of prescribed fire is generally well accepted, although public views are not often positive due to the haze and smell that it creates (Shindler et al.

2007). Prescribed burns are often difficult to perform because they require extensive supervision and a narrow window of fuel moisture and weather conditions. Several variables such as wind, temperature, and fuel load will dictate the intensity of the fire. Extremely intense fires can remove nearly all vegetation in their path, which can lead to drastic ecological changes. Wyoming big sagebrush stands burned by intense fires can have almost no noticeable recovery for 30 years (Wambolt and Payne 1986). Recovery is defined as a system returning to pre-treatment conditions; generally it takes over 12 years for mountain big sagebrush to recover, and at least 50 years for Wyoming big sagebrush stands to recover (Blaisdell 1953, Winward 1991, Colket 2003, Baker 2006).

Still, under the proper fuel conditions, prescribed fires can be used in many situations, regardless of slope or other obstacles of the terrain being treated. From a management perspective, fire is beneficial because it can leave a mosaic pattern that is hard to replicate, and can provide connectivity between patches or islands of habitat that are very beneficial to wildlife.

Fire is an effective way of reducing sagebrush, and it has been shown to increase grass and forb species (Wright 1985). Pyle and Crawford (1996) found that sage-grouse use of burned areas increased post-burn. Gates (1983), Martin (1970) and Benson et al. (1991) did not find any significant impacts of fire on breeding sage-grouse populations. Fischer et al. (1996a) showed fire had marginal effects on migratory movements of female sage-grouse. Klebenow (1970), Gates (1983) and Sime (1991) showed that fire may improve sage-grouse brood-rearing habitat. Robertson (1991) reported that a 2000 ha fire on a sage-grouse winter range had minimal immediate impacts on the sage-grouse population in Idaho. However, grouse use of the area declined in subsequent years.

Fire in sagebrush habitat can adversely affect sage-grouse populations, depending on the intensity, size, and timing of the fire. Fire can lead to lower male lek attendance post-burn (Connelly et al. 2000b). Hulet (1983) found that fire resulted in the loss of sage-grouse leks. Nelle et al. (2000) showed that canopy cover of mountain big sagebrush was significantly reduced following a fire. The site didn't return to adequate nesting cover for 14 years after being burned.

In general, fire can be a very effective way of creating or improving specific sage-grouse habitat types if properly controlled. Fire removes much of the sagebrush canopy, so caution must be used when selecting areas to burn. It is critical to avoid burning areas used for nesting or wintering habitat, where sage-grouse depend on the structure and canopy of sagebrush and other shrubs.

Chemical Management

The primary purpose of using herbicides has been to increase livestock forage on sagebrush rangelands (Braun 1987). Herbicide applications are very effective in reducing sagebrush canopy cover. Herbicides are typically applied aerially over large areas at a time; slope and terrain do not limit aerial applications. They are less costly than mechanical treatments, and require less time and manpower to perform. However, public perception of chemical treatments is not good (Shindler et al. 2007). Olsen and Whitson (2002) recommend tebuthiuron on big sagebrush to increase herbaceous cover. Herbicide applications in early spring have been shown to increase herbaceous cover in brood rearing areas in Idaho (Autenrieth 1981). Herbicides also leave "sagebrush skeletons", which can provide escape cover, thermal cover, and moisture which can enhance forb response (Dahlgren et al. 2006).

While herbicides are effective in reducing sagebrush densities, they can adversely affect grass and forb species (Hurd 1955, Blaisdell and Muegglar 1956). Peterson (1970) found that chemical reduction treatments adversely impacted sage-grouse on breeding sites in Montana. Klebenow (1970) reported a complete cessation of sage-grouse nesting in newly sprayed areas due to a lack of adequate sagebrush canopy cover. Pyrah (1972) showed chemical treatments negatively impacted sage-grouse use of wintering sites in Montana. If treated areas are reseeded with crested wheatgrass, the affects of the treatment can become even more severe (Enyeart 1956).

Under the proper conditions, chemical methods for treating sagebrush will be successful in creating or improving sage-grouse habitat. Low application rates are recommended to avoid overkill of sagebrush (Dahlgren et al. 2006). This will also increase herbaceous cover, particularly forb species. However, good forb seed bases or forb seeding are required for positive forb response. Treatments that are several hectares in size are preferred to large-scale landscape manipulations. Chemical methods will be most beneficial when used to create brood rearing sites. Reductions in sagebrush canopy cover could adversely affect nesting and wintering sage-grouse (Klebenow 1970).

Mechanical Management

Mechanical implements are designed for varying degrees of disturbance intensity. They are typically used to increase vegetation diversity within sagebrush habitat (Wambolt and Payne 1986). Plows and disks cause the greatest disturbance because of disrupted soil (Parker 1979). Dixie or pipe harrows, pasture aerators, and chaining are considered less invasive because they remove taller, usually older sagebrush, and have less of an affect on smaller, less mature plants. Mechanical treatments are typically applied to smaller areas than chemical and fire treatments.

In the past, mechanical implements have been used to completely eliminate sagebrush from the system. Many areas were reseeded using aggressive, non-native species like crested wheatgrass which provide high quantities of forage for cattle, but little wildlife value. Eventually the native species are excluded and the area becomes a monoculture of the aggressive species.

The use of mechanical treatments for removing sagebrush habitat has changed in recent years. This is largely because of greater cooperation between private landowners and wildlife and land management agencies. The results of these partnerships are manipulations that are less intense and more wildlife friendly. Sagebrush is reduced but not completely eliminated from the system. Treated areas are often reseeded with native and naturalized grass and forb species that provide forage for livestock, as well as forage and cover for wildlife.

A significant management drawback for mechanical reduction treatments is their limited effectiveness under certain conditions. Steep slopes, rocky terrain, hills, ravines, and other physical features can reduce access and effectiveness of mechanical tools. The benefit of mechanical treatments is that they are easily controlled. This allows planning for specific shapes of treatments, intensity of treatment, and areas that need to be avoided. It can also allow for connectivity between treatments and habitat, islands of untreated habitat within treatments, and edges that are used frequently as escape cover by wildlife. Timing of mechanical treatments can also be more flexible than other treatment methods. Public perception of mechanical treatments is generally good (Shindler et al. 2007).

Little research has been conducted on the effects of these newer mechanical treatment techniques on sage-grouse habitat. Watts and Wambolt (1996) reported on several treatment methods for Wyoming big sagebrush. Plowing of sagebrush stands returned to similar levels of their control plots quicker than burned, chemical, and rotocut treated areas. Mechanical reduction treatments appear to enhance sage-grouse brood rearing habitat when done in strips 4-8 meters wide (Connelly et al. 2000a). Dahlgren et al. (2006) found that in degraded sagebrush brood-rearing habitat, Dixie-harrow or Lawson-aerator treatments can successfully increase sage-grouse use. This was attributed to sagebrush structure remaining in the treated area after the treatment occured. Conversely, when sagebrush is completely removed from the site, Swenson et al. (1987) showed that mechanical manipulations decreased male lek attendance by 73% after plowing.

PURPOSE

The purpose of this study is to determine the response of greater sage-grouse to mechanical sagebrush reduction treatments in Rich County, Utah. The need for this study came after a petition to list the greater sage-grouse and a threatened or endangered species occurred in July of 2002. In January of 2005, a 12-month finding by the U.S. Fish and Wildlife Service (USFWS) was released (USFWS 2005). It specifically lists the present or threatened destruction, modification, or curtailment of sage-grouse habitat as one of their potential listing factors. The finding mentions habitat modifications such as fences, roads, mining, energy development, urbanization, fire, grazing, and invasive weeds as potentially negative impacts on sage-grouse populations. After an extensive review process, the petitioned action to list the greater sage-grouse as threatened or endangered was found to not be warranted at that time. However, much discussion has continued over the status of sage-grouse populations, and an additional court-ordered review began in 2008 to determine if the species warrants protection under the Endangered Species Act. In March of 2010 the USFWS announced that the greater sage-grouse will be placed on the list of species that are candidates for Endangered Species Act protection (USFWS 2010). The USFWS will continue their review of the sage-grouse annually and will propose it for listing when funding and workload permit.

The USFWS findings emphasize that much destruction of sagebrush habitat has occurred, and loss or degradation of sagebrush habitat would be a direct threat to the sustainability of sage-grouse populations. Rich County has had many of the above-mentioned activities occur since its settlement in the 1800s; many which came in the form of attempted sagebrush removal treatments. Thus, it is our prerogative to further investigate the effects that sagebrush treatments are having on sage-grouse populations in Rich County. We will specifically investigate pasture aerator treatments because they are the most common current treatment type in Rich County.

Sage-grouse populations in Rich County are estimated using male lek count data. Lek data has shown that male lek attendance county-wide has been increasing since the spring of 2003 (UDWR 2009). Sage-grouse populations on our study sites are stable to increasing; some of the highest concentrations of sage-grouse in the county have been observed on or near our study sites, with some leks averaging over 80 birds per lek.

The objectives for our study were to:

1) Determine whether sage-grouse habitat use in pasture aerator sagebrush reduction treatment areas is different than in untreated areas.
2) Determine how sage-grouse habitat use changes in response to pasture aerator sagebrush reduction treatments.

In Chapter 2 we outline the effects of pasture aerator treatments that occurred at different elevations on the Duck Creek study area in 2003. In Chapter 3 we discuss the effects of a pasture aerator treatment on Deseret Land and Livestock study area before and after a 2007 treatment.

STYLE

The Abstract, Acknowledgments, Contents, and Chapter 1, 2, 3 and 4 are written following a modified version of The Journal of Wildlife Management 2008 unified style guidelines (Chamberlain and Johnson 2008).

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CHAPTER 2

GREATER SAGE-GROUSE USE OF A RESTORED SAGEBRUSH RANGELAND

ABSTRACT Managing greater sage-grouse populations in the west has changed over the last several decades, due to environmental and anthropogenic causes. To better manage sage-grouse populations, many land and wildlife management agencies have begun treating sagebrush with herbicides, machinery, and fire. The intent of these treatments is to reduce sagebrush canopy cover and increase the density of grass and forb species, thus providing higher quality sage-grouse brood-rearing habitat. However, monitoring of sage-grouse response to such sagebrush reduction treatments has often been lacking or non-existent. The objective of our study was to determine the response of sage-grouse to pasture aerator sagebrush reduction treatments that occurred in 2003 on our Duck Creek study are in Rich County, Utah. We used pellet density transects, occupancy sampling, and GPS radio telemetry to quantify sage-grouse habitat use in treated and untreated areas at higher (2120 – 2250 m) and lower (1950 – 2110 m) elevations from 2007 to 2009, during the breeding and brood-rearing periods. We found high sage-grouse use in treated sites compared to untreated habitats. We found that sage-grouse were utilizing lower elevation treated areas at a higher rate than untreated sites during the spring and early summer. As living herbaceous cover on lower elevation treated sites began to decrease, sage-grouse moved to late brood-rearing areas outside of Duck Creek. In contrast to lower elevation sites, very low sage-grouse use was observed in higher elevation sites in both treated and untreated areas. This indicates that sage-grouse use were unafected by sagebrush reduction at these sites. Our results suggest that

sagebrush manipulations can have positive impacts on sage-grouse use under certain conditions. Elevation differences and period of sage-grouse use were significant factors in our study in determining how beneficial sagebrush reduction treatments were for sage-grouse.

INTRODUCTION

The focus on greater sage-grouse (*Centrocercus urophasianus*) populations has increased over the last several decades as localized populations of sage-grouse have decreased in response to the alteration of sagebrush ecosystems through agricultural conversion, drought, fire, invasive species, and urban and commercial development (Knick et al. 2003). The U.S. Fish and Wildlife Service has been reviewing the status of greater sage-grouse for the last 5 years to determine if sage-grouse populations warrant further protection. Their findings specifically list habitat modification and loss as a significant factor affecting sage-grouse (USFWS 2010).

Brood-rearing habitat for sage-grouse has been identified as limiting in many areas where heavy sagebrush canopy cover may be inhibiting vegetation understory. Within the state-and-transition framework (Westoby et al. 1989, West 1999), sagebrush dominated stands are converted through fire, chemical, or mechanical treatments to brood-rearing habitat by reducing shrub cover, moving the system from a late to an earlier seral stage within a single shrubsteppe state. The intent of treatments is to remove or reduce sagebrush and shrub canopy cover. Achieving sagebrush canopy cover between 10% and 25% can positively affect sage-grouse brood-rearing habitat by increasing densities of grasses and forbs which can provide nutrients for sage-grouse broods and increase insect abundance (Winward 1991, Beck and Mitchell 2000, Connelly et al.

2000). Areas rich in forbs and insects are important components of sage-grouse brood-rearing habitat (Dunn and Braun 1986).

The effects of sagebrush reduction treatments on sage-grouse have shown mixed results. Negative results were found by Wallestad (1975) who observed decreases in lek counts in populations that were close (<0.5 km) to sagebrush manipulations while populations >4 km from leks did not exhibit decreases. Pyrah (1972) also found negative impacts in that treatments in wintering habitat could decrease sage-grouse use depending on the severity of the treatment.

