GREATER SAGE-GROUSE BROOD-REARING HABITAT MANIPULATION IN MOUNTAIN BIG SAGEBRUSH, USE OF TREATMENTS, AND REPRODUCTIVE ECOLOGY ON PARKER MOUNTAIN, UTAH

by

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ABSTRACT

Greater Sage-grouse Brood-rearing Habitat Manipulation in Mountain Big Sagebrush, Use of Treatments, and Reproductive Ecology on Parker Mountain, Utah.

by

David K. Dahlgren, Masters of Science
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Sage-grouse (Centrocercus spp.) populations have been declining, along with sagebrush habitat degradation in recent years. To address these concerns, the Western Association of Fish and Wildlife Agencies (WAFWA) sage-grouse framework team published their habitat assessment in 2004. In this assessment, managers called for more experiments concerning habitat manipulation, and its affect on sage-grouse.

To address some of these concerns, I used an experimental design to treat greater sage-grouse (C. urophasianus) brood-rearing habitat in a high elevation (2700 to 2900m) pasture containing even-aged dense (> 38% canopy cover) stands of mountain big sagebrush (Artemisia tridentata vaseyana). I used two mechanical treatments; Dixie harrow and Lawson aerator. The Dixie harrow has connected pipes with alternating harrows, and is dragged behind a large tractor. The Dixie harrow rips sagebrush from and scarifies the bare soil. The Lawson aerator is a large drum aerator, pulled behind a large tractor. The aerator has a more crushing effect on the sagebrush and does not impact the soil.
I monitored vegetation response for both shrub and herbaceous components. Both treatments effectively reduced shrub canopy to sage-grouse habitat guidelines for brood-rearing habitat (between 10 and 25%). Only the Dixie harrow increased herbaceous cover overall in the first two years post treatment. The Lawson aerator had some time period effects within the summers of 2002 and 2003 on herbaceous cover, but was ineffective overall.

I also monitored (pellet count and birddog survey) sage-grouse use within these mechanically treated plots and control plots. Additionally, I monitored use within adjacent Tebuthiuron (chemically treated) plots. The Tebuthiuron plots were treated in 2000. Sage-grouse in general, and broods specifically preferred Tebuthiuron treated areas compared to the other treatments or control. All treatments had more use than control.

I monitored sage-grouse hens during their reproductive efforts in the summers of 2003 and 2004. In 2003 and 2004 nest initiation rates were 95% and 56%, nest success was 50% and 80%, and mortality was 36% and 22%, respectively. Preferred nest and brood sites exhibited vegetation characteristics similar to those reported in previous studies, though forb cover was consistently lower. Nest sites exhibited an average of 9.3% herbaceous and 13.2% shrub cover, although nest bush diameter and height averaged 97.5 cm and 64.4 cm, respectively. Brood sites on average exhibited 20.1% shrub and 16.5% herbaceous cover. Additionally, these sites exhibited 2.6% forb cover. This work was a continuation of research that began in 1998.
I thank Terry Messmer for the opportunity to conduct this research. His ability to get various members from differing agencies and private parties to the same table is inspiring. I am grateful that through this cooperation between various public and private entities, funding necessary to conduct my research was provided. I also thank Terry for his leadership, guidance, and hands-off approach towards me throughout this research.

I would like to thank the Parker Mountain Adaptive Resource Management partnership for their association and governing of research that has and will take place on Parker Mountain. This partnership has become a model for managing natural resources within a cooperative of state, federal, and private parties. All partners have been essential to my work, but I would like to thank in particular members of the Parker Mountain Grazing Association who co-chair this partnership, and who provided the first funds to purchase radio collars, which began the monitoring of hen sage-grouse on Parker Mountain. I would also like to thank in particular the Utah Division of Wildlife Resources for the field vehicle and all associated expenses.

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I could not have collected all the data by myself, and I give thanks to all technicians who have been part of this work, namely Lee Rinlesbacher, Ron Daigle, Terron Pickett, Chris Perkins, and Kevin Labrum.
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The trapping of sage-grouse hens is very taxing work. I thank all who volunteered their time in this activity for this research.

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CHAPTER 1
INTRODUCTION

Description

Greater sage-grouse (*Centrocercus urophasianus*) are the largest species of native grouse in North America. Males may weigh up to 3.2 kg and females 1.5 kg (Patterson 1952, Autenrieth 1981). Sage-grouse habitat includes both sagebrush (*Artemisia* spp.) steppe and sagebrush semi-desert ecosystems (West 1983). Sage-grouse are considered sagebrush obligates and depend on sagebrush habitat throughout their life cycle (Patterson 1952, Braun et al. 1977).

Current greater sage-grouse range includes southeast Alberta and southwest Saskatchewan, southwest North Dakota and northwest South Dakota, most of Montana and Wyoming, western Colorado, parts of southern and eastern Idaho, north, northeast and southern Utah, northern Nevada, east to northeast California, southeast Oregon, and north-central Washington (Connelly and Braun 1997, Schroeder et al. 2004). Gunnison sage-grouse (*Centrocercus minimus*) occur in small isolated populations in southwest Colorado and southeast Utah (Young et al. 2000). Sage-grouse have been extirpated from the fringes of their range in Arizona, New Mexico, Oklahoma, Nebraska, Kansas, and British Columbia (Patterson 1952).

General Habitat Requirements

Sage-grouse depend on sagebrush communities to complete their life cycle (Connelly et al. 2000a). These ecosystems provide wintering, pre-laying, lekking, nesting, and brood-rearing habitat.
Preferred winter habitat consists of medium to tall (25 to 80 cm, or 25 to 35 cm above snow) sagebrush with canopy coverage from 15 to 20% (Connelly et al. 2000a). Sage-grouse depend on sagebrush almost exclusively for their winter diet (Patterson 1952). Big sagebrush species are preferred as they will provide thermal cover, escape cover, and food for greater sage-grouse (Connelly et al. 2000a), though other sagebrush species are used, such as Gunnison sage-grouse use of black sagebrush in San Juan County, Utah. Greater sage-grouse may actually gain weight during the winter (Beck and Braun 1978), and are not impacted by severe weather conditions unless snow completely covers the sagebrush (Hupp and Braun 1989).

During pre-laying periods, 50 to 80% of a hen’s diet consists of sagebrush leaves with the remainder being various forbs (Barnett and Crawford 1994). Nutrient content primarily comes from the forb component of a hen’s diet, and appears to enhance reproductive success (Barnett and Crawford 1994).

During the spring breeding season, lek sites are used for displaying and breeding activities. Lekking habitat consists of bare ground or sparsely vegetated areas with little or no shrub canopy (Patterson 1952). Males display and call from these areas to attract females.

Sage-grouse nests are typically located under sagebrush plants, and are often under the tallest sagebrush in the stand (Wallestad and Pyrah 1974, Apa 1998). Connelly et al. (1991) in Idaho reported that 79% of 84 nests were located under sagebrush. Those nests under sagebrush were more successful than nests under non-sagebrush plants. Sveum et al. (1998) reported nest-sites in Washington exhibited higher shrub canopy coverage and more ground and lateral cover than random sites. Gregg et al.
(1994) noted that high canopy cover (i.e. 41%) and tall (>18 cm) residual bunchgrass cover were a characteristic common to successful nests. Residual forbs also may provide nest-screening cover, though exotic herbaceous species may not (Sveum et al. 1998b). Sage-grouse hens can renest following nest failure. Schroeder (1997) reported that 87% of the hens in central Washington renested. Distance between nests and nearest lek varies and nests sites are selected independent of lek locations (Wakkinen et al. 1992).

One of the most common reasons for nest failure is predation (both avian and mammalian). Ample vegetation structure may mitigate predation (Gregg et al. 1994, Schroeder and Baydack 2001). Common nest predators include ground squirrel (Spermophilus spp.), badger (Taxidea taxus), coyote (Canis latrans), and common raven (Corvus corax) (Shroeder and Baydack 2001). Common predators of sage-grouse adults and young include golden eagle (Aquila chrysaetos), red-tailed hawk (Buteo jamaicensis), Swainson’s hawk (B. regalis), northern harrier (Circus cyaneus), common raven, weasel (Mustela spp.), and coyote (Schroeder and Baydack 2001). Most biologists believe that predation can be managed best by increasing and enhancing habitat quality (Messmer and Rowher 1998). In areas where habitat fragmentation and increased densities of exotic predators have isolated and decreased populations of sage-grouse, direct predator management may be necessary (Schroeder and Baydack 2001).

Brood-rearing habitat.--For brood-rearing activities, shrub canopy cover tends to be less, while herbaceous understory is higher (Connelly et al. 2000a). As sagebrush communities desiccate through the summer birds tend to move to more mesic areas (Klebenow 1969, Braun 1998, Connelly et al. 2000b).
Insects are the major portion of a chick’s diet until 12 weeks of age when sagebrush starts to be consumed (Klebenow and Gray 1968, Peterson 1970, Patterson 1952). Availability of forbs and insects is positively correlated with chick recruitment into the population (Drut et al. 1994). Agricultural habitats, such as alfalfa fields, may be used heavily by sage-grouse adults and chicks during the summer months (Patterson 1952). Brood-rearing takes place until early fall when the birds group into flocks for the winter.

