GREATER SAGE-GROUSE SEASONAL ECOLOGY AND RESPONSES TO HABITAT MANIPULATIONS IN NORTHERN, UTAH

by

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ABSTRACT

Greater Sage-Grouse Seasonal Ecology and Responses to Habitat

Manipulations in Northern, Utah

by

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Declining greater sage-grouse populations (*Centrocercus urophasianus*; hereafter sage-grouse) have led to increased concern regarding the long-term stability of the species. Previous research has identified factors contributing to the observed population declines. Habitat degradation and loss have been implicated as major factors in population declines. Although much is known about sage-grouse biology, more information is needed about population responses to specific management actions. This research was conducted to document sage-grouse responses to site-specific management actions. Additionally, I evaluated sage-grouse temporal and seasonal habitat-use and the comparability of techniques used by range and wildlife managers to measure vegetation responses of habitat management. Specifically, I evaluated 1) whether chemical analysis (gas chromatography) of sage-grouse fecal pellets could identify sagebrush species in sage-grouse winter diets, 2) the comparability of the line-point intercept and Daubenmire canopy cover methods for estimating canopy cover, 3) the response of sage-grouse broods to prescribed burns in a high elevation sagebrush community in northeastern Utah, and 4) the vegetation and insect characteristics of sites used by sage-grouse broods during a 24-hour period. I was able to determine wintering sage-grouse diets using gas chromatography by analyzing fecal pellets. This research also confirmed that black sagebrush (*Artemisia nova*) was an important component of sage-grouse winter diets in western Box Elder County and Parker Mountain populations. The line-point intercept and Daubenmire methods for estimating canopy cover are not comparable. Sage-grouse broods selected small (~ 25 ha) patchy prescribed burns in high elevation mountain big sagebrush (*A. tridentata vaseyana*) communities in northeastern Utah. Sage-grouse brood-site use in northwestern Utah did not differ during the diurnal hours, but nocturnal roost sites were characterized by shorter statured shrubs and more bare ground when compared to midday sites.

(138 pages)

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Eric T. Thacker

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) are sagebrush (*Artemisia* spp.) obligates that inhabit sagebrush-steppe ecosystems in western North America. They have lower reproductive rates when compared to other game birds (Connelly et al. 2000a, Crawford et al. 2004). The dependence of sage-grouse on sagebrush and their low reproductive rates make them highly susceptible to changes in sagebrush-steppe ecosystems (Connelly et al. 2000a).

Schroeder et al. (2004) estimated that prior to European settlement, sage-grouse occupied 1,200,483 km^2 of habitat encompassing 13 states and 2 Canadian providences. Currently sage-grouse inhabit 11 western states and 2 Canadian providences, and inhabit approximately 668,412 km^2 of habitat. This is a 44% reduction from pre-settlement estimates (Schroeder et al. 2004). Sage-grouse populations have also declined range wide by as much as 47% in the last 50 years (Connelly and Braun 1997). These declines have been largely attributed to direct loss and degradation of habitat attributed to agriculture, oil and gas exploration, recreation , urban development, invasive weeds, and overgrazing by livestock (Connelly et al. 2000a, Crawford et al. 2004). Ecological processes have been altered since the 1800's due to changes in land use implemented by settlers' in the sagebrush communities of the west (West and Young 2000). Miller et al. 1994 and West 1996 suggested that little of the sagebrush biome remains unaltered since settlement. In some areas herbaceous understories have been altered through decades of improper grazing and altered disturbance regimes.

Sage-grouse population declines have received increased attention because of petitions submitted to the U.S. Fish and Wildlife Service (USFWS) to list the species as threatened and endangered.

The USFWS must address the stipulations stated in the Policy for Evaluating Conservation Efforts (PECE) when considering a petition to list a species. The PECE Policy establishes guidelines to quantify the effects of conservation actions on a species population and its habitats. Some of the major threats to sage-grouse identified by Connelly et al. 2004 are: exotic invaders (i.e. cheatgrass, *Bromus tectorum*), diseases such as West Nile virus, natural resource extraction activities (i.e. oil and gas exploration and production), and continued habitat degradation from livestock grazing. Furthermore, habitat is one of the most crucial factors that managers are able to manipulate to improve sage-grouse populations. Although much is known about sage-grouse biology, more information is needed regarding the effects of conservation actions on sage-grouse, and response of local populations to specific management actions (Connelly et al. 2004).

Crawford et al. (2004) suggested that reversing sage-grouse population declines will require increased integration of science with management to solve the problems facing sage-grouse. Several authors have argued for the increased use of adaptive management approaches to manage sage-grouse habitat (Beck and Mitchell 2000, Connelly et al. 2000a, Connelly et al. 2004, Crawford et al. 2004). Connelly et al. (2004) suggested that the adaptive management process is important because effects of management must receive unbiased evaluation to determine its effectiveness and then management adjustments must be made.

In 1999, the Western Association of Fish and Wildlife Agencies (WAFWA) suggested there was a need for replicated, controlled studies to investigate effects of sage-grouse management activities and the impact on sage-grouse populations. Periodic management of sagebrush by chemical, mechanical and biological means has been suggested as a way to benefit sage-grouse. But more research is needed to quantify the site-specific impacts these treatments may have on sage-grouse. More importantly can sagebrush manipulations have a stabilizing effect on sage-grouse populations (Connelly et al. 2000a, Crawford et al. 2004, Dahlgren et al. 2006)?

Dyer et al. 2009 suggested that sage-grouse managers must evaluate management in the context of habitat quality to insure that resources are used wisely. Otherwise resources will be spent on perceived problems that will distract resources from legitimate problems facing sage-grouse.

The purpose of my research was to evaluate the effects of management actions on local populations, to investigate and compare the application of techniques used to monitor sage-grouse responses to management, and to evaluate sage-grouse use of seasonal habitats. Specifically, I wanted to determine if: 1) gas chromatography analysis of fecal pellets could be used to determine sage-grouse winter diets; 2) vegetation cover estimates obtained using Daubenmire and line-point intercept methods were comparable, 3) sage-grouse selected for small scale prescribed burns; and 4) vegetation characteristics of daily grouse-use sites differed over a 24 hours period. The results of my research will increase managers understanding regarding the applications of specific management action and monitoring methodologies in the conservation of the species.

SAGE-GROUSE REPRODUTIVE ECOLOGY

Lekking Habitat

Male sage-grouse display annually during the spring on strutting grounds called leks in an attempt to attract and breed females. Leks are typically described as openings in sagebrush stands ranging in size from 0.04 to 40.5 ha, that are located near suitable nesting habitat (Patterson 1952, Gill 1965, Call and Maser 1985). Lek vegetation is usually low or sparse affording the birds increased visibility. Some areas that have been documented as leks include roads, gravel pits, burned areas, tilled fields, pastures, low sagebrush flats, ridges, reservoirs, salting grounds, and sheep bedding grounds (Patterson 1952, Dalke 1963, Call and Maser 1985). Many leks tend to be permanent and are used repeatedly through time. However, new lek sites have been established in recently disturbed areas (Dalke 1963, Connelly et al. 1981). Connelly et al. (2000a) suggested that lek habitat can be created or enhanced by removing vegetation from a small area in close proximity to existing leks. This may only be effective if lekking areas are limited near suitable nesting habitat.

Pre-laying Habitat

Prior to and during the lekking season hens use specific habitat to prepare for breeding. Pre-laying habitats are typically adjacent to the leks (Connelly et al. 2000a, Crawford et al. 2004). During this time sage-grouse hens require a diversity of forbs that are high in calcium, phosphorus and protein (Barnett and Crawford 1994, Coggins 1998, Gregg et al. 2006, Gregg et al. 2008). Gregg et al. (2006) suggested that hens who achieved higher plasma protein levels were more likely to re-nest. Gregg et al. (2008) suggested that adult hens consumed more forbs than juvenile hens, this accounting for the elevated levels of plasma protein, calcium and phosphorus in adult hens. They also suggested that management activities that increase the quantities and quality of available forbs could be advantageous for pre-laying sage-grouse (Barnett and Crawford 1994, Gregg et al. 2008)

Nesting Habitat

Patterson (1952), Gill (1965), Gray (1967), Pyrah (1972) and Wallestad (1975) identified sagebrush as a critical component of nesting habitat. Most sage-grouse nests were located under sagebrush plants that ranged from 29-80 cm in height, exhibiting a robust canopy cover (15-30%) with more lateral and ground cover (Wakkinen 1990, Gregg 1991, Fischer et al.1994, Heath et al. 1997, Sveum et al. 1998, Holloran 1999, Connelly et al. 2000a). Sage-grouse will use other shrub species as nesting cover but these nests are typically not as successful (Klebenow1969, Connelly et al. 1991, Gregg 1991, Sveum et al. 1998).

Gregg et al. (1994) reported that nest predation decreased with increasing grass cover. Gregg (1991) also reported that mountain big sagebrush communities (*A. tridentata vaseyana*) had more successful nest than other sagebrush community types. Delong et al. (1995) and Gregg et al. (1994) both suggested that dense herbaceous cover and adequate sagebrush cover was the key to protecting sage-grouse nests from predators.

Brooding Habitat

Brooding habitat is classified as early brooding and late brooding habitat (Connelly et al. 2000a, Connelly et al. 2004). Generally early brooding habitat is in close proximity to nesting sites (Connelly 1982, Gates 1983). Connelly et al. (2000a) reported that even though broods are typically found closer to the nests site after hatching, they tended to select more open sagebrush stands with abundant herbaceous understories. The herbaceous understories provide forage and escape cover for chicks (Wallestad 1975, Aldridge 2000, Connelly et al. 2000a, Crawford et al. 2004).

During this early brooding period, the abundance of insects is critical for young sage-grouse chicks, whose diets contain 88% insect material during the first 10 days (Patterson 1952, Klebenow and Gray 1968). Ants (Hymenoptera) and beetles (Coleoptera) were found to be more common among brood sites when compared to non-brood sites (Fischer et al. 1996). Habitats that typically contain abundant insect populations exhibit greater vegetation diversity (Haddad et al. 2001). As chicks mature they begin to incorporate more forbs into their diets (Klebenow and Gray 1968).

At 4-5 weeks post hatch sage-grouse hens move broods into more mesic habitats. Apa (1998) reported that late brooding locations had twice the forb cover as compared to random locations. These habitats include mesic sagebrush sites (Martin 1970), wet meadows, irrigated pastures and alfalfa (*Medicago sativa*) fields (Connelly et al. 2000a).

Although the published sage-grouse literature contains numerous descriptions of brooding habitats, little information is available regarding temporal patterns of use over a 24 hour period. Dunn and Braun (1986) provided the only published reference to daily temporal use by summering sage-grouse. They used three time periods: morning (< 4 hours after sunrise), mid-day (> 4 hours after sunrise and < 4 hours before sunset) and evening (< 4 hours before sunset). They concluded that sage-grouse exhibit preference for sites that differ in structure and composition during the three time periods. They reported that sage-grouse tend to use more open sagebrush stands during the morning and evening hours while feeding and use taller dense stands of sagebrush during the mid part of the day. One of the limitations of this study is they used a small sample of broods (n = 2). It would be useful to perform a similar study with a greater number of broods to determine temporal use patterns for broods in a 24-hour period.

SAGE-GROUSE WINTER ECOLOGY

Sage-grouse rely entirely upon sagebrush as their food source through the winter (Patterson 1952, Dalke et al. 1963, Wallestad et al. 1975). Thus, unlike for many other species, winter is not typically a stressful period for sage-grouse (Beck and Braun 1978). Beck and Braun (1978) reported that sage-grouse actually gained weight in Colorado during the winter. Sage-grouse winter habitat is characterized by large expanses of sagebrush that is available above the snow with a live canopy cover from 15-20% (Wallestad 1975, Robertson 1991). Even though sage-grouse may have hundreds of hectares of sagebrush habitat available to them, Beck (1977) reported that they may only use a small percentage of available habitats. He identified seven major sage-grouse wintering areas in North Park, Colorado which accounted for only 7% of the total available sagebrush habitat.

Remington and Braun (1985) showed that sage-grouse select sagebrush stands with the highest protein levels; they also suggested that sage-grouse were selecting individual plants within stands that had the highest protein levels. Remington and Braun (1985) reported that Wyoming big sagebrush (A. *t. wyomingensis*) was consumed more frequently than mountain big sagebrush. They suggested that sage-grouse were selecting their diets based upon protein levels of the sagebrush plants. However, Welch et al. (1989, 1991) suggested that sage-grouse preferred mountain big sagebrush over other varieties including Wyoming sagebrush in a Utah study. Connelly et al. (2000a) suggested that sage-grouse exhibit preferences for several species of sagebrush. Dalke et al. (1963) reported that sage-grouse in central Idaho inhabited black sagebrush (*A. nova*) communities until the snow depth exceeded sagebrush height.

Remington and Braun (1985), Welch et al. (1989) and Welch et al. (1991) reported sage-grouse using varieties of big sagebrush but little research has been done to document the importance of other sagebrush species for wintering sage-grouse. Beck (1977) and Remington and Braun (1985) acknowledged that black sagebrush was present in their study area, but they did not indicated whether it made a meaningful contribution to the winter diets in Colorado. Sage-grouse researchers in Utah have suggested black sagebrush may be very important to wintering sage-grouse in Utah (Chi 2004, Dahlgren 2006, Ward 2006). Research is needed to identify what sagebrush species are important in the diet of wintering sage-grouse in Utah.

HABITAT MANAGEMENT

Concern over sage-grouse population declines has increased interest in the management of sagebrush habitats to benefit the species. There are basically 3 categories of manipulations that have been used to manage sagebrush. These include mechanical, chemical, and biological. These techniques have been used to remove sagebrush to increase livestock forage and to manage sagebrush habits to increase sage-grouse productivity. The scale at which projects are carried out may be critical to their success as sage-grouse management strategies.

Connelly et al. (2000a) recommended that habitat improvements that result in the direct loss of sagebrush cover should be implemented at small scales. Additionally, prior to implementing a management action, it is crucial to identify how the habitat to be managed is used by sage-grouse. Management objectives for managing winter habitat will differ from summer habitat. These different habitat requirements will dictate the selection and appropriateness of management actions.

Connelly et al. (2000a) classified sage-grouse habitat into 4 main categories: breeding, late brooding, fall and wintering. Breeding habitat includes lekking, pre-laying, nesting and early brooding. They recommended that less than 20% of the habitat is treated every 20-30 years. Connelly et al. (2000a) also suggested that treated areas should be treated in strips or patches and the total acreage not to exceed 20% of the total area.

Mechanical Treatments

Mechanical brush management techniques have been used to manipulate sagebrush for decades (Stoddart et al. 1975). Common mechanical brush treatments for sagebrush include; Lawson aerator, mowing, disking, chaining and the Dixie harrow (Stoddart et al. 1975). However, it has been suggested that impacts of these treatments may have a negative impact on sage-grouse (Klebenow 1970, Peterson 1970, Pyrah 1972). Although previous research suggested that site specific sagebrush manipulations may benefit sage-grouse (Martin 1970, Pyrah 1972, Johnson et al. 1996, Chi 2004, Dahlgren et al. 2006). It is important to point out that there is little data to show a positive correlation between these treatments and sage-grouse. Connelly et al. (2000a), Beck and Mitchell (2000), and Dahlgren et al. (2006) stated that treatments should only be conducted where sagebrush abundance is limiting the herbaceous understory. They also cautioned that treatments should only be carried out in areas where large contiguous stands of sagebrush persist. Dahlgren et al. (2006) suggested that caution needs to be exercised when replicating these types of treatments at lower elevations or in areas with different species of sagebrush. There is a need to further understand impacts of mechanical treatments and their effects on sage-grouse.

Chemical Treatments

Herbicides are commonly used to remove woody vegetation on shrub dominated rangelands (Stoddard et al. 1975). Common herbicides used include 2, 4-D, and tebuthiron. Over 810,000 ha of sagebrush have been sprayed with chemicals by 1970 (Schneegas 1967, Vale 1974). Rogers (1964) suggested that using herbicides to remove sagebrush had negative impacts on sage-grouse populations. Martin (1970) suggested that grouse rarely frequented areas that had been treated by herbicides. Klebenow (1970) also suggested that chemical treatments may have reduced quality of brooding habitat. However it has been reported that treating sagebrush with selective herbicides can increase the herbaceous production (Waltenberg et al. 1979, Kearl and Freeburn 1980). Halstvedt et al. (1996) reported an increase of 12-127% on treated sites. Consequently they suggested that the sagebrush cover was reduced to 12-15%. Johnson et al. (1996) also reported that reducing sagebrush cover could increase diversity and abundance of herbaceous understories. Autenrieth (1981) suggested that by reducing sagebrush cover to moderate levels the herbaceous component may be increased to benefit sage-grouse. Connelly et al. (2000a) and Beck and Mitchell (2000) agreed that if the sagebrush overstory is suppressing the herbaceous understory then treatments targeted to open sagebrush canopy may be beneficial to sage-grouse. However, few examples exist that showed a positive correlation between sage-grouse use of treated sites. Dahlgren et al. (2006) reported that chemical treatments (tebuthiron) were the most effective at reducing sagebrush canopy cover, increasing forb cover, and thus increasing brood use in mountain big sagebrush communities in south central Utah. This management tool needs to be explored more fully in other sagebrush communities at different elevations. Dahlgren et al. (2006) suggested that more research needs to be done to document the cumulative effect of these treatments on a landscape scale.

Biological Treatments

The role of fire in managing sagebrush for sage-grouse has received increased scrutiny as populations have declined. Wildfires have been cited as a major factor in declines of sage-grouse populations. Fire also facilitates the increase of invasive annual grasses that can replace the native vegetation (Connelly and Braun 1997, Connelly et al. 2000a, Connelly et al. 2000b,). Crawford et al. (2004) suggested that fire in sagebrush steppe ecosystems has been over generalized and the effects of fire in sagebrush habitats are more complex. Fire may be used as a management tool for improving sage-grouse habitat if it is properly applied (Connelly et al. 2000a, Connelly et al. 2000b, Crawford et al. 2004).

Knick et al. (2005) compiled a synthesis on the role of fire in structuring sagebrush habitats and bird communities. He summarized studies that investigated the effects of fire on sage-grouse. Of the 5 studies that dealt with mountain big sagebrush (*A. t. vaseyana*) they suggested that only 2 reported a positive relationship between fire, sage-grouse, and the abundance of sage-grouse forage (Martin 1990, Pyle and Crawford 1996). Knick et al. (2005) reported that three of the studies were inconclusive as to the impact on sage-grouse forage (Pyle and Crawford 1996, Nelle et al. 2000).

Using prescribed fire in breeding habitats negatively impacted breeding sage-grouse. Connelly et al. (2000b) reported an 80% decline in the breeding population and a decrease in active leks. Hulet (1983) also reported an increase in lek abandonment. It is also important to note that both of these studies took place in an areas dominated by Wyoming big sagebrush. Byrne (2002) and Nelle et al. (2000) both reported that fire had a negative impact on nesting activities regardless of community type. Knick et al. (2005) summarized six studies where fire was used to manage sage-grouse brooding habitat. One study showed a negative correlation (Byrne 2002); two reported a positive response (Martin 1990, Pyle and Crawford 1996), while three were inconclusive (Fischer et al. 1996, Fischer et al. 1997, Nelle et al. 2000,). Ambient conditions (temperatures, precipitation, ecological conditions, sage-brush community type, etc.) of sites are not likely the same; this makes it very difficult to draw comparisons among sites. None of the authors of the studies discussed above differentiated between early or late brooding habitats. Connelly et al. (2000a) suggested that there are in fact two different brooding habitats; early and late brooding. This clarification may help bring some consensus to the question of whether fire can be used to positively manage sage-grouse habitats. Early brooding occurs close to the nests, meaning that most of the early brooding areas occur within nesting habitat (Connelly et al. 2000a). Nelle et al. (2000) and Byrne (2002) both suggested that fire had negative impacts on nesting sage-grouse therefore using fire in early brooding habitat may negatively affect nesting habitat. In light of this distinction outlined by Connelly et al. (2000a) the use of prescribed fire needs to be evaluated in high elevation (>2000m) late brooding habitats.

STUDY PURPOSE

The specific questions I addressed through my research were; 1) could gas-chromatography analysis of fecal pellets be used to determine sage-grouse winter diets; 2) are vegetation cover estimates obtained using Daubenmire and line-point intercept methods comparable, 3) do sage-grouse select for small scale prescribed burns in high elevation mountain big sagebrush communities; and 4) do vegetation characteristics of daily grouse-use sites differ over a 24-hour period?