In contrast, more modern treatments designed to create sage-grouse brood-rearing habitat have shown positive impacts for greater sage-grouse. Dahlgren et al. (2006) recorded positive results when using manipulations to create brood-rearing habitat in south-central Utah. They treated sagebrush using chemical and mechanical methods and showed increased use by sage-grouse hens and broods in both areas post-treatment. Additional support for sagebrush reduction treatments by Danvir (2002) in Rich County suggests that mechanical treatments in dense stands of low elevation sagebrush can have positive impacts on sage-grouse.

The objectives of this study were to determine sage-grouse response 4 to 6 years after pasture aerator reduction treatments that occurred in 2003 in Rich County, Utah. Pasture aerators have been used recently in several recent studies to show their effects at removing sagebrush canopy cover (Dahlgren et al. 2006, Yeo 2009). We used pellet density transects, occupancy sampling, and GPS radio telemetry to obtain sage-grouse use and density data from 2007 to 2009. We compared results from each method to obtain an understanding of sage-grouse use of treatments, and how use changed throughout the spring and summer. We examined sites at 2 different elevations to see how elevation might affect sage-grouse habitat use.

STUDY AREA

Rich County was located in northeastern Utah, approximately 184 km northeast of Salt Lake City, Utah (Fig. 2.1). Mean temperatures ranged from -12.2─28.3 ºC throughout the year. The county received 25─30 cm of precipitation annually, with most occurring from October to December as snow and April to May as rain (WRCC 2009). The county was 2740km², with 40% of that being dominated by shrubsteppe communities. Within shrubsteppe, dominant shrub species included Wyoming big sagebrush (*A. t. wyomingensis*), mountain big sagebrush (*A. t. vaseyana*), basin big sage (*A. t. tridentata*), black sage (*A. nova*), antelope bitterbrush (*Purshia tridentata*), snowberry (*Symphoricarpos* spp.), Utah serviceberry (*Amelanchier utahensis*), rubber rabbitbrush (*Ericameria nauseosus*) and yellow rabbitbrush (*Chrysothamnus viscidiflorus*). Common forbs included phlox (*Phlox* spp.), daisy (*Erigeron* spp.), milkvetch (*Astragolus* spp.) and penstemon (*Penstemon* spp.). Common grasses included gramma (*Bouteloua* spp.), fescue (*Festuca* spp.), *Poa* species and, wheatgrasses (*Agropyron spp*.).

Our study was conducted on the Duck Creek Grazing Allotment at the north end of Rich County, 20 kilometers south of the Idaho border (Fig. 2.1). Duck Creek was a 95km² grazing allotment created by a mosaic of federal, state and private lands. Cattle grazing on Duck Creek occurred from May to October. Permittees rotated their cattle throughout the 4-pasture allotment during the grazing period.

Elevations in Duck Creek ranged from 1950 m to 2250 m. The lower elevation habitat (1950-2110 m) was dominated by Wyoming big sagebrush and a variety of grasses and forbs. Higher elevation habitats (2120-2250 m) in Duck Creek contained more shrub species, including snowberry, serviceberry, and antelope bitterbrush.

METHODS

The sagebrush reduction treatments on Duck Creek were conducted in 2003 using a pasture aerator (Fig. 2.2). Approximately 270 and 265 hectares were treated to reduce shrub cover in higher and lower elevation habitats respectively (Fig. 2.1). The aerator treatments selectively crushed and killed older, mature shrubs while leaving younger plants alive. Treatments created little soil disturbance and did not completely remove shrub or herbaceous cover from the area. Seeding during the treatment process of a grass and forb mix designed specifically for wildlife was also part of the treatment protocol (Appendix Table A.1). Cattle grazing was not permitted on the treated sites for 2 growing seasons post-treatment, which allowed establishment of grass and forb species. The treatments were designed to drive the treated areas to an earlier successional stage by reducing shrub cover and increasing grass and forb species.

A systematic (tessellation) grid system with a random start, similar to the Forest Inventory and Analysis grid (USFS 2005), was created for Rich County in 2005. Sampling locations for pellet density transects and occupancy sampling were chosen randomly from these tessellation points that occurred in treated and untreated areas in Duck Creek. We used the same points for pellet density transects, occupancy plots, and vegetation sampling.

Pellet Density Transects

Distance sampling (Buckland et al.1993) was used to estimate density of sage-grouse pellets in treated and untreated areas in May and June. Sage-grouse pellets were used as the response variable. Adequate transect line lengths were calculated using the Buckland et al. (1993) line length equation. We used preliminary data to determine sample line lengths. Pellet density transects were 500 meters in length in treated areas and 600 meters in untreated areas.

Locations for pellet density transects were chosen from the tessellated grid system. The grid points were used as a starting point for pellet transects. The same grid points were used each year for each transect; the transect direction was randomly chosen each year to avoid double counting pellets. We slowly walked along the transect looking for sage-grouse pellets. We measured from the transect line to the center of each pellet cluster to the nearest centimeter.

We monitored pellets of known age to develop color-coded pellet age charts to determine the age of sage-grouse pellets. We also monitored known age pellets through time to determine pellet persistence on the landscape. This allowed us to estimate the time of sage-grouse use of study sites and to avoid recounting pellets in subsequent transects.

Occupancy Sampling Plots

We sampled occupancy plots during 4 seasonal periods: Period 1 (Breeding Period) began May 1 and ended June 15; Period 2 (Early Brood-rearing) began June 16 and ended July 28; Period 3 (Late Brood-rearing) began July 29 and ended September 9;

Period 4 (Fall) began September 10 and ended October 22. These periods coincide with changing sage-grouse behavior and habitat needs during these periods.

Occupancy (presence/absence) sampling (MacKenzie et al. 2006) was used to estimate the probability of study plots being occupied by sage-grouse. We established 60 permanent ½ hectare plots at tessellation grid points in treated and untreated areas. We marked the corner of each plot with a 1-meter surveying flag. Surveying tape was placed at several locations along the outside edges of the plot to aid observers in identifying the plot boundaries.

A single observer slowly walked through each plot for a 10-minute period. Observers searched for direct sign (sage-grouse) and indirect sign (feathers, pellets, tracks) in each plot. We sampled each plot during each of the 4 seasonal periods to estimate seasonal use. Each plot was sampled 3 times per period.

GPS Radio Telemetry

GPS radio-telemetry was also used to verify sage-grouse use of treated and untreated areas during the breeding, early and late brood-rearing, and fall periods in 2008. Telemetry data provided information about sage-grouse use throughout the spring, summer, and fall of 2008. Telemetry also yielded information on sage-grouse use of treatment edges, as well as roosting, nesting, lekking, and foraging areas.

The ~33 g GPS/VHF radio units for our study were manufactured by Sirtrack™ (Private Bag 1403, Goddard Lane, Havelock North 4157, New Zealand). Total weight of each transmitter was approximately 33 g. We field tested the GPS radios for accuracy by placing them in known locations and allowed them to acquire locations for 1 week. We estimated the maximum mean accuracy of the radios to under 3 meters (16 locations per transmitter/ SE = 0.37). GPS locations were downloaded from recaptured radios to a computer from the transmitter using a USB cord. VHF units were glued to each GPS transmitter which allowed us to locate the sage-grouse in real time. Radioed birds were located using Communication Specialists, Inc.™ (426 West Taft Avenue, Orange, CA, USA) receivers, handheld 5-element Yagi folding antennas, and Telonics, Inc.™ (932 East Impala Avenue, Mesa, AZ, USA) vehicle mounted Omni antennas (RA-2A).

A total of 15 male and 12 female sage-grouse were fitted with radios in May through July of 2008. Sage-grouse were located at night using a spotlight from an ATV and captured using a dip net which was thrown over the sage-grouse (Geisen et al. 1982, Wakkinen et al. 1992). GPS radios were attached to each sage-grouse by trimming the back feathers to 3 cm length and cleaning them with acetone. Radios were glued to the backs of sage-grouse using cyanoacetate (Perry et al. 1981).

GPS radios were designed to take sage-grouse locations 2 times per day (0200 and 0800), and provided a robust measure of habitat use through time. Most radios stayed attached to sage-grouse for 30-60 days, after which time the glue would break down and radios would drop off sage-grouse. Birds were located once per week using VHF telemetry equipment to track sage-grouse movements and retrieve dropped radios. The battery life of our GPS units was approximately 80 days, and sage-grouse fitted with radios that did not fall off needed to be recaptured to download the data and recharge the unit. We retrieved the radios from sage-grouse in the fall of 2008 using trapping and spotlighting techniques.

Vegetation Measurements

We took vegetation measurements in the summer months of 2007, 2008, and 2009 at occupancy sampling and pellet density transect locations. The line-intercept method was used to obtain measures of shrub canopy cover (Canfield 1941); Daubenmire method was used to estimate vegetation cover (grass and forb) (Daubenmire 1959); and a Wiens pole was used to measure shrub height (Wiens 1969). We collected sage height data at a center point, and in each of the cardinal directions at 2 m from the center, for a total of 5 samples per site. We collected daubenmire data at the center point and in 2 randomly chosen cardinal directions for a total of 3 samples per site. We collected line intercept data in thirty meter lengths in a random direction, with the center point as the starting point (Fig. 2.3).

DATA ANALYSIS

Pellet Density Transects

We evaluated the relative support for *a priori* models of factors affecting pellet density (D_s) and detection probability (p) of sage-grouse pellets (Table 2.1) using program Distance 5.0.2 (Thomas et al. 2010). Akaike Information Criteria (AIC) (Burnham and Anderson 2002) values were used to determine which models best fit our data. Estimates of D_s and p per transect were calculated for treated and untreated areas using program Distance and post hoc means comparisons were performed in SAS 9.3.1 (SAS Institute Inc. 2007); we used a one-tailed t-test with 0.10 alpha level to test whether pellet densities were lower on treated than untreated areas.

Occupancy Sampling Plots

We assessed *a priori* models of factors affecting occupancy rates and detection probability (Table 2.2) using program MARK (White and Burnham 1999). We estimated occupancy (ψ), probability of local extinction (ϵ), and detection probability (p) on treated and untreated plots across the 4 sampling periods for 2 years. Covariates considered in the analyses included elevation (high or low), vegetation cover, and vegetation height. AIC values were used to estimate which models best fit our data (Burnham and Anderson 2002). Models within 2 ΔAIC units were considered top competing models and were model averaged.

GPS Radio Telemetry

We analyzed telemetry data by totaling the number of points each sage-grouse spent in treated and untreated areas during each period using ArcGIS 9.2 Geographic Information System (ArcGIS). This also allowed us to derive elevation information for each sage-grouse location. A chi-squared analysis was performed on sage-grouse location points to determine whether sage-grouse used treated areas more than expected by chance alone. Values with alpha $\leq$0.05 alpha level in treated areas were considered significant.

Vegetation Measurements

We analyzed vegetation data in SAS 9.3.1 (SAS Institute Inc. 2007) using analysis of variance. We performed post hoc means comparisons with a two-tailed t-test with a 0.10 alpha level to determine if vegetation used by sage-grouse was different between treated and untreated areas. We compared shrub canopy cover, shrub height, grass cover, and forb cover in treated and untreated areas at higher and lower elevation sites.

RESULTS

Pellet Density Transects

Pellet transect data showed that overall pellet densities were higher in treated areas than untreated areas (Table 2.3, Table 2.4). Lower elevation treated sites (D_s = 1296.9, SE = 178.9) had a greater density of pellets per hectare than higher elevation sites (D_s = 102.6, SE = 30.9). We found no differences in means among higher elevation treated and untreated sites. Lower elevation treated and untreated sites were significantly different (Fig. 2.4).

Probability of detection ranged from 0.31 to 0.37 and was highest in lower elevation treated plots (p = 0.37). Lower elevation treated plots differed statistically from lower elevation untreated sites (P = <0.001, Table 2.3).

Occupancy Sampling Plots

Our top 2 occupancy models accounted for nearly 80% of the model weights. We used model averaging for these two models and used them to account for site occupancy. Occupancy (ψ) showed a treatment effect, but there was also a year and trend in occupancy. The proportion of sites occupied by sage-grouse was highest during the 2008 breeding period in treated plots (Table 2.5). We were not able to sample during the breeding period in 2007. Sage-grouse site occupancy declined in the following period (early brood-rearing), and remained constant throughout the late brood-rearing and fall periods in 2007 and 2008. Proportion of occupied plots at treated sites was consistently and significantly higher than at untreated sites except during the 2008 breeding period (Fig. 2.5).

Detection probabilities were constant among periods for treated and untreated sites in our top model (Table 2.5). Differences in vegetation characteristics did not appear to affect detection probability. Elevation covariates enabled us to achieve greater model fit, and evidence of elevation affect did occur. The probability of plots being abandoned or going extinct (ϵ) among periods was generally constant through time (Table 2.5).

GPS Radio Telemetry

Male sage-grouse spent approximately 21% of their time in treated areas on the Duck Creek site during the breeding period (Table 2.6, Fig. 2.6). Immediately following lekking activities, all radioed male sage-grouse moved approximately 6 km from the Duck Creek area to their summer range (South Eden Canyon treatments, (SEC), Fig. 2.1). Male use of SEC locations in treated sites increased each period throughout the summer (Table 2.6).

Female sage-grouse utilized the treated areas 40.8% of the time during the lekking period (Table 2.6). Number of female locations declined in Duck Creek during the early brood-rearing period (20%) as females began transitioning to late-brood rearing areas. Few females used the Duck Creek sagebrush reduction treatments during the late brood-rearing and fall periods. Female use of the SEC treated sites was very high during the brood-rearing periods (Table 2.6, Fig. 2.6).