Sage-grouse use of sagebrush communities is dynamic. Thus maintaining heterogeneous sagebrush habitats in various states is essential to sustaining sage-grouse habitat (Westoby et al. 1989). Consequently, the identification and implementation of management practices that maintain heterogeneous sagebrush communities that exhibit different age classes of sagebrush and a diverse herbaceous understory are important to sage-grouse conservation strategies.

Factors Impacting Greater Sage-grouse Populations

The sagebrush semi-desert and sagebrush steppe ecosystems comprise much of western North American rangelands (West 1983). Vegetation within these sagebrush ecosystems has been changing over the past 10,000 years (Miller et al. 1994). Climatic changes over time affected sagebrush community abundance and altitudinal distributions (Miller et al. 1994). European settlers (~150 years ago) and their use of sagebrush rangelands for domestic livestock grazing hastened these changes (Miller et al. 1994, CAST 2002).

Braun et al. (1976, 1977) argued that mismanagement of the sagebrush-steppe ecosystem has led to the current condition of sage-grouse populations and their habitats.
Specific factors that have led to degradation of sage-grouse habitat include, but are not limited to, change in fire regime, improper livestock grazing, invasion of exotic plants, and conversion of sagebrush to seeded pastures, croplands, development, and roads.

Continued settlement increased conversion of sagebrush lands to agricultural uses (Cottam and Stewart 1940). Overgrazing of livestock in the late 1800s and early 1900s led to decreased sagebrush distribution, degradation, and change in plant species composition (CAST 2002). Increased concern that public rangeland was being degredated across the western United States led to the passage of the Taylor Grazing Act. The act brought most of these lands under federal control ending nomadic grazing thus stabilizing the livestock industry.

In general livestock producers perceived conversion of sagebrush habitat to grasslands as a goal of range management. Vale (1974) suggested that sagebrush treatment (i.e. burning, spraying, plowing, disking, chaining, cutting, and beating) would eventually take place on most sagebrush habitat. Following World War II in the 1940s, 50s, and 60s, contemporary demands for red meat exacerbated the conversion sagebrush to grasslands. Braun et al. (1977) stated that management activities conducted to enhance forage for livestock grazing generally have been detrimental to sage-grouse.

Sagebrush communities with the gentlest slopes and deepest soils were plowed and planted with introduced grass species to increase livestock forage production (Vale 1974, Beck and Mitchell 2000). As a result crested wheatgrass (Agropyron cristatum) had become a monoculture in many areas (Shown et al. 1969). Though livestock benefited from such treatments, in many cases those species that require diverse sagebrush communities for part or all of their life cycle were impacted. Crested
wheatgrass provides poor habitat sage-grouse habitat (Reynolds and Trost 1980, Ritchie et al. 1994).

European settlement also interrupted fire intervals. Fire helped maintain the codominance of herbaceous cover with sagebrush (Burkhardt and Tisdale 1976). With the suppression of fire and the selection of herbaceous food by livestock, expansion of native shrubs likely occurred (West 1983). Sagebrush stands then became decadent and lost vigor over time, which reduced the mosaic of sagebrush habitat types available to sage-grouse. Fire suppression and overgrazing have also led to pinyon-juniper (Pinus edulis, Juniperus spp.) woodland encroachment into sagebrush habitat which has further impacted on sage-grouse (Commons et al. 1999).

The invasion of exotic plant species, specifically annuals, has had a significant impact on sagebrush communities and the interplay of fire as a natural disturbance factor. Stewart and Hull (1949) reported improper livestock grazing can also aid exotic species establishment, which can be detrimental to sage-grouse (Beck and Mitchell 2000). Cheatgrass (Bromus tectorum) and Medusa-head (Taeniatherum asperum) are very invasive within sagebrush habitats (West 1983, Stewart and Hull 1949, Young and Allen 1997). These annual grasses have the advantage of early sprouting in the spring and following disturbances (such as fire). Cheatgrass has increased fire return intervals in sagebrush habitat (Bunting et al. 1987). With an increasing fire return interval, exotic annuals and shrub resprouters, such as rabbitbrush (Chrysothamnus spp.) and/or horsebrush (Tetradymia spp.), may become dominant at a site where fire has eliminated sagebrush (West 1983). Annual-dominated communities may be considered a separate steady state (Laycock 1991). These communities are not suitable sage-grouse habitat.
Because of the historical changes in sagebrush habitat, greater sage-grouse populations have declined as the quality and quantity of sagebrush habitat within their range (Miller and Eddleman 2000). Connelly and Braun (1997) pointed out that sage-grouse populations have declined between 17 to 47% throughout much of their range. Connelly et al. (2000a), Wisdom et al. (2000), and West and Young (2000) expressed concerns that long-term loss, degradation, and fragmentation of sagebrush vegetation throughout the Intermountain West have hastened sage-grouse decline. The overall relationship between habitat degradation and sage-grouse population decline can be demonstrated by the remaining sage-grouse populations’ close association with intact habitats in relatively northern latitudes, high elevations, and/or mesic environments (Connelly and Braun 1997).

**Sage-grouse in Utah**

Utah has not been exempt from factors causing sage-grouse population decline (Utah Division of Wildlife Resources 2002, Beck et al. 2003). Sage-grouse once inhabited all of Utah’s 29 counties (Beck et al. 2003). Now only 5 counties (Box Elder, Garfield, Rich, Uintah, and Wayne) contain abundant sage-grouse numbers (Beck et al. 2003). Beck et al. (2003) reported a 60 and 70% decline in potential habitat for greater sage-grouse and Gunnison sage-grouse, respectively, although those populations with greater than 500 breeding sage-grouse (populations within Box Elder, Garfield, Rich, Uintah, and Wayne Counties) are stable or increasing.

Greater sage-grouse are identified as a “species of special concern” by the Utah Division of Wildlife Resources (UDWR) (Utah Division of Wildlife Resources 1998). To address these declines UDWR prepared the Utah Strategic Management Plan for sage-
grouse. This plan, approved by the Utah Wildlife Board in 2002, identifies 13 “Management Areas” to facilitate conservation efforts. Currently a community-based conservation effort is underway in these areas. This effort will culminate in the development and implementation of conservation plans for most of Utah’s sage-grouse populations (Terry Messmer, Utah State University, personal communication).

Because concerns of habitat and population degradation several groups have petitioned the U. S. Fish and Wildlife Service (USFWS) to list the greater sage-grouse under the Endangered Species Act (ESA) of 1973 (Kritz, USDI Bureau of Land Management, unpublished data). The possibility of listing affects both state and federal management actions on public and private lands. Sage-grouse occur on various land ownership including Bureau of Land Management (BLM), U. S. Forest Service (USFS), state owned lands, and private lands. The UDWR estimates that about 50% of Utah sage-grouse habitat and populations inhabit private land. Sage-grouse issues involve many institutions including federal land agencies, state wildlife agencies, private livestock operations, and environmental organizations.

The USFWS concluded in 2004 that a range-wide listing was not warranted for greater sage-grouse (L. Romin, USFWS, SLC, Utah, personal communication). Local working groups and their sage-grouse habitat recovery plans will play a major role sage-grouse conservation.

**Sage-grouse Management Techniques**

Many public and private partners are getting involved with sage-grouse conservation efforts. Management activities must be balanced with state and federal agency regulation, and the public’s interest. Researchers have been studying sage-grouse
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biology since the early 1900s. Information from these studies can be used to help understand sage-grouse habitat needs and how to manage sagebrush ecosystems for sage-grouse and other sagebrush obligates.

*Fire Management.*--Pyle and Crawford (1996) reported that greater sage-grouse use of mesic sagebrush habitat increased after small areas were burned. Fischer et al. (1996) observed fire negatively impacted brood-rearing habitat in more xeric sagebrush habitat. Similarly, Connelly et al. (2000a) concluded that fire may negatively impact greater sage-grouse using Wyoming big sagebrush (*A. t. wyomingensis*) habitat. Wambolt and Payne (1986) reported fire suppressed sagebrush cover over an 18-year study. Fischer et al. (1997) reported fire having little effect on movements of migratory female greater sage-grouse from breeding to summer ranges. However, Connelly et al. (2000b) reported significant negative impacts of fire on male lek attendance after treatment. Fire’s effect on sage-grouse in big sagebrush habitat needs further investigation, as the role of fire in maintaining big sagebrush habitat is unclear. In areas where invasive plants such as cheatgrass occur, fire may have limited use as a management tool.

*Biological Management.*--Domestic livestock grazing in sage-grouse habitat has occurred the last 100+ years. Connelly and Braun (1997) implicated livestock grazing as a range-wide factor exacerbating the decline in sage-grouse populations. Beck and Mitchell (2000) reported mixed impacts of livestock grazing to sage-grouse habitat. Negative impacts were largely attributed to overgrazing and seasonal use.

The seasonality of grazing can impact sagebrush habitat in several ways. Season-long grazing and spring grazing of nesting and brood rearing habitats can be detrimental
to sage-grouse production (Laycock 1979, Beck and Mitchell 2000). However, sheep and goats can be used seasonally to reduce sagebrush canopy coverage to increase herbaceous cover (Laycock 1979, Riggs and Urness 1989, Sharrow et al. 1989). This may be more incident with fall grazing (Bork et al. 1998).