I have also included another chapter in the Appendices which was removed from the body of the dissertation by the request of my graduate committee. One of the original premises of my research was the evaluation of a landscape level NRCS cost-share programs implemented in west Box Elder County, Utah. Specifically, BARM had designed a project to evaluate vegetation and sage-grouse response to two mechanical (Lawson aerator and chaining) and one chemical brush (tebuthiron) treatments. As the project moved forward problems arose with implementation of the experimental design due to issues with treatment implementation and the amount of time the pastures were rested from grazing. These problems compromised my experimental design to such a degree that I was not able to reliably report the data in the main body of this dissertation. The chapter has been relegated to the appendices of this document in order to provide insight as to how these types of problems may be avoided in the future.

The results of my research will provide managers with new techniques and increased insights to better manage sagebrush habitats to benefit sage-grouse populations. I used the *Journal of Wildlife Management* style guide for citations; headings sub headings, table titles, and figure captions (Chamberlain and Johnson 2008)

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CHAPTER 2

USING GAS CHROMOTOGRAPHY TO DETERMINE GREATER SAGE-GROUSE WINTER DIETS IN TWO UTAH POPULATIONS

ABSTRACT Although it is generally accepted that sagebrush (*Artemisia* spp.) is a major component of greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) winter diets, there is little consensus as to which species or subspecies is most commonly consumed. The composition of sage-grouse winter diets has typically been determined from crop analysis or observational studies. Crop analysis requires harvesting individual birds. It is accurate but may not be a viable option in areas where sage-grouse populations are small or declining. Observational studies require the investigator to observe sage-grouse as they forage or to identify signs of herbivory to determine the sagebrush species grouse are selecting. Determining sage-grouse winter diets through observational studies requires extensive time in the field to collect data in order reliably determine diet composition. The objective of the study was to evaluate if gas chromatography of sage-grouse fecal pellets could be used to determine diet composition. To conduct the study, I analyzed pellets and sagebrush samples from 29 random sage-grouse flocks in Box Elder County and Parker Mountain, Utah. Additionally I wanted to determine if the technique could be used at population levels to determine whether black sagebrush (*A. nova*) was consumed more frequently than Wyoming sagebrush (*A. tridentata wyomingensis*). My results confirmed that gas chromatography can be used to determine the sagebrush composition of sage-grouse pellets. Additionally black sagebrush was consumed more frequently than Wyoming sagebrush. These results suggest that black sagebrush was an important winter forage for grouse in the populations studied.

INTRODUCTION

Wintering greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse) use sagebrush species (*Artemisia* spp.) as their primary winter food source (Patterson 1952, Dalke et al. 1963, Gullion 1966, Wallestad et al. 1975). Thus, for wintering habitat to be considered adequate it must contain expansive tracts of sagebrush cover (Connelly et al. 2000a). However, even in some areas classified as important winter habitat, Beck (1977) reported that wintering sage-grouse only used 7% of the available sagebrush habitat. He suggested that sage-grouse were preferentially selecting for relatively small patches of sagebrush in a landscape dominated by sagebrush.

Remington and Braun (1985) suggested that winter habitat selection for these relatively small areas could be explained by sagebrush protein levels. They demonstrated that wintering sage-grouse in the North Park Colorado selected Wyoming big sagebrush (*A. tridentata wyomingensis*) over mountain big sagebrush (*A. t. vaseyana*) due to nutritional differences. Their analysis of sagebrush protein levels suggested that patches of Wyoming big sagebrush being used by sage-grouse contained more protein than sagebrush at random sites. Thus they suggested that sage-grouse exhibited a preference for sites on the landscape where the sagebrush contained the highest protein levels. Further, they also suggested that sage-grouse selected for individual Wyoming sagebrush plants that had the highest protein levels within these patches.

However in Utah, Welch et al. (1989) and Welch et al. (1991) suggested that wintering sage-grouse preferred mountain big sagebrush over other varieties of big sagebrush. Dalke et al. (1963) reported that sage-grouse in central Idaho inhabited black sagebrush (*A. nova*) communities until the snow covered the shrubs. Beck (1977) and Remington and Braun (1985) acknowledged that black sagebrush was present in their study area, but they did not indicated whether it could make a meaningful contribution to the winter diets. While these findings are important little published information exists regarding the role of black sagebrush as an important winter forage.

Wildlife biologists working with greater sage-grouse and Gunnison sage-grouse (*C. minimus*) in Utah have observed that sage-grouse appear to prefer black sagebrush communities during the winter (Chi 2004, Dahlgren 2006, Ward 2006). Ranchers who participate in the Box Elder Adaptive Management (BARM) local working group have also suggested that wintering sage-grouse are commonly found in black sagebrush communities (A. Kunzler and J. Tanner, BARM, personal communication.). Currently there is little consensus as to which species or subspecies of sagebrush is most used by wintering sage-grouse, and it likely varies from population to population. This underscores the importance of finding methods that can be used to readily determine sage-grouse winter diets. To better manage sage-grouse winter habitat it may be important to know which species of sagebrush is used most frequently.

Determining sage-grouse diets in the past has been conducted using two methods; crop analysis and observational studies and crop analysis (Wallestad 1975, Barnett and Crawford 1994, Gregg 2006). Crop sampling is accurate but may not be a viable option in areas where sage-grouse populations are small or declining.

Observational studies require the investigator to observe sage-grouse as they forage or to look for signs of grouse herbivory to identify the sage-brush species that are being selected by grouse (Barbar et al. 1969, Beck 1977, Remington and Braun 1985, Welch et al. 1991). Observational studies can be effective, but have some limitations. It can be problematic to approach a flock of wintering sage-grouse within an acceptable distance to reliably observe sage-grouse foraging behavior. Additionally, indirect observations (identifying evidence of herbivory) may not quantify numbers of grouse foraging in a given area, when the foraging took place, or whether diet mixing may have occurred. Likewise, observational studies that take place in an exclosures (cages) such as Welch et al. (1991) have limited inferences to sage-grouse populations at a landscape level, because grouse are restricted and researchers have no way of quantifying how the behavior of grouse in an exclosure relates to free ranging grouse. In general determining diet composition through observation requires lots of time. Therefore labor costs may limit the use of observational studies.

There is a need to be able to reliably determine sage-grouse diets. While some researchers still used crop analysis to determine diet selection this may not be a feasible option for many areas (Gregg 2006). Researchers and managers need a reliable and cost effective method for determining sage-grouse diet composition.

Sage-grouse present an ideal situation to use chemical analysis of fecal material to determine diet selection. Sagebrush contains a suite of secondary compounds called terpenoids (Kelsey et al. 1976). Kelsey et al. (1976) suggested that these compounds could be used to taxonomically separate sagebrush species. If unique terpenoids are detectable in the fecal pellets it may be possible to derive diet composition from fecal material. The objective of the study was to determine if chemical analysis of fecal pellets could be used to identify the sagebrush composition in sage-grouse winter diets. Additionally, I wanted to determine if this method was a viable alternative to traditional methods. I hypothesized that crude terpene profiles were different for Wyoming and black sagebrush species. Thus managers would be able to use those profiles to identify the sagebrush species contained in sage-grouse fecal pellets. Further I hypothesized that black sagebrush would be consumed more frequently than Wyoming sagebrush in my study areas, because wintering sage-grouse flocks are commonly found in black sagebrush communities (Chi 2004, Dahlgren 2006, E. Thacker Utah State University unpublished data).

STUDY AREA

The pellets used to conduct this study were collected from two of the largest populations in Utah. One of the study areas was located in the western Box Elder County (WBE) in northwestern Utah and the other was located on Parker Mountain in Wayne and Piute County in south central Utah. In WBE sage-grouse winter habitat occurs between 1500-1600 m of elevation (E. Thacker unpublished data). Parker Mountain sage-grouse winter habitat ranges from 2400-2500 m in elevation (Dahlgren 2006). Grazing by domestic livestock is the primary land use in both study areas.

In WBE wintering areas were characterized by Wyoming sagebrush flats with black sagebrush inclusions on shallow soils and ridge tops. Juniper (*Juniperus osteosperma*) was located on ridge tops as elevation increased toward the higher ridges and mountains. The herbaceous community was dominated by bluebunch wheatgrass (*Pseudoroegneria spicata*), sandberg bluegrass (*Poa secunda*), wheatgrass (*Bromus tectorum*), Phlox (phlox spp.) vetches (Astragalus spp.) and desert parsley (*Lomatium* spp.). The predominant management concern in WBE as it relates to sage-grouse is loss of winter habitat due to encroachment by invasive annual grasses, which lead to destructive wildfires.

The climate of WBE was characterized by warm summers with an average daily temperature of 27° C, while the winters are cool with an average daily temperature of -3°C. The area received 50% of its moisture during the growing season (April – September). Precipitation ranges from 15cm to 30cm annually. The precipitation is quite uniform throughout the year. January and December were the highest snowfall months with 27 cm and 17cm respectively. Snow depth data are collected at Park valley, Utah which has a higher elevation (1725 m) than major grouse wintering areas (1500-1600) therefore the average snow depths are likely less than reported (Loerrch et al. 1985).

The PM study area was characterized by black sagebrush flats and ridge tops, and Wyoming and mountain big sagebrush draw bottoms. However, on the northern portion of the study site there were vast expanses of Wyoming sagebrush. The annual precipitation ranges from 25 – 40 cm annually. Most of the precipitation occurs in the winter months. The herbaceous community was dominated by bluebunch wheatgrass and blue grasses (*Poa* spp.) and blue grama (*Bouteloua gracilis*). Common forbs include vetches, desert parsley, and phlox. Other shrubs commonly found on the study site include rabbitbrush (*Chrysothamnus* spp.) and snakeweed (*Gutierrezia sarothrae*). There were pockets of junipers located on rocky slopes and barren ridges (Dahlgren 2006).

METHODS

The study was conducted using sage-grouse hens that were radio collared for summer habitat studies. The hens were weighed, aged and fitted with a 19g Holohil Systems™ necklace radio-collar (Holohil Systems Ltd., 112 John Cavanaugh Drive, Carp, Ontario, Canada K0A 1L0). The grouse were located using a Communications Specialists™ receiver (426 West Taft Ave. Orange, California 92865-4296) and a 3 element yagi antenna. Grouse were located with spotlights and captured with long-handled dip nets. All bird handling was conducted under protocols approved by the Utah State University Institutional Animal Care and Use Committee (#1194 and #942).

In WBE, the hens were captured at the quaking aspen and Red Banks leks in April of 2006 and 2007. I also used two male sage-grouse that were collared in spring 2006 on the Badger Flat lek. I collared additional hens in Cotton Thomas Basin and on Kimball Creek Mountain in July of 2007. The sage-grouse on PM were captured at the Bull Roost lek in April 2006 and 2007. All grouse were captured in breeding habitats and were not captured in winter habitats. Thus by locating these radio-collared grouse in winter habitats we were able to locate flocks random flocks of sage-grouse on the landscape. This allowed us to evaluate habitats that sage-grouse had selected from across the landscape ensuring us an unbiased sample.

I located a total of 29 sage-grouse flocks (using the radio marked grouse) totaling more than 1383 sage-grouse, 19 flocks were located in WBE and the other 10 were located on PM. I collected 286 pellet samples from both study sites; 186 and 100 from WBE and PM, respectively. To locate the sage-grouse winter flocks I located grouse that were previously radio collared. Radio collared birds were located only once during the study period. I defined a flock of sage-grouse as five or more grouse in a group (this was determined by the size of the smallest flock I observed). If a flock was smaller than 10 grouse I collected as many pellet piles as there were grouse. At each winter flock location grouse were flushed and counted. At flock locations vegetation communities were categorized as Wyoming sagebrush, black sagebrush, or mixed sagebrush. These vegetation categories were categorized by which shrub species dominated in the area inhabited by the flock. If the communities contained both black sagebrush and Wyoming sagebrush species then it was classified as a mixed sagebrush community. Most mixed sagebrush communities occurred at seams where black sagebrush and Wyoming sagebrush converged and both species occurred at roughly equal proportions.

At each flock location 10 fresh pellet clusters (> 2 pellets) were collected and each pellet cluster sample was stored in plastic bags. Pellet clusters were collected by walking a transect within the feeding area. I assumed all pellets in a single pile were deposited by one individual grouse. The pellet samples were stored in a cooler packed with snow or ice until they could be transferred to a freezer.

At each flock location a sagebrush branch was collected from 10 sagebrush plants for identification and chemical analysis. Sagebrush samples were collected by walking a 50 m of transect within the feeding area. Sagebrush samples were collected by cutting one branch off of the shrub nearest each 5 m interval along the transect. The feeding area was identified by observing fresh tracks and sagebrush that showed evidence of browsing by sage-grouse (Remington and Braun 1985).

The pellet samples were transported to the USDA-ARS Poisonous Plant Lab in Logan Utah where they were placed in a freezer awaiting chemical analysis. The pellets were removed from the freezer and allowed to thaw at room temperature. Each pellet cluster sample was crushed and 100 mg was placed into a 10 ml screw cap test tube. Dichloromethane (5 ml) was added to each sample and the sample was mixed by mechanical rotation (inverting the tubes) for 15 minutes to extract the terpenes from the pellet material. A 1 ml aliquot was removed with a glass pipette and filtered through an anhydrous sodium sulfate filter into a 2 ml auto sample vial. The samples were then analyzed using gas chromatography (GC) with flame ionization detection (FID) using a Shimadzu GC-2010 gas chromatograph and a Shimadzu AOC 20 auto sampler. Samples (1.5 µl) were injected in a split mode (30:1 split ratio) with an injection port temperature of 250°C. The GC column was a DB-5 capillary column (30 m x 0.32 mm, 0.25 um) using helium as the carrier gas at a flow rate of 2 ml/min. Detector (FID) temperature was 325°C. Column temperature was set to 60°C for 1 min, increased to 160°C at 5°/min and then held at 160°C for 1 min for a total analysis time of 22 min. The terpene profile or fingerprint of the samples was characterized by the GC retention time and relative peak intensities of the resulting GC chromatogram. A simple visual examination of the terpene patterns was used to determine differences between plants by comparing retention time peaks. Sagebrush samples were handled in a similar fashion, except the leaves were stripped from the stems and placed in 10 ml screw cap vial.

Terpene profiles from pellets and sagebrush were compared by visual pattern recognition to identify which sagebrush terpene profile matched the pellet cluster sample. Examples of the terpene profiles for pellets and plant material are compared in Figure 3-2. In some cases the terpene profiles may be a mixture from both plants and in those cases the presence of the marker peaks were used to verify the presence of both plant species (Figure 3-3).

RESULTS

Terepene profiles for black and Wyoming sagebrush differed (Figure 2-1). Two marker compounds were selected for each plant species to help discriminate between the samples. These markers compounds had retention times of 4.95 and 6.91 min for black sagebrush, and 7.78 and 10.71 min for Wyoming sagebrush. Furthermore, the resulting chromatograms from the fecal pellets had similar terpene profiles unique to black sagebrush and Wyoming sagebrush (Figure 2-2). This allowed for identification of sagebrush species consumed by wintering sage-grouse using gas chromatography. Additionally I was able to identify both sagebrush species in mixed pellet samples.

Analysis of the pellet samples suggested that WBE and PM sage-grouse consumed black sagebrush more frequently than Wyoming sagebrush (Figure 2-3). Most pellet clusters in WBE contained black sagebrush (72%), while only 5% contained Wyoming sagebrush and 22% contained mixed sagebrush (Table 3-1). Over half (61%) of PM pellets cluster contained black sagebrush, while 33% contained Wyoming sagebrush and 6 % consisted of mixed sagebrush (Table 2-1). These results suggest that sage-grouse were consuming black sagebrush most frequently.

Additionally I compared species contained in pellet samples with vegetation communities that pellets were located in. In WBE 84% of the flocks located were in black sagebrush communities. Of those pellet clusters collected in black sagebrush communities79% contained only black sagebrush, while 22% were mixed (Table 2-1). Only 1 flock (5%) was located in a Wyoming sagebrush community, but 100% of the pellet clusters contained only Wyoming sagebrush. Pellet clusters collected in mixed sagebrush communities (11% of flocks) 60% of the pellet contained only black sagebrush and the remaining 40% were mixed. On PM 60% of the flocks were found in black sagebrush communities and 100% of pellets collected contained only black sagebrush. Thirty percent of the grouse were located in Wyoming sagebrush habitats; the pellet samples collected from these sites contained 100% Wyoming sagebrush (Table 2-1). The remaining 10% (1 flock) were located in a mixed sagebrush community, of those pellet clusters collected in a mixed community 18% of the pellet samples contained only black sagebrush, 25% contained Wyoming sagebrush, and 55% were mixed (Table 2-1).

DISCUSSION

This study makes two contributions to the body of sage-grouse literature. I demonstrated sage-grouse diets can be determined using gas chromatography. This technique will allow biologists to determine winter diet selection without using invasive or costly observational sampling techniques. Although Remington and Braun (1985) used evidence of herbivory at flock locations to determine diets; such observational studies may have limitations and not reflect actual diets. If observational studies would have been used, I would not have been able to detect diet mixing. For example in WBE 79% of the pellet samples in a black sagebrush community were composed entirely of black sagebrush with 21% were mixed sagebrush. It would have been difficult to determine this fact using traditional field observations. This would only have been feasible by collecting crop samples from harvested grouse or by using chemical fecal analysis. If pellets are mixed the proportions of sagebrush species cannot be proportioned, only that both species are contained in the pellets. Proportioning mixed diets may be feasible using crop analysis.

A limitation of fecal analysis is that it will only work for winter diets. Summer diets are too complex (composed of numerous plant species) and thus it may be impossible to isolate unique chemical marker compounds or chemical profiles for all types of summer forage. Winter diets are composed of sagebrush and because sagebrush has terpenoid profiles that are unique to each sagebrush species gas chromatography is possible (Kelsey 1976). This creates a favorable situation for fecal analysis to determine diet composition.

Based on my findings, gas chromatography analysis of fecal pellets provides researchers and managers a tool for determining sage-grouse winter diets. This method also allows researchers a simple way to determine diets at population scale or even regional levels.

The results of this study suggest that black sagebrush is an important winter forage for the two sage-grouse populations studied. All of the flocks from which samples were collected were selected at random by locating all radio-collared grouse in the study areas. Thus for WBE, even though the results showed that pellets collected in Wyoming sagebrush communities contained 100% Wyoming sagebrush, only one sage-grouse flock (5% of the total flocks) were located in a Wyoming sagebrush community. The results for PM differed slightly because more flocks were located in Wyoming sagebrush communities (3of 10flocks). This may be explained by the landscape patterns on PM. On PM the plant community is more homogenous than WBE. On PM there are vast homogeneous expanses of black sagebrush or Wyoming sagebrush. If grouse were located in black sagebrush communities there was little Wyoming sagebrush readily available to them. Conversely the same is true for sage-grouse flocks located in Wyoming sagebrush communities on PM.

These results suggest that black sagebrush is important to wintering sage grouse in these populations. This is supports the findings of Dalke (1963), who suggested that sage-grouse were using black sagebrush communities in Idaho. No current research has shown sage-grouse consuming black sagebrush as a winter food source. Previous research suggested the importance of Wyoming sagebrush and mountain big sagebrush as important food sources for wintering sage-grouse (Remington and Braun1985, Welch et al. 1991).

I was not able to determine why sage-grouse were consuming black sagebrush more frequently. It could be argued that grouse were consuming black sagebrush because it may have higher protein levels (Remington and Braun 1985). However, Welch et al. (1989) suggested that nutritional differences did not explain preferences in their study. Rosentreter (2005) reported that palatability of sagebrush is interplay of nutrition and secondary compounds. Thus it is likely that black sagebrush provided a balance between nutritive value and avoidance of defensive compounds (i.e. terpenoids).

MANAGEMENT IMPLICATIONS

Given the relatively small number of research papers dealing with winter sage-grouse diets, it is important to identify the species or subspecies of sagebrush that are important to wintering sage-grouse range wide. As sage-grouse habitats experience more demands from energy development, recreation and urban development this information may prove essential for proper sage-grouse conservation planning. By identifying important winter food sources sage-grouse managers could prioritize sagebrush habitats critical to wintering sage-grouse populations which must be protected. Gas chromatography is a tool that will enable managers and researchers the ability to easily identify winter food sources of different sage-grouse populations.

The results from this study suggest that managers need to prioritize management actions that will maintain large contiguous blocks of black sagebrush that are critical for wintering sage-grouse in West Box Elder and Parker Mountain populations. One of the important findings of this research is that black sagebrush constitutes and important winter forage for wintering sage-grouse in these populations. However, perhaps the most important finding of this research is that gas chromatography offers managers a cost effective, less evasive technique for determining what species of sage-brush is important to wintering sage-grouse in their respective populations.