The chi-squared analysis showed that sage-grouse observation values differed from expected values in treated areas during the breeding period ($p<0.001$). All other chi-squared values showed no significant deviations from what we would expect based on sage-grouse use (Table 2.6).

Vegetation Measurements

Treated sites in Duck Creek had less shrub canopy cover than untreated sites (Table 2.7). Higher elevation treated sites had less canopy cover ($\bar{x}$ = 34.9-38.0%) than higher elevation untreated sites ($\bar{x}$ = 46.7-50.5%, P = <0.001); low elevation treated sites ($\bar{x}$ = 24.3-28.7%) had less canopy cover than lower elevation untreated sites ($\bar{x}$ = 31.8-38.5%, P = <0.001). Shrub height was greater on untreated than treated sites at both higher and lower elevations. Shrub heights were similar on treated sites at higher and lower elevations (P = 0.633, Table 2.7).

Grass cover showed a non-significant difference between treated sites and untreated sites at higher elevations (Table 2.8). Lower elevation treated sites had lower mean grass canopy cover ($\bar{x}$ = 6.0-14.1%) than lower elevation untreated sites ($\bar{x}$ = 3.9-38.3%, P = <0.001) (Table 2.7). At higher elevations, treated sites ($\bar{x}$ = 9.8-10.9%) had less mean forb cover than untreated sites ($\bar{x}$ = 15.0-19.7%, P = 0.027); at lower elevations, treated sites ($\bar{x}$ = 5.1-32.7%) had more forb cover than untreated sites ($\bar{x}$ = 6.7-18.9%, P = 0.076) (Table 2.7).

DISCUSSION

The pasture aerator sagebrush reduction treatments on our Duck Creek study area did not negatively affect sage-grouse habitat use. On the contrary, at lower elevations in Duck Creek, sage-grouse used treated sites more than untreated sites. Sage-grouse exhibited relatively low use of higher elevation Duck Creek sites and use of treated and untreated sites was similar. Sage-grouse use of treated habitat in Duck Creek occurred primarily during the breeding and early brood-rearing periods. Following early brood-rearing, sage-grouse used areas outside of Duck Creek that were dominated by historically treated lands (Table, 2.5, Fig. 2.6).

The application of pellet densities as an index to sage-grouse habitat use, while imperfect, has received support from our research and that of others over the past several years. Dahlgren et al. 2006 used distance-based pellet transects and trained dogs to assess sage-grouse use on Parker Mountain. They found that both techniques resulted in comparable measures of relative sage-grouse use and performed similarly in detecting differences in use between treated and untreated sites.

Pellets persistence and double counting of pellets could influence pellet density estimates (Wik 2002, Dahlgren et al. 2006). To assess pellet persistence, we monitored pellet piles which were exposed to sunlight, moisture, and other variables that would influence pellet persistence on the landscape. Our monitoring of pellets showed that a considerable number of sage-grouse pellets had disappeared after 1year. We were not able to determine if all pellets disintegrated or were carried off, but the majority of pellet piles that we monitored were disrupted or missing less than 1 year after monitoring occurred. This indicates that recounting pellets in subsequent years was not likely.

We employed several techniques to avoid recounting counting pellets. We never performed a pellet density transect in the same location in different years. We also sampled a narrow corridor; pellet clusters that we included in our analysis were never more than 3 meters from our centerline. Finally, observes were informed about the importance of following the abovementioned techniques to avoid recounting pellets. The possibility of recounting pellets can occur, but we feel that we successfully minimized the possibilities of that occurring. The chance of recounting pellet clusters in multiple years was low.

Our occupancy data supported differences in sage-grouse use of treated and untreated areas. Treated areas consistently had higher occupancy rates and were generally significantly different than untreated areas. We did not have sufficient sample sizes to adequately estimate occupancy rates at different elevational levels, so we were not able to calculate ψ values for different elevations. We did, however, apply elevational covariates to our analysis.

Recommendations for early brood-rearing habitat are 10-25% shrub canopy cover (Connelly et al. 2000), but shrub cover in our sites was above that level. The lower elevation treated site was only slightly higher (27.23%), but this site still received a high amount of sage-grouse use. Shrub canopy cover at higher elevation treated site (36.15%) was substantially higher than the recommendation (Table 2.7). This could be one of the reasons why sage-grouse use in the higher elevation sites on Duck Creek was significantly less than at lower elevation sites.

Recommendations for productive early brood-rearing sites are ≥15% grass and forb cover (Sveum et al. 1998, Connelly et al 2000, Lyon 2000). Combined grass and forb cover on all Duck Creek sites was close to or exceeded recommended levels (Table 2.7). However, grass cover in untreated lower elevation sites was significantly greater than at any other site. This suggests that lower elevation treated sites may have lost grass cover after being treated, even though these sites were reseeded with grass species following the aerator treatment (Appendix Table A.1). We were not able to collect vegetation data prior to the treatment occurring, so we do not know what vegetation conditions existed pre-treatment. We assumed that grass cover would increase in treated areas due to the reduction in shrub canopy cover, and because of reseeding efforts that occurred during the treatment process. Another possible explanation for low grass cover could be from competition with forb species. The seed mix that was applied after treatment contained high numbers of forbs, which may be outcompeting grass species in treated areas.

Recent treatments can enhance sage-grouse habitat because they are generally smaller in scale, less destructive to soils, and don’t focus on complete removal of shrub species (Connelly et al. 2000, Dahlgren et al. 2006). In contrast to sagebrush removal treatments, the pasture aerator treatments on our study area created conditions favorable to sage-grouse as indicated by our observations of sage-grouse use on our treated sites.

Sagebrush reduction treatments that occurred prior to the 1990s focused on completely removing sagebrush from a system. These types of treatments had many adverse affects on sage-grouse populations (Klebenow 1970, Peterson 1970, Pyrah 1972, Swenson et al. 1987).

In contrast, the SEC area used by male and female sage-grouse for summer range was a large tract of land that was converted to CRP (Conservation Reserve Program) during the 1980s, and much of it has burned in the last 10 years (Fig. 2.1, Fig. 2.7). The elevation for this site is between 2100-2150 meters. The area had sagebrush canopy cover ($\bar{x}$ = 6.3%, SE = 4.9) and sagebrush height ($\bar{x}$ = 17.07, SE = 2.4) below levels considered suitable as sage-grouse habitat (Patterson 1952, Braun et al. 1976, Connelly et al. 2000), although the area surrounding the treatment had stands of mature sagebrush. Following the state-and-transition framework (Westoby 1989, West 1999), this area would be considered a completely different and novel state from the Duck Creek site. Connelly et al. (2000) outlined what habitats components are dominant in each habitat used by sage-grouse throughout the year, and these areas all occur in a single state-and-transition model state. We did not anticipate sage-grouse using multiple states in the state-and-transitional model, particularly one which would not ordinarily be viewed by managers and biologists as sage-grouse habitat.

We found that many sage-grouse were using the SEC site (Fig. 2.7) for feeding, loafing and roosting locations, particularly hens with broods. We did not see find high forb cover in this area (2.2%, SE = 1.1), which often characterizes brood-rearing habitat (Sveum et al. 1998, Connelly et al 2000, Lyon 2000). Yet, one reason for the high use may be attributed to insect densities, which also play an important role for sage-grouse broods (Drut et al. 1994, Fischer et al. 1996). We did not do any formal insect sampling, but densities in the SEC treatments appeared to be higher than the surrounding areas. High insect densities may have been positively correlated to the high herbaceous growth. We did not anticipate sage-grouse using such heavily treated sites for summer range. However, it gives further evidence that treated sites for sage-grouse can be extremely valuable habitat.

We found that radioed sage-grouse stayed around lower elevation sites during the majority of the early brood-rearing period, then headed for summer habitat sites outside of the Duck Creek area. We did not observe any of our radioed sage-grouse using the higher elevation treated sites in Duck Creek though they were at similar elevations as the SEC area. The major difference between the sites was higher shrub cover and height at

Duck Creek which may inhibit brood-rearing. This suggests that treated sites at higher elevations in our study were more beneficial for sage-grouse during the late brood-rearing period where shrub cover was low (5-10%) and herbaceous cover is high (>30%) following treatment (Table 2.7). Habitat with less shrub cover and high herbaceous cover is consistent with literature describing sage-grouse summer habitat (Savage 1969, Connelly et al. 1988, Pyle and Crawford 1996).

MANAGEMENT IMPLICATIONS

This study emphasizes the importance of different age classes of sagebrush for sage-grouse habitat use. In the Duck Creek area, sagebrush reduction treatments have proven to be very beneficial for sage-grouse, particularly as early brood-rearing habitat. However, consideration must be taken as to when and where sagebrush reduction treatments occur. Elevation was a particularly important component in our study. Higher elevation habitat in Duck Creek had significantly less sage-grouse use than lower elevation habitat, which could partly be attributed to differences in shrub cover. Identifying areas of sage-grouse use prior to a treatment can improve the probability of treatments being used by sage-grouse.

We also recommend determining what type of habitat may be limiting for each sage-grouse population before treating sagebrush. This particular treatment at Duck Creek was a success because it occurred in areas sage-grouse used during the early brood-rearing period. During our study sage-grouse did not use the areas to any great extent during late brood-rearing. Impacts to existing stands of sagebrush habitat used for winter range can be detrimental to sage-grouse populations during severe winters. It is important to remember that manipulations will only benefit sage-grouse if the target habitat type is limiting. Consideration of timing and purpose of sage-grouse use of an area, e.g., early brood-rearing, must be considered before initiating sagebrush treatments.

RECOMMENDATIONS FOR FUTURE RESEARCH

We looked at relatively new treatment sites (4 to 6 years since treatment) during our study. The affect of sagebrush reduction treatments on sage-grouse populations over the long-term is an important key to fully understanding the impact sagebrush treatments have on sage-grouse. It is also important to know how sage-grouse will respond to these areas as shrub, forb, and grass components change in treated areas over time.

We saw lek attendance in the Duck Creek area grow substantially 4 to 6 years after treatments occurred (Appendix Table A.2). Many studies have shown that disturbances of this magnitude have had deleterious effects on sage-grouse lekking activities (Wallestad 1975, Swenson et al. 1987). Additional research on this subject would be important in understanding the full affect of sagebrush reduction treatments.

Our study could have been improved if we had used a Before-After-Control-Impact (BACI) design (Underwood 1994, Smith 2002) on the Duck Creek study area as we did in our Chapter 3 study. The only information we had on sage-grouse use of our treatment areas before the reduction treatments occurred were male lek counts. Lek data is an index to sage-grouse population size, but does not necessarily explain sage-grouse use of a habitat type. This data does provide some strong evidence of sage-grouse use of treated areas, but does not capture the immediate impacts of the sagebrush reductions on sage-grouse use.

We did not see the vegetative response from grasses and forbs that we had anticipated from removing sagebrush canopy cover. Additional research looking at vegetation response pre- and post-treatment would be very beneficial in determining if treatments are actually increasing grass and forb cover. This would need to be done on a finer scale, perhaps at the species level. This would allow managers to know if reduction treatments were actually making more forbs and grass available for sage-grouse and their broods.

Insects are very important for sage-grouse broods (Drut et al. 1994, Fischer et al. 1996). Many studies have looked at insect abundance in treated sites, but no work has been done with insects in Rich County treatments. We saw very high abundances of insects in areas used by sage-grouse during the summer and fall. Reseeding treatments with plants that increase insect abundance would be very beneficial for sage-grouse. Studies on insects should include environmental samples (availability) and samples of sage-grouse diet (use).

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Table 2.1. Greater sage-grouse pellet density transect models of treated and untreated sites in Rich County, 2007-2009.

Factors	Model	Adjustments[1]	ΔAIC_c[2]	W_i[3]	K[4]
	Uniform	Cosine	0.00	0.67	7
	Hazard-rate	Poly	1.55	0.31	10
Treated	Half-normal	Cosine	6.42	0.03	7
	Half-normal	Herm	173.90	0.00	2
	Global	None	NA	0.00	5
	Uniform	Cosine	0.00	0.91	22
	Hazard-rate	Poly	4.91	0.08	27
Treated+Year	Half-normal	Cosine	9.08	0.01	15
	Half-normal	Herm	165.26	0.00	6
	Global	None	NA	0.00	4
	Uniform	Cosine	0.00	0.93	13
	Half-normal	Cosine	6.32	0.04	9
Treated+Elev	Hazard-rate	Poly	6.87	0.03	17
	Half-normal	Herm	166.78	0.00	4
	Global	None	NA	0.00	4
	Half-normal	Cosine	0.00	0.99	23
	Hazard-rate	Poly	9.20	0.01	45
Treated+Year+Elev	Uniform	Cosine	71.99	0.00	38
	Half-normal	Herm	155.69	0.00	12
	Global	None	NA	0.00	5

[1] = All models received a stratum adjustment
[2] = ΔAICc — Delta Akaike's Information Criterion with a second order correction for small sample sizes
[3] = Wi — Akaike's Information Criterion Weights
[4] = K — Number of model parameters

Treated = Treated (pasture aerator) and untreated sites
Year = 2007, 2008, and 2009
Elev = High (2120 – 2250 m)and low (1950 – 2110 m) elevation
NA = Values were not calculated, but were >200

Table 2.2. Greater sage-grouse occupancy models of treated and untreated sites in Rich County, Utah, 2007-2008.