Van Pollen and Lacy (1979) in a synthesis of 18 western grazing studies reported increases in herbaceous cover after removal of livestock grazing. However, West et al. (1984) reported no increases in herbaceous cover following 13 years of livestock removal in semi-desert sagebrush habitat in west-central Utah.

Chemical Management.--Prior to the 1980s, herbicides were commonly used to enhance livestock forage within sagebrush habitat (Braun 1987). Klebenow (1970) and Peterson (1970) reported a negative impact on breeding sage-grouse in areas that were chemically treated to enhance livestock forage. Pyrah (1972) reported negative impacts to wintering sage-grouse in large acreages of chemically treated sagebrush, although areas which were partially treated strips received increased use after the initial year of treatment. Martin (1970) reported 96% of adult sage-grouse locations were within strips that did not receive chemical treatment. These areas exhibited similar vegetation composition to analyses of sage-grouse crop contents. He did find sage-grouse broods using habitat with reduced sagebrush cover.

Autenrieth (1981) determined chemical treatments in early spring might be used to enhance mesic brood rearing habitat by increasing herbaceous cover. Johnson et al. (1996) reported that the use of chemical treatment, (i.e. tebuthiuron) on big sagebrush could enhance vegetation composition and diversity. Olson and Whitson (2002) suggested that low rates of tebuthiuron in late successional big sagebrush communities
could be used to enhance herbaceous cover. Both Beck and Mitchell (2000) and Connelly et al. (2000a) suggest chemical and mechanical treatments in brood-rearing habitat, where sagebrush canopy may be limiting the understory, to achieve approximately 15% sagebrush canopy coverage while increasing the grass and forb component.

**Mechanical Treatment.**—Little research has been conducted to document the effects of mechanical treatments on sage-grouse habitat. Mechanical treatments of sagebrush have been used in the past to increase vegetation diversity within sagebrush habitat (Wambolt and Payne 1986, Rasmussen et al. unpublished data). Connelly et al. (2000a) recommended mechanical treatment in 4-8m wide strips in areas with ≥ 35% shrub cover for restoration of late sage-grouse brood-rearing habitat.

Mechanical treatments were not recommended in wintering habitat because of possible detrimental impacts. Mechanical treatments that impact too much area, especially in wintering or breeding habitat, have been shown to negatively impact sage-grouse (Swenson et al. 1987). Watts and Wambolt (1996) reported mechanical treatment (plowing) of Wyoming big sagebrush recovered much faster (~10 years) than the burned, chemical, and rotocut treated areas.

The Dixie Harrow, a mechanical treatment developed by the BLM, has been used to reduce big sagebrush canopy cover. The Dixie Harrow is a large spike tooth harrow pulled behind a tractor removing sagebrush and is sometimes used to broadcast a seed-mix into the treated area. This method has been used in central Utah for the past 5 years (Rasmussen et al., US Forest Service, unpublished data). Three-year post treatment
monitoring indicated that big sagebrush decreased from 32.3 to 5.8%; grasses increased from 8.6 to 47.2%; and forbs increased from 3.0 to 17.4%.

The Lawson Aerator is another mechanical management tool that can be used to reduce shrub cover (Hart 2000). The Lawson Aerator is a large drum aerator, which is rolled behind a tractor to apply treatment. The Lawson Aerator has more of a crushing effect on sagebrush plants rather than total removal. This crushing effect leaves more structure on the ground and could provide for better snow accumulation and therefore higher soil moisture content when compared to other methods. In Montana, the Powder River Conservation District used the Lawson Aerator to treat Wyoming big sagebrush areas (Montana Extension Service 2001). The Lawson Aerator treatment method is relatively new and has rarely been used in sagebrush habitat in the Intermountain West.

**Purpose**

The purpose of my research was to assess the effect of Dixie harrow and Lawson aerator treatments in dense stands of mountain big sagebrush on enhancing sage-grouse brood-rearing habitat. In addition, I evaluated the impact of lagamorphs on treatment response. In conjunction with this research I continued to monitor sage-grouse habitat use patterns and conducted surveys of sage-grouse use in treatments and control. I followed 2006 unified manuscript guidelines for The Wildlife Society publications for this document.
November 2005 Draft

**Literature Cited**


November 2005 Draft


http://farwest.tamu.edu/rangemgt/pdfs/00bookme.pdf As seen on 4-15-03.


Montana Extension Service. 2001. Powder River County Pasture and Range Aerator Demonstration. animalrangeextension.montana.edu/Natural/GLCI/Projects/2001/PwdrRvr%20Range%20Renov.htm. As seen on 4-14-03.


Pyrah, D. B. 1972. Effects of chemical and mechanical sagebrush control on sage grouse. Montana Fish and Game Department, Job Completion Report W-105-R-6, Helena, USA


CHAPTER 2

EFFECTS OF MECHANICAL TREATMENTS ON SAGE-GROUSE BROOD-REARING HABITAT IN MOUNTAIN BIG SAGEBRUSH

Abstract: In 2001 the Western Association of Fish and Wildlife Agencies (WAFWA) adopted a range-wide sage-grouse (*Centrocercus* spp.) conservation plan. In this plan WAFWA identified a need to determine the effect of management practices on sage-grouse and sagebrush (*Artemisia* spp.) ecosystems under different environmental conditions. Currently, little information exists regarding the effects of mechanical treatments on high elevation sagebrush communities for use in sage-grouse habitat management. I evaluated the effects of 2 mechanical treatments, the Dixie harrow and Lawson aerator on vegetation diversity in mountain big sagebrush communities located on Parker Mountain, south central Utah. To conduct this experiment we identified 12 40.5 ha plots within an area that exhibited ~ 38 % shrub canopy cover. The plots were located in sage-grouse brood-rearing habitat that is seasonally grazed by domestic livestock. The plots were randomly assigned to treatment or control groups. The mechanical treatments were conducted in the fall of 2001. The treatments reduced shrub canopy cover from 38.2 and 38.9% to 18.4 and 14.3% for Dixie harrow and Lawson aerator, respectively. Herbaceous cover (grass and forb combined) increased on the Dixie harrow plots in response to the treatment (+ 5.5%, $P = 0.02$, respectively). Herbaceous cover post- treatment did not differ on the Lawson aerator and control plots. Both grass and forb cover was higher on the Dixie harrow treatments than the control ($P = 0.02$ and 0.01, respectively). During the 2 years studied, vegetation diversity was highest on the Dixie harrow treatments.
Introduction

Sagebrush ecosystem types (including sagebrush semi-desert and sagebrush steppe) extend over nearly 63 million ha of western North American landscapes (West 1983). Climatic changes over time have caused shifts in altitude, abundance, and vegetation composition of sagebrush communities (Miller et al. 1994). With European settlement (~ 150 years ago) these changes occurred at much faster rates (Miller et al. 1994, CAST 2002).

Greater sage-grouse (*Centrocercus urophasianus*) are sagebrush obligates that inhabit western North America (Patterson 1952). Within the last 100 years sage-grouse populations have declined as sagebrush communities have been impacted (Braun et al. 1977). In some areas of the West sagebrush canopy cover has increased to such densities that an herbaceous understory is limited or lacking (West 1983). Reduced herbaceous understory diversity in sagebrush communities may also impact sage-grouse productivity (Connelly et al. 2000).

Sage-grouse prefer a more open shrub canopy cover (Martin 1970, Wallestad 1971) that exhibits a high grass and forb component (~15% cover) for brood-rearing habitat (Sveum et al. 1998). These areas typically provide the forb and insect abundance and diversity that are important components of brood-rearing habitat (Dunn and Braun 1986). Apa (1998) reported broods using areas with double the amount of forb cover compared to independent sites. Ants (Hymenoptera) and beetles (Coleoptera) are especially important food sources for chicks (Fischer et al. 1996). Late brood-rearing takes place in more mesic habitats, where desiccation of herbaceous plants is not as severe (Klebenow 1969).
Connelly et al. (2000) and Beck and Mitchell (2000) suggested treatment of sagebrush where canopy cover may be limiting the understory diversity in brood-rearing habitat. The treatments should be designed to achieve approximately 10 to 25% sagebrush canopy cover while increasing the grass and forb component. The area, methods, timing, landscape design, and climatic factors may influence vegetation response with a given treatment.

Autenrieth (1981) reported that early spring chemical treatments could increase herbaceous cover in mesic areas, thereby enhancing brood-rearing habitat. Johnson et al. (1996) reported that the use of chemicals such as tebuthiuron, could enhance vegetation composition and diversity in dense big sagebrush stands. Olson and Whitson (2002) reported that low rates of tebuthiuron used in late successional big sagebrush (A. tridentata) communities could enhance herbaceous cover.