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Table 2-1 Greater sage-grouse (*Centrocercus* urophasianus) diet consumption by sagebrush (*Artemisia* spp.) community type in West Box Elder and Parker Mountain, Utah, 2007-2998. ARNO = black sagebrush (*Artemisia nova*), ATRTW = Wyoming sagebrush (*A. tridentata wyomingensis*), MIX = mixed sagebrush

	Diet Composition					
	West Box Elder			Parker Mountain		
Community type	ARNO	ARTRW	MIX	ARNO	ARTRW	MIX
Black sagebrush	79%	0%	21%	100%	0%	0%
Wyoming sagebrush	0%	100%	0%	0%	100%	25%
Mixed Sagebrush	60%	0%	40%	18%	25%	55%
Flocks (n)	16	1	2	6	3	1

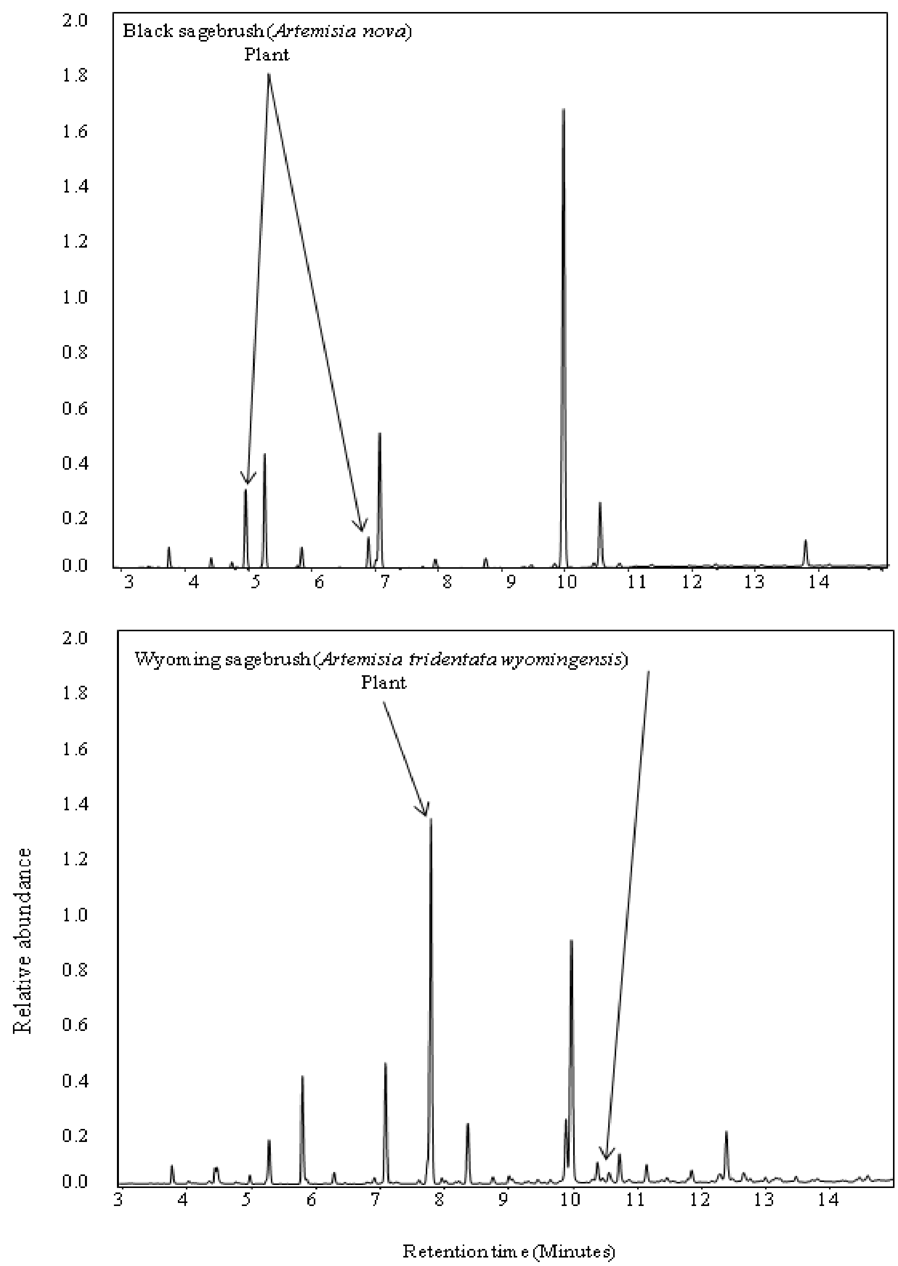

Figure 2-1 Comparison of gas chromatograms of terpene profiles from black sagebrush (*Artemisia nova*) and Wyoming sagebrush (*A. tridentata wyomingensis*) from West Box Elder County, Utah in 2008. This shows the crude terpene profile for both species of sagebrush to illustrate differences in profiles between the two species. Relative abundance is the relative abundance of each compound (chromatogram peak) and retention time (x-axis) is the amount of time it takes each compound (peak) to travel through the column.

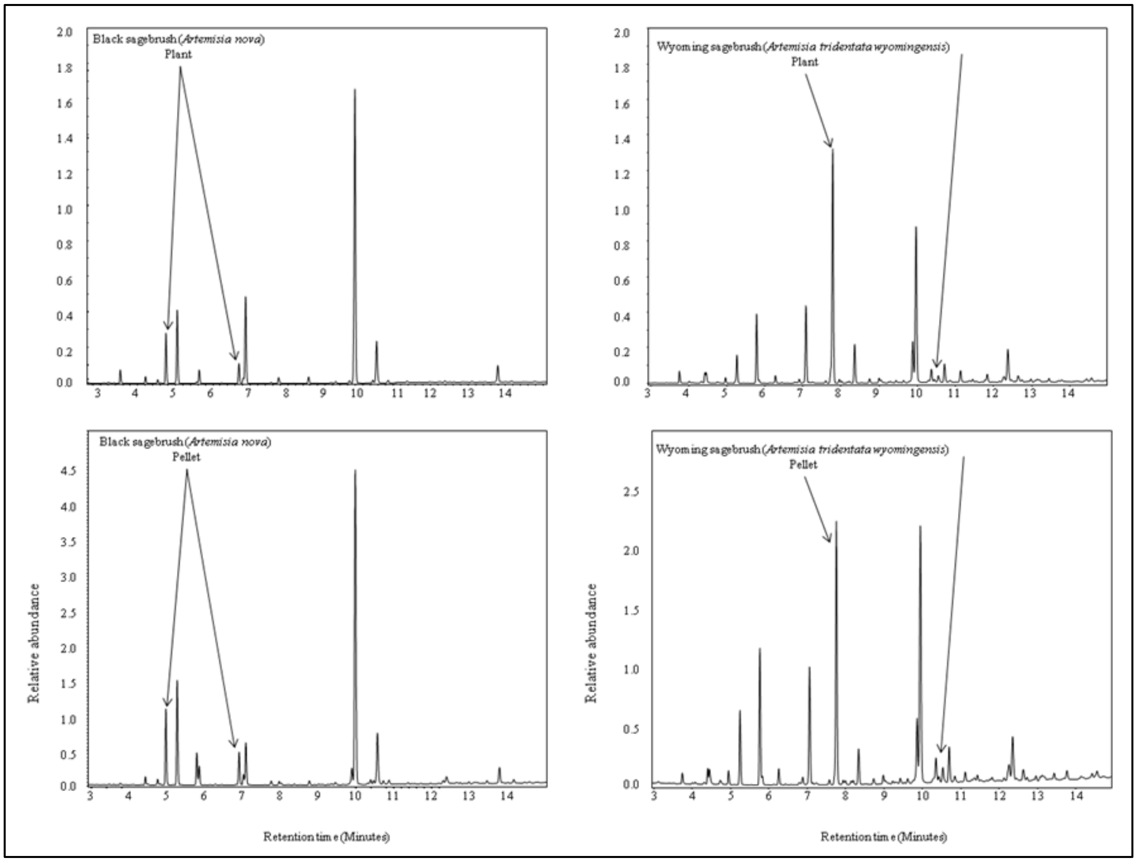

Figure 2-2 Gas chromatograms for terpene profiles from black sagebrush (*Artemisia. nova*) and Wyoming sagebrush (*A. tridentata. wyomingensis*) plants and fecal pellets collected in West Box Elder County, Utah 2008. These show the similarities between plant and pellet profiles for black sagebrush and Wyoming sagebrush. Relative abundance is the relative amount of each compound (chromatogram peak) and retention time (x-axis) is the amount of time it takes each compound to travel through the column.

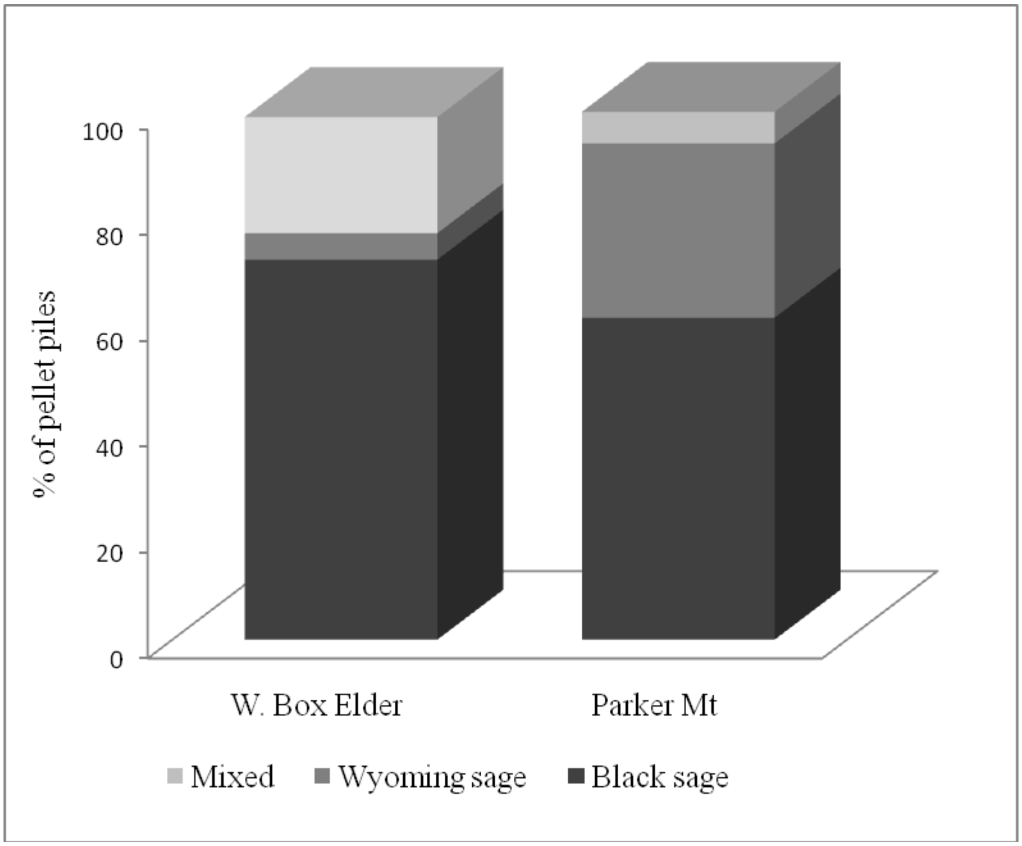

Figure 2-3 Composition of pellet piles of wintering greater sage-grouse (*Centrocercus urophasianus*) in West Box Elder County and Parker Mountain, Utah during the winter of 2007-2008. (Black sage= *Artemisia nova*, Wyoming sage = *A, tridentata wyomingensis*).

CHAPTER 3

COMPARABILITY OFDAUBENMIRE AND LINE-POINT INTERCEPT METHODS FOR GREATER SAGE-GROUSE HABITAT PARAMETERS

ABSTRACT Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) population declines have increased public interest in the role of cost-share or challenge grant programs to improve sage-grouse habitat. In response to this interest, the Natural Resource Conservation Service (NRCS) has implemented several cost-share programs designed to help private landowners improve sage-grouse habitat on their lands. Project planners subsequently monitor vegetation response to the practices implemented to determine if sage-grouse habitat quality has improved as a result of a management action. Wildlife biologists typically use the Daubenmire canopy cover method to estimate herbaceous canopy cover for sage-grouse. Concomitantly, NRCS range conservationists use the line-point intercept method for estimating herbaceous vegetation cover to determine vegetation responses. If the methods used by wildlife and range managers to measure vegetation responses are not comparable, determining management outcomes may be difficult to assess. To evaluate the techniques I measured herbaceous cover using both techniques on the same transect at grouse-use sites during the summer of 2008 in Grouse Creek Valley, Utah. Daubenmire canopy cover and line-point intercept did not yield similar results. Additionally as herbaceous canopy cover increased, the differences between the estimates increased. Line-point intercept consistently yielded higher estimates of herbaceous cover than Daubenmire canopy cover. Thus, NRCS staff should consider adopting the Daubenmire method and

wildlife biologists adopt the line-point intercept method when evaluating vegetation responses of projects implemented for sage-grouse. This would allow both groups of to share comparable data collected on these projects.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations have been declining over the last five decades (Schroeder et al. 1999). Habitat loss and degradation have been cited as major factors in observed population declines (Connelly and Braun 1997, Connelly et al. 2000). An important component of sage-grouse management is the evaluation of herbaceous vegetation response to projects implemented to improve habitat quality (Connelly et al. 2003). Connelly et al. (2003) recommended using standardized methods to assess sage-grouse habitat quality. This would allow valid comparisons among years, areas and populations (Connelly et al. 2003).

Sagebrush (*Artemisia* spp.) communities provide escape cover and forage for sage-grouse, so assessing vegetation parameters related to escape cover and forage are critical for assessing sage-grouse habitat (Connelly et al. 2003). Common metrics recorded to describe sage-grouse habitat include cover, density, height, frequency and visual obstruction (Connelly et al. 2003). Canopy cover of shrubs and herbaceous vegetation are important because they are used as an indicator of habitat quality (Connelly et al. 2003). Additionally canopy cover of forbs species can be used to estimate the abundance of foods important to sage-grouse (Connelly et al. 2003, Gregg 2006).

Connelly et al. (2003) described three methods for assessing herbaceous cover (line transect, point-intercept, and quadrat). They suggested that all three methods were adequate with the point-intercept and quadrat methods being the most efficient. They also noted that the Daubenmire canopy cover method was used more frequently by biologist studying sage-grouse to assess habitat conditions.

The Natural Resources Conservation Service (NRCS) has established sage-grouse habitat management as a conservation priority. Subsequently, the NRCS will provide cost-share to landowners through the Wildlife Habitat Improvement Program (WHIP) and the Environmental Quality Incentive Program (EQIP) for landowners who chose to implement conservation practices that benefit sage-grouse. The NRCS currently uses the line-point intercept method to measure vegetation condition and response to management (Herrick et al. 2005). Herrick et al. (2005) recommended that the line-point cover method can be used to determine soil cover, vegetation cover, rock cover, litter cover and cover of biotic crusts.

It is important to emphasize that both the line-point intercept and Daubenmire methods are commonly used to estimate the same vegetation parameters (percent canopy cover) of a given community (Connelly et al. 2003). However, because of the increased emphasis of NRCS to cost-share programs to benefit sage-grouse, it is important to determine if the two methods employed by the NRCS and wildlife biologists yield comparable results.

Floyd and Anderson (1987) compared the line intercept, point-intercept, and the Daubenmire canopy cover estimates. They concluded that the point-intercept was more time efficient and yielded more precise estimates. However, they used point-intercept frames rather than a line-point intercept transects similar to the ones employed by the NRCS (Floyd and Anderson 1987, Herrick et al. 2005). Dethier et al. (1993) also evaluated the point-intercept method and visual plot cover estimates. They suggested that in their simulation visual estimates within subdivided plots showed less variation between observers and yielded closer cover estimates of the true cover (Dethier et al. 1993). However in their study they did not use the cover categories such as those recommended by Connelly et al. (2003) for evaluating sage-grouse habitat quality, additionally because their experiment was a laboratory simulation with frames that were 4 x 5 cm and it is impossible to determine how closely this simulation represented field conditions.

In summary, most wildlife biologists working with sage-grouse estimate vegetation cover using the Daubenmire canopy cover method. Most NRCS range conservationists use the line-point intercept method to determine vegetation cover. Even though both of these methods were mentioned in Connelly et al. (2003) as adequate measures of sage-grouse habitat they may not be comparable. Currently there are no published studies comparing these two methods (line-point intercept and Daubenmire) as they are used by sage-grouse biologists and NRCS personnel to evaluate sage-grouse habitat. The purpose of this study was to compare cover estimates obtained in a field experiment using Daubenmire canopy cover and line-point intercept methods.

STUDY AREA

The study was conducted in the Grouse Creek Valley in west Box Elder County, Utah. Grouse Creek Valley is located between the Goose Creek and Grouse Creek Mountains. The primary land use in the study area is grazing by domestic livestock. The vegetation in the study area consists mainly of sagebrush-steppe communities intermixed with grassy meadows, and woodlands. Common shrubs included basin big sagebrush (*A. tridentata. tridentata*), mountain big sagebrush (*A. t. vaseyana*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), rabbitbrush (*Chrysothamnus* spp.), serviceberry (*Amelanchier utahensis*), snowberry (*Symphoricarpos albus*), and bitterbrush (*Purshia tridentata*). Common trees included stands of junipers (*Juniperus osteosperma*), quaking aspen (*Populus tremuloides*), and chokecherry (*Prunus virginiana*). Perennial grasses included bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca* idahoensis), basin wildrye (*Leymus cinereus*), and bluegrass species (*Poa* spp.). Common forbs in the study area included phlox (*Phlox* spp.), astragalus (*Astragalus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus* spp.*)*, western yarrow (*Achillea millefolium*), wild onion (*Allium acuminatum*), false dandelion (*Agoseris* spp.) and hawksbeard (*Crepis* spp.).

The climate of the study area was characterized by warm summers with an average daily temperature of 27° C while the winters were cool with an average daily temperature of -3°C. The area receives 50% of its precipitation as rain during the growing season (April – September). Most of this precipitation occurs in May and June (3.7 and 3.3 cm, respectively). The study area averaged between 33 and 56 cm of precipitation at the lower and higher elevations, respectively (Loerch et al. 1985).

METHODS

I used the line-point intercept and Daubenmire methods in 2008 to measure herbaceous vegetation at sage-grouse brood locations (Connelly et al. 2003, Herrick et al. 2005). The techniques were used concurrently on vegetation transects established as part of ongoing research on sage-grouse habitat use. Study sites were identified by locating sage-grouse hens with broods every 3 to 5 days. Each time a hen was located GPS coordinates were recorded so the site could be revisited within 5 days and to estimate habitat parameters. Vegetation data were recorded on four 10 m transects that bisect each other at the brood center for a total of 40 m of transect at each location (Knerr 2007, Dahlgren 2006).

Daubenmire canopy cover was estimated using a 20 x 50 cm Daubenmire (1959) frames. The frame was placed at 2.5, 5.0, 7.5, and 10 m marks along each of 4 transects for a total of 16 frames per brood location (Knerr 2007, Dahlgren 2006. I used 5 cover categories, each species or functional group received a number ranging from 1 to 6, 1 = 0-1% cover, 2 = 1.1-5% cover, 3 = 5.1% - 25% cover, 4 = 25-50% cover, 5 = 50-75% cover and 6 = 75-100% cover (Daubenmire 1959, Connelly et al. 2003). I deviated from the recommendations of Connelly et al.(2003) in that I placed a Daubenmire frame every 2.5 m instead of every 1 m, but the methodologies used are consistent with studies other sage-grouse studies (Knerr 2007, Dahlgren 2006)

I subsequently used the point-intercept technique (Herrick et al. 2005) to measure vegetation along the same transects used to record the Daubenmire estimates. I recorded 50 points per transect for a total of 200 points per site. Line-point intercept data was recorded by dropping a pin (3 mm x 120 cm that had been sharpened to < 1 mm) every 20 cm along the 10 m (1000 cm) transect. The observer would hold the pin perpendicular to the tape on the top side (where the numbers meet the tape edge) and drop the pin. The observer would identify what species or functional group (perennial grass, forb, or annual grass) the pin struck as it was dropped. The observer counted hits on herbaceous species, rock, litter and bare ground (hits on shrubs were ignored). The tapes used for the transect lines were kept taut by using logging pins inserted through both ends and forced into the ground (Herrick et al. 2005). Herbaceous cover using both methods was separated by species and functional categories. To avoid misclassification of individual species I combined all species into respective functional groups; the functional groups included perennial grass, forbs, and annual grasses.