Model	ΔAIC_c[1]	W_i[2]	K[3]
ψ(Treament+Year+Period+Elevation) p(.) ϵ(Treament+Trend)	0.00	0.47	13
ψ(Treament, Trend+Year+Elevation) p(Treatment, Trend+Year+Cover) ϵ(Treament+Trend)	0.85	0.31	18
ψ(Treament+Year+Period+Elevation) p(Cover) ϵ(Treament+Trend)	3.90	0.07	13
ψ(Treament+Year+Period+Elevation) p(Cover+Height) ϵ(Treament+Trend)	4.10	0.06	14
Global	4.19	0.06	68
ψ(Treament, Year+Period) p(Cover) ϵ(Treament+Trend)	7.32	0.01	14
ψ(.) P(Cover+Height) ϵ(Treament+Trend)	8.23	0.01	11
ψ(Treament+Year+Period) p(Cover+Height) ϵ(Treament+Trend)	9.29	0.00	15
ψ(.) P(Cover) ϵ(Treament+Trend)	11.13	0.00	10
ψ(Treament+Year+Period) p(Height) ϵ(Treament+Trend)	11.23	0.00	14
ψ(Treament, Trend+Year) p(Treament, Trend+Year+Cover) ϵ(Treament+Trend)	12.18	0.00	19
ψ(.) p(Treament, Trend+Year+Cover) ϵ(Treament+Trend)	12.82	0.00	14
ψ(Treament+Year+Period+Elevation) p(Height) ϵ(Treament+Trend)	13.66	0.00	14
ψ(Treament+Year+Period) p(.) ϵ(Treament+Trend)	13.73	0.00	14
ψ(Treament+Trend+Year) p(.) ϵ(Treament+Trend)	13.78	0.00	14
ψ(.) p(Treament, Trend+Year+Cover+Height) ϵ(Treament+Trend)	13.82	0.00	15
ψ(.) p(Treament, Trend+Year+Height) ϵ(Treament+Trend)	14.14	0.00	13
ψ(.) p(.) ϵ(Treament+Trend)	14.21	0.00	9
ψ(Treament, Trend+Year) p(Treatment, Trend+Year) ϵ(Treament+Trend)	19.73	0.00	19
ψ(.) p(Treament, Trend+ Year) ϵ(Treament+Trend)	22.64	0.00	14

[1] = ΔAICc ─ Delta Akaike's Information Criterion with a second order correction for small sample sizes
[2] = Wi ─ Akaike's Information Criterion weights
[3] = K ─ Number of model parameters
ψ = Occupancy
p = Detection probability
ϵ = Probability of local extinction

Year = 2007 and 2008
Period = Breeding, Early Brood-Rearing, Late Brood-Rearing, Fall
Elevation = High (2120–2250m) and low (1950–2110m) elevation
Cover = Shrub cover (continuous variable)
Height = Shrub height (continuous variable)
Treatment = Treated (pasture aerator) and untreated

Table 2.3. Greater sage-grouse utilization (pellet densities) of treated and untreated sites at different elevations in Rich County, Utah, 2007-2009.

Plot Type	C	*n*	D_s	$SE(D_s)$	CI		P	SE(p)	CI	
TRT HIGH	851	70	102.6	30.9	57.0	184.8	0.34	0.01	0.32	0.36
UT HIGH	549	45	92.3	32.6	46.2	184.1	0.31	0.01	0.30	0.34
TRT LOW	8506	51	1296.9	178.9	984.5	1708.5	0.37	0.00	0.36	0.38
UT LOW	2406	56	361.6	65.1	252.9	517.3	0.31	0.01	0.30	0.32

C = Total pellet clusters
D_s = Pellet cluster density (per hectare)
p = Probability of detection of D_s

TRT HIGH = High elevation treated sites
TRT LOW = Low elevation treated sites
UT HIGH = High elevation untreated sites
UT LOW = Low elevation untreated sites

Table 2.4. Greater sage-grouse pellet density transect models from SAS of treated and untreated sites at Duck Creek, Rich County, 2007-2009.

Factors	Model Df	Error Df	F Value	Pr > F
Treatment	1	161	29.40	<0.001
Elevation	1	161	39.45	<0.001
Treated * Elevation	1	161	20.69	<0.001

Elevation = High (2120 – 2250 m) and low (1950 – 2110 m) elevation

Table 2.5. Greater sage-grouse utilization (site occupancy) of treated and untreated sites in Rich County, Utah. 2007-2008.

Type	Period	Year	ψ*	SE[1]	ϵ	SE[2]
Treated	Early Brood	2007	0.58	0.03	–	–
Treated	Late Brood	2007	0.61	0.02	0.40	0.11
Treated	Fall	2007	0.60	0.02	0.42	0.00
Treated	Breeding	2008	0.81	0.06	–	–
Treated	Early Brood	2008	0.70	0.06	0.10	0.04
Treated	Late Brood	2008	0.73	0.02	0.01	0.03
Treated	Fall	2008	0.73	0.02	0.14	0.00
Untreated	Early Brood	2007	0.38	0.06	–	–
Untreated	Late Brood	2007	0.41	0.03	0.68	0.09
Untreated	Fall	2007	0.41	0.03	0.70	0.00
Untreated	Breeding	2008	0.63	0.13	–	–
Untreated	Early Brood	2008	0.49	0.08	0.25	0.09
Untreated	Late Brood	2008	0.52	0.05	0.03	0.11
Untreated	Fall	2008	0.52	0.05	0.35	0.02

ψ = Probability of a site being occupied by sage-grouse
ϵ =Probability of sage-grouse leaving a site before the next sampling period
* p (detection probability) for all periods was 0.471, SE = 0.02

Table 2.6. Greater sage-grouse utilization (GPS telemetry locations) for treated and untreated areas in Rich County, Utah, 2008.

	Period	χ^2	*P**	n (M | F)	$\%^M$	$\%^F$	$\%^A$
DC	BREEDING	20.6	0.00	214 | 240	21.0	40.8	31.5
	EARLY BROOD	18.7	0.00	89 | 329	1.1	20.1	16.0
	LATE BROOD	0.0	0.93	7 | 104	0.0	1.9	1.8
	FALL	–	–	1 | 19	0.0	0.0	0.0
SEC	BREEDING	3.2	0.07	214 | 240	9.8	15.5	12.8
	EARLY BROOD	5.8	0.02	89 | 329	55.1	40.7	43.8
	LATE BROOD	0.0	0.95	7 | 104	71.4	76.0	75.7
	FALL	0.2	0.69	1 | 19	100.0	21.1	25.0
ALL TRT	BREEDING	29.6	0.00	454	30.8	56.3	44.3
	EARLY BROOD	0.6	0.43	418	56.2	60.8	59.8
	LATE BROOD	0.0	0.92	111	71.4	77.9	77.5
	FALL	0.2	0.69	20	100.0	21.1	25.0
ALL UT	BREEDING	29.6	0.00	454	69.2	43.8	55.7
	EARLY BROOD	0.6	0.43	418	43.8	39.2	40.2
	LATE BROOD	0.0	0.92	111	28.6	22.1	22.5
	FALL	0.2	0.69	20	0.0	79.0	75.0

DC = All Duck Creek treated areas
SEC = South Eden Canyon treated areas
ALL TRT = All data combined from DC and SEC treated areas
ALL UT = All data combined from DC and SEC untreated areas
% = Percent sage-grouse locations within treated sites
* Degrees of freedom was 1

Table 2.7. Vegetation cover from treated and untreated sites at 2 elevations in Duck Creek and South Eden Canyon (SEC) areas, Rich County, Utah, 2007-2009.

		Shrub Height[1]		Shrub Cover[1]		Grass Cover[1]		Forb Cover[1]	
	Year	$\bar{x}^2$	SE	$\bar{x}^3$	SE	$\bar{x}^4$	SE	$\bar{x}^4$	SE
TRT HIGH	2007	–	–	34.9	3.5	18.7	3.9	10.9	1.6
	2008	17.7	1.8	38.0	3.2	18.7	4.2	9.8	2.6
	2009	–	–	35.6	3.2	13.1	3.9	10.9	1.6
TRT LOW	2007	–	–	28.7	8.1	14.1	11.2	11.7	2.4
	2008	10.8	22.8	28.7	11.0	13.8	2.3	5.1	1.3
	2009	–	–	24.3	8.0	6.0	1.5	32.7	4.9
UT HIGH	2007	–	–	46.7	3.7	14.2	0.8	15.0	0.0
	2008	34.6	4.3	50.5	2.4	17.2	4.4	19.7	4.0
	2009	–	–	47.7	2.4	5.9	5.7	12.3	3.2
UT LOW	2007	–	–	31.8	1.2	38.3	3.3	6.7	2.5
	2008	26.2	2.5	36.1	2.7	35.2	3.3	7.1	2.6
	2009	–	–	38.5	1.5	3.9	1.2	18.9	3.6
SEC	2008	17.0	2.4	6.3	4.9	31.3	6.1	2.2	1.1

[1] = Sample size was 15 for each cell

Table 2.8. Vegetation data models from SAS of treated and untreated sites at Duck Creek, Rich County, 2007-2009.

Shrub Height

Factors	Model Df	Error Df	F Value	Pr > F
Treatment	1	59	34.74	0.026
Elevation	1	59	5.22	<0.001
Treated * Elevation	1	59	0.35	0.555

Shrub Cover

Factors	Model Df	Error Df	F Value	Pr > F
Elevation	1	179	58.36	<0.001
Treatment	1	179	50.99	<0.001
Year	2	179	1.31	0.272
Elevation * Year	2	179	0.13	0.881
Elevation * Treatment	1	179	1.93	0.167
Treatment * Year	2	179	1.36	0.261
Elevation * Treatment * Year	2	179	1.23	0.296

Grass Cover

Factors	Model Df	Error Df	F Value	Pr > F
Elevation	1	179	3.28	0.072
Treatment	1	179	8.00	0.005
Year	2	179	24.66	<0.001
Elevation * Year	2	179	4.85	0.009
Elevation * Treatment	1	179	22.07	<0.001
Treatment * Year	2	179	6.93	0.001
Elevation * Treatment * Year	2	179	3.23	0.042

Forb Cover

Factors	Model Df	Error Df	F Value	Pr > F
Elevation	1	179	0.00	0.973
Treatment	1	179	0.08	0.780
Year	2	179	13.48	<0.001
Elevation * Year	2	179	14.80	<0.001
Elevation * Treatment	1	179	13.78	0.003
Treatment * Year	2	179	3.21	0.043
Elevation * Treatment * Year	2	179	1.21	0.300

Elevation = High (2120 – 2250 m) and low (1950 – 2110 m) elevation
Year = 2007, 2008, and 2009

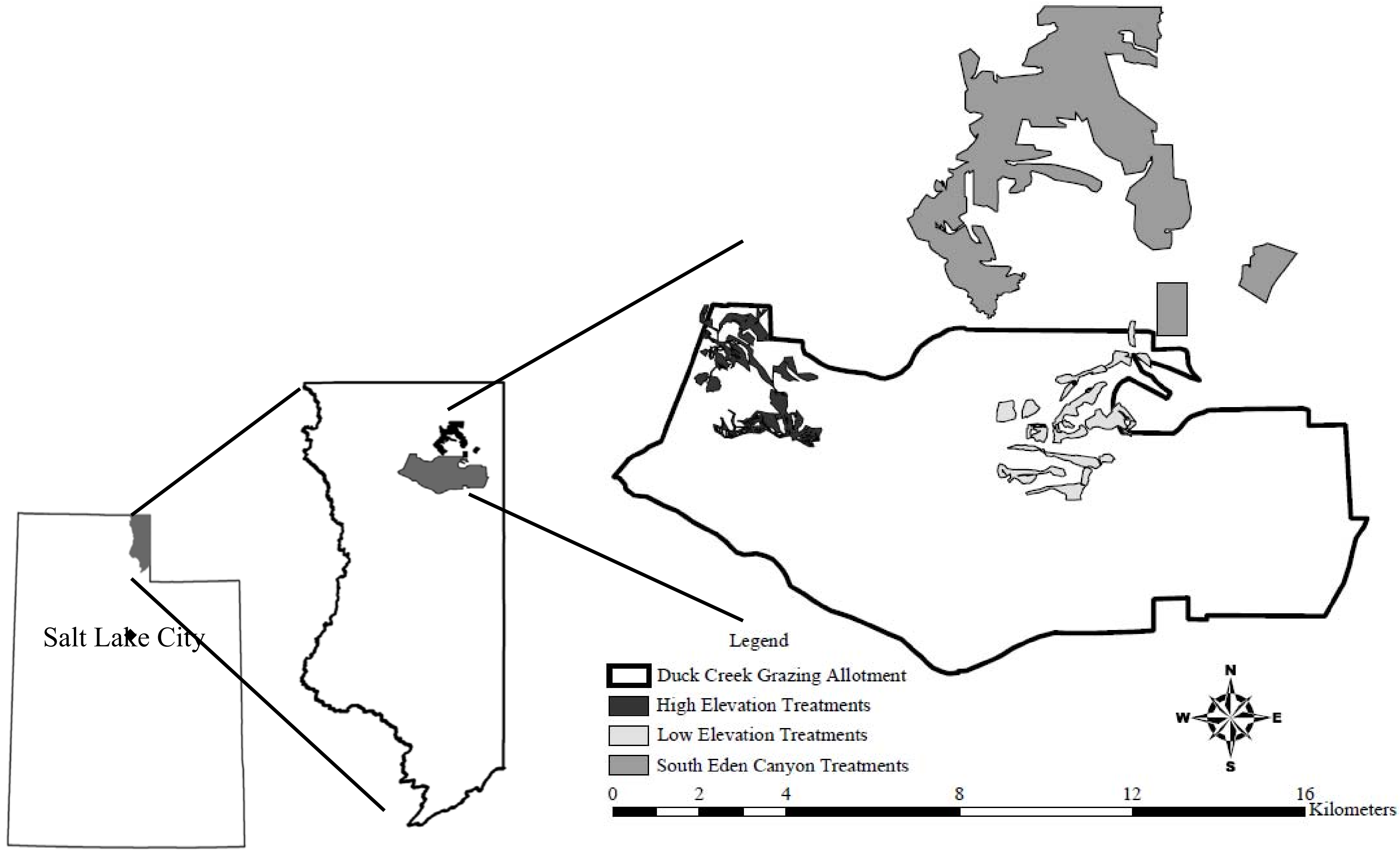


Fig. 2.1. Duck Creek Grazing Allotment study area and South Eden Canyon treatments, Rich County, Utah. 2007-2009.