The Dixie harrow and the Lawson aerator have been used by federal and state agencies to treat sagebrush in Utah to benefit wildlife (K. Rassmussen, USFS, L. Greenwood, BLM, and D. Mitchell, UDWR, personal communication). Dixie harrow treatments used on Forest Service (USFS) and the Bureau of Land Management (BLM) lands reduced big sagebrush canopy cover from 32.3 to 5.8%. Grasses increased from 8.6 to 47.2%, and forbs from 3.0 to 17.4% (K. Rassmussen, USFS, unpublished data). These results were based on non-random, unreplicated treatments. To date no replicated experiments have been conducted to validate the effect of these mechanical treatments on mountain big sagebrush (A. t. vaseyana) communities. The purpose of this research was to determine if these mechanical treatments could increase herbaceous understory, thus enhancing sage-grouse brood-rearing habitat.
Study Area

This study was conducted on Parker Mountain. The Parker Mountain study area is located in Garfield, Sevier, Piute, and Wayne counties of Utah and encompasses both the Aquarius and Awapa Plateaus (Figure 1). Parker Mountain consists of ~107,478 hectares, of which 21,685 ha are managed by the U.S. Forest Service (USFS), 36,398 ha by Bureau of Land Management (BLM), 43,863 ha by Utah School and Institutional Trust Lands Administration (SITLA), and 5,532 ha are privately owned.

The predominant land use in the area is grazing by domestic livestock. The area is divided into several pastures. Livestock grazing is initiated in June at lower elevation pastures. As these pastures dry out livestock are sequentially herded into higher elevation pastures. In addition to livestock, a large herd of pronghorn (*Antilocarpa americana*) graze the mountain throughout the year.

The sagebrush habitat on the Parker Mountain is one of the largest contiguous tracts in Utah, and has escaped development and land use pressures, other than livestock use. Parker Mountain continues to be one of the few areas remaining in Utah with relatively stable numbers of greater sage-grouse (Beck et al. 2003).

Annual precipitation on Parker Mountain varies in elevation, ranging from 25 to 51 cm. Precipitation comes mostly in the winter in the form of snow and late summer monsoons (Figure 2). In addition to a few springs at higher elevations (>2700 m), many water developments are scattered throughout the area.

The mid-elevation pastures (2700 m to 2900 m) are used by sage-grouse primarily during nesting and early and late brood-rearing activities (Chi 2004). These pastures
most likely receive precipitation in the higher range (40 to 51 cm/yr). One of these pastures, the Parker Lake Pasture (PLP), was selected for this study (Figure 3).

The PLP contains lower lying draws that are dominated by mountain big sagebrush with some silver sage (*A. cana*) in the more mesic bottoms. Hill sides and tops are dominated by black sage (*A. nova*). Common forb species include cinquefoil (*Potentilla* spp.), phlox (*Phlox* spp.), dandelion (*Taraxacum* spp.), lupine (*Lupinus* spp.), daisy (*Erigeron* spp.), penstemon (*Penstemon* spp.), and milkvetch (*Astragalus* spp.). Common grass species include wheatgrass (*Agropyron* spp.), bluegrass (*Poa* spp.), gramma grass (*Bouteloua* spp.), squirrel tail grass (*Hordeum* spp.), and June grass (*Koeleria* spp.). Also dry land sedge (*Carex siccata*) is common in the study pasture.

**Methods**

To conduct this experiment we identified twelve 40.5 ha plots in mountain big sagebrush communities that exhibited dense shrub canopy cover and a limited herbaceous understory. Canopy cover was initially estimated from aerial photographs to be greater than 40%. The plots were randomly assigned as Dixie harrow, Lawson aerator, or control (4 replicates each, Figure 4). The plots were flagged and the corners GPS’d to ensure accuracy during treatment. Five random 20 m transects were placed within each plot. Random transects were placed only within mountain big sagebrush. Pre-treatment vegetation sampling for grass, and forb percent cover was conducted in July 2000 and August 2001. Pre-treatment shrub canopy data was collected in August 2001. The treatments were conducted in the fall of 2001.

Because of the mosaic treatment pattern followed, post-treatment vegetation data reflects the sum effect of a treatment (Figure 4). To mimic actual
contracting operations, the contractors who conducted the work were given some general
guidelines regarding the area to be treated. The contractors were not told the actual
location of the vegetation transects. Thus, within each plot, some or all of the
pre-treatment vegetation transects were not treated. This allowed us to evaluate the
cumulative or landscape effects of the treatment on plot vegetation. Post-treatment
vegetation sampling was conducted in June and July of both 2002 and 2003. The 2 time
periods were sampled to determine vegetation characteristics during early and late brood-
rearing. We sampled a total of 160 independent transects within the treated plots (97
treated, 63 untreated).

Shrub canopy was measured using the line intercept method (Connelly et al.
2003). A variation of the point intercept method was used to measure ground cover,
including herbaceous cover (Levy and Madden 1933). This variation consisted of using a
pole with a nail point that was lowered to the soil surface at each meter along the 20
meter transects. As the pole was lowered we recorded which ground cover the point
touched; bare ground, rock, litter, grass, or forb.

The Dixie harrow is a spike-toothed pipe harrow that is pulled behind a large
tractor. The teeth of the harrow are at alternating angles which causes it to grab and rip
the sagebrush out of the ground leaving scarified bare soil. An archaeology survey was
completed by SITLA prior to treatment (R. Torgerson, SITLA biologist, personal
communication). A two-way treatment was applied. Dixie harrow plots were seeded
with a mixture provided by the Utah Division of Wildlife Resources (UDWR) (Appendix
A). Dixie harrow treatment took place on 43.91 ha within the 4 plots (Figure 4). (Note:
The seed mixture failed to germinate post-treatment. This was verified by the fact that
none of the seeded species were found in the vegetation transects during sampling activities).

The Lawson aerator is a large drum aerator that is pulled behind a tractor. The Lawson aerator has a crushing effect on the sagebrush. This crushing effect leaves some sagebrush plants or partial plants alive. The Lawson aerator is presumed not to have an impact on the soil, thus no archaeology survey was done. Lawson aerator treatment took place on 50.97 ha within the 4 plots (Figure 4).

PLP is part of a rotation grazing regime managed by SITLA. Regular grazing regimes were followed in 2000 and 2001, and uniform grazing is assumed. Livestock grazing did not take place in PLP during 2002 and 2003 except for moving cattle down in elevation in the fall of each year.

Data Analysis

Initially, I compared pre-treatment means within treatments and control using a Z-test with a 0.05 alpha level. I then used a variation of a Before-After-Control-Impact (BACI) design to test for treatment effects and to compare treatment to control plots (Underwood 1994). Within the BACI design I used proc MIXED for analyses of variance comparing changes in treatments to control with a 0.05 alpha level (SAS Institute Inc. 2002-2003). Within these analyses I used comparisons of before means to after means to assess overall treatment effect. I also used time period comparison including; before treatment (July 2000 to August 2001, for herbaceous components only), within years (June to July of 2002 and 2003), and between months and years (June and July of 2002 to June and July of 2003). The 4 variables tested were: shrub canopy cover, grass cover, forb cover, and total herbaceous cover (grass and forb cover combined).
Results

Pre-treatment Vegetation Characteristics.--Pre-treatment shrub canopy cover was similar for Dixie harrow ($\bar{x} = 38.2$, SE = 2.9) and Lawson aerator plots ($\bar{x} = 38.9$, SE = 2.9), and between control plots ($\bar{x} = 38.9$, SE = 2.8) and treatments (comparisons; control to Dixie $P = 0.87$, control to Lawson $P = 0.99$, and Dixie to Lawson $P = 0.87$). Pre-treatment grass cover was similar for Dixie harrow ($\bar{x} = 11.1$, SE = 1.7) and Lawson aerator plots ($\bar{x} = 8.0$, SE = 1.7), and between control plots ($\bar{x} = 9.4$, SE = 1.7) and treatments (comparisons; control to Dixie $P = 0.48$, control to Lawson $P = 0.56$, and Dixie to Lawson $P = 0.20$). Pre-treatment forb cover was similar for Dixie harrow ($\bar{x} = 7.9$, SE = 1.9) and Lawson aerator plots ($\bar{x} = 8.1$, SE = 1.9), and control plots ($\bar{x} = 7.1$, SE = 1.9) and treatments (comparisons; control to Dixie $P = 0.76$, control to Lawson $P = 0.72$, and Dixie to Lawson $P = 0.94$). Pre-treatment total herbaceous percent cover was similar for Dixie harrow ($\bar{x} = 18.4$, SE = 1.9) and Lawson aerator plots ($\bar{x} = 15.8$, SE = 1.8), and control plots ($\bar{x} = 16.4$, SE = 1.8) and treatments (comparisons; control to Dixie $P = 0.45$, control to Lawson $P = 0.81$, and Dixie to Lawson $P = 0.32$).