Daubenmire cover estimates were calculated by averaging cover for functional group across all frames for all transects at each location. Midpoints for cover categories were used to average percent cover for functional groups. Midpoint values are as follows: 1 = 1%, 2 = 3%, 3 = 15%, 4 = 38%, 5= 63%, and 6 = 88%. Line-point intercept data were summarized by totaling all hits along all 4 transects for each functional group and dividing the sum by the total number of points (200), yielding the percent cover for each functional group.

Mean differences and confidence intervals were calculated for each functional group. This was done by taking an absolute difference between line-point intercept and Daubenmire cover estimates at each brood location. Means and 95% CI were then calculated for the differences for each functional group across all brood locations.

Scatter plots for each functional group were created to view data characteristics. Scatter plots were created by plotting point-intercept cover estimates (y axis) against Daubenmire cover estimates (x axis) for each functional group. Each scatter plot was fitted with a one to one line, with an “x” and “y” intercept of “0”. This line represented where values should be distributed if the mean differences were equal “0”, meaning the methods yield the same cover estimates. The mean differences and CI were then used to test for differences between the two methods. If the confidence intervals overlapped "0" for any functional group then the two methods were similar, but if the CI do not overlap "0" then the results of the two methods are statistically different.

Additionally, I evaluated what impact increasing cover estimates may have on mean differences for each functional group. To do this I separated the cover data for each functional group into 4 equal quartiles using point-intercept cover estimates (I arbitrarily chose line-point intercept cover). Then the mean differences were calculated for each of the 4 quartiles. The results were then graphed to show the general trend of mean differences as cover estimates increased.

RESULTS

The results for perennial grass and forb cover were skewed above the expected value line suggesting that point-intercept estimates yielded higher cover values (Figure 3-1). Annual grasses were not skewed; however, there appears to be more variability between the estimates as cover values increases (Figure 3-1). The scatter plot results also suggest that differences between the two methods may increase as cover increases (Figure 3-1).

When I compared the means of functional groups by method the results suggested that line-point intercept yielded higher cover estimates (Figure 3-2). This difference was more pronounced with perennial grasses. The results of the mean differences and 95% CI suggested that the cover estimates were not comparable (Figure 3-3). As cover increased the mean differences by methods also increased (Figure 3-4).

DISCUSSION

The evaluation demonstrated that the two methods do not yield comparable estimates of herbaceous cover (Figure 3-3). Additionally, the variation in cover estimates increased as vegetation cover increased in all functional groups. My results indicate that line-point intercept cover estimates were consistently higher than Daubenmire estimates (Figure 3-2). I do not know what the true cover values were therefore I cannot speculate as to the accuracy or precision of these methods when compared to each other.

Because the methods were not comparable biologists and range conservationist need to find a compromise to mitigate the differences between these two methods. One way to reduce such controversies is to standardize methods for measuring response of sage-grouse habitat management actions. However this may become problematic since it would require agencies to change methods their institutions have become familiar with. The United States Department of Agriculture, Agricultural Research Service, Jornada Experimental Range (JER) in Las Cruces, NM has developed quantitative monitoring protocols in an attempt to standardize range monitoring and assessment (Herrick et al. 2005). Additionally, sage-grouse biologists have created a fairly unified system of gathering biological data for sage-grouse (Connelly et al. 2003). It could be recommended that both groups adapt to a unified system. However the JER has already created a monitoring protocol that has been adapted by NRCS and BLM (JER 2009). It could be suggested that sage-grouse biologists simply use the line-point intercept method rather than the Daubenmire method. However, this may not be a feasible option as sage-grouse biologists have collected vast amounts of valuable data over the last decade using the Daubenmire method. If sage-grouse biologists adopted the line-point intercept method it would render comparisons of future results to past results meaningless. Each respective group has much invested in their own respective methods so it is not likely for either group to begin employing a new method. Rather than forcing one group or the other to conform to a unified method both groups could collect both line-point intercept and Daubenmire canopy cover data for NRCS projects dealing with sage-grouse. This would double the amount of time required to collect vegetation data and increase cost of data collection. In our research we estimate it would add approximately 10 minutes to each vegetation site (E. Thacker unpublished data Utah State University). However, it would allow agencies to have comparable data. Some have suggested that the methods employed by the NRCS are not adequate to assess sage-grouse habitats. However Connelly et al. (2003) suggested the point intercept (line-point intercept) method is adequate to asses herbaceous and shrub cover.

Research should be implemented to assess the relative accuracy and precision of these two methods prior to calling for one group or the other to conform to the others method. This is needed in order to determine which method has the greatest reliability, repeatability and accuracy. With those results the NRCS and sage-grouse biologists could make an informed decision about reaching a consensus.

MANAGEMENT IMPLICATIONS

Line-point intercept method consistently yielded higher estimates of herbaceous cover than Daubenmire method. My study confirmed that herbaceous cover estimates obtained using the line-point intercept and Daubenmire canopy cover methods are not comparable metrics. Thus, NRCS staff and wildlife biologists should consider using both methods when evaluating vegetation response of cost-share projects. This would ensure that data collected by biologists and NRCS staff is comparable when evaluating sage-grouse projects.

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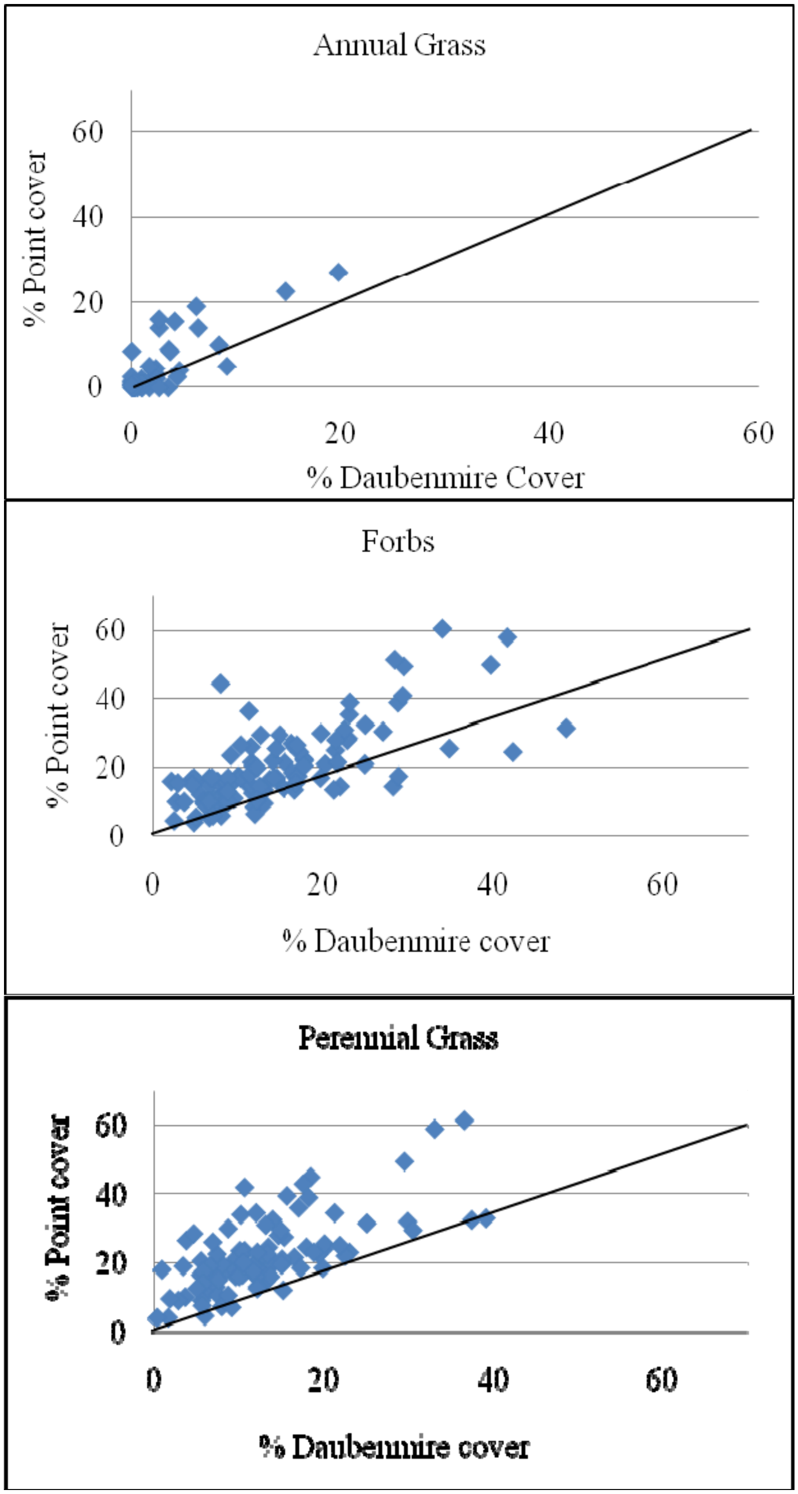

Figure 3-1. Scatter plots for each functional group (perennial grasses, annual grasses and forbs). Plots were created by plotting line-point intercept (point cover) and Daubenmire (Daubenmire cover) cover estimates. The one to one line represents where the points should fall (predicted) if the two methods were similar. Data was collected in Grouse Creek, Utah in 2008.

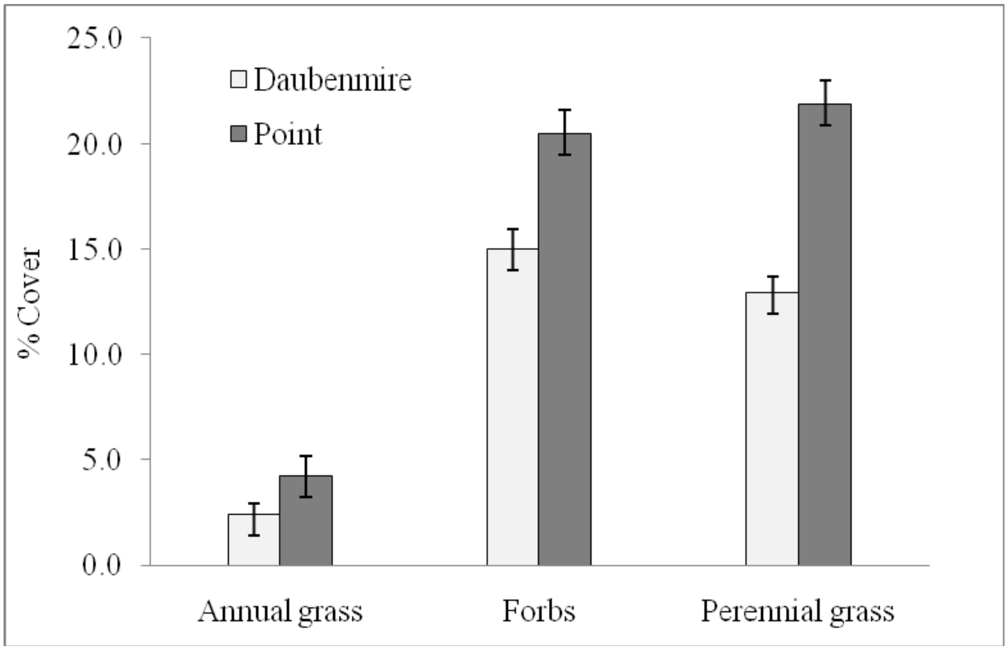

Figure 3-2 Daubenmire and line-point intercept cover estimates for functional groups with error bars for data collected in Grouse Creek, Utah, 2008.

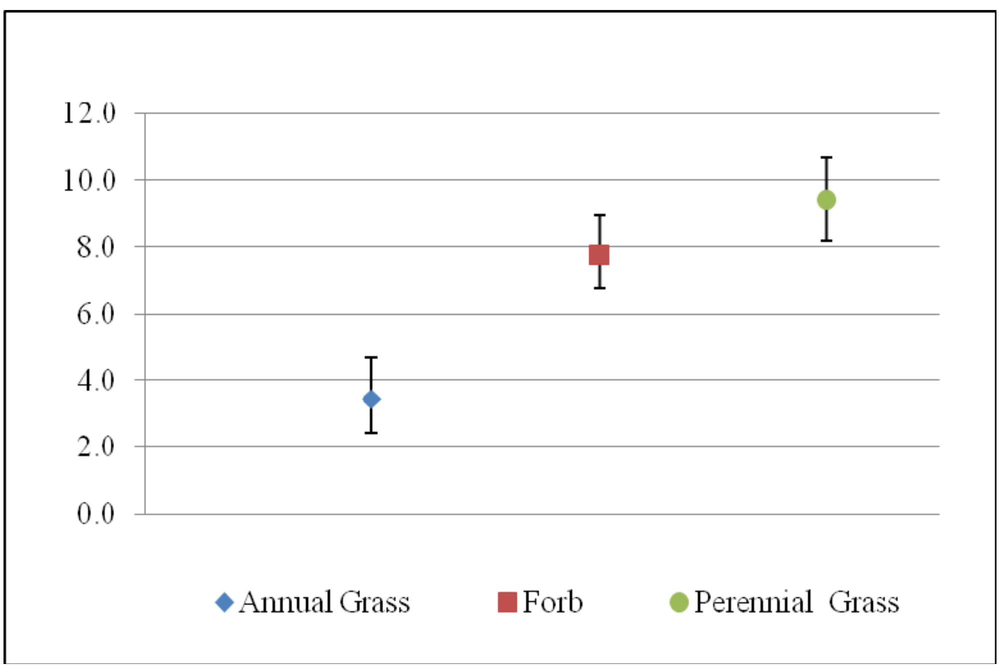

Figure 3-3. Mean differences between Daubenmire canopy cover and line-point intercept cover estimates for each functional group. Error bars represent 95% confidence intervals (CI). If CI's overlap 0 the methods would be considered to reliably yield the same response 95% of the time. Data were collected in Grouse Creek, Utah, 2008

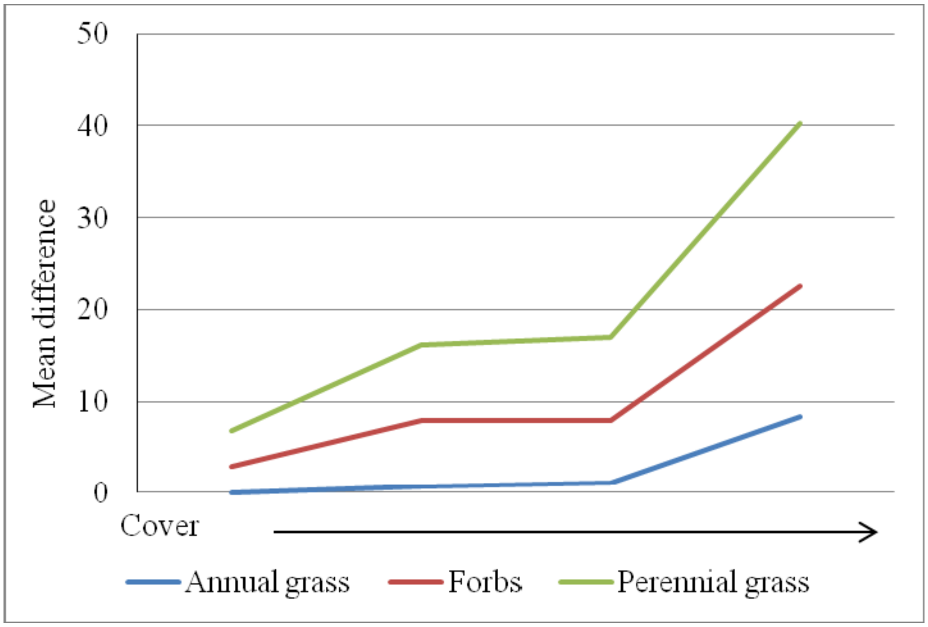

Figure 3-4. This graph compares mean differences between line-point intercept and Daubenmire cover estimates as cover increases. Data were collected in summer 2008 in Grouse Creek, Utah.

CHAPTER 4

GREATER SAGE-GROUSE BROOD RESPONSE TO PRECRIBED FIRE IN HIGH ELEVATION SAGEBRUSH COMMUNITIES IN NORTHEASTERN, UTAH

ABSTRACT The role of fire as a tool to manage greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) habitats has been a topic of much debate. Previous research has suggested that prescribed fire may not be appropriate to manage sage-grouse wintering, breeding, and nesting habitats. However, there is little consensus regarding the role of prescribed fire in managing brooding habitats. The objective of this research was to evaluate sage-grouse brood-use of small-scale prescribed burns in high elevation (>2500 m) mountain big sagebrush (*Artemisia tridentata* vaseyana) communities. The burns evaluated were < 20 years old, and ranged in size from 2 ha to 176 ha. I compared brood locations of radio-collared hens from 2003-2009 to randomly generated locations using ArcMap, to determine if brood hens were selecting burned areas more frequently than random locations. I also compared vegetation data recorded from brood locations inside and outside of prescribed burns to determine if the sites differed and these differences could explain habitat-use patterns. Broods used prescribed burns more than expected ($p < 0.00001$). Grass cover was greater ($p = 0.0154$) and sagebrush cover was lower ($p = 0.0001$) at prescribed burn locations. Forb cover was similar ($p = 0.421$) at brood sites within and outside of prescribed burns. Sage-grouse broods did appear to be selecting prescribed burned areas more than would be expected, however the effect of prescribed burns on sage-grouse production remains unknown.

INTRODUCTION

The role of fire in managing sagebrush (*Artemisia* spp.) habitats for greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse) has received increased scrutiny as populations have declined range wide. Wildfires have been cited as a contributing factor in observed population declines, especially in more arid areas of the species range (Connelly et al. 2004). Wildfires can eliminate sagebrush habitats and can damage native vegetation; this can lead to an increase in invasive annual grasses, which degrade sage-grouse habitat (Connelly and Braun 1997, Connelly et al. 2000a, Connelly et al. 2000b). The expansion of invasive species such as cheatgrass (*Bromus tectorum*) has increased the frequency and intensity of wildfires in sagebrush steppe ecosystems (Baker 2006). These cumulative effects have exacerbated sage-grouse habitat degradation and losses.

Crawford et al. (2004) suggested that the impact of fire in sagebrush steppe systems has been over generalized because the effects are spatially and temporally complex. The factors that may make it difficult to evaluate and or predict the response of sagebrush steppe systems to fire include: plant species present, fuel loads, ecological condition prior to burning, ambient weather conditions, fire temperature, fire speed, and season of burn (Miller and Eddleman 2000). These factors confound potential comparisons of the effects of the fire even when comparing similar sagebrush communities (Byrne 2002, Knick et al. 2005).

Knick et al. (2005) summarized the effects of fire on sage-grouse and their habitats. Of the 5 studies they reviewed in mountain big sagebrush (*A. tridentata* *vaseyana*) communities they determined only 2 reported a positive relationship between fire and sage-grouse habitat (Martin 1990, Pyle and Crawford 1996). Furthermore Knick et al. (2005) continued by suggesting that 3 studies reported a neutral relationship, or were inconclusive (Pyle and Crawford 1996, Nelle et al. 2000). Even though the effects of fire on the mountain big sagebrush communities is inconclusive, biologists agree that the use of prescribed fire in breeding habitats has negatively impacted sage-grouse (Connelly et al. 2000a). Connelly et al. (2000b) reported an 80% decline in a breeding population and a decrease in the numbers of active leks in southern Idaho. Hulet (1983) also reported an increase in lek abandonment following fire. However, it is important to note that both of these studies were conducted in habitats dominated by Wyoming big sagebrush (*A. t. wyomingensis)*. Byrne (2002) and Nelle et al. (2000) both reported that fire had a negative impact on nesting activities regardless of sagebrush community type. The differences reported by these studies regarding the effects of fire on sage-grouse brooding habitat may be related to site specific conditions and sage-grouse habitat-use patterns.

Early brooding habitat is closely associated with the nest sites, while late brooding typically occurs after the brood has moved away from the nest (Connelly et al. 2000a). Often late brooding occurs at higher elevations in mountain big sagebrush habitats (Connelly et al. 2000a). Nelle et al. (2000) and Byrne (2002) both suggested that fire had negative impacts on nesting sage-grouse and concluded using fire in early brooding habitat may negatively affect nesting habitat.