Fig. 2.2. Pasture Aerator; photo courtesy of Scott Walker, Utah Division of Wildlife Resources (DWR).

X = Wiens Pole for sage height at center and cardinal directions

■ = Daubenmire (1 m^2) at center and 2 randomly chosen cardinal directions

– – = line intercept in one random cardinal direction

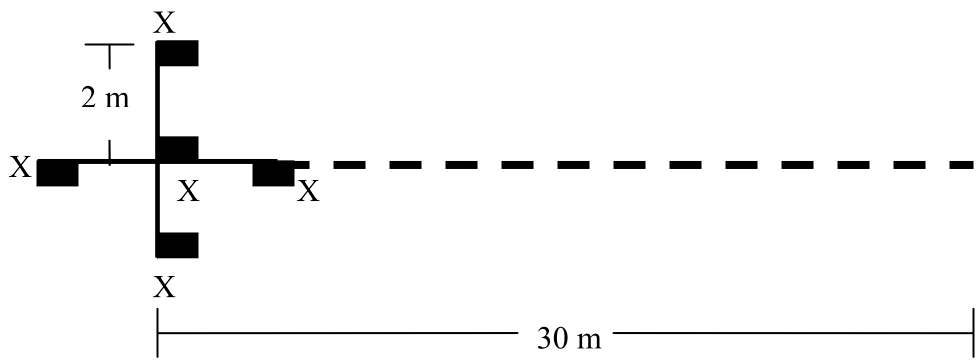
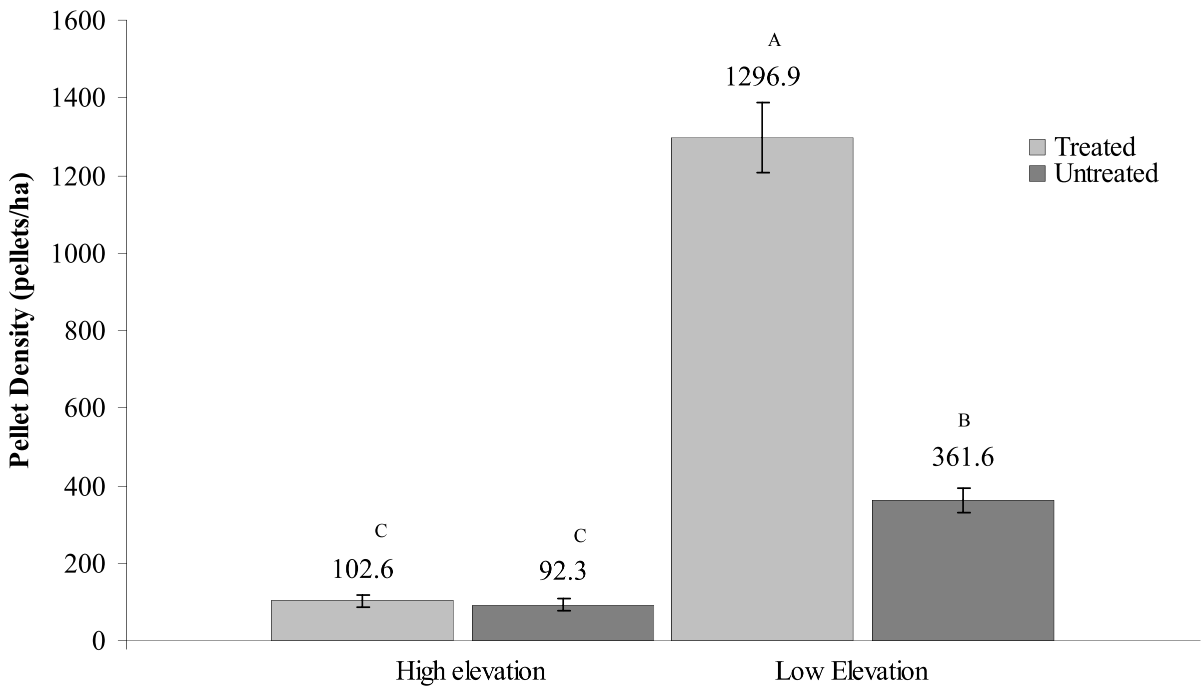
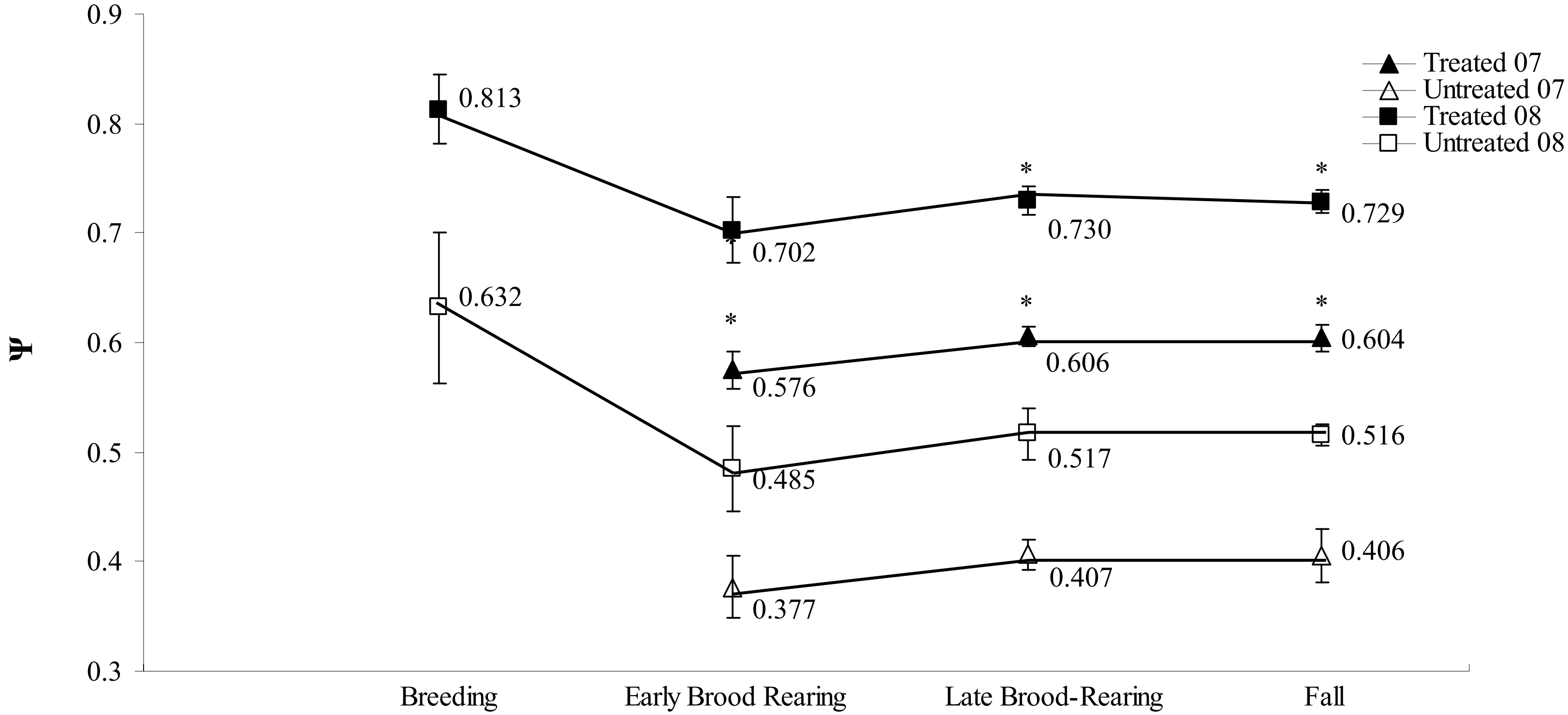


Fig. 2.3. Diagram of how vegetation data was collected at treated and untreated locations at the Duck Creek study site and throughout Rich County, Utah, 2007-2009.



A, B, C denote a significant difference between all other treated and untreated sites based on non-overlapping 95% CI.

Fig. 2.4. Greater sage-grouse pellet densities from treated and untreated sites at high (2120 – 2250 m) and low (1950 – 2110 m) elevation, Rich County, Utah, 2007-2009.



* Significant difference between treated and untreated within period indicated by non-overlapping 95% CI

Fig. 2.5. Greater sage-grouse utilization (site occupancy) of treated and untreated sites in Rich County, Utah, 2007-2

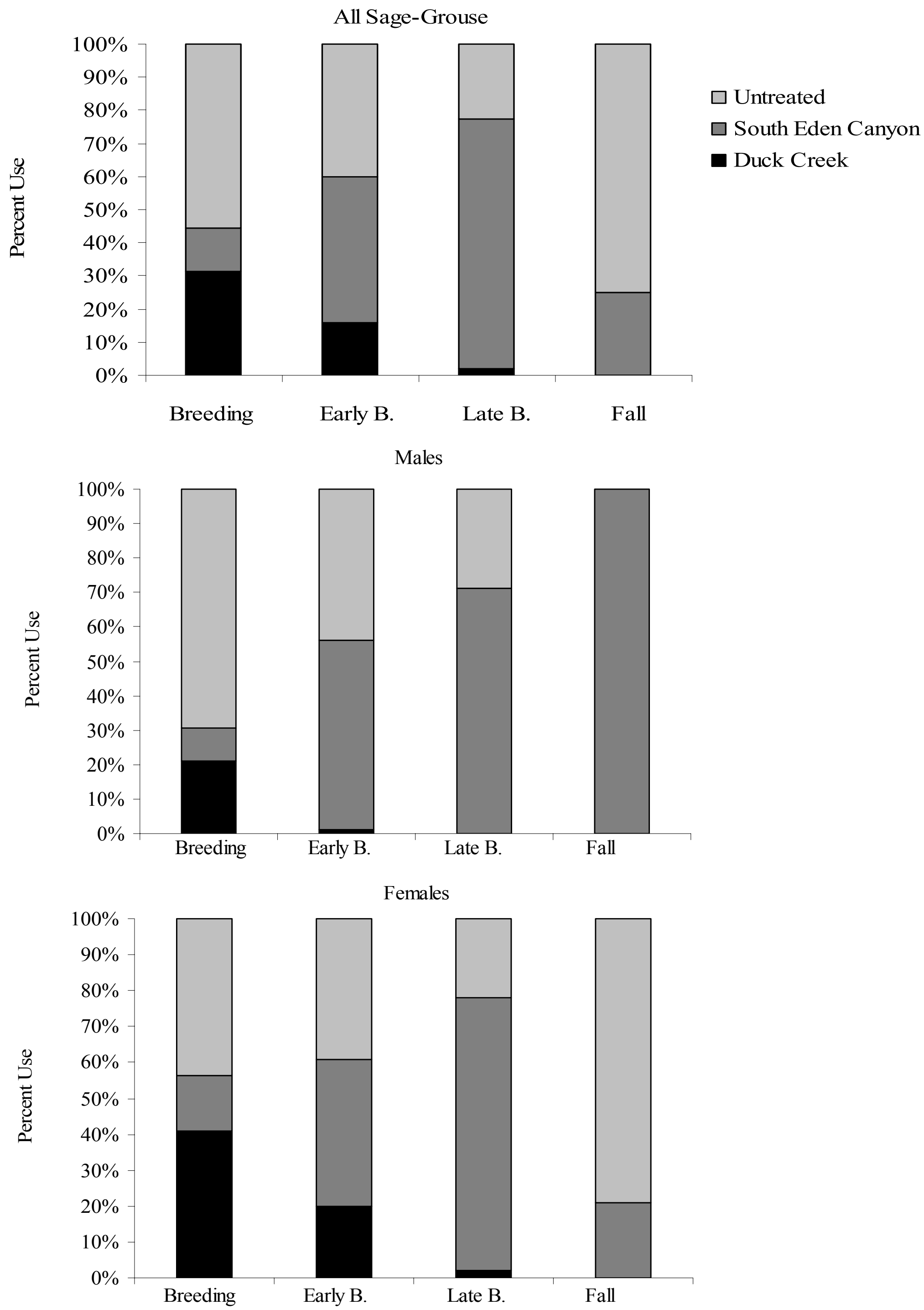


Fig. 2.6. Greater sage-grouse utilization (percent of total sage-grouse locations from GPS telemetry) for treated and untreated areas in Rich County, Utah, 2008 (for significant χ^2 differences and sample sizes see Table 2.6).