Post Treatment Vegetation Response.--The before to after change in mean comparison of shrub canopy cover showed a reduction for both Dixie harrow ($\bar{x} = 18.4\%$, SE = 2.5, $P = 0.01$) and Lawson aerator ($\bar{x} = 14.3\%$, SE = 2.5, $P = <.01$) compared to control ($\bar{x} = 32.8\%$, SE = 2.5). There was no difference in shrub canopy for treatments ($P = 0.36$). Grass cover with Dixie harrow ($\bar{x} = 13.5\%$, SE = 1.4) increased compared to control ($\bar{x} = 7.6\%$, SE = 1.4, $P = 0.02$), but not Lawson aerator ($\bar{x} = 9.1\%$, SE = 1.4, $P = 0.08$), and did not differ for treatments ($P = 0.45$). Forb cover increased with Dixie harrow ($\bar{x} = 10.4\%$, SE = 1.8, $P = <.01$) compared to control ($\bar{x} = 8.0\%$, SE = 1.8, $P = 0.02$).
November 2005 Draft

6.3%, SE = 1.8) and Lawson aerator (\( \bar{x} = 8.1\%, SE = 1.8, P = 0.01 \)), but did not differ for the control and Lawson aerator (\( P = 0.41 \)). Total herbaceous cover increased with Dixie harrow (\( \bar{x} = 23.9\%, SE = 1.4, P = <.01 \)), but not Lawson aerator (\( \bar{x} = 17.2\%, SE = 1.4, P = 0.08 \)), compared to control (\( \bar{x} = 13.9\%, SE = 1.4 \)) and did not differ for treatments (\( P = 0.07 \)).

*Time period comparisons.*--Time period comparisons are contained in Table 1. Shrub canopy cover with Dixie harrow differed from control in June to July 2002 (\( P = 0.05 \)), and in July 2002 to July 2003 (\( P = 0.01 \)), and from Lawson aerator in July 2002 to July 2003 (\( P = 0.03 \)). Total herbaceous cover with Dixie harrow differed pretreatment (July 2000 to August 2001, \( P = 0.01 \)), and from July 2002 to July 2003 (\( P = 0.01 \)). Total herbaceous cover with Lawson aerator differed from control June to July 2003 (\( P = 0.01 \)), and July 2002 to July 2003 (\( P = 0.01 \)). Grass cover with Dixie harrow differed from control in July to June 2002 (\( P = 0.05 \)), and June 2002 to June 2003 (\( P = 0.01 \)). Grass cover with Lawson aerator differed from control in July to June 2002 (\( P = 0.01 \)), and June 2002 to June 2003 (\( P = 0.01 \)). Forb cover differed for treatments for pretreatment (July 2000 to August 2001, \( P = 0.05 \)). All other time period comparisons for all variables did not differ.

**Discussion**

Dixie harrow and Lawson aerator treatments effectively reduced shrub canopy cover (Figure 5). All plots started with an average shrub canopy cover of \( \sim 38\% \) (Figure 5). Connelly et al. (2000) recommends shrub canopy of 10 to 25\% for brood-rearing areas. Mountain big sagebrush in PLP had become dense even-age stands, which is not optimal brood-rearing habitat for sage-grouse. Dixie harrow and Lawson aerator opened
up the dense shrub canopy cover on average to percentages within habitat guidelines for brood-rearing habitat (Connelly et al. 2000, Figure 5).

Dixie harrow was the most effective treatment at increasing herbaceous cover by reducing shrub canopy. Dixie harrow increased all herbaceous components and specifically forb cover in before to after treatment comparisons (Figures 6, 7, and 8). Forb cover is the most important herbaceous component for sage-grouse broods (Connelly et al. 2000). In before to after treatment comparisons Lawson aerator was ineffective in the 2 years post treatment at increasing herbaceous cover in the grass and forb component. However, Lawson aerator along with Dixie harrow, increased grass cover during the summer of 2002 (Table 1).

In the summer of 2002 southern Utah was impacted by a severe drought (Figure 2). Therefore, the measured grass response to sagebrush treatment may have helped to alleviate the impact of the drought conditions on the herbaceous component. Comparisons from July 2002 to June 2003 showed the greatest increase in herbaceous cover for both Dixie harrow and Lawson aerator (Figures 6, 7, and 8), which is most likely due to an increase in precipitation in 2003 (Figure 2).

Conclusions

Both mechanical treatments effectively reduced shrub canopy cover to within brood-rearing habitat guidelines (Connelly et al. 2000). The Dixie harrow was the most effective treatment at improving herbaceous diversity. Dixie harrow can be used to improve and restore mountain big sagebrush to meet sage-grouse brood-rearing habitat guidelines. The Dixie harrow was the only treatment that increased forb cover within the first two years post-treatment. Jarvis (1973) reported the limiting factor of the Parker
Mountain sage-grouse population was the lack adequate food in brood habitats, except in exceptionally wet years. Forb cover is the most important component of sage-grouse brood-rearing habitat, as it provides food in the form of vegetation mass and insect abundance (Dunn and Braun 1986, Fischer et al. 1996, Apa 1998).

Lawson aerator treatment during the period studied produced mixed results. Although the treatment was effective at reducing shrub canopy cover, it did not generated the anticipated increase in herbaceous understory. This response may have been both a consequences of drought conditions coupled with the rocky soils on Parker Mountain caused problems in aerator operation.

Caution should be exercised in applying these observations at lower elevations, on sites with less annual precipitation, or a different subspecies of big sagebrush. Specific sage-grouse use patterns of the proposed treatment sites should be delineated prior to implementation, as large scale sagebrush treatment projects would not be appropriate within sage-grouse wintering or nesting habitat (Connelly et al 2000).

Literature Cited


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Figure 1. Parker Mountain Study Area, Utah, 2000 – 2003.
Figure 2. Richfield, Utah (~30 miles from study area), Precipitation Data October 1998 to Sept 2003 (Data from http://www.ksvcradio.com/weather.html).
Figure 3. Parker Lake Pasture within Parker Mountain Study Area, Utah, 2000 – 2003.
Figure 4. Experimental Plots, Parker Lake Pasture, Parker Mountain, Utah, 2000 – 2003.
Table 1. Time Period Comparisons, Parker Mountain, Utah, 2000 – 2003.

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a Means from July 2000 to August 2001
b Means from June 2002 to July 2002
c Means from June 2003 to July 2003
d Means from June 2002 to June 2003
e Means from July 2002 to July 2003
Figure 5.

Figure 6.
Figure 7.

Figure 8.
CHAPTER 3
GREATER SAGE-GROUSE USE OF MOUNTAIN BIG SAGEBRUSH HABITAT TREATMENTS

Abstract: Greater sage-grouse inhabit sagebrush steppe communities throughout western North America. These communities occur at different elevations that are subject to diverse climatic and environmental conditions. The Western Association of Fish and Wildlife Agencies in a range-wide assessment of sage-grouse populations cited a need for more specific information on the effects of habitat manipulations on the species. Little management information exists regarding the specific effect of contemporary chemical and mechanical treatments on sage-grouse in higher elevation big mountain sagebrush communities. To evaluate the effect of the Dixie harrow, Lawson aerator, and Tebuthiuron on sage-grouse habitat use in a mountain big sagebrush communities we treated twelve 40.5 ha plots on Parker Mountain located in south central Utah. These plots were located in brood-rearing areas that exhibited ~ 38% sagebrush canopy cover before treatment. The plots were randomly assigned to treatment and control groups. We subsequently monitored greater sage-grouse with pellet counts and birddog flushing surveys of the plots to determine if any differences in use were observed. Sage-grouse use was higher in Tebuthiuron treatments than control and mechanically treated plots. The Tebuthiuron treatments exhibited the greatest increase in forbs. These results suggest that the use of Tebuthiuron to enhance sage-grouse brooding rearing habitat may have a more immediate effect than mechanical treatments in big mountain sagebrush communities. Within treatment and control plots grouse use was highest along edges. When using these treatments, managers should treat patches in large contiguous stands of
sagebrush as opposed to leaving islands of sagebrush in larger treated areas.
Additionally, they should use a mosaic or sinuous treatment pattern designed to
maximize edge effects.

Introduction

Greater sage-grouse (*Centrocercus urophasianus*) are sagebrush (*Artemesia* spp.)
obligates that inhabit western North American shrub-steppe rangelands (Patterson 1952).
Shrub-steppe vegetation has changed over the past 10,000 years (Miller et al. 1994).
European settlement (~150 years ago) has exacerbated the rate of change (Miller et al.

Following World War II increased demands for red meat promoted the conversion
of sagebrush landscapes to grasslands. These conversions likely impacted sage-grouse
populations (Braun et al. 1977). Sagebrush habitat that exhibited the gentlest slopes and
deepest soils were the first areas to be converted (Vale 1974, Beck and Mitchell 2000).
Though many of these sagebrush conversion projects have had detrimental impacts on
sage-grouse, some of the very treatments used could actually benefit sage-grouse (Beck
and Mitchell 2000).

Connelly et al. (2000) and Beck and Mitchell (2000) suggested that using
chemical and mechanical treatments in areas where sagebrush canopy may be limiting the
vegetation understory may improve sage-grouse brood-rearing habitat. They suggested
that the proper application of sagebrush treatment to achieve approximately 10 to 25%
shrub canopy coverage, while increasing the grass and forb component, might have
positive effects.
Previous studies on sage-grouse early brood-rearing habitat have shown a more open shrub canopy cover (~ 15%) (Martin 1970, Wallestad 1971) and high grass and forb cover (Sveum et al. 1998). Forbs and insect abundance and diversity are important components of early brood-rearing areas (Dunn and Braun 1986). Apa (1998) reported broods using areas with double the amount of forb cover compared to independent sites. Ants (Hymenoptera) and beetles (Coleoptera) are especially important food sources for chicks (Fischer et al. 1996). Late brood-rearing takes place in more mesic habitats, where desiccation of herbaceous plants is not as severe (Klebenow 1969).