However, fire may have different effects on late brooding habitats. Klebenow (1969), Dunn and Braun (1986) and Drut et al. (1994) have suggested that broods tend to use areas with more open stands of sagebrush with an abundant herbaceous understory. Some have suggested that prescribed fire may create this type of habitat (Pyle and Crawford 1996, Connelly et al. 2000a). In light of the distinctions outlined by Connelly et al. (2000a) the use of prescribed fire to manage late brooding habitat needs further investigation. The purpose of this study was to evaluate sage-grouse and vegetation response to prescribed fire in late brood rearing habitats

STUDY AREA

This study was conducted on Anthro Mountain located on the Ashley National Forest, near Duchesne, Utah. The study area is managed by the U. S. Forest Service (USFS) and is located approximately 29 km southeast of Duchesne, Utah. The area is a high elevation (2500 - 2900 m) mountain big sagebrush community with pockets of quaking aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii) occurring* on north facing exposures. Two needle pinyon-pine (*Pinus edulis)* occur at the lower elevations. Black sagebrush (*A. nova*) is fairly limited but can be found on some ridge tops scattered across the mountain. The current and historical land use is grazing by domestic livestock. Water is not well distributed across the mountain so grazing intensity is not uniform

In the 1950's approximately 80% of the arable land in the study area was disked and seeded to smooth brome (*Bromus inermis*, Christensen 2006). Smooth brome has become the dominant herbaceous species but native forbs have returned (A. Huber, USFS, personal communication). The areas that have not been seeded to smooth brome are dominated by blue bunch wheatgrass (*Pseudoroegneria spicata*). There is an array of native forbs including vetches (*Astragalus* spp.) and penstemon (*Penstemon* spp.) across the mountain in both native and smooth brome sites. Common shrub species present include snowberry (*Symphoricarpos occidentalis*), rabbitbrush (*Chrysothamnus* spp.) and wild rose (*Rosa woodsii*).

The precipitation in the study area averages 49 cm annually, with most of the precipitation occurring as snow in the winter and monsoonal rains in July and August. The mean annual daily maximum temperature is 13°C and a mean annual daily minimum temperature of 1.7°C (Utah Climate Center 2008).

Prescribed burns have been implemented on Anthro Mountain over the last 2 decades. The study area was defined by the project area used by the USFS to plan and implement prescribed burns in mountain big sagebrush communities. The prescribed burn history for the purpose of this study began in 1991 and continued through 2008. The prescribed burn sites were chosen in mountain big sagebrush communities with sagebrush canopy cover > 20% with shrub heights > 61 cm. Sites were on level ground where slope did not exceed 15%. The burns were conducted in the fall to achieve low intensity fire that would create a mosaic burn pattern.

The Anthro Mountain study area contains 4424 ha of mountain big sagebrush. Approximately 18% (1267 ha) was altered by prescribed burning between 1991- 2009 (Table 4-1). The actual sagebrush area burned was 783 ha when non-sagebrush habitat was excluded. The acreage of the individual burns ranged from 2-176 ha, the average burn is 25 ha.

METHODS

I used brood locations from 25 radio-collared hens to conduct this study. Sage-grouse hens have been captured, radio-collared, and monitored since 2003. Hens were located with spotlights and captured with long-handled dip nets. The hens were weighed, and fitted with a 19g ATS Systems™ necklace radio-collar (ATS, PO Box 398470 First Ave. N. Isanti, MN 55040). Radio-collared hens were re-located using a Communications Specialists™ receiver (426 West Taft Ave. Orange, CA) and a 3 element yagi antenna. From 2003-2007, sage-grouse broods were located a minimum of once a week following nest hatch. In 2008-2009 broods were located every 3 days.

I compared sage-grouse brood locations from 2003-2009 using ArcMap to determine if brooding sage-grouse hens were selecting burned areas more frequently than would be expected. To do this I created shape files of brooding locations from location files obtained from the USFS. Late brooding locations were defined as individual brood locations older than 14 days post hatch (Dahlgren 2006).

Shapefiles were created for each burn by the USFS personnel. Burns shapfiles were created by digitizing the burned area from maps. Burns were sorted by year of burn and a shapefile was created for all burns initiated in a given year. Prescribed burns were conducted in 1991, 1992, 1996, 1999, 2006, 2007, and 2008 (Table 4-1). All burn shapefiles were buffered by 30 m. Dahlgren et al. (2006) suggested that grouse were frequently found within 30 m of an edge (vegetation change), the buffer was applied to include any grouse that may have moved out of the burn while being approached by researchers.

The Southwest Regional Gap Map (30 m resolution) was clipped by the study area and reclassified. All mountain big sagebrush habitat was classified as a "1 "and all other vegetation classes were classified as "0" (non habitat mostly aspen). This raster layer also represented the brooding habitat available to sage-grouse in the study area. The brood locations were overlaid onto the study area habitat and burn polygons to identify the proportion of broods and brood locations located within the burn polygons. Additionally random points were generated (equal number to actual locations) and distributed using "Hawth's tools" in ArcMap (Beyer 2004). These were distributed throughout the study area polygon but were restricted from falling into non-habitat. The proportion of brood locations within the burn polygons were compared the proportion of random locations that fell within burn polygons. I used a Z-test test to for significance differences; using an alpha level of (0.05). I also tested all brood locations against late brooding locations to see if more grouse were using burns during the late brooding season. I was not able to analyze brood use by individual years because of limited sample sizes; and because the amount of burned area differed each year, as well as the number of brood locations making by year comparisons invalid.

I used vegetation data collected at brood sites to determine if there were differences between burned and unburned brood sites. In 2006 and 2007 one 100 m transect was located where the radio collared brood hens had been observed. Line-point intercept cover data were collected for grass, forbs, sagebrush and shrubs (Bonham 1989). There were 200 points along each transect. In 2008 and 2009 methods similar to those described by Connelly et al. (2003) were employed at brood locations. However in 2008 point cover data were collected along 4 10 m transects utilizing 200 total points, while the Daubenmire technique was used in 2009 (Connelly et al. 2003). Even though these methods vary they provide the only data available to compare vegetation responses between burned and unburned sites. I also realize that sage-grouse locations are not randomly located across the landscape; however the use of the brood vegetation data is the only data I had available to me to evaluate vegetation differences inside and outside burn polygons.

RESULTS

To conduct the analysis I used 297 brood locations representing 25 broods, of the 297 locations 197 were late brooding locations. Of the 25 broods studied, 68% (17) used a prescribed burn at least 1 time during the brooding season. Broods that were found using burns had 40% of their locations occurred within the burn polygons. There were no differences between total brood locations and late brooding use of burns ($p = 0.2628$) so hereafter I report the results based on total brood locations. Incidentally only 10% of the brood locations occurred within the 30m buffer.

Of the 297 total brood locations, 33% were within the burn polygons. Randomly selected points occurred within burn polygons 16% of the time. Broods were located in burn polygons more frequently than random locations ($p < 0.0001$), suggesting sage-grouse broods were found using prescribed burns more frequently than would be expected. It is important to note that 18% of the total area was treated by prescribed fire (Figure 4-2) and 16% of the random points fell within burns. This suggests that the random locations occurred within the burned areas relatively proportionate to their availability.

All burns were not used proportionally (Table 4-3). From 2003-2007 most of the brood use occurred in the 1996 burn polygons (Table 4-3). However in 2008 sage-grouse broods used only 2007 burn polygons. In 2009 when burned habitats were most abundant, brooding grouse used the 2007 burns most frequently (19.4%) while using the

2008 burns (8.97%). Of the 58 brood locations that were located in prescribed burn polygons in 2009, 70% of these locations were in burns less than 2 years old.

Brood sites in burn polygons exhibited less ($p = 0.0001$) sagebrush canopy cover (Figure 4-1). Forb cover was not different between burned and unburned brood locations ($p = 0.4201$, Figure 4-1). However grass cover was higher at brood locations in the burn polygons ($p = 0.0154$, Figure 4-1).

DISCUSSION

My results suggest that sage-grouse occurred in prescribed burn polygons more frequently than would be expected (based on a random distribution). Sage-grouse broods used burns < 10 yrs old. This contradicts Byrne's (2002) results; he suggested that sage-grouse broods did not use burns < 20 yrs old. In this study all burns were < 20yrs old, with higher use occurring in burns < 10 yrs old.

Pyle and Crawford (1996) and Martin (1990) suggested that important forb species did increase following prescribed burning of mountain big sagebrush communities especially in the first few years. My brood site vegetation did not show a similar increase of forbs within burned areas. The results for forb cover were similar to Nelle et al. (2000), Wambolt et al. (2001), and Byrne (2002). They all suggested that there was no tangible increase in forbs following fire. However grass cover did increase in the study (Figure 4-1). While it has been shown that grass provides escape cover for sage-grouse broods it is not considered an important forage component for sage-grouse broods (Connelly et al. 2000a). However it could be suggested that increases in abundance of herbaceous plants in the sagebrush community may increase insect abundance, thus increasing insects available for sage-grouse (Haddad et al. 2001)

The problem with using brood vegetation data to assess vegetation differences between treatments is that brood locations are not random samples. Sage-grouse select areas of higher forb cover (Klebenow 1969, Dunn and Braun 1986, Apa 1998), therefore one could suggest that sage-grouse outside of the burned areas were selecting areas with similar forb cover when compared to brood sites within the burns. This could confound the results by obscuring any differences that may be occurring between burned and unburned sites. It is likely that there was an increase in either insects or forbs within the plots that would explain broods leaving the safety of sagebrush cover to forage in burned areas.

My results present a unique perspective on the use of small scale prescribed fire to manage sage-grouse habitat. Most studies published on the effects of prescribed burns on sage-grouse have involved large fires (Fischer et al. 1996, Fischer et al. 1997, Nelle et al. 2000, Byrne 2002). The average size of the burns in the Byrne (2002) study was 268 ha, burns in Nelle et al. (2000) averaged 390 ha and the burn evaluated by Fischer et al. (1996) and Fisher et al. (1997) was 3306 ha. The average size of burns studied on Anthro Mountain was 25 ha. This may help explain why sage-grouse were using burns more than was expected. Connelly et al. (2000a) suggested that any sagebrush reduction treatment is better if it uses small patches distributed across the landscape, rather than large blocks. Previous studies dealing with prescribed fire have dealt with relatively large burned areas (Fischer et al. 1996, Fischer et al. 1997, Nelle et al. 2000 and Byrne 2002).

Further research is needed to evaluate productivity of sage-grouse and survival of sage-grouse chicks within burn treatments. Knick et al. (2005) suggested there is no evidence suggesting that fire actually increased sage-grouse productivity. Even though this study has shown grouse using prescribed burns there is no evidence to suggest that these burns have increased sage-grouse productivity or hurt sage-grouse productivity. Aside from fire there is little evidence that any of the management actions meant to improve sage-grouse habitat actually improve sage-grouse productivity. Ultimately I was not able to identify the relationship between management actions and sage-grouse populations. Studies of sufficient scale are needed to evaluate effects of prescribed fire on brood productivity. These experiments may be difficult to realize, but should be the objective of future sage-grouse research.

MANAGEMENT IMPLICATIONS

Even though my research suggested that broods selected for areas treated by prescribed burns there are important factors that must be acknowledged before managers use fire in sage-grouse habitat. Prescribed fire has very limited application in areas that are known to be wintering or breeding (leking and nesting) habitats. Fire should only be used in brooding habitats in high elevation mountain big sagebrush communities where the risk of annual grass invasion is non-existent. Additionally, caution needs to be exercised because nesting and early brooding habitats often overlap, so use of fire in early brooding habitats needs to be used very judiciously as it may negatively impact nesting habitat. Burns on Anthro Mountain were relatively small (25 ha) and were conducted at cool ambient temperatures creating slow creeping fires that created a mosaic; this likely contributed to the success of these treatments. Further, the results of this study suggest that fire may be appropriate for Anthro Mountain; however, it does not demonstrate that fire should be used in all brooding habitats. The results do suggest that brooding sage-grouse will use small patchy burns. To further justify the use of fire researchers need empirical data to suggest that these types of treatments actually have tangible benefits to sage-grouse populations.

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Table 4-1 Burn history from 1991 - 2008 on Anthro Mountain, Utah. These numbers reflect the actual size of the burns and include non-sagebrush (*Artemisia* spp.) habitat.

Year	Hectares burned	# of Burns	Average burn size
1991	8	1	8
1992	121	1	121
1996	323	2	161.5
1998	91	6	15.1
1999	9	2	4.5
2006	205	8	26.6
2007	257	19	13.5
2008	254	11	23.1
total	**1267**	**50**	**25.3**

Table 4-2 Area of burns and proportion of study area treated by prescribed fire on Anthro Mountain, Utah. These values are calculated from a 30 m resolution raster and excluded non-sagebrush (*Artemisia* spp.) habitat.

Year	ha	% burned
1991	2	< .1
1992	21	0.5
1996	185	4
1998	58	1
1999	8	0.2
2006	33	0.8
2007	225	5
2008	205	5
total	**737**	**17**

Table 4-3. Percent of greater sage-grouse (*Centrocercus urophasianus*) broods using prescribed burns on Anthro Mountain, Utah 2003-2009

			Year of Prescribed Burns							
		n	1991	1992	1996	1998	1999	2006	2007	2008
Year of Broods	2003	18	0	0.00	0.00	0.00	0.00	.	.	.
	2004	5	0	0.00	100.00	0.00	0.00	.	.	.
	2005	18	0	0.00	4.00	0.00	0.00	.	.	.
	2006	54	0	1.85	14.81	0.00	0.00	.	.	.
	2007	64	0	11.63	30.23	0.00	0.00	0.00	.	.
	2008	34	0	0.00	0.00	0.00	0.00	0.00	16.22	.
	2009	128	0	0.69	3.45	5.52	0.00	2.07	19.31	8.97

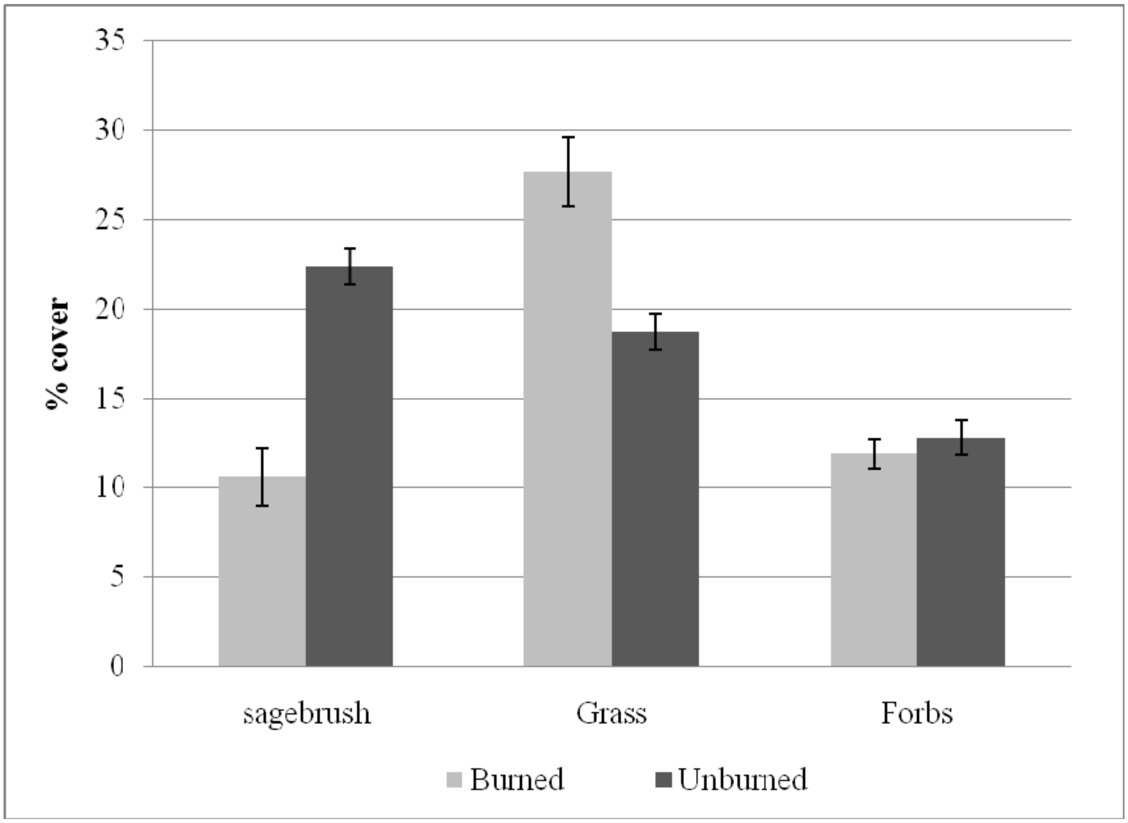

Figure 4-1 Results comparing vegetation cover at greater sage-grouse (*Centrocercus urophasianus*) brood locations in burned and unburned polygons on Anthro Mountain, Utah, 2003-2009

CHAPTER 5

TEMPORAL HABITAT-USE BY GREATER SAGE-GROUSE BROODS IN NORTHWESTERN UTAH

ABSTRACT Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) ecology and habitat requirements have been extensively studied. Previous research has documented that sagebrush (*Artemisia* spp.) communities provide important seasonal habitats to sage-grouse broods. Low juvenile recruitment, a characteristic of declining populations, may be symptomatic of poor brood habitat conditions. Because sage-grouse broods may use different sites within brooding habitats for daily activities such as feeding (morning and evening), loafing (midday) and roosting (nocturnal hours), more information is needed regarding the influence of vegetation structure and composition on temporal brood habitat use. The objective of this study was to determine if the sites sage-grouse broods used in a 24 hour period differed in vegetation structure or forage abundance. To conduct this study, I monitored the daily locations of 14 radio-collared hens with broods in 2007 and 2008 in Grouse Creek Valley, Utah. Brood-use sites were randomly assigned based on 4 time periods: AM (sunrise - 0900 hrs), NOON (01200-1600 hrs), PM (1800 - sunset), and ROOST (2100 - 0300 hrs). I measured herbaceous cover, shrub cover, herbaceous height, shrub height, and insect abundance at 134 brood-use sites. The habitat characteristics measured were similar at all diurnal brood-use sites; however nocturnal sites (ROOST) were characterized by shorter statured shrub and more bare ground when compared to NOON locations. In Grouse Creek, sage-grouse broods selected sites that were relatively similar in structure and forage abundance. In this area, brood habitat management should focus on maintaining large tracts of habitat that

provide abundant forage with adequate sagebrush cover rather than creating open patches of forage with little or no shrub cover.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse) populations have declined across much of their range over the last 50 years (Schroeder et al. 1999). Declining populations exhibit low juvenile recruitment. It is believed that this is due in part to deteriorating habitat conditions (Crawford and Lutz 1985, Connelly and Braun 1997). Sage-grouse are considered sagebrush (*Artemisia* spp.) obligate species because they inhabit areas dominated by shrub species and are thus dependent upon it for their survival (Klebenow 1969, Wallestad 1971, Connelly et al. 1988).

Sagebrush vegetation diversity is an important factor in recruitment of juvenile sage-grouse (Klebenow and Gray 1968, Klebenow 1969). Sage-grouse chicks require foods rich in protein during the first few weeks of life (Klebenow and Gray 1968, Peterson 1970, Drut et al. 1994). Previous studies also have documented that insects constitute an important source of protein (Klebenow and Gray 1968, Peterson 1970, Drut et al. 1994, Gregg 2006). Habitats that exhibit greater vegetation diversity and abundance of forbs typically support greater insect abundance (Haddad et al. 2001).

Connelly et al. (2000) summarized data from several studies across several studies on greater sage-grouse to identify vegetation characteristics that are important to brooding sage-grouse. They recommended that 10-20% sagebrush canopy cover provides adequate escape cover for sage-grouse broods. Additionally, they recommended that forb and grass cover should be > 15% to provide sage-grouse broods with adequate escape cover and provide valuable forage for chicks. Others have reported that wet meadows, irrigated agricultural fields, and small burned areas are important habitats for sage-grouse broods (Savage 1969, Oakleaf 1971, Connelly and Markham 1983, Connelly et al. 1988, Pyle and Crawford 1996).

Little published information is available regarding daily temporal use of brooding habitats. It has been suggested that sage-grouse broods feed in morning and evening hours and loaf or roost in the afternoon hours (Savage 1969, Dunn and Braun 1986). These observations suggest that sage-grouse broods may be using different sites corresponding with different activities (Savage 1969, Dunn and Braun 1986). For example, sage-grouse broods may use wet meadows in the morning and evening hours presumably to feed (Savage 1969, Oakleaf 1971) and dense, tall stands of sagebrush during the middle of the day to seek shade and protection while resting (Savage1969, Dunn and Braun 1986).

Dahlgren (2008) reported that sage-grouse in south central Utah commonly used black sage (*A. nova*) ridge tops at night while roosting. Hausleitner (2003) reported that sage-grouse broods in her study were roosting at sites that had shorter sagebrush and less sagebrush cover. These examples suggest that sage-grouse may use sites exhibiting differences in vegetation structure and composition.