Duck Creek Treatments

South Eden Canyon Treatments (SEC)

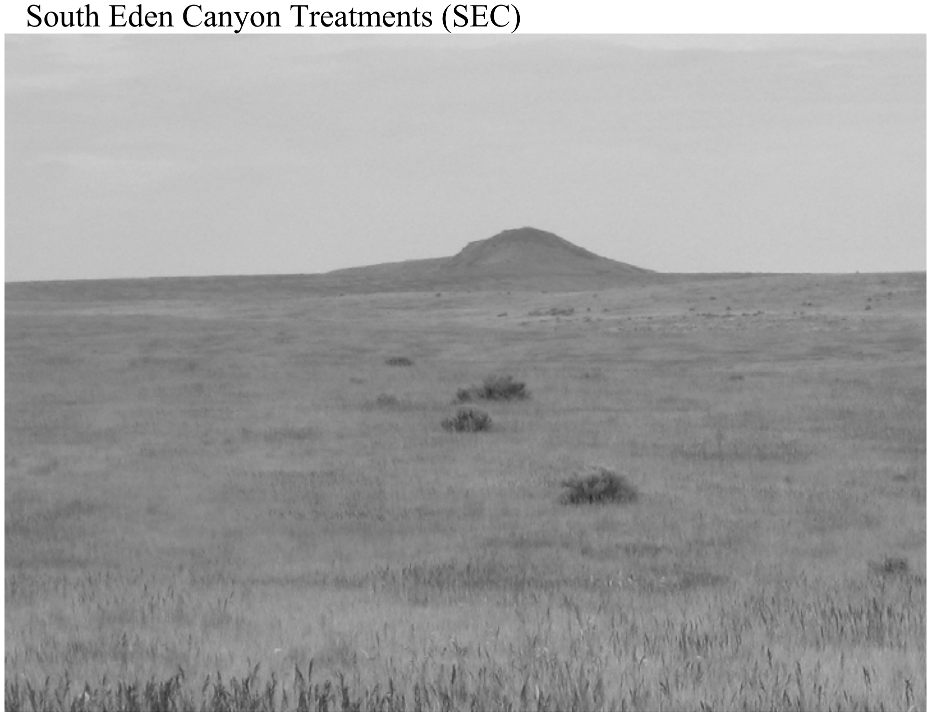


Fig. 2.7. Photographs of typical vegetation cover at Duck Creek and SEC treatments in Rich County, Utah, 2008; see text for descriptions.

CHAPTER 3

GREATER SAGE-GROUSE USE OF WYOMING SAGEBRUSH HABITAT TREATMENTS IN RICH COUNTY, UTAH

ABSTRACT The effects of sagebrush reduction treatments on greater sage-grouse (*Centrocercus urophasianus*) are not well understood, despite the continued effort of management agencies to treat sagebrush in the west. Sage-grouse use of a treatment site before and after manipulation provides a powerful tool to understanding how this species reacts to the disturbance, and the environmental conditions anthropogenic disturbances create. The objectives of this study were to measure sage-grouse pellet densities as an index to sage-grouse habitat use before and after a pasture aerator sagebrush reduction treatment. We monitored sage-grouse use 1 year before and 2 consecutive years after treatment to determine how sage-grouse responded to habitat alteration. Prior to treatment we saw no significant differences in pellet densities between treated and untreated areas. The first year after treatment sage-grouse pellet densities decreased in both treated and untreated sites, but did not differ significantly between treated and untreated areas suggesting that treatment effects may have influenced the area adjacent to the physically altered areas. Two years after treatment pellet density levels in both treated and untreated plots returned to pre-treatment levels. Our results suggest that physical disturbance caused by treating an area can reduce sage-grouse use of an area immediately, but sage-grouse use can return to pre-treatment levels after a short period of time. Long-term monitoring efforts may be the key to fully understanding all the effects a sagebrush manipulation treatment have on sage-grouse.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*) are considered shrubsteppe-obligate species due to their dependence on sagebrush communities for most of their life cycle (Braun et al. 1977). Greater sage-grouse ranges occur in portions of western North America that support sagebrush (*Artemisia* spp.) species. The alteration of sagebrush ecosystems through agricultural conversion, drought, fire, invasive species, and urban development have become a significant threat to many sage-grouse populations (Knick et al. 2003). The U.S. Fish and Wildlife Service specifically list habitat modifications and loss as a significant factor affecting sage-grouse across the west (USFWS 2010).

One major complication in managing rangelands in the west is balancing cattle grazing with quality wildlife habitat (West 1993, Bernardo et al. 1994). Many sagebrush removal treatments have occurred throughout the west to increase understory grass species to provide additional forage for cattle grazing. The effects of these reduction treatments on wildlife species have been both positive and negative, usually depending on the extent of sagebrush use by the individual species (Knick et al. 2003, Lee et al. 2008, Norvell et al. 2008). Sagebrush reduction treatments have been shown to decrease sage-grouse use of lekking and winter habitat (Pyrah 1972, Wallestad 1975), but have also been shown to increase use in brood-rearing sites (Dahlgren 2006, Chapter 2).

Brood-rearing habitat for sage-grouse has been identified as limiting in many areas and reducing sagebrush canopy cover through sagebrush manipulations can improve sage-grouse brood-rearing habitat (Winward 1991, Beck and Mitchell 2000, Connelly et al. 2000). The objective of our study was to determine sage-grouse response to a pasture aerator treatment that occurred in 2007 in Rich County, Utah. We used pellet density transects as an index to sage-grouse use. We BACI design (Underwood 1994, Smith 2002) to compare sage-grouse use before (2007) and after (2008 - 2009) a pasture aerator treatment to determine effects of reducing sagebrush cover.

STUDY AREA

Rich County was located in northeastern Utah, approximately 184 km from Salt Lake City, Utah (Fig. 3.1). Our study area was located within Deseret Land and Livestock (DLL), an 87,000 hectare privately owned cattle ranch located at the southern end of the Rich County (Fig. 3.1). DLL had a management plan in which the ranch treats 1-2% of their sagebrush range annually. The purpose of those reduction treatments were to increase understory grass and forb species to provide grazing opportunities for cattle and create wildlife habitat for sage-grouse and ungulates. DLL also used a high intensity short duration cattle grazing scheme that allowed for heavy use by cattle for short periods, thus allowing rest of grazed site for relatively long periods of time.

The eastern side of the DLL, which contained our study area, was made up of rolling hills of sagebrush steppe, ranging in elevation from 1980-2130 meters. Annual precipitation in this area averaged 25 cm (Danvir et al. 2005). Dominant shrub species included Wyoming big sagebrush and basin big sagebrush. Crested wheatgrass (*Agropyron christatum*) and mixed herbaceous species dominated the understory. The western side of the ranch was higher in elevation (2200-2650 m) and had higher rainfall (38-89 cm) (Danvir et al. 2005). Dominant vegetation included aspen (*Populus tremuloides*) and conifer stands (*Pinus* and *Abies* spp.), with mountain meadows containing mountain big sagebrush.

DLL contained several one square mile parcels of public land managed by the U.S. Bureau of Land Management (BLM) and U. S. Forest Service (FS). Our study area was located on the eastern side of DLL in lower elevation sagebrush habitat managed by the BLM (Section 14, Fig. 3.1). The area was 259 hectares in size and was dominated by sagebrush.

METHODS

Sampling locations for pellet density transects were chosen randomly from the grid points that occurred in treated and untreated areas in DLL. Starting points for data collection occurred at the tessellation point (see Chapter 2 for description). We collected pre-treatment pellet density data several months before the treatment took place. In October of 2007, 119 hectares (44.2%) of our study area was treated (Fig. 3.1) using a pasture aerator (Fig. 3.2); no seed was applied. We did not have control over where the treatment occurred, so we randomly placed our sampling locations throughout the study area so we would have samples inside and outside the treatment. The 2007 data were pre-treatment pellet densities, while data collected in the summers of 2008 and 2009 were post-treatment.

We used distance sampling (Buckland et al.1993) to estimate density of sage-grouse pellets in treated and untreated areas. We performed twenty transects every year; 10 transects in treated areas and 10 transects in untreated areas. A detailed description of this technique is provided in Chapter 2.

We used pellets of known age to develop color-coded pellet age charts to determine the age of sage-grouse pellets. We also monitored known age pellets through time to determine pellet persistence on the landscape. This allowed us to avoid recounting pellets in subsequent transects.

Vegetation data was collected at the location of each pellet transect in 2007 (pre-treatment) and 2009 (post-treatment). We recorded shrub canopy cover, grass and forb cover, and shrub height.

DATA ANALYSIS

We evaluated the relative support for *a priori* models (Table 3.1) of year and t reatment factors on pellet density (D_s) and detection probability (p) of sage-grouse pellets using program Distance 5.0.2 (Thomas et al. 2010). Using program Distance, we estimated pellet densities and probability of detection in treated and untreated areas. Akaike Information Criteria (AIC) (Burnham and Anderson 2002) values were estimated to determine which models best fit our data (Table 3.1).   Post hoc means comparisons of pellet densities per transect were performed in SAS 9.3.1 (SAS Institute Inc. 2007) using a one-tailed t-test with 0.10 alpha level (Table 3.3) to determine whether sage-grouse use declined after treatment ($H_O = D_{sBEFORE} > D_{sAFTER}$; $H_A = D_{sBEFORE} \leq D_{sAFTER}$).

A two-tailed ANOVA ($\alpha = 0.10$) (SAS Institute Inc. 2007) was used to test for differences in vegetation between treated and untreated areas before and after treatment. We compared shrub canopy cover, shrub height, grass cover, and forb cover between the treated and untreated areas to determine if vegetation differed as a result of the treatment.

RESULTS

Sage-Grouse Use

Sage-grouse pellet densities did not differ significantly between treated and untreated areas either before or after treatment (Table 3.2, 3.3). We saw a first-year post treatment decline in pellet densities in 2008 on both treated and untreated sites; and in 2009 pellet densities increased to pre-treatment levels on both treated and untreated sites. Post hoc mean comparisons showed a significant effect of year and a treatment*year interaction (Table 3.4). Detection probabilities ranged from 0.33 to 0.44 and did not differ significantly between treated and untreated areas (Table 3.2).

Vegetation Measurements

Pre-treatment shrub canopy cover, shrub height, and forb cover was similar for treated and untreated areas. Grass abundance was slightly higher in untreated areas, but it did not differ significantly from treated sites (Table 3.4).

Treated sites showed a non-significant reduction in shrub canopy cover (P = 0.838) and shrub height post-treatment; untreated sites had no difference in higher shrub cover (P = 0.964) or shrub height after the treatment. Shrub cover was significantly less in treated than untreated areas in 2009 (Table 3.4). Grass and forb cover showed no significant differences after treatment (Table 3.4).

DISCUSSION

We hypothesized that sage-grouse use would decrease on treated plots immediately following sagebrush reduction and increase in the years following the disturbance as the habitat returned. And, we predicted that use on treated plots would vary between years but would remain above use levels on treated plots. The decline in sage-grouse use following the treatment was not as large as we had anticipated, and sage-grouse use returned to pre-treatment levels within only 2 years post-treatment. This stands in sharp contract to older sagebrush reduction methods which often resulted in persistent negative impacts on sage-grouse (Pyrah 1972, Swenson et al. 1987).

Nonetheless, the immediate post-treatment dip in sage-grouse use on the entire 259-ha study area, including both treated and untreated sites (Fig. 3.3), may have been a result of the treatment. While the sagebrush cover was reduced on only 44% of the study area, that may have been sufficient to cause sage-grouse to significantly reduce their use of the entire study area including the untreated portions of the study area. However, Utah Division of Wildlife Resources (UDWR) did record a dip in male lek attendance near our study area and across DLL in 2008 followed by an increase in 2009 (Appendix Table A.3). Thus, the reduction in sage-grouse use we saw on the study area may have not been treatment related, but a reflection of an unrelated population fluctuation.

Pellet densities on lower elevation treated areas at Duck Creek (1950-2110 m) were similar in elevation to our DLL (2000 m) treatment site. Pellet densities in Duck Creek 4 to 6 years after treatment were D_s = 1296.9/hectare; DLL treatments 2 years after treatment were D_s = 1543.1/hectare. Pellet densities were remarkably similar before and 2 breeding seasons after treatment, suggesting that only a short recovery period was needed before sage-grouse use in the area returned to pre-treatment levels (Table 3.2). Wiens et al. (1996) documented similar responses to disturbance when monitoring marine bird communities following an oil spill. Effects of disturbance on some species, but not all species, are often immediate but short in duration.

One potential drawback of pellet transects is the possibility of double counting pellets that persist between annual sampling periods (Chapter 2). We do not believe this was an issue in our study. Had pellets persisted over winter, i.e., accumulated, we would have found higher densities on the untreated areas in 2008 than in 2007. In the treated areas, we would expect all pellets to be destroyed by the treatment process, thus pellets would not accumulate there from 2007 to 2008. Our data showed that both treated and untreated sites had substantial declines in pellets between 2007 and 2008 and no difference in pellet densities between sites in 2008. If double counting of pellets had been an issue we would have expected to see pellet numbers in untreated areas remained constant or increased.