Autenrieth (1981) reported that chemical treatments in early spring might be used to increase herbaceous cover, thereby enhancing mesic brood rearing habitat. Johnson et al. (1996) and Olson and Whitson (2002) reported that use of the chemical Tebuthiuron could enhance vegetation composition and diversity in big sagebrush communities.

Pyrah (1972) reported sage-grouse use (based on pellet counts) in wintering habitat declined proportionally to the severity of the treatment. Wallestad (1975) reported much lower increases in lek counts where populations were close (< 0.5 km) to sagebrush treatment compared to leks farther away (> 4 km), and a decrease in strutting males where there was a 31% loss of suitable habitat. However, Pyle and Crawford (1996) reported sage-grouse use of mesic sagebrush habitat increased after small areas were burned. Commons et al. (1999) reported total male sage-grouse counts doubling in areas where pinyon (Pinus edulis)-juniper (Juniperus spp.) was removed. Danvir (2002) suggested that mechanical treatments within dense stands of big sagebrush may have the most positive impact on sage-grouse in lower elevation sagebrush-steppe communities in
northern Utah. To date few replicated studies have been published on greater sage-grouse response to habitat manipulation in higher elevation sagebrush communities.

**Study Area**

Parker Mountain is located in Garfield, Sevier, Piute, and Wayne counties of Utah and encompasses both the Aquarius and Awapa Plateaus (Figure 1). Parker Mountain encompasses ~ 107,478 hectares; 21,685 ha managed by the U.S. Forest Service (USFS), 36,398 ha by Bureau of Land Management (BLM), 43,863 ha by Utah School and Institutional Trust Lands Administration (SITLA), and 5,532 ha is privately owned (Figure 1). The predominant land use in the area is grazing by domestic livestock. The sagebrush habitat on the Parker Mountain is one of the largest contiguous tracts in Utah. Because of its remoteness, Parker Mountain has escaped development and land use pressures occurring at lower elevations. Parker Mountain continues to be one of the few remaining areas in Utah with relatively stable numbers of greater sage-grouse (Beck et al. 2003).

Annual precipitation on Parker Mountain varies by elevation ranging from 25 to 51 cm per year. Precipitation comes mostly in winter in the form of snow and in late summer monsoons (Figure 2). A few natural springs occur at higher elevations (> 2700 m). These springs have been augmented by > 80 water developments. These water developments have improved livestock distribution during the grazing season and provide seasonal water sources for wildlife.

The Parker Lake Pasture (PLP) was selected as an experimental study area. PLP consists of ~ 2000 ha (Figure 3) and is between 2700m and 2900m elevation. This area generally receives more precipitation (~ 40 to 51 cm/yr). This area is used by sage-
grouse primarily during early and late brood-rearing periods, although limited nesting takes place as well (Chi 2004).

Lower lying draws in the study area are dominated by mountain big sagebrush (*A. tridentata vaseyana*). Silver sagebrush (*A. cana*) also occurs in the more mesic bottoms. Hill sides and tops are dominated by black sagebrush (*A. nova*). Common forb species include cinquefoil (*Potentilla* spp.), phlox (*Phlox* spp.), dandelion (*Taraxacum* spp.), lupine (*Lupinus* spp.), daisy (*Erigeron* spp.), penstemon (*Penstemon* spp.), and milkvetch (*Astragalus* spp.). Common grass species include wheatgrass (*Agropyron* spp.), bluegrass (*Poa* spp.), gramma grass (*Bouteloua* spp.), squirrel tail grass (*Hordeum* spp.), and June grass (*Koeleria* spp.). Also dry land sedge (*Carex siccata*) is common in PLP.

**Methods**

Sixteen experimental plots (40.5 ha) were delineated in the study area in 2000 (Figure 4). The plots exhibited ~38% sagebrush canopy cover. The plots were randomly assigned to treatment and control. Treatments included Dixie harrow and Lawson aerator (mechanical) and Tebuthiuron (chemical). The Tebuthiuron (1.6 kg/ha at 0.3 active ingredient) was flown onto 4 experimental plots in the fall of 2000. The application rate was designed to achieve ~60% reduction in sagebrush canopy (Chi 2004). The Dixie harrow and Lawson aerator treatments were conducted in the fall of 2001. A two way treatment of Dixie harrow was applied. A total of 43.91 ha and 50.97 ha of mountain big sagebrush were treated in Dixie harrow and Lawson aerator plots, respectively. Because Tebuthiuron results in partial kill of sagebrush and the herbicide pellets were applied over the entire plot, we were not able to determine the exact area
affected. Tebuthiuron may also have a delayed effect because the herbicide can be active up to 3 years.

Prior to conducting the Dixie harrow treatments an archeological survey was completed within the plots. The survey yielded no significant findings. Lawson aerator was assumed to not impact the soil surface, and therefore no archeological survey was done. In addition, because Utah prairie dogs (*Cynomys parvidens*) were believed to have historically inhabited the area, we consulted with the USFWS. The USFWS issued a no significant impact finding thus allowing the project to proceed.

To determine sage-grouse use we surveyed all the plots (control, Dixie harrow, Lawson aerator, and Tebuthiuron) for sage-grouse pellets. Each plot was divided into thirds to spread transects throughout the plot, and a random transect was placed within each third. Transects were walked slowly while researchers recorded pellet type (regular pellet or cecal), number of pellets or cecal droppings per cluster, distance of pellets to centerline (meters), estimated distance of pellet to edge of habitat type (meters), and habitat type the pellet cluster was found in. The edge of habitat was determined by a change in species of dominant shrub, or abrupt change like edge of a treated area or road. Roost piles were counted separately, but equaled one cluster occurrence.

Birddog surveys, to assess sage-grouse use in general and brood use specifically, were conducted mid to late July and early August of both 2003 and 2004. Each plot was surveyed twice annually. The entire plot was covered by a dog in ~ 1.5 hours. Both sampling times in 2003 were completed by one of two dogs. In 2004 the first survey was done using the same one of two dogs, while the second was conducted by 16 dogs, each covering a plot all during the same time period. This birddog survey was conducted in
one morning from 8:00 am to 9:30 am. This was done to assess the risk of double sampling, especially where plots were located in such close proximity. Utah Chukar Foundation members volunteered their time and most experienced dogs for the second 2004 survey. Grouse were flushed and classified as chick, hen, male, or unknown. Broods were counted as a hen with any number of chicks. If more than one hen flushed with multiple chicks, the number of broods equaled the number of hens. The survey effort was similar for all plots.

Vegetation was measured in all experimental plots in June and July of 2003 and 2004 along 5 random 20 m transects per plot using Daubenmire frames (Daubenmire 1959) for herbaceous cover (forbs and grasses) and line intercept (Connelly et al. 2003) for percent shrub cover. Forb cover being the most important component of brood-rearing habitat (Connelly et al. 2000), was assessed for overall abundance and abundance of specific genera to determine if it caused any difference in use.

**Data Analyses**

For pellet counts, cluster densities and probability of detection by treatment type were calculated using program DISTANCE (Buckland et al. 2001), then cluster densities and probabilities of detection were compared between treatments, and treatments to control using a Z-test with a 0.05 alpha level. Bird dog surveys were analyzed using proc MIXED for analyses of variance with a 0.05 alpha level (SAS Institute Inc. 2002-2003). Distance to edge data was graphed in a histogram format for pellets found in untreated big sagebrush (UTRA) or within treated areas (TRA) for each treatment type and control. For herbaceous vegetation, forb and grass cover means were compared between treatments and controls and among treatments using a Z-test, with a 0.05 alpha level.
Results

Sage-grouse pellets were found in black sagebrush, mountain big sagebrush, silver sagebrush, aspen (*Populus tremuloides*), and the treated areas within each plot. Only black sagebrush, mountain big sagebrush, and treatment area pellet data were analyzed because of the low sample sizes found in the other habitat types. Most of the pellets found in black sagebrush were roost piles.

Pellet cluster density was highest in Tebuthiuron plots (Table 1 and 2). Lawson aerator and Dixie harrow treatments pellet counts were higher than control plots (Table 1), but did not differ statistically (Table 2 and Figure 5). Probability of detection was highest in Lawson aerator plots (Table 1, Table 2, and Figure 6). Detection probabilities were similar for all plots (Table 2). Detection probabilities ranged between 24.8 to 31.2%.

For distance-to-edge frequency data for the Dixie harrow TRA and UTRA exhibited a marked drop off between ~ 20 and 30 meters (Appendix A). Lawson aerator TRA extended out to 80 m, and a marked drop off was not detected, though for UTRA a drop off was detected between ~ 30 and 40 m (Appendix A). Tebuthiuron TRA showed a drop off between ~ 40 and 50 m, though it wasn’t as dramatic (Appendix A). Tebuthiuron UTRA showed a drop off between ~ 20 and 30 m, similar to other areas (Appendix A). Interestingly, in the control areas, the grouse were still using mountain big sagebrush habitat within 30 m of the edge (Appendix A).