Dunn and Braun (1986) attempted to quantify the relationship between daily temporal use and selected vegetation parameters. They reported that broods used open canopy sagebrush stands in the morning (<4 hours after sunrise) and evening (< 4 hours prior to sunset) hours while feeding. They also suggested that these sites were selected because they offered greater forb abundance. Later in the day (>4 hours after sunrise and > 4 hours before sunset) grouse roosted (loafed) in sites that exhibited greater canopy cover and herbaceous cover. However, their research did not include sage-grouse nocturnal roosting periods (between sunset and sunrise). Another limitation of their study is they had a small sample size of broods (2 broods). Hausleitner (2003) did not attempt to look at site variations during diurnal hours but she did describe nocturnal brood site characteristics.

Connelly et al. (2000) reported that brood hens select moderate levels of sagebrush canopy cover (10-20%) with an abundant understory of herbaceous species (> 15%). This balancing optimizes shrub cover for escape cover while providing forage for chicks. The balancing of forage demands and the need of escape cover could be described graphically (Figure 5-1). Sagebrush abundance increases along the x-axis and forage abundance increases along the y-axis. A line representing escape cover would be positively correlated with sagebrush cover, while a line representing forage abundance is negatively related to sagebrush cover (Figure 5-1). The intersection of these two lines represent the theoretical balance of escape cover and forage abundance, this represents the habitat parameters suggested by Connelly et al. (2000). However, some of the research previously mentioned herein suggests that grouse broods may be using sites that do not lie at the intersection of these lines. For example Savage (1969) and Oakleaf (1971) suggest that wet meadows are important foraging areas for sage-grouse broods. This is an area that has an abundance of forage with little sagebrush for escape cover (Figure 5-2). Currently many of the habitat treatments are focused on creating patches with high forage abundance at the expense of sagebrush cover. It has also been suggested that broods may use brood sites of varying amounts of sagebrush for different activities (Dunn and Braun 1986).

The purpose of this study was to determine if habitat characteristics differed at sage-grouse use sites as defined by temporal daily activities. Based on previous work regarding sage-grouse grouse use patterns (Dunn and Braun 1986, Hausleitner 2003), I hypothesized that vegetation structure, composition, and insect abundance would differ at sage-grouse brood use sites based on daily active patterns (Figure 5-3). During feeding periods (mornings and evening) broods would tend to use areas with less sagebrush canopy cover and greater forb cover and insect abundance (i.e., forage availability). Concomitantly when broods were loafing during midday they would select sites exhibiting taller shrubs, greater shrub cover. Additionally nocturnal roost sites would have less shrub and herbaceous cover and shorter shrubs (Figure 5-3).

STUDY AREA

The study was conducted in the Grouse Creek Valley, west Box Elder County, Utah. The Grouse Creek Valley is located between the Goose Creek and Grouse Creek Mountains. The primary land use in the study area is grazing by domestic livestock. The vegetation in the study area consists mainly of sagebrush-steppe communities intermixed with riparian meadows, and woodlands. Common shrubs included basin big sagebrush (*A. tridentata. tridentata*), mountain big sagebrush (*A. t.* vaseyana), black sagebrush, low sagebrush (*A.* arbuscula), rabbitbrush (*Chrysothamnus* spp.), serviceberry (*Amelanchier utahensis*), snowberry (*Symphoricarpos albus*), and bitterbrush (*Purshia tridentata*). Common trees included stands of juniper (*Juniperus osteosperma*), quaking aspen (*Populus tremuloides*), and chokecherry (*Prunus virginiana*). Perennial grasses included bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca* idahoensis), basin wildrye (*Leymus cinereus*) and bluegrass species (*Poa* spp.).

Cheatgrass (*Bromus tectorum*) also occurs in limited quantities (< 5%) in the study area. Common forbs in the study area included phlox (*Phlox* spp.), astragalus (*Astragalus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus* spp.), western yarrow (*Achillea millefolium*), wild onion (*Allium acuminatum*), false dandelion (*Agoseris* spp.) and hawksbeard (*Crepis* spp.).

The climate of the study area was characterized by warm summers with an average daily temperature of 27° C while the winters were cool with an average daily temperature of -3°C. The area receives 50% of its precipitation as rain during the growing season (April – September). Most of this precipitation occurs in May and June (3.7 and 3.3 cm, respectively). The study area averaged between 33 and 56 cm of precipitation. January and December are the highest snowfall months with 27 and 17 cm respectively (Loerch et al. 1985).

The predator community of the study area contained several raptors and some mammalian predators. Common avian predators that were observed included: red-tailed hawks (*Buteo jamaicensis*), golden eagles (*Aquila chrysaetos*), Swainson's hawk (*Buteo seainsoni*), northern harriers (*Circus cyaneus*) and prairie falcons (*Falco mexicanus*). Mammalian predators observed in the study area included badgers (*Taxidea taxus*), coyotes (*Canis latrans*), and long-tailed weasels (Mustela frenata). No foxes (*Vulpes* spp.) were observed in the study area during the study period. In July 2006 a single striped skunk (*Mephitis mephitis*) was documented within brooding habitat in the study area.

METHODS

Sage-grouse hens were captured and radio-collared in the spring and summer 2007 and spring 2008. I captured and radio-collared 25 in 2007 and 42 hens 2008. Hens were radio-collared at leks and during the summer in brooding habitats. Hens were located with spotlights and captured with long-handled dip nets. The hens were weighed, aged and fitted with a 19g. Holohil Systems™ necklace radio-collars (Holohil Systems Ltd., 112 John Cavanaugh Drive, Carp, Ontario, Canada K0A 1L0). These hens were located using a Communications Specialists™ receiver (426 West Taft Ave. Orange, CA, 92865-4296) and a 3 element yagi antenna to locate hens to determine nest and brood success and seasonal movements. Hens that successfully hatched their nests were then relocated every 3-5 days. To locate broods a general location was first established by triangulation. Then the observer would slowly circle the hen until an observer had a visual location of the hen. I used the brood hen location as the brood center for grouse-use sites.

To study daily temporal use of brooding habitats I re-located hens with broods at four different time periods (Dunn and Braun 1986). The time periods included: 2100-0300 (midnight or ROOST), sunrise - 0900 (morning feeding or AM), 1200 - 1600 (afternoon or NOON), and 1800 - sunset (evening feeding or PM). Broods were assigned to time periods by randomly assigning each brood a time period for the first location and then sequentially rotating each brood sequentially through the time periods. Each time the hen was located GPS coordinates were recorded at the brood center and vegetation measures were taken within 5 days.

Sagebrush communities were classified using the dominant shrub at brood-use sites. I classified habitat into 4 categories; big sagebrush (all big sagebrush species), low sagebrush, riparian (creek bottoms, wet meadows, springs etc.), and disturbed (burned, treated etc.). Habitat measurements included herbaceous cover, shrub cover, herbaceous height, shrub height and insect abundance. Vegetation measurements were taken on four 10 m transects that bisected each other at the brood center (Connelly et al. 2003). Herbaceous cover was measured using a 20 cm x 50 cm Daubenmire frame, which was placed at 2.5 m, 5 m, 7.5 m, and 10 m along each transect for a total of 16 frames per brood location. The percent herbaceous cover was estimated using 5 categories for each species. Each species received a number ranging from 1-6 (1 = 0-1%, 2 = 1.1-5%, 3 = 5.1% - 25%, 4 = 25-50%, 5 = 50-75% and 6 = 75-100%) (Connelly et al. 2003). Vegetation heights were recorded for each species by measuring the maximum droop height within each Daubenmire frame (Connelly et al. 2003). Shrub cover was estimated using the line intercept method and was calculated according to shrub species gaps < 5 cm were included and gaps > 5 cm were considered breaks in the canopy (Canefield 1941). Shrub height was measured by measuring the maximum height (cm) of each shrub intersecting the transect.

At each brood location insect abundance was estimated using pitfall traps (Morrill 1975). The traps were placed at the end of each of the four transects and one pitfall trap was placed at the intersection of the transects for a total of 5 traps per grouse-use site (Knerr 2007, Dahlgren 2008). The pitfalls traps were 473 ml metal cans that were buried flush with the ground; 30 ml of propylene glycol was added to each trap to act as a killing agent (Knerr 2007, Dahlgren 2008). The traps were left in the ground for 48 hours, the samples were retrieved, separated from the kill solution and frozen in plastic bags until they could be cleaned and sorted (Southwood and Henderson 2000, Connelly et al. 2003). Insects were sorted into 5 orders: Hymenoptera, Orthoptera, Coleoptera, Lepidoptera, and other. Gregg (2006) identified these orders of insects as being important to sage-grouse chicks. Insect volume was calculated by volume displacement for each of the chosen insect categories at each site (Knerr 2007, Dahlgren 2008).

Data were analyzed utilizing a complete randomized design in PROC MIXED (α = .05) in SAS (SAS 2003). I used time periods as the fixed factor. Years (2007 and 2008) were combined due to a small a sample size in 2007 (3 broods). My brood sample size (n = 14) precluded us from being able to block by brood. I analyzed vegetation variables as both structure and forage (i.e., forb composition and insect abundance).

Structure was defined as those variables that described vegetation attributes as they relate to escape or hiding cover. Structure measurements included total shrub cover (TSC), perennial grass cover (PGC), total forb cover (TFC), bare ground (BGC), total shrub height (TSH), and total herbaceous height (THH). Forage was defined as those habitat characteristics that provided food for sage-grouse chicks. Forage included total insect volume (GIV) and cover of forbs important to grouse (GFC). GFC was defined as the total canopy cover of forbs present at grouse-use sites (Table 5-1) that are important to sage-grouse chicks (Klebenow and Gray 1968, Gregg 2006). The GIV category was defined by insect orders Hymenoptera, Orthoptera, Coleoptera, and Lepidoptera (Gregg 2006).

RESULTS

Sage-grouse nests in the study hatched between May 22 to July 4 in 2008, and May 15 to May 30 2007. Three and 12 broods hatched in 2007 and 2008, respectively. Average brood size was 5 and 6 chicks per brood for 2007 and 2008, respectively. Of the 15 broods, 12 were successful. A successful brood was defined as a brood containing at least 1 chick at 42 days (Dahlgren 2008). I used locations from 13 broods (1 was excluded because it only had 1 location) for a total of 134 brood locations. The brood locations were distributed evenly among time periods; 36 AM locations, 36 NOON locations, 29 PM locations, and 33 ROOST locations. Of the 8 variables (TSC, TSH, PGC, GFC, TFC, THH, BGC and GIV) analyzed only BGC and TSH differed by time period (Table 5-2). Upon further analysis, I determined that ROOST exhibited more BGC than NOON sites ($p = 0.0200$) but ROOST sites did not differ from AM or PM sites ($p = 0.9996$ and $p = 0.1853$, respectively). Both AM and PM sites did not differ from NOON ($p = 0.7931$ and $p = 0.8895$, respectively, Table 5-3). TSH was less at ROOST sites when compared to NOON and AM sites ($p = 0.0059$ and $p = 0.0310$, respectively, Table 5-3). TSH did not differ between ROOST and PM sites ($p = 0.8390$) but PM TSH did not differ from NOON or AM sites ($p = 0.0819$ and $p = 0.2603$, respectively). While vegetation structural characteristics differed for TSH and BGC by time periods, I did not detect any differences in forage variables (Table 5-2). GFC and GIV were similar across all time categories (Table 5-3.)

DISCUSSION

My results did not support the hypothesis that vegetation structure and forage abundance differed among temporal grouse-use sites. The only differences I recorded were in vegetation structure at the ROOST sites (BGC and TSH) when compared to NOON sites. However, I did not detect any differences among the other structural and forage variables.

The sage-grouse broods I studied selected areas exhibiting lower TSH and more BGC for ROOST sites within brooding habitat. These results are similar to Hausleitner (2003). Others have also reported that sage-grouse broods prefered areas exhibiting increased forage in close proximity to escape cover (Dunn and Braun 1986, Drut et al. 1994, Connelly et al. 2000). However, ROOST sites in my study suggested that hens were selecting areas with lower TSH and more BGC. Although these results may seem contradictory to the previous statement, this observation could be explained as an attempt by brood hens to select open areas to reduce potential risks associated with different types of predators during nocturnal hours.

Most avian predators in the study area do not hunt at night, so overhead cover may be less important to broods while roosting at night. Mammalian predators commonly hunt at night, thus by choosing areas with shorter TSH and more BGC sage-grouse hens may be able to more easily detect mammalian predators and evade them. Hausleitner (2003) suggested a similar explanation for sage-grouse selecting areas with less shrub structure in her study. Similar results have been reported with ruffed grouse (*Bonasa umbellus*) and prairie chickens (*Tympanuchus cupido*) (Jones 1963, Gullion and Martinson 1984). Jones (1963) suggested that prairie chickens selected roost sites in small areas with little cover within a larger area of taller dense cover. This approximates what I observed with nocturnal roosts in the study area.

The lack of differences in forage abundance in diurnal grouse-use sites suggests that hens may be selecting sites throughout the day that provide forage for their chicks. This does not support the findings of Dunn and Braun (1986) or Savage (1969). They suggested that in the AM and PM grouse were selecting feeding sites that were generally more open (less sagebrush) with an abundance of forbs and using areas with denser sagebrush cover during midday. It could be explained by variation among grouse populations, or differences in sample sizes. Dunn and Braun's (1986) sample included only 2 broods and non brooding females and males. This may have lead to discrepancies when comparing the results.

When considering management of brooding habitat it is important to recognize that sage-grouse hens are theoretically selecting habitats that balance escape cover with forage requirements for their broods (Figure 5-1). Thus, wet meadows, irrigated agricultural fields, and other such areas may constitute important habitat for sage-grouse broods if the benefit of the increased forage outweighs the accrued risk associated with foraging in areas with less escape cover (Figure 5-2). The commonality between all of these areas is that they have abundant forage (insects and forbs) with little sagebrush or shrub cover. Therefore these areas may have an abundance of forage, but there may be risks associated with them in terms of broods being exposed to higher predation rates.

Dunn and Braun (1986) and Dahlgren et al. (2006) suggested that sage-grouse will only use the edges of these areas and remain within 30 m to 150 m of the edge. These observations suggest that sage-grouse may be an edge species. However, Gullion and Martinson (1984) explained that ruffed grouse (*Bonasa umbellus*) have typically been considered an edge species (a species benefiting from edges), but he suggests that edges are death traps for ruffed grouse. He contended that edges constrict the distribution of grouse into narrow corridors that make it easier for predators to search the available habitat for prey (Gullion and Martinson 1984). He further suggested that ruffed grouse use edges only when overall habitat has deteriorated and the only adequate balance of cover and forage lie at the juncture of habitat edges. Additionally if adequate habitats exist (that provides cover and forage) then ruffed grouse cease to use edges and distribute themselves across the landscape (Gullion and Martinson 1984). This may have direct application for sage-grouse. If sage-grouse are using edges to find adequate forage it may concentrate them into narrow corridors and thus increase depredation of sage-grouse. Thus if adequate forage is available across the landscape with adequate escape cover grouse would not be restricted to narrow corridors related to edges potentially increasing juvenile survival.

High quality forage patches (wet meadows, sagebrush treatments, and agricultural fields) may concentrate sage-grouse in to narrow corridors and increase risk of depredation (Figure 5-2). If adequate habitats are available with structure and forage then broods may not use areas such as wet meadows and agricultural fields. The lack of forage in the uplands may explain why sage-grouse are willing to leave the safety of the sagebrush habitats to venture into areas where escape cover is limited and forage is abundant (Drut et al. 1994, Savage 1969, Connelly et al. 2000, Figure 5-2). Gullion and Martinson argued that if quality habitat exists at landscape scales then it will increases juvenile survival. There is currently no data to suggest that this may be happening with sage-grouse; however, research needs to be initiated to determine what effect use of these habitats may have on sage-grouse juvenile survival. Accordingly it may be more advantageous for managers to manage the landscape to provide adequate forage while maintaining adequate escape cover rather than develop high quality forage patches (Gullion and Martinson 1984, Figure 5-1).

Additionally by focusing on creating suitable habitat on a landscape scale may have greater impacts on sage-grouse production than the current approach of creating small forage patches. This approach has been attempted with other game birds with limited success. Williams et al. (2004) referred to it as token management for bobwhite quail. They suggested activities centered in producing high quality islands of habitat in a landscape of degraded habitat would not compensate for a lack of quality habitat across the landscape. Similarly small patches of high quality foraging habitat for sage-grouse broods will not compensate for an overall lack of large contiguous blocks of quality habitat on the landscape (Aldridge et al. 2008).

Some have suggested that the sage-grouse management guidelines are unrealistic for some sagebrush communities (Bates et al. 2004). However, if managers shift the paradigm from one of compliance (achieving numerical habitat values) to more functional approach of providing a balance of structure (sagebrush cover) and forage for sage-grouse broods. This allows for management to be tailored to specific sites by identifying the balance of escape cover and forage abundance.

MANAGEMENT IMPLICATIONS

The sage-grouse broods I studied selected nocturnal roost sites that have shorter shrub cover and more bare ground than midday use sites. Additionally, sage-grouse broods I studied also selected diurnal sites that were similar in structural characteristics and forage abundance. Based on these results, I recommend that brood habitats in the study area should be managed to maximize sage-grouse access to large contiguous blocks of habitat that exhibit a balance of structure and forage availability (Figure 5-1). Managers should strive to increase herbaceous understory while maintaining adequate sagebrush cover. My results suggest that although sage-grouse broods may select for forage rich patches (wet meadows, alfalfa fields etc.) within the landscape, maintaining a sagebrush canopy in Grouse Creek may be more crucial in sustaining the species locally. Additional research is needed to evaluate the relationship between edge habitats (meadows burns, treatment edges etc.) and sage-grouse chick survival.

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Table 5-1. List of forbs found in Grouse Creek, Utah that are important to sage-grouse (*Centrocercus urophasianus*) chicks.) This list is adapted from Klebenow and Gray 1968, Martin et al. 1984, Gregg 2006).

Grouse Forbs	
Common names	*Genus species*
Alfalfa/Clovers	*Medicago spp.*
Buckwheat	*Erigeron spp.*
Common Yarrow	*Achillea millefolium*
Common dandelion	*Taraxacum officinale*
Desert-parsley	*Lomatium spp.*
Everlasting	*Antennaria spp.*
Hawks beard	*Crepis spp.*
Mountain dandelion	*Agoseris/Micoseris spp.*
Phlox	*Phlox spp.*
Vetches	*Astragalus spp.*
Yellow salsify	*Tragopogon dubius*

Table 5-2. Results from a complete randomized design testing for significance (α = .05) by time periods for sage-grouse (*Centrocercus urophasianus*) brood locations in Grouse Creek, Utah in 2007-2008.

P value Table	
Variable	Time Period
TSC	0.1310
PGC	0.5142
TFC	0.3408
BGC	**0.0266**
THH	0.3766
TSH	**0.0030**
GFC	0.5763
GIV	0.7830

Table 5-3. Means and SE for structure and forage measured at sage-grouse (*Centrocercus urophasianus*) brood locations in Grouse Creek, Utah, 2007-2008. (Greater sage-grouse broods were located during 4 time periods. Time periods were as follows: AM (sunrise - 0900 hrs), NOON (1200-1600 hrs), PM (1800 - sunset), and ROOST (2100 - 0300 hrs). TSC = total shrub cover, PGC = perennial grass cover, TFC = total forb cover, BGC = bare ground cover, TSH = total shrub height, THH = total herbaceous height, GFC = grouse forb cover, GIV = grouse insect volume).