We had expected shrub canopy cover and shrub height to decrease significantly on our treated sites post-treatment. While this was not the case, shrub cover was less on treated than untreated sites after the treatment (Table 3.4). Average shrub height before treatment was relatively low on both sites (Table 3.4), and increased slightly on both sites post-treatment. The effect of our treatment on vegetation cover and height was visible, despite the lack of significant results. This might be due, in part, to a small sample size that did not adequately captured shrub height and cover changes. Also, while shrub cover was similar between this study site and the Duck Creek study area (Chapter 2), shrub height was significantly lower on the DLL study area. The use of pasture aerators on small shrubs could have resulted in less shrub removal, thus not statistically affecting shrub height or cover in treated areas. Nonetheless, the treatment did have a marked affect on the area.

Connelly et al. (2000) and Beck and Mitchell (2000) suggest that shrub canopy cover may be limiting understory diversity in brood-rearing habitat. Sagebrush canopy cover recommendations for brood-rearing habitat are between 10-25% (Connelly et al. 2000). Our treated sites were slightly higher than the recommended requirements (26.6%), which may be why we did not see as great of response in grass and forb cover post-treatment (Table 3.4).

Sagebrush reduction treatments conducted prior to the 1990s focused on complete removal of sagebrush from large landscapes. These types of manipulations had many adverse affects on sage-grouse populations (Klebenow 1970, Peterson 1970, Pyrah 1972, Swenson et al. 1987). More modern approaches (Wilson et al. *in press*) are designed to reduce, not eliminate, shrub cover and are conducted on a smaller scale with manipulations resulting in mosaic of patches with varying horizontal and vertical cover. Such reduction treatments are also designed to be less destructive to soils and promote more rapid recovery and, in the case of aerator manipulations, leave small shrubs in treated patches. This study and others (Connelly et al. 2000, Dahlgren et al. 2006) have shown that this modern approach has fewer short-term negative impacts on sage-grouse use.

MANAGEMENT IMPLICATIONS

Guidelines for productive early brood-rearing sites recommend ≥15% cover of grasses and forbs, and 10-25% shrub cover (Sveum et al. 1998, Connelly et al 2000, Lyon 2000), and our treated sites met these recommendations. Treated sites did not negatively affect sage-grouse use after 2 years, although there was some indication of less use 1 year after treatment. Pellet densities indicate that sage-grouse use of treated areas are at least equivalent to untreated areas. Anecdotal observations indicate that sage-grouse are using treated areas for brood-rearing habitat.

The pasture aerator treatment did not include seeding and did not increase grass and forb species on treated sites though combined grass and forb cover was near the 15% canopy cover recommendation given by Connelly et al. (2000). It is also possible that grass and forb cover will increase in subsequent years. If managers are hoping to increase grass and forb species immediately following treatment then pasture aerator treatments alone may not be sufficient. Reseeding of grass and forb species may help to increase herbaceous plant densities, and provide more foraging opportunities for sage-grouse (Chapter 2).

RECOMMENDATIONS FOR FUTURE RESEARCH

We did not compare additional treatment prescriptions in our study. Dahlgren et al. (2006) found that sage-grouse use varied between chemical and several mechanical treatment types. A similar study in the Rich County region may be beneficial in understanding how specific reduction treatments will affect sage-grouse use in Rich County.

Our monitoring study was conducted over a 3 year period. The disturbance of sagebrush steppe systems can take decades to recover (Blaisdell 1953, Winward 1991, Colket 2003, Baker 2006). Long-term studies of sagebrush reduction treatments would be beneficial when trying to understand how ranges recover over time and if sage-grouse use of treated sites changes over time.

Our treatment, which was not accompanied by seeding, resulted in lower than expected grass and forb response. Comparing treatments without seedings to those with seedings could improve our understanding of how to increase grasses and forbs with mechanical reduction treatments.

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Table 3.1. Greater sage-grouse pellet density transect models from program Distance for treated and untreated sites in Rich County, 2007-2009.

Factors	Model	Adjustments[1]	ΔAIC_c[2]	W_i[3]	K[4]
Treated	Hazard-rate	Poly	0.00	1.00	10
	Uniform	Cosine	11.25	0.00	8
	Half-normal	Cosine	17.48	0.00	4
	Half-normal	Herm	51.50	0.00	2
	Global	None	NA	0.00	4
Treated+Year	Half-normal	Cosine	0.00	1.00	15
	Uniform	Cosine	17.83	0.00	19
	Hazard-rate	Poly	30.94	0.00	25
	Half-normal	Herm	60.26	0.00	6
	Global	None	NA	0.00	4

[1] = All models received a stratum adjustment
[2] = ΔAICc ─ Delta Akaike's Information Criterion with a second order correction for small sample sizes
[3] = Wi ─ Akaike's Information Criterion Weights
[4] = K ─ Number of model parameters
Treated = Treated (pasture aerator) and untreated sites
Year = 2007, 2008, and 2009
NA = Values were not calculated, but were >100

Table 3.2. Greater sage-grouse utilization (pellet densities) of treated and untreated sites before (2007) and after (2009) a sagebrush reduction treatment in Rich County, Utah.

Year	Area Type	C	*n*	D_s	SE(D_s)	CI		p	SE(p)	CI	
2007	TRT	1283	10	993.3	229.4	594.8	1658.6	0.36	0.01	0.34	0.38
2007	UT	1859	10	1288.9	157.4	983.1	1689.9	0.40	0.01	0.38	0.42
2008	TRT	641	10	437.2	127.1	230.0	830.9	0.41	0.01	0.38	0.43
2008	UT	474	10	297.2	53.2	199.8	442.1	0.44	0.02	0.43	0.47
2009	TRT	1834	10	1543.1	298.3	1006.4	2366.1	0.33	0.01	0.30	0.36
2009	UT	1187	10	999.6	213.1	624.0	1601.3	0.33	0.01	0.30	0.36

C = Total pellet clusters
D_s = Pellet cluster density (per hectare)
p = Probability of detection

TRT = Treated sites (pasture aerator)
UT = Untreated sites

Table 3.3. Greater sage-grouse pellet density transect models from SAS of treated and untreated sites at Deseret Land and Livestock, Rich County, 2007-2009.

Factors	Model Df	Error Df	F Value	Pr > F
Treated	1	58	0.16	0.691
Year	2	57	10.93	0.001
Treated * Year	2	57	3.13	0.052

Year = 2007, 2008, and 2009

Table 3.4. Vegetation cover from treated and untreated sites before (2007) and after (2009) a sagebrush reduction treatment at Deseret Land and Livestock, Rich County, Utah.

	SHRUB HEIGHT[2]				SHRUB COVER[3]				GRASS COVER[4]				FORB COVER[4]			
	Before		After		Before		After		Before		After		Before		After	
Treatment[1]	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
TRT	16.6	2.4	18.8	4.1	31.9	3.1	26.6	2.9	11.0	2.0	8.3	2.3	11.3	3.5	9.9	3.6
UT	15.6	1.9	19.0	3.5	27.7	3.3	38.9	3.9	18.3	4.6	18.4	3.5	10.0	2.0	7.8	2.0

[1] = Sample size was 10 for each cell

Table 3.5. Vegetation data models for treated and untreated sites at Deseret Land and Livestock, Rich County, 2007-2009.

Shrub Height

Factors	Model Df	Error Df	F Value	Pr > F
Treated	1	38	0.02	0.899
Year	1	38	0.81	0.375
Treated * Year	1	38	0.04	0.848

Shrub Cover

Factors	Model Df	Error Df	F Value	Pr > F
Treated	1	38	1.46	0.235
Year	1	38	0.77	0.387
Treated * Year	1	38	6.22	0.017

Grass Cover

Factors	Model Df	Error Df	F Value	Pr > F
Treated	1	38	7.12	0.011
Year	1	38	0.16	0.693
Treated * Year	1	38	0.18	0.670

Forb Cover

Factors	Model Df	Error Df	F Value	Pr > F
Treated	1	38	0.34	0.561
Year	1	38	0.39	0.538
Treated * Year	1	38	0.02	0.891

Year = 2007, 2008, and 2009

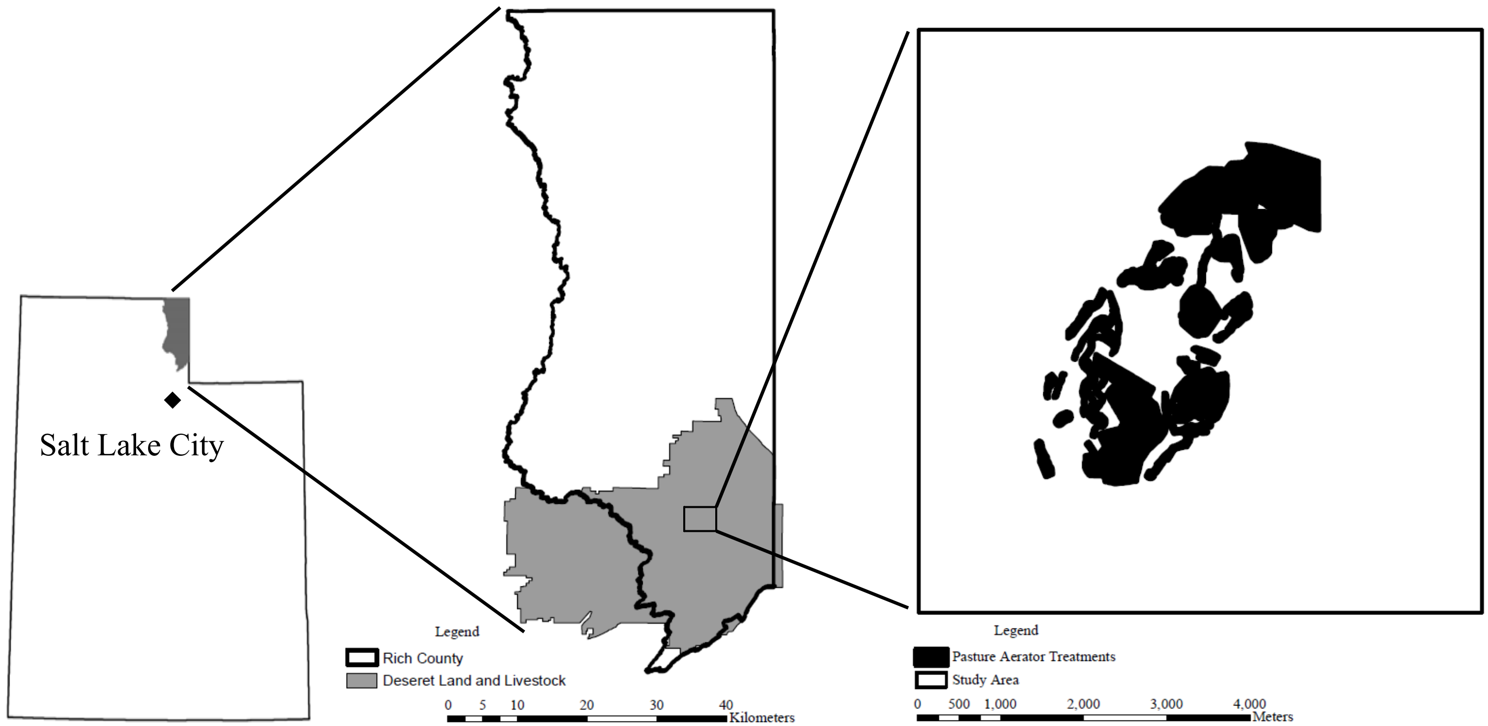

Fig. 3.1. Location of sagebrush reduction treatments on Deseret Land and Livestock, Rich County, Utah, 2007-2009.

Fig. 3.2. Pasture Aerator; photo courtesy of Scott Walker, Utah Division of Wildlife Resources (DWR).