During birddog surveys, more grouse overall and broods specifically were flushed in the Tebuthiuron plots (Table 3 and Figures 7 and 8). Total number of flushed grouse
in general and broods specifically in all treatments were higher than control, though only Tebuthiuron plots differed statistically from control (Tables 3 and 4).

Year effects were also observed for brood counts. More broods were flushed in 2004 \( (F = 6.72, P = 0.0236) \) than 2003 (Table 3). Total grouse counted did not differ by year \( (F \text{ value} = 0.49, P = 0.4959; \text{Table 3, Figures 9 and 10}) \).

For the birddog surveys of plots done on multiple days in 2004 we counted 120 sage-grouse. For the survey done within the same day and time period in 2004 we counted 121 sage-grouse. Hence, I assume we did not double sample while conducting birddog surveys on multiple days.

For shrub cover, control plots maintained canopy cover between 30 \% and 38 \%, while all treatments had shrub canopy cover between 12 \% and 25 \%, which approximated published guidelines for shrub canopy in brood-rearing habitats (Figure 11, Connelly et al. 2000). For forb cover, Tebuthiuron treatments were higher than control and Lawson aerator \( (P \text{ value} = 0.0003, \text{and 0.0040 respectively}) \). All other comparisons for forb cover did not differ. For grass cover Dixie harrow and Tebuthiuron treatments were higher than Lawson aerator \( (P \text{ value} = 0.0160, \text{and 0.0466 respectively}) \). All other comparisons, including all treatments to controls, did not differ for grass cover. The Tebuthiuron plots exhibited the highest dandelion \( (\text{Taraxacum spp.}) \) densities and percent cover when compared to the other plots (Appendix B).

**Discussion**

For pellet counts, detection probabilities differed between treatment types. We had anticipated that the control and Tebuthiuron plots would have lower probabilities of detection because of greater intact shrub canopies. This was true, but detection
probability was only slightly lower because most pellets were seen within 1 or 2 meters of the transect centerline.

Based on pellet count data and birddog survey data, the Tebuthiuron plots were clearly preferred sage-grouse use areas (Table 1, Figure 5). Based on birddog surveys, sage-grouse broods overwhelmingly used Tebuthiuron plots. Birddog surveys were useful in addition to pellet counts because we were able to classify most birds according to chick or adult, and sex most adults.

Forb response, particularly dandelion (Appendix B), may be the reason broods and sage-grouse in general preferred the Tebuthiuron plots. This forb is highly palatable for sage-grouse (Klebenow and Gray 1968, Wallestad et al. 1975, Johnson et al. 1990, Peterson 1970), and is probably the reason for Tebuthiuron plot preference. Additionally, the Tebuthiuron treatments left “sagebrush skeletons” which in addition to providing a barrier to avian predators, may have served to intercept more moisture. In effect, they could have created more ameliorated micro environments by providing moisture, shade, and blocking wind, thus enhancing forb response. Also, while providing abundant forbs, these plots exhibited 18% to 25% shrub canopy cover. The two mechanical treatments offered similar shrub cover on average for brood-rearing, but exhibited lower forb abundance. Additionally, mechanical treatments created large distinct patches or edges, while the Tebuthiuron treatment created a multitude of “feathered” or less distinct edges.

Tebuthiuron distance-to-edge data need to be assessed differently. These treatments exhibited partial kill of mountain big sagebrush making it difficult to determine edge within the plots when compared to Dixie harrow and Lawson aerator plots. If partial kill of sagebrush results from this treatment, distance to edge of intact
sagebrush may not be as important. This partial kill resulted from the low rate of Tebuthiuron applied.

Distance-to-edge information helps in determining the sage-grouse’s preference for habitat, even though the area was not treated. Frequency data for UTRA in all plots showed a decline in pellets after 20 m from edge and almost none after 40 m, suggesting an edge preference. The distance-to-edge habitat data for pellet counts can help determine sage-grouse preferences for treated areas. If the assumption is made that sage-grouse pellet location is associated with use, then these data could be used as guidelines for future treatments of mountain big sagebrush in brood-rearing areas on Parker Mountain.

A caution is in order regarding distance-to-edge data. Data may relate to the shape of the sagebrush stand, as many of the stands of mountain big sagebrush are long and narrow (following drainages) in PLP, though most exceed widths of ~ 100m. This width most likely makes the distance-to-edge data reported herein relate more to sage-grouse preference than the shape of the sagebrush stand.

Conclusions

Sage-grouse on Parker Mountain are demonstrating a clear preference for the treatment plots, especially Tebuthiuron plots, for brood-rearing and general use. This preference can be attributed to increased herbaceous cover, particularly forb cover due to a reduced shrub cover. However, even in the mechanically treated plots, sage-grouse still preferred to use the edge of the treatments where intact sagebrush cover was still available. These observations need to be validated by other studies at different elevations.
As the vegetation matures in the treated areas, sage-grouse may switch their preference of treatment type over time. We recommend that sage-grouse use data on Parker Mountain continue to be collected and analyzed along with vegetation data to determine how the birds respond to these treatments over time. This type of information will be important as managers seek long-term solutions to the issue of sage-grouse conservation.

Management Implications

When applying Tebuthiuron for sage-grouse brood-rearing habitat treatment, a low rate of active ingredient that results in partial kill of sagebrush is most desirable. Soil depth, sagebrush vigor, precipitation regimes, and other environmental conditions would affect the resulting percent kill of sagebrush. Pre-treatment data measuring these various factors would help guide the best application rate.

Distance-to-edge data may help guide managers to a reasonable mechanical treatment design for brood-rearing habitat on Parker Mountain. The frequency data shown in the histograms (Appendix A) may be of more use in determining distance to edge for treatments than “mean distance to edge” as histograms show the distance where sage-grouse frequency of use decreases dramatically. Recommendations for treatment width and untreated width are in Table 5.

These observations support a management strategy that creates a mosaic of different aged stands of sagebrush. This strategy is probably most desirable in brood-rearing habitats on Parker Mountain. Rather than treat large blocks at a time, we suggest an alternative strategy of treating smaller patches or plots. More sinuous treatment designs with treatment width following the above guidelines when using the Dixie
harrow or Lawson aerator would create more edge habitat, and may be better for sage-grouse using the area.

The PLP treatments were completed on a small scale in a vast expanse of sagebrush habitat. Additional research may be needed to document the effect of large-scale treatment. However, our work seems to suggest that the use of small treatments within a large-scale area of continuous sagebrush habitat may create resource patches which are particularly attractive to broods. Treatments sites were selected because they were within known brood-rearing habitat that was receiving little documented use. Habitat selection of specific areas by the local sage-grouse population needs to be identified before implementing such treatments. It would not be appropriate to do large-scale treatment of sagebrush in wintering or nesting habitat (Connelly et al. 2000).

**Recommendations for Future Research**

When conducting pellet counts, I detected most pellets within 1 or 2 meters from the transect line. I measured distances to transect in large units (meters), and would have had better model fit and less variability if I would have used decimeters or centimeters.

When conducting birddog surveys, the individual dog’s abilities must be questioned. All dogs are not equal, and those with sage-grouse experience are preferred. I tried to minimize the number of different dogs (for 3 surveys I used one of two dogs) used for surveys, though when I used 16 dogs at once, I asked for the most experienced dogs. I used pointing dogs, though flushing dogs may work as well, as long as they stay within a reasonable distance from the observer. Most of the time, pointing dogs allowed the observer to approach very close to flushing grouse, which made classification possible. Additionally, I didn’t begin birddog surveys until all broods observed through
my course of research reached an age where they were capable of sustained flight. I used relatively young dogs (< 4 years old), and didn’t want to risk a dog catching a chick. Thus my surveys were taken within the late brood-rearing period. If I had absolutely “broke” (completely trained) dogs I would have liked to look for broods during the early brood-rearing period as well.

**Literature Cited**


Connelly, J. W., K. P. Reese, and M. A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. Station Bulletin 80, College of Natural Resources Experiment Station, Moscow, Idaho.


Figure 1. Parker Mountain Study Area, Utah, 2002-2004.
Figure 2. Richfield UT (~ 30 miles from Parker Mountain Study Area), Precipitation Data October 1998 to Sept 2003, Rich (Data from http://www.ksvcradio.com/weather.html)
Figure 3. Parker Lake Pasture, Parker Mountain, Utah, 2002-2004.
Figure 4. Plots and Treatment Type within Parker Lake Pasture, Parker Mountain, Utah, 2002-2004.
Table 1. Pellet count probability of detection and cluster densities, Parker Mountain, Utah, 2003-2004.