	Structure												Forage			
	% cover								Height cm				% cover		ml of insects	
	TSC	SE	PGC	SE	TFC	SE	BGC	SE	TSH	SE	THH	SE	GFC	SE	GIV	SE
AM	26	*3.11*	14	*1.70*	15	*2.45*	45	*2.90*	39.5	*2.20*	15.5	*1.03*	5	*0.57*	5.9	*1.27*
NOON	28	*2.86*	15	*1.56*	17	*2.03*	41	*2.97*	44.1	*2.25*	16.5	*1.08*	6	*0.61*	5.8	*1.25*
PM	23	*3.21*	16	*1.28*	15	*1.92*	45	*3.38*	36.2	*2.32*	14.9	*0.89*	6	*0.70*	4.6	*1.42*
ROOST	21	*2.24*	14	*1.51*	12	*1.39*	54	*2.92*	32.2	*2.47*	14.7	*0.90*	5	*0.62*	6.6	*1.36*

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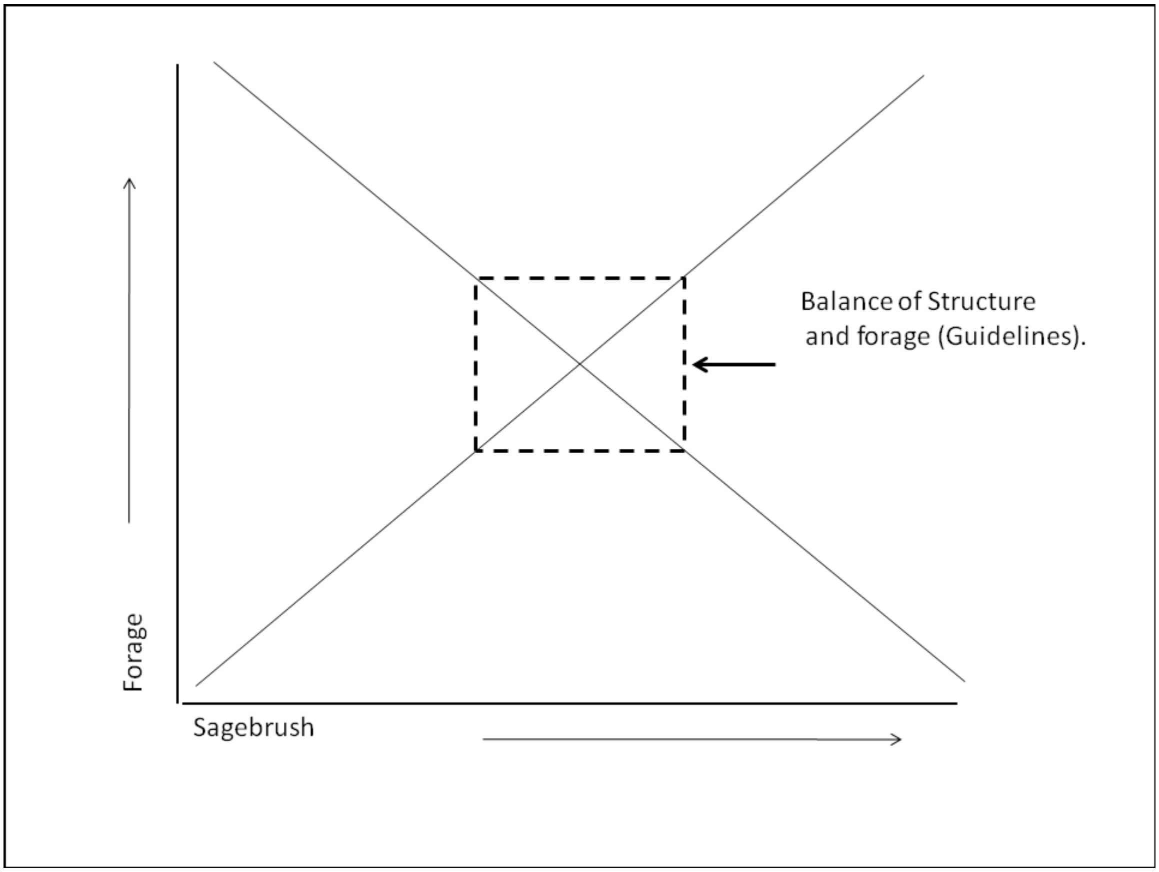

Figure 5-1 Theoretical balance of forage and escape cover for brooding sage-grouse (*Centrocercus urophasianus*). The dashed box represents the optimal balance of structure and forage (Connelly et al. 2000).

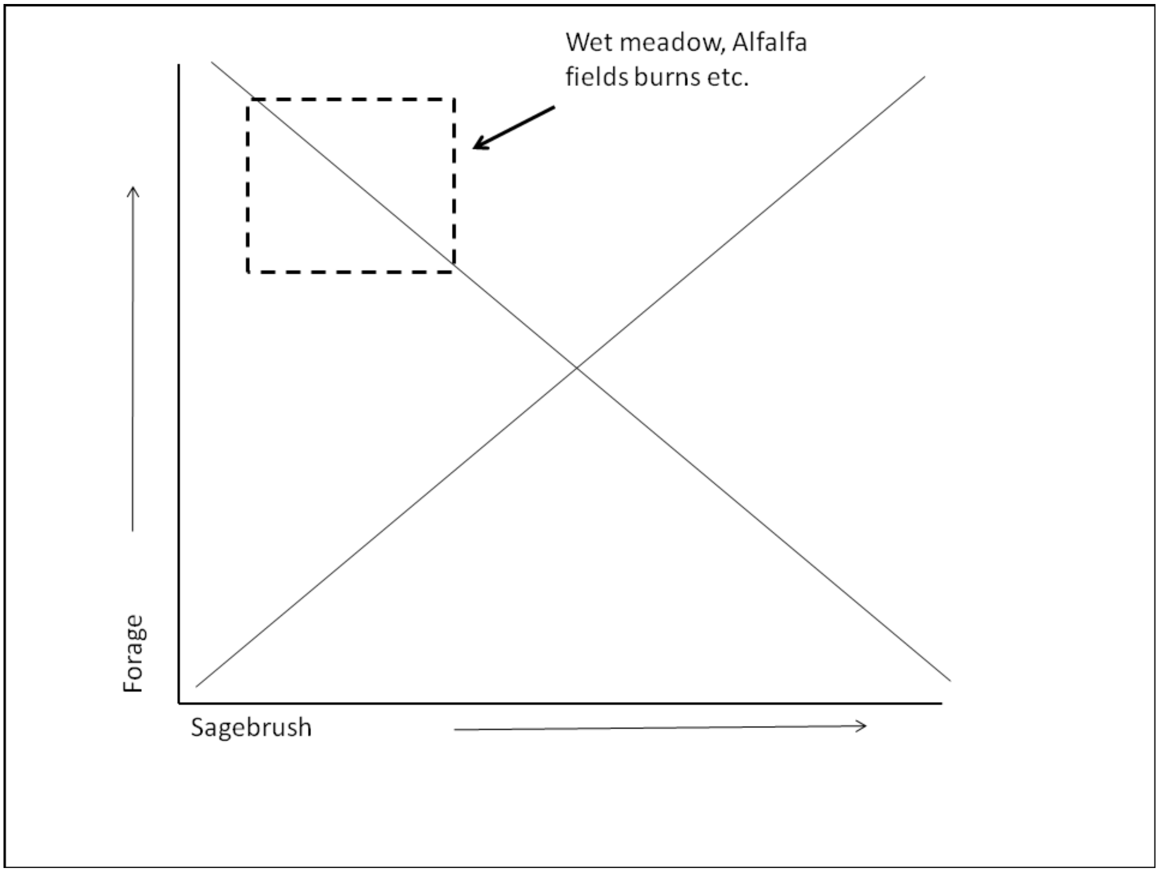

Figure 5-2. Theoretical balance of forage and escape cover for Greater sage-grouse (*Centrocercus urophasianus*) broods. Optimal brood lies at the intersect of the two lines. The dashed box represents brood use of areas with adequate forage and little structure for cover such as wet meadows, agriculture fields or burns.

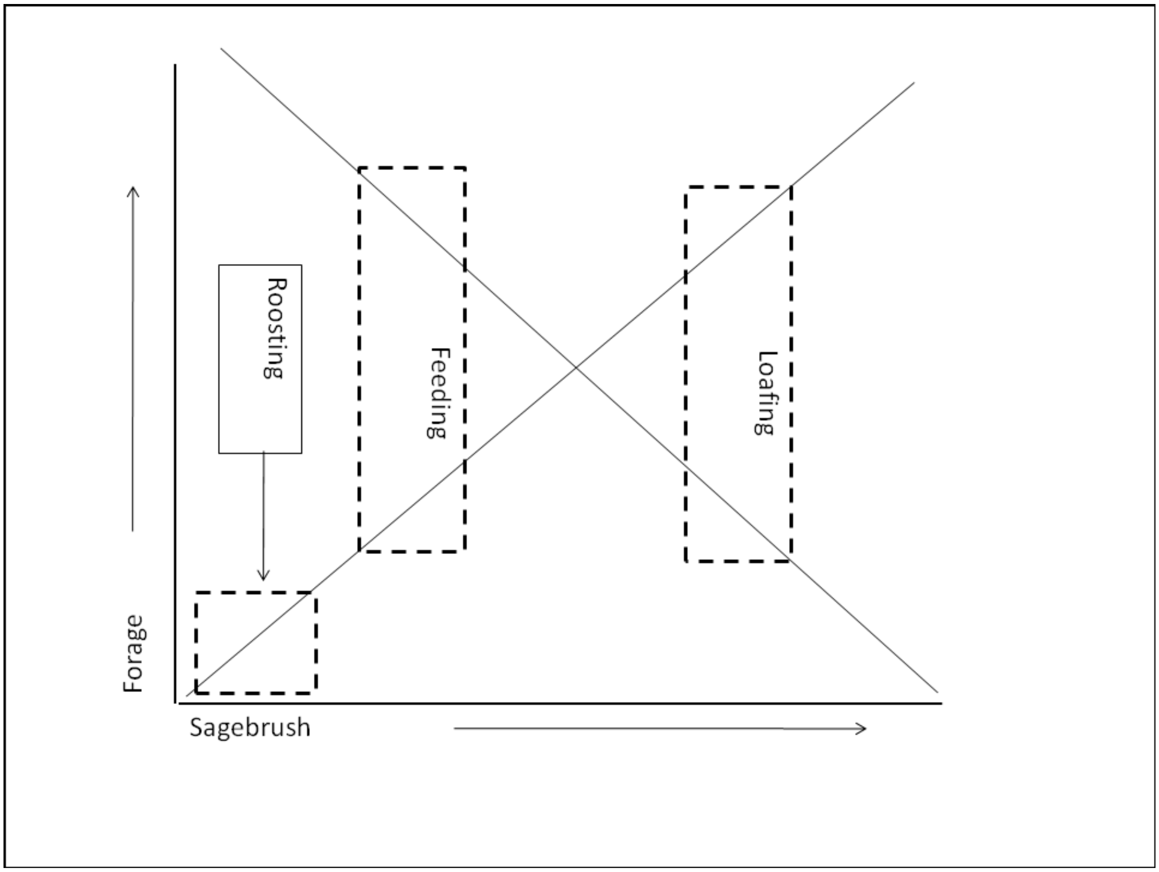

Figure 5-3. Theoretical placement of greater sage-grouse (*Centrocercus urophasianus*) broods activities. Dashed boxes represent vegetation structure and composition for daily activities. Loafing = resting during diurnal hours, feeding is early morning post sunrise and prior to sunset and roosting is after sunset, before dawn.

CHAPTER 6

CONCLUSIONS

Greater sage-grouse (*Centrocercus urophasianus*) populations have been declining for the several decades (Schroeder et al. 2004, Connelly et al. 2004). This has resulted in the U. S. Fish and Wildlife Service (USFWS) being petitioned to list the species as threatened and endangered. Although much is known about sage-grouse biology, more information is needed regarding the effects of conservation actions on sage-grouse, and the response of local populations to specific management actions (Connelly et al. 2004). The overall objective of this research was to evaluate the effects of management actions on sage-grouse habitats and use of seasonal habitats.

Winter habitat for sage-grouse has been described as large contiguous tracts of sagebrush. However, little information is available regarding the importance of individual sagebrush species in sage-grouse winter diets. (Remington and Braun 1985, Welch et al. 1989, Welch et al. 1991). Sage-grouse biologists need a less invasive and more reliable method to determine sage-grouse diets. My study attempted to determine if chemical analysis of sage-grouse fecal pellets could be used to determine sage-grouse winter diets. My results indicate that gas chromatography can be used to determine sage-grouse diets. By comparing crude terpene profiles from sagebrush plants and sage-grouse fecal pellets I could determine which sagebrush species the pellet contained. Using gas chromatography I determined that black sagebrush (*A.* nova) was consumed more frequently in both study locations (Box Elder County and Parker Mountain Utah). My results suggested that black sagebrush is important forage for wintering sage-grouse in the Utah populations studied. Sage-grouse in these areas appear to be selecting black sagebrush due to its nutritive value and lack of secondary compounds (Remington and Braun 1985, Welch et al. 1988, Welch et al. 1989).

The Natural Resource Conservation Service (NRCS) began implementing cost-share projects on private land to improve sage-grouse habitat through the Wildlife Habitat Improvement Program and the Environmental Quality Incentive Program. Monitoring vegetation and sage-grouse responses to NRCS projects designed to improve habitat quality is integral to determine project success. However NRCS staff and wildlife biologists currently use different methods to measure herbaceous canopy cover to assess habitat quality. When measuring sage-grouse habitat, wildlife biologists commonly use the Daubenmire method to estimate herbaceous canopy cover (Connelly et al. 2003). The NRCS conservationists use line-point intercept to estimate herbaceous cover (Herrick et al. 2005). These methods may not yield comparable cover estimates when evaluating sage-grouse habitat. My results confirmed that the methods are not comparable. The line-point intercept method continually yielded higher cover estimates than the Daubenmire technique. Additionally, as cover percentages increased so did the variation between these two methods. One solution to this dilemma maybe to record both line-point intercept and Daubenmire cover data for all NRCS projects designed specifically to benefit sage-grouse.

I evaluated sage-grouse use of small scale (¸25 ha) prescribed fire in high elevation (>2500 m) mountain big sagebrush (*A. t. vaseyana*) communities. Of the 25 broods monitored 68% (n = 17) used a prescribed burn sites at least once during the brooding season. Of those broods using burn polygons 40% of their locations were within burn polygons over the course of the brooding season. Thirty-three percent of the total locations (97 out of 297) were located in prescribed burn polygons. My analysis also revealed that grouse were located in burn sites more than would be expected. Sagebrush cover was lower and grass cover was higher at brood sites within the burn polygons when compared to brood sites not located in the burn polygons. There were no differences in forb cover. It is likely to assume that there was an abundance of forbs or insects that I was not able to detect that explain brood use of burns. I was not able to determine what impacts prescribe burns may have had on chick survival (productivity). My results suggest that sage-grouse broods did use prescribed burns, however it is still unknown what impact the use of these burns may have on brood survival. If fire is to be used I recommend that it is only to be used in high elevation (>2500 m) mountain big sagebrush communities. Burns must remain relatively small (< 25 ha) and must not impact more than 20% of the sagebrush in the area inhabited by the population.

Much of the research conducted on sage-grouse brooding habitats has explained the seasonal use of brooding habitats. The focus of my study was to determine how broods used brooding during the day (24-hour period), or in other words, do grouse use sites that differ in vegetation structure, composition or insect abundance during the day. My results suggested that brood hens are selecting sites that exhibited similar vegetation structure throughout the day. The day (24-hour period) was divided into 4 periods AM (sunrise – 0900) NOON (1200-1600), PM (1800-sunset) and ROOST (2100-0300). The results suggested that structure at ROOST sites was different; ROOST sites had lower shrub height and more bare ground than noon sites. The amount of forage (insects and forbs) was similar across all sites. This suggests that sage-grouse brood hens are selecting areas with an abundance of forage in an attempt to balance structure (cover) and forage demands of their broods. Therefore management in the Grouse Creek Valley should be focused on maintaining a balance of forage and hiding cover (sagebrush cover) rather than creating forage patches adjacent to escape cover.

In summary, my research suggested the following. 1. Wintering sage-grouse diets can be assessed using gas chromatography. Thus, analysis of fecal pellets revealed that sage-grouse in western Box Elder County and Parker Mountain, Utah consumed black sagebrush more frequently than Wyoming sagebrush. 2. Line-point intercept and Daubenmire canopy cover estimates are not comparable. Thus managers need to collect vegetation data using both methods. 3. Sage-grouse broods on Anthro Mountain did select for burned areas more than would be expected. However, managers must evaluate their specific habitat to ensure fire is appropriate. 4. Brooding sage-grouse in Grouse Creek, Utah used sites that exhibited similar structural and forage characteristic throughout the diurnal hours, roost sites were characterized by shorter statured shrubs and more bare ground. Thus it may more important for sage-grouse managers to maintain habitat balancing forage and cover need rather than creating forage patches devoid of escape cover.

In light of the results from my research I would recommend research to address the following topics. In terms of sage-grouse winter diets additional research needs to be conducted to understand why sage-grouse are selecting certain species of sagebrush and whether it changes from year to year based on nutrient and terpene levels.

In terms of the method comparison before any one method is advocated over the other researchers must determine which methods are more accurate and precise to ensure the best methods are being used to measure habitat characteristics. Additionally, if we are going to advocate the use of fire for sage-grouse management we must understand the effect small patchy burns have on sage-grouse production. Until this key piece of evidence is added managers and researchers can only speculate as to the effect small scale prescribed fire may have on sage-grouse brood production. Similarly, what effect do forage patches have on sage-grouse juvenile survival? The results from WBE suggest grouse broods were using habitats that appeared to maximize escape cover while providing adequate forage, does this increase juvenile recruitment, and conversely does juvenile recruitment decline if grouse broods are using forage patches adjacent to escape cover. Future research must do a more adequate job of assessing the impact of management on sage-grouse production.

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APPENDICES

APPENDIX A.

CASE STUDY: LESSONS LEARNED FROM A COST-SHARE PROJECT INTENDED TO BENEFIT GREATER SAGE-GROUSE IN UTAH

ABSTRACT Greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse) populations have been declining over the last 5 decades. Degraded brood-rearing habitat has often been implicated as a major factor contributing to declining populations. In 2005, The Box Elder Adaptive Resource Management (BARM) Local Working Group identified the need to improve brood-rearing habitat in the Grouse Creek valley of northwestern Utah. Utah State University and BARM worked to develop a rigorous experimental design to evaluate use of two mechanical (chaining, and Lawson aerator) and one chemical (tebuthiron) treatment to improve sage-grouse brooding habitat. However, in the end several factors inhibited our ability to reliably conduct statistical analysis on these projects. Herein we will detail the factors that plagued the project and what may be done to avoid similar problems in the future. I recommend four points that may help others to avoid these problems in the future. 1) There must be more researcher/manager oversight of project implementation. There needs to be an individual on the ground with contractors to ensure projects are carried out as intended. 2) Specific objectives (i.e. where and what are you going to do) must be written, outlining the intended outcomes; these must be included in proposals and NRCS contracts. This will ensure that all parties involved will have a clear view as to how and where treatments are to be conducted. 3) Landowners must clearly understand the objectives of the project, and how they are to be implemented. 4) Contractors must be held accountable to ensure project objectives are met. By writing contracts with specific objectives it provides

guidance to help contractors and NRCS personnel avoid circumstance where miscommunication may result in a failed project. In my opinion these four elements will help circumvent the complications that hindered the Grouse Creek Livestock Association cost-share project.

INTRODUCTION

Habitat loss and degradation are cited as contributing factors responsible for the declining greater sage-grouse (*Centrocercus urophasianus*: hereafter sage-grouse) populations (Connelly et al. 2000). The West Box Elder County Adaptive Resource Management (BARM) LWG was organized in 2002 to begin sage-grouse conservation planning. The group is composed of individuals from public agencies, and private organizations interested in conserving sage-grouse and sagebrush steppe habitats and sustaining local community socio-economics. The BARM group is administered by Utah State University Extension (USUEXT).

Knerr (2007) recommended that BARM consider implementing management strategies to open existing sagebrush (*Artemisia* spp.) canopies in brood habitat in an attempt to increase forb cover. She hypothesized this would result in enhanced forage for sage-grouse chicks in the areas where dense stands of basin big sagebrush (*A. tridentata tridentata*) may be suppressing the herbaceous understory.

Therefore BARM recommended brush management techniques to manipulate sage-grouse brooding habitats. The original objectives of this study were to evaluate the effect of Chemical (tebuthiron), and mechanical (chaining and Lawson aerator) sagebrush reduction treatments to determine what impacts these treatments may have on sage-grouse and their habitat.

The project experimental design was incorporated into a Natural Resources Conservation Service (NRCS) cost-share agreement (Appendix B). The Wildlife Habitat Improvement Project (WHIP) monies were used to implement these treatments. However, because of complications in the implementation phase, my project design was compromised and thus impeded my evaluation of the management techniques. Thus, I will provide recommendations to mitigate the potential for this to occur in future NRCS cost-share projects.

STUDY AREA

The study area was located in the Grouse Creek Mountains in western Box Elder County, in northwestern Utah. The study area ranges from 1700 to 2000 m in elevation. The study area is owned by the Grouse Creek Livestock Association (GCLA) and is located in the Twin Meadows pasture (2500 ha). The dominant land use of the study site is cattle grazing from mid-May through mid September.

Common shrubs and trees included basin big sagebrush, mountain big sagebrush, black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), green rabbitbrush (*C. viscidiflorus*.), serviceberry (*Amelanchier utahensis*), snowberry (*Symphoricarpos albus*), bitterbrush (*Purshia tridentata*), juniper (*Juniperus osteosperma*), and chokecherry (*Prunus virginiana*). Common grasses included wheatgrasses (*Agropyron* spp., *Elymus* spp.), Kentucky bluegrass (*Poa pratensis*), Great Basin wildrye (*Elymus cinereus*) and limited amounts of cheatgrass (*B. tectorum*). Common forbs included phlox (*Phlox* spp.), vetches (*Astragalus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupines (*Lupinus* spp.), western yarrow (*Achillea millefolium*), wild dandelion species (*Agoseris and Crepis* spp.) and wild onion (*Allium acuminatum*).