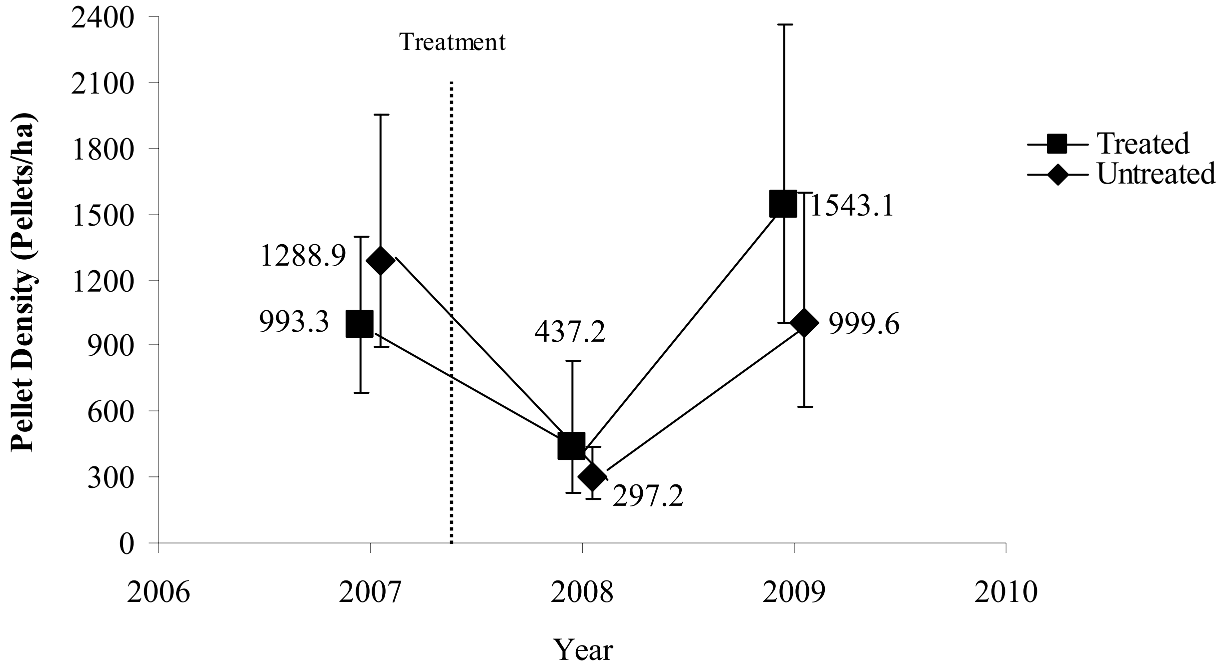

Fig. 3.3. Greater sage-grouse utilization (pellet densities with 95% CI) from treated and untreated sites in Rich County, Utah, 2007-2009.

CHAPTER 4

CONCLUSIONS

This work has allowed us to assess greater sage-grouse (*Centrocercus urophasianus*) use in response to sagebrush reduction treatments in Rich County. With a few exceptions, sage-grouse responded favorably to our pasture aerator manipulations. At our Duck Creek study site, we found that sage-grouse were utilizing lower elevation (1950 - 2110 m) treated areas at a higher rate than untreated sites during the spring and early summer. As living grass and forb cover on lower elevation treated sites began to desiccate and decrease, sage-grouse moved to late brood-rearing areas outside of Duck Creek. Late brood-rearing habitat was largely composed of historically treated sagebrush with low shrub cover and forb cover, and high grass cover. Sage-grouse use of these grass/forb dominated areas continued through the fall. In contrast to lower elevation sites, very low sage-grouse use was observed in higher elevation sites (2120 - 2250 m), whether treated or untreated. This indicates that sage-grouse use was neither enhanced nor diminished sagebrush reduction at these sites.

The Deseret Land and Livestock study area showed that sage-grouse use dropped immediately following a sagebrush reduction treatment, but use returned to pre-treatment levels just 2 years following treatment. It is unclear whether the initial drop was a result of the treatment since both treated and untreated plots showed depressed sage-grouse use in 2008 and lek count data indicated that the entire DLL sage-grouse population may have dipped in 2008.

Thus, our studies indicate that sage-grouse responded favorably and in a relatively short time to our pasture aerator sagebrush reduction treatments. Sage-grouse appeared to use these areas primarily as early brood-rearing habitat.

Our study was conducted concurrently with several other studies which were assessing sagebrush reduction treatment effects on pygmy rabbits, small mammals, and passerine bird species in Rich County (Edwards et al. 2006, Norvell et al. 2008, Wilson et al. 2010). These studies found that some species do not respond as positively as sage-grouse to sagebrush reduction treatments. Most small mammal populations were not impacted by aerator treatments (Edwards et al. 2006). Pygmy rabbits (*Brachylagus idahoensis*), however, did not appear to enter areas treated with the pasture aerator at the Duck Creek site. Pygmy rabbit use did occur near treatment edges, but no rabbit activity was observed in the treated sites (Wilson et al. 2010). Treatments also had some adverse effects on several shrubsteppe obligate passerines in Rich County. Sage Sparrows (*Amphispiza belli*) rarely used treated sites; sage thrashers (*Oreoscoptes montanus*) and Brewer's sparrows (*Spizella breweri*) continued to use treated sites but avoided nesting in areas directly impacted by the aerators (Norvell et al. 2008). These results stand as a reminder that reduction treatments are not a one size fits all solution for shrubsteppe management. Careful consideration for other species needs to be taken when planning sagebrush reduction treatments for sage-grouse.

Our assessment of sage-grouse use of treated sites was generally positive. We have shown that sagebrush reduction treatments using pasture aerators did not adversely affecting sage-grouse habitat use on our study areas in Rich County and in most cases enhanced sage-grouse use. We would expect that future pasture aerator sagebrush reduction treatments conducted under conditions similar to those of this study would likely benefit greater sage-grouse. However, because of differing reaction of other species, we caution against wholesale reduction of mature sagebrush habitats.

Our sagebrush reduction treatments that were heavily used by sage-grouse may have been so beause similar habitat was not available in the surrounding areas. These treatment sites, while large in area, were relatively small in scale in relation to the remaining intact sagebrush habitat on Duck Creek.

The intent of our treatments was to create early brood-rearing habitat. It has been proposed that early brood-rearing habitat is lacking in many areas (Beck and Mitchell 2000, Connelly et al. 2000), and appears to be the case with our study. It is important to remember that these treatments were only used during the early brood-rearing period (April-June), and additional sagebrush habitat varying in cover and height are needed for summer, fall, and winter sites.

Sagebrush reduction treatments are occurring at a very rapid pace throughout the west. These treatments do appear to provide early brood-rearing habitat for sage-grouse, however utilize various stages of sagebrush steppe habitats throughout the year. Management foresight must be used when planning sagebrush treatments in order to not saturate the system with sagebrush at an early stage, but provide a mosaic of different stages across space and time which in turn provide breeding, brood-rearing, and winter sage-grouse habitats.

Modern approaches to sagebrush reduction using pasture aerators or similar tools can enhance sage-grouse habitat because they are generally smaller in scale, less destructive to soils, focus on reduction not complete removal of shrubs, and leave patch mosaics of varying cover on the landscape. Sagebrush treatments that occurred prior to the 1990s focused on completely removing sagebrush from a system. These types of treatments had many adverse affects on sage-grouse populations (Klebenow 1970, Peterson 1970, Pyrah 1972, Swenson et al. 1987).

We did, however, see very high sage-grouse use in a 1980s disk-and-seed treatment designed to completely remove sagebrush. Radio-telemetry revealed that sage-grouse from our Duck Creek study area utilized these treated areas, which were within 5 km of Duck Creek, that contained very high grass and forb cover and very low shrub cover during the late brood-rearing and fall periods. Areas adjacent to these treatments contained relatively heavy shrub cover and were also heavily used be our radioed grouse. The 1980s treatments lacked interior shrub cover except for a few small pockets of scattered isolated shrubs, and shrub cover was well below the recommendations presented in the sage-grouse management guidelines (Connelly et al. 2000). Although we do not know why these areas had such high sage-grouse use, insect densities on this site appeared very high, which may have contributed to sage-grouse use of the site, particularly for brood-rearing habitat (Drut et al. 1994, Fischer et al. 1996).

The pasture aerator treatments created a disturbance that moved treated areas from a late to an earlier successional stage within a single shrubsteppe state. Periodic disturbance will move disturbed sites to a new stage within a state, but rarely are disturbances intense enough to move a system to a new state. The 1980s disk-and-seed treatments, however, created a more intense disturbance that caused the treated areas to cross a threshold into a completely different and novel state, one dominated by non-native perennial grass. We did not anticipate sage-grouse using multiple states, particularly a state which would not ordinarily be viewed by managers and biologists good as sage-grouse habitat. Additional research is needed to understand why sage-grouse were using these novel sites and how frequently such sites are used.

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APPENDICES

Table A.1. Duck Creek Grazing Allotment seed mix for Lawson Pasture Aerator treatments in 2003.

Common Name	Latin Name	Pounds/Acre	Kilograms/Hectare
Alfalfa	*Medicago* spp.	1.00	1.12
Small Burnet	*Sanguisorba minor*	0.50	0.56
Cicer Milkvetch	*Astragalus cicer*	0.50	0.56
Yellow Sweetclover	*Melilotus officinalis*	0.25	0.28
Sainfoin	*Onobrychis viciifolia*	2.00	2.24
Great Basin Wildrye	*Leymus cinereus*	0.50	0.56
Russian Wildrye	*Psathyrostachys juncea*	1.00	1.12
Paiute Orchardgrass	*Dactylis glomerata*	1.00	1.12
Indian Ricegrass	*Achnaherum hymenoides*	0.50	0.56
Bluebunch Wheatgrass	*Pseudoroegneria spicata*	1.00	1.12
Four-winged Saltbush	*Atriplex canescens*	1.00	1.12
Antelope Bitterbrush	*Purshia tridentata*	0.50	0.56
Forage Kochia	*Bassia prostrata*	0.25	0.28

Table A.2. Lek surveys assessing male greater sage-grouse lek attendance on leks on our Duck Creek study site, Rich County, Utah, 1995-2009. Data courtesy of Utah Division of Wildlife Resources.

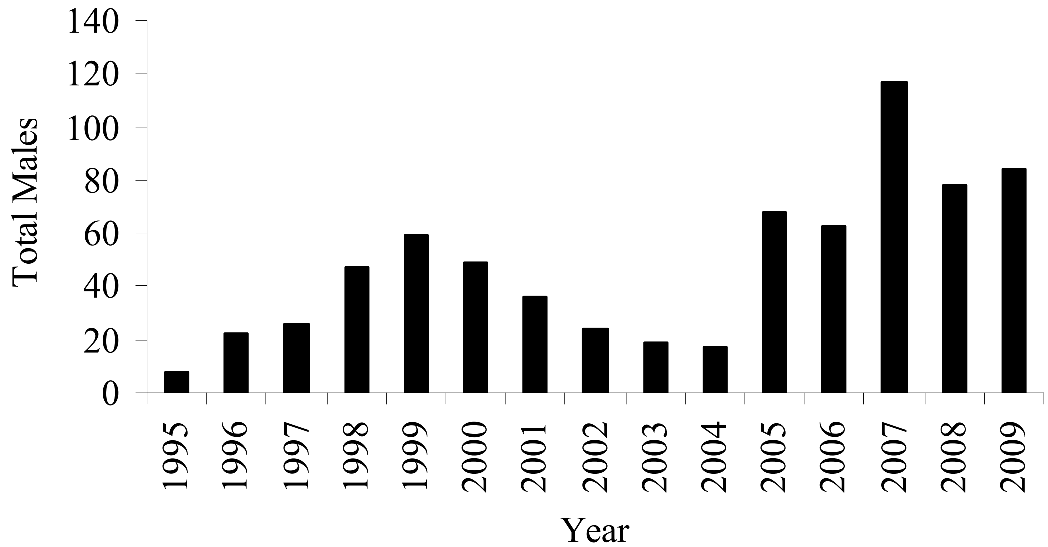
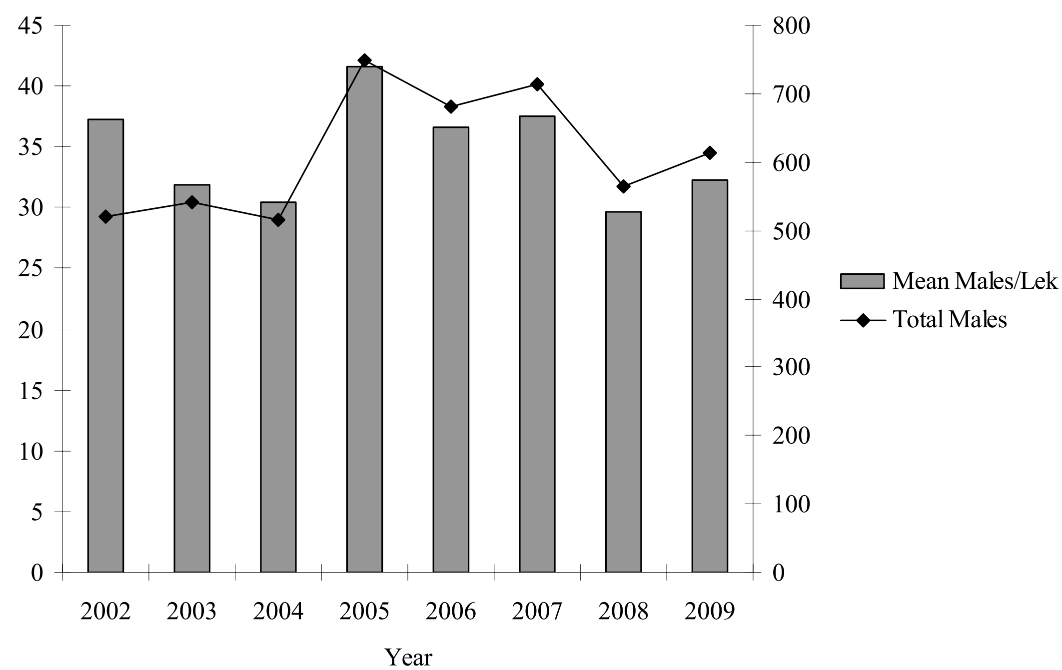


Table A.3. Lek surveys assessing male greater sage-grouse lek attendance on all leks and total number of males per lek (A) and leks near our study area (B) on Deseret Land and Livestock, Rich County, Utah, 2002-2009. Data courtesy of Utah Division of Wildlife Resources.

A



B .