The climate of the study area is characterized by relatively warm summers with an average daily temperature of 27° C. Winters are relatively cool with an average daily temperature of -3°C. The area receives 50% of its moisture during the growing season (April – September), most of this moisture occurs in May and June (3.7 and 3.3cm respectively). The Twin Meadows pasture averages ~ 33cm of precipitation. The precipitation is quite uniform throughout the year with an average of 2.5 cm a month. January and December are the highest snowfall months with 26.9 cm and 16.5 cm respectively. The study area is approximately 1000 m higher in elevation than the site where weather data were collected so it is likely to have a higher snowfall totals (Loerrch et al. 1985).

ORIGINAL DESIGN

The experimental design for this study was a randomized block design which included 6 replicates of four treatment types: control (untreated), Lawson aerator, chaining and tebuthiron (chemical, Figure A-1). The treatments were supposed to be implemented in the fall of 2005. The mechanical treatments were to be implemented using large tractors (~ 300 hp) to pull the Lawson aerator and the Ely chain (Cain 1971, Dahlgren et al. 2006). Tebuthiron was applied at a rate of 0.45 active ingredient per hectare and was to be applied aerially, using fixed wing aircraft (Dahlgren et al. 2006).

Vegetation monitoring locations were established in each treatment plot. I established 4 vegetation monitoring points within each treatment. Each vegetation point consisted of two 10 m transects.

Additionally, a grazing exclosure was established within each treatment replication, each exclosure was 2.5 m wide, 5 m long and 1.5 m high. The exclosures were placed within 200 m of one of the vegetation points within each plot.

RESULTS

There were a series of events that permanently altered my experimental design, which precluded analysis of the data that was collected for the project. In the fall of 2005 equipment malfunctions during the implementation of Lawson aerator treatments forced the contractor to suspend treatments in 2005. Lawson aerator treatments were not able to resume in earnest until fall of 2006. In the spring of 2006 I remove the Chaining treatments from the design because the project was not able to secure an Ely chain. Additionally the contractor identified some plots that were "too steep for his equipment" therefore some of the chaining plots were reassigned as Lawson aerator treatments.

In July of 2006 Fencing was erected to better manage grazing, and to provide rest for the treated areas. When the fencing was erected the new fences bisected several treatment plots (Figure A-1). All of the treatment plots north and west of the fence lines were excluded because they would not be protected from grazing (Figure A-1).

In the summer of 2006 I met with the GCLA and the contractor responsible for the Lawson aerator treatments in an attempt to reassign some treatment sites in order to salvage our experiment design. These realignments were conducted on the assumption that the tebuthiron treatments had been applied per the original experimental design (Figure A-1). Unbeknownst to this group the contractor in charge of applying the herbicide had not followed the original study design. The contracting pilot deviated from the original design and applied herbicide in a single 491 ha block, instead of 6 50 ha blocks. This occurred even though maps and GPS locations of all the treatment plots were given to the pilot prior to implementation. This deviation was costly, as some of the areas treated with tebuthiron occurred in control sites. This was not reported to researchers or the contracting officer. It takes approximately 2 years to begin to evidence of chemical action on the sagebrush when using tebuthiron, therefore this mistake was not detectable until summer 2008 (Dahlgren et al. 2006).

The original contract also called for the treated areas to be rested for 2 full growing seasons. Grazing was rested for 2 full growing seasons (2006 and 2007), but because treatments were delayed the treatments were only rested for 1 growing season (2007) post treatment. However, because the region was experienced droughts in 2007 cattle were allowed to graze the pastures in September 2007. This created a situation where the treatment plots received no grazing in 2006, dormant season grazing in 2007 and season long (May – September) grazing in 2008. This confounded our design because the level of grazing was different in each year of the study.

The net results of these incidents compromised our experimental design. These mishaps limited the number of control plots that had not been compromised. Additionally the confounding influence of grazing forced us to include only data collected from the inside the grazing exclosures. There was only 1 control site with an exclosure that remained uncompromised. This left us with a very anemic experimental design that would not allow for dependable analysis of the data. Therefore this precluded us from providing any real evaluation of the chemical and mechanical treatments in Grouse Creek Valley.

DISSCUSION

The most important message for researchers, land managers and sage-grouse biologists may not have anything to do with sagebrush ecology or sage-grouse biology. The lesson that may be most beneficial is how to avoid similar blunders while implementing NRCS cost-share projects. Like most problems there is no one single factor or influence, that lead to the study being compromised. However, I feel there are some recommendations that may help managers using the cost-share programs in the future.

Project objectives of the project need to be **very clear and transparent** to all parties involved, including contractors and landowners. The groups involved must reach a consensus on the objectives so there is ownership and understanding of the project objectives. Objectives are the means of guiding a project in order to obtain the desired outcomes. Additionally Objectives must be specific in identifying when (specific seasons and dates), where (specific sites rather than simply areas) and how (specific prescriptions) the treatments are to be carried out.

Project over sight is critical. Many of the problems I experienced could have been avoided if implementation errors could have been avoided. This may need to be specified in the contract to ensure that the desired outcomes are obtained. It could be possible that contractors were not clear as to our objectives and therefore dismissed the importance of strict compliance to the treatment boundaries. Additionally contractors may need some additional help using newer technologies (GPS) to ensure they are clear as to the treatment boundaries. Even though the objectives of the project were clear to researchers and NRCS staff they were not reflected in the contract or in the final outcome of the project (Appendix B.). Additionally the objectives may not have been as clear to all of the GCLA members thus having a negative impact on the treatment implementation. The objective stated in the NRCS contract was as follows "improve *habitat for sage-grouse and determine which method of brush management provides the best long term results.*" (Appendix B.). While the contract objective is likely adequate it does give any specifics as to the importance of the project design or implementation. This is further evident in that the contract only reflects how many hectares are to be treated and does not require the contractor to follow the project design explicitly.

In order to help managers, and landowners deal with grazing issues related to cost-share projects, it would be extremely important to have areas where grazing can take place during project implementation (i.e. grass banks etc.). Often the costs associated with deferring grazing during the implementation of these projects can be greater than the cost of the projects; therefore the use of grass banks or similar programs may be critical to ensure success of these projects (T. Forrest Utah Association of Conservation Districts, personal communication).

MANAGEMENT IMPLICATIONS

In order to ensure that projects meet the desired project results there are four points that managers may emphasize in order to avoid potential complications with cost-share projects. 1) More researcher/manager oversight of project implementation. 2) Specific objectives (i.e. where and what are you going to do) must be outlined in written proposals and NRCS contracts and be clear to all parties involved. 3) Landowners must clearly understand the scope and objectives of the project, and how they are to be implemented. 4) Contractors must be held accountable to ensure project objectives are met. In my opinion these three things will help managers achieve desired outcomes from NRCS cost-share projects.

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Table A-1. Seed mixture developed by the Utah Division of Wildlife Resources specifically for reseeding treatment plots in Grouse Creek Conservation Area, West Box Elder County, Utah 2006.

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Seeded species	Seeded species (common names)	% in mix
Agropyron cristatum "Douglas"	Crested Wheatgrass 'Douglas'	0.85
Agropyron cristatum "Ephraim"	Crested Wheatgrass 'Ephraim'	2.12
Agropyron cristatum "Hycrest"	Crested Wheatgrass 'Hycrest'	2.12
Pseudoroegneria spicata "Anatone"	Bluebunch WG 'Anatone'	5.86
Elymus wawawaiensis "Secar"	Snake River Wheatgrass 'Secar'	5.29
Psathyrostachys juncea	Russian Wildrye	8.47
Leymus cinereus	Great Basin Wildrye 'Trailhead'	6.77
Medicago sativa "Ladak"	Alfalfa 'Ladak+'	15.24
Onobrychis viciifolia	Sainfoin 'Eski'	22.86
Sanguisorba minor	Small Burnet 'Delar'	15.24
Atriplex canescens "Emery"	Fourwing Saltbush--Emery UT	3.75
Atriplex canescens "juab"	Fourwing Saltbush--Juab UT	3.82
Kochia prostate "beaver"	Forage Kochia--Beaver UT	7.62

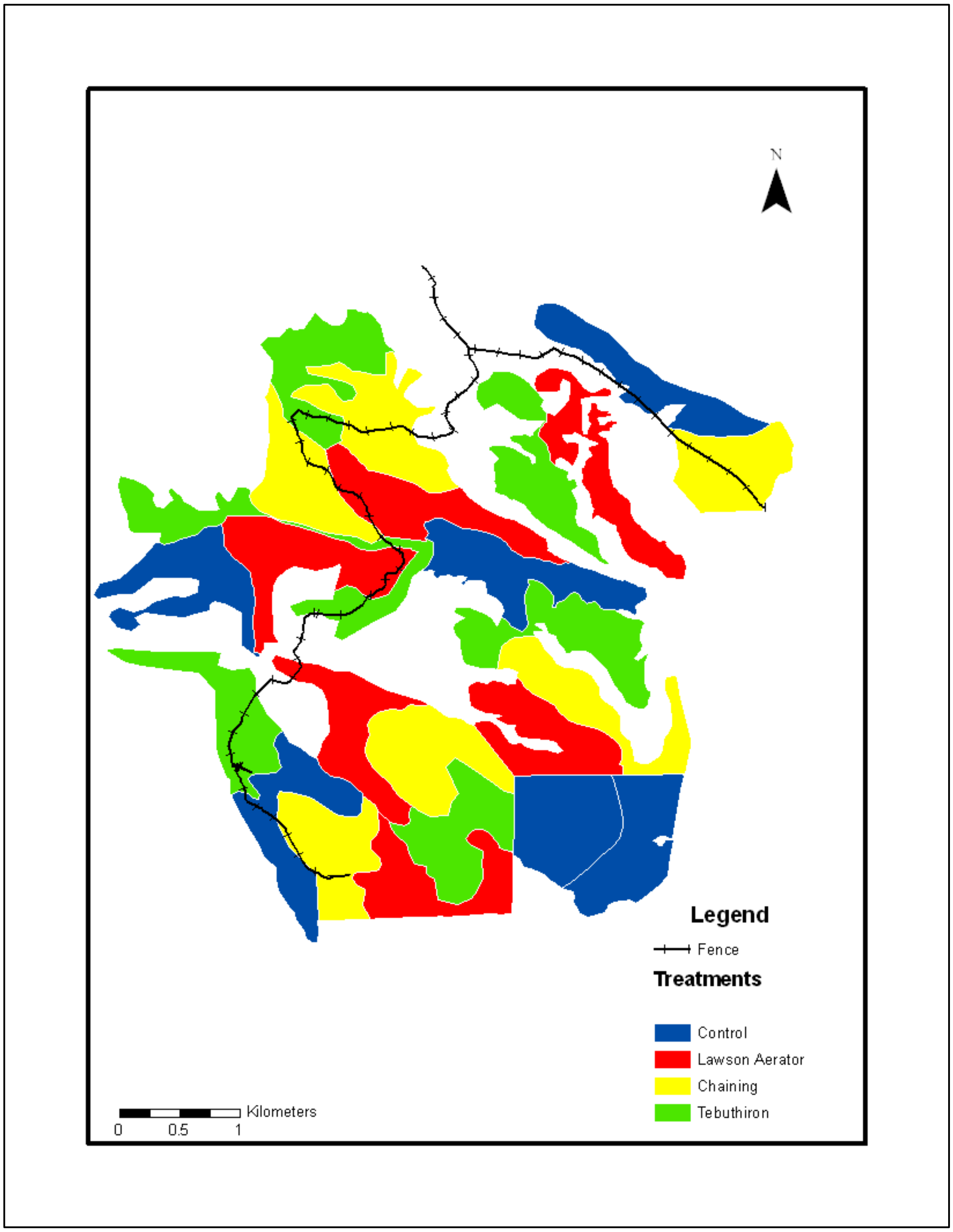

Figure A-1. Treatment plot layout for a NRCS cost-share sage-grouse project in Grouse Creek, Utah 2006-2008. Figure shows location and arrangement of original plot layout and location of fences constructed to keep cattle off of treated areas.

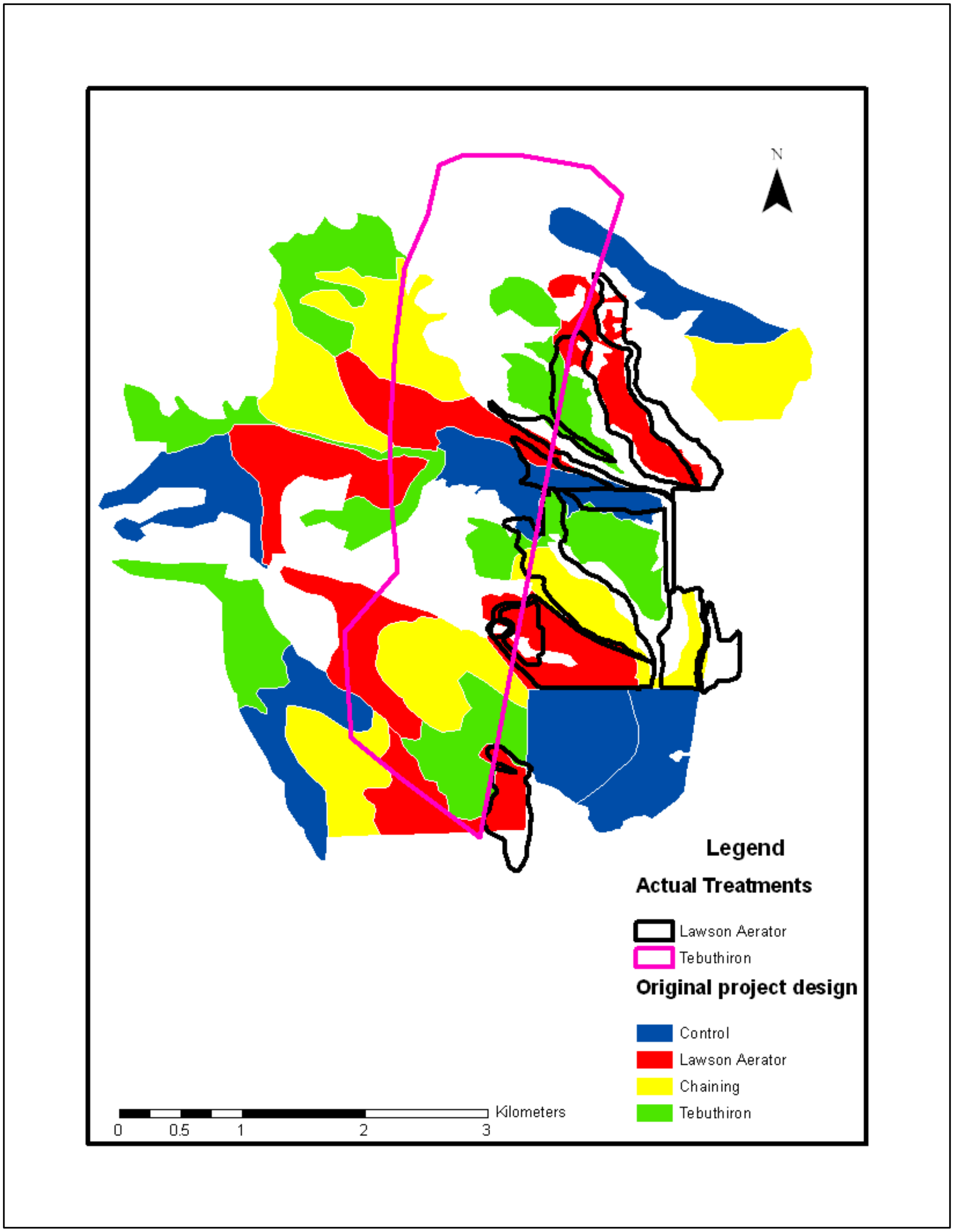

Figure A-2. This Figure reflects the layout of the Sage-grouse habitat improvement project in Grouse Creek Valley, Utah 2006-2008. The original treatment plots are in blue, red, yellow, and green. While the outlines of black and pink represent what the treatments actually looked like following treatment implementation.

APPENDIX B: GROUSE CREEK LIVESTOCK ASSOSIATION CONSERVATION PLAN

NRCS
Natural Resources Conservation Service
TREMONTON SERVICE CENTER
85 S 100 E
TREMONTON, UT 84337-1605
(435) 257-5402

Jeff Schick
District Conservationist

Conservation Plan

GROUSE CREEK LIVESTOCK ASSOCIATION
PO BOX 15
GROUSE CREEK, UT 84313

Objective(s)

Objective of the plan is to improve habitat for Sage Grouse and determine which method of brush management provides the best long term results.

Brush Management (314)

Remove, reduce or manipulate brush species using a chain, an aerator and spike to achieve the desired plant community for use by sagegrouse.

Tract	Field	Planned Amount	Month	Year	Applied Amount	Date
3814	1001	600 ac	9	2005		
3814	1001	600 ac	10	2005		
3814	1001	600 ac	11	2005		
	Total:	600 ac				

Prescribed Grazing (528)

Grazing will be managed according to a schedule that meets the needs of the soil, water, air, plant and animal resources and the objectives of the resource manager.

Tract	Field	Planned Amount	Month	Year	Applied Amount	Date
3814	1001	4426.5 ac	7	2007		
3814	1001	4426.5 ac	7	2008		
	Total:	4426.5 ac				

Range Planting (550)

Establish adapted perennial vegetation to restore a plant community similar to historic climax or establish the desired plant community based on land manager's objectives.

Tract	Field	Planned Amount	Month	Year	Applied Amount	Date
3814	1001	1800 ac	11	2005		
	Total:	1800 ac				

Upland Wildlife Habitat Management (645)

Create, maintain or enhance area(s) to provide upland wildlife flood and cover.

Tract	Field	Planned Amount	Month	Year	Applied Amount	Date
3814	1001	4426.5 ac	7	2007		
3814	1001	4426.5 ac	7	2008		
	Total:	4426.5 ac				

CERTIFICATION OF PARTICIPANTS

7/07/05

GROUSE CREEK LIVESTOCK AS Date

CERTIFICATION OF:

District Conservationist

7/14/05

Jeff Schick Date

CONSERVATION DISTRICT

7-7-05

WEST BOX ELDER SOIL CONSE Date

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1993 Altamont High School, Altamont, Utah

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1997 Field Technician working under Dr. Michael Ralphs USDA, Poisonous Plant Research Lab. Work location was Maxwell, NM and Yampa Co.

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2000 - 2006 Range Science Technician (full time) working under Dr. Michael Ralphs, USDA, Poisonous Plant Research Lab.

2003 - 2006 Graduate Research working under Dr. Michael Ralphs, USDA, Poisonous Plant Research Lab.

2006-2009 Graduate Research under Dr. Terry Messmer, Utah State University.

Extension Experience

2006-2009 Participated in Box Elder Adaptive Resource Management (BARM) local working group as a representative of USU Extension.

2006-2009 Participated in Uinta Basin Adaptive Resource Management (UBARM) local working group as a representative of USU Extension.

2007 West Box Elder Soil conservation district Field tour

2008 UBARM Field Tour: Anthro Mountain prescribed fire use to manage for Greater Sage-grouse.

2008 West Box Elder Soil Conservation District summer field tour presentation: Status of sage-grouse in Western Box Elder County, Utah.

2009 UBARM summer field tour: Use of bird dogs for sage-grouse research.

Teaching Experience

2003 - 2005 Under Graduate Range Management Exam coach: Conducted 1-2 hour lecture and tutoring session. Instruction included Range ecology, Range regions, Multiple use, Range monitoring and assessment, and Grazing management

2002-2006 Boy Scouts of America Volunteer: Organized events and instructed boys from 12-14 years of age, weekly. Topics ranged from environmental sciences, moral conduct and outdoor skills

Skills

- Vegetation monitoring and analysis.
- Identification of sagebrush steppe plant species.
- Design and implementation of livestock grazing studies.
- Design and implementation of plant community dynamics experiments
- Design and implementation of plant synecology experiments.
- Monitoring and evaluation of wildlife habitat treatments.
- Quantification of sage-grouse habitat.
- Basic SAS operation for statistical analysis.
- Basic ArcMap GIS operation.
- Understanding of data collection and organization.
- Extensive use of Radio telemetry to track wildlife.
- Preparation of plant samples for chemical and nutritional analysis.
- Operation of ATV's, 4X4 pickup trucks, and stock trailers.
- Livestock handling and care.

Publications

Peer-reviewed publications:

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