<table>
<thead>
<tr>
<th>Plot Type</th>
<th>Total # of Clusters</th>
<th>Probability of Detection</th>
<th>Clusters</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>135</td>
<td>0.255</td>
<td>23.38 6.46</td>
</tr>
<tr>
<td>D</td>
<td>225</td>
<td>0.274</td>
<td>36.26 15.13</td>
</tr>
<tr>
<td>L</td>
<td>207</td>
<td>0.312</td>
<td>29.33 9.04</td>
</tr>
<tr>
<td>T</td>
<td>433</td>
<td>0.248</td>
<td>77.12 20.71</td>
</tr>
</tbody>
</table>

aP(d) = Probability of Detection  
bSE = Standard Error  
cVar = Variance  
dDs = Density (per acre)


<table>
<thead>
<tr>
<th>Comparison of Treatments</th>
<th>Cluster Density</th>
<th>Probability of Detection</th>
</tr>
</thead>
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<tr>
<td></td>
<td>Z value</td>
<td>P value</td>
</tr>
<tr>
<td>C - D</td>
<td>-0.783</td>
<td>0.4336</td>
</tr>
<tr>
<td>C - L</td>
<td>-0.536</td>
<td>0.5922</td>
</tr>
<tr>
<td>C - T</td>
<td>-2.477</td>
<td>0.0132</td>
</tr>
<tr>
<td>D - L</td>
<td>0.393</td>
<td>0.6942</td>
</tr>
<tr>
<td>D - T</td>
<td>-1.593</td>
<td>0.1112</td>
</tr>
<tr>
<td>L - T</td>
<td>-2.115</td>
<td>0.0344</td>
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</table>


Figure 5.
Figure 6.


<table>
<thead>
<tr>
<th>Treatment or Year</th>
<th>n</th>
<th>Mean</th>
<th>SE</th>
<th>n</th>
<th>Mean</th>
<th>SE</th>
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</tr>
<tr>
<td>C</td>
<td>6</td>
<td>0.75</td>
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<td>0.13</td>
</tr>
<tr>
<td>D</td>
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<td>4.28</td>
<td>6</td>
<td>0.75</td>
<td>0.41</td>
</tr>
<tr>
<td>L</td>
<td>109</td>
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<td>7.85</td>
<td>7</td>
<td>0.88</td>
<td>0.48</td>
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<tr>
<td>T</td>
<td>252</td>
<td>31.5</td>
<td>7.63</td>
<td>38</td>
<td>4.75</td>
<td>1.21</td>
</tr>
<tr>
<td>2003</td>
<td>205</td>
<td>12.81</td>
<td>4.54</td>
<td>16</td>
<td>1</td>
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<tr>
<td>2004</td>
<td>241</td>
<td>15.06</td>
<td>5.31</td>
<td>36</td>
<td>2.25</td>
<td>0.81</td>
</tr>
</tbody>
</table>

\(^a\)Any grouse, male, hen, unknown, or chick

\(^b\)Broods equaled 1 or more chicks with a hen, if more than one hen was flushed with multiple chicks broods equaled the number of hens

\(^c\)Standard Error
Total Sage-grouse Flushed with Birddogs by Treatment (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

Figure 7.

Sage-grouse Broods Flushed with Birddogs by Treatment (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

Figure 8.
Figure 9. Total Sage-grouse Flushed with Birddogs by Year (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

Figure 10. Sage-grouse Broods Flushed with Birddogs by Year (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

<table>
<thead>
<tr>
<th>Comparisons of Treatments</th>
<th>Total Grouse</th>
<th></th>
<th>Total Broods</th>
<th></th>
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<td></td>
<td>t value</td>
<td>P value</td>
<td>t value</td>
<td>P value</td>
</tr>
<tr>
<td>C - D</td>
<td>-1.58</td>
<td>0.1404</td>
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<td>0.2962</td>
</tr>
<tr>
<td>C - L</td>
<td>-1.85</td>
<td>0.0887</td>
<td>-1.39</td>
<td>0.1902</td>
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<tr>
<td>C - T</td>
<td>-4.04</td>
<td>0.0017</td>
<td>-5.41</td>
<td>0.0002</td>
</tr>
<tr>
<td>D - L</td>
<td>-0.27</td>
<td>0.7888</td>
<td>-0.30</td>
<td>0.772</td>
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<tr>
<td>D - T</td>
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<td>0.0302</td>
<td>-4.31</td>
<td>0.001</td>
</tr>
<tr>
<td>L - T</td>
<td>-2.18</td>
<td>0.0496</td>
<td>-4.02</td>
<td>0.0017</td>
</tr>
</tbody>
</table>

a Any grouse, male, hen, unknown, or chick
b Broods equaled 1 or more chicks with a hen, if more than one hen was flushed with multiple chicks broods equaled the number of hens

Figure 11.
Table 5. Recommendations for creating distance to edge (double the width of dropped off use) for Dixie harrow and Lawson aerator in mountain big sagebrush treatments in sage-grouse brood-rearing habitat (Based on Figures in Appendix A), Parker Mountain, Utah, 2004.

<table>
<thead>
<tr>
<th></th>
<th>(^a)UTRA</th>
<th>(^b)TRA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dixie</td>
<td>40-60 m</td>
<td>40-60 m</td>
</tr>
<tr>
<td>Lawson</td>
<td>60-80 m</td>
<td>160 m+</td>
</tr>
</tbody>
</table>

\(^a\)UTRA-width of intact mountain big sagebrush

\(^b\)TRA-width of treatment
Appendix A: Distance-to-edge Histograms of Pellet Count Data

Dixie UTRA Histogram for Distance to Edge, Parker Mountain, Utah, 2003-2004.

Dixie TRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.


Spike TRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.
## Appendix B: Relative Forb Cover Abundance

Table 1. Control Forb data using Daubenmire Frames in June and July 2003 and 2004

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Genus</th>
<th>Mean % Cover</th>
<th>Stddev</th>
<th>°Freq.</th>
<th>°Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>penstemon</td>
<td><em>Penstemon</em> spp.</td>
<td>2.70</td>
<td>1.78</td>
<td>66</td>
<td>178.00</td>
</tr>
<tr>
<td>cinquefoil</td>
<td><em>Potnetilla</em> spp.</td>
<td>2.82</td>
<td>2.31</td>
<td>46</td>
<td>129.60</td>
</tr>
<tr>
<td>phlox</td>
<td><em>Phlox</em> spp.</td>
<td>1.90</td>
<td>1.90</td>
<td>39</td>
<td>74.00</td>
</tr>
<tr>
<td>lupine</td>
<td><em>Lupinus</em> spp.</td>
<td>1.93</td>
<td>1.95</td>
<td>38</td>
<td>73.20</td>
</tr>
<tr>
<td>astragolus</td>
<td><em>Astragalus</em> spp.</td>
<td>1.35</td>
<td>1.12</td>
<td>52</td>
<td>70.40</td>
</tr>
<tr>
<td>daisy</td>
<td><em>Erigeron</em> spp.</td>
<td>1.64</td>
<td>1.44</td>
<td>43</td>
<td>70.40</td>
</tr>
<tr>
<td>dandelion</td>
<td><em>Taraxacum</em> spp.</td>
<td>1.70</td>
<td>2.01</td>
<td>35</td>
<td>59.40</td>
</tr>
<tr>
<td>clover</td>
<td><em>Trifolium</em> spp.</td>
<td>1.33</td>
<td>1.30</td>
<td>11</td>
<td>14.60</td>
</tr>
<tr>
<td>buckwheat</td>
<td><em>Eriogonum</em> spp.</td>
<td>1.07</td>
<td>0.80</td>
<td>11</td>
<td>11.80</td>
</tr>
<tr>
<td>pussytoes</td>
<td><em>Antennaria</em> spp.</td>
<td>1.05</td>
<td>0.91</td>
<td>11</td>
<td>11.60</td>
</tr>
<tr>
<td>pepperweed</td>
<td><em>Lepidium</em> spp.</td>
<td>1.27</td>
<td>1.85</td>
<td>9</td>
<td>11.40</td>
</tr>
<tr>
<td>unknown</td>
<td>N/A</td>
<td>0.09</td>
<td>0.79</td>
<td>12</td>
<td>10.80</td>
</tr>
<tr>
<td>indian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paintbrush</td>
<td><em>Castilleja</em> spp.</td>
<td>0.84</td>
<td>0.26</td>
<td>5</td>
<td>4.20</td>
</tr>
<tr>
<td>arabis spp.</td>
<td><em>Arabis</em> spp.</td>
<td>0.70</td>
<td>0.46</td>
<td>5</td>
<td>3.60</td>
</tr>
<tr>
<td>knotweed</td>
<td><em>Polygonum</em> spp.</td>
<td>0.40</td>
<td>0.00</td>
<td>2</td>
<td>0.80</td>
</tr>
</tbody>
</table>

(n=15) °Total Weight: 723.80

°the number of transects the genus was detected in out of 80 total transects

°the mean % cover multiplied by the frequency, which gives a weighted value as to that genus’s contribution to the vegetative composition of the forb community

°for comparative purposes against other treatment types and control, it is a total of the weights for all genera, this value shows a relative weighted value for forb % cover for each treatment type
Table 2. Tebuthiuron Forb data using Daubenmire Frames in June and July 2003 and 2004

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Genus</th>
<th>Mean % Cover</th>
<th>Stddev</th>
<th>aFreq.</th>
<th>bWeight</th>
</tr>
</thead>
<tbody>
<tr>
<td>dandelion</td>
<td>Erigeron spp.</td>
<td>5.15</td>
<td>7.03</td>
<td>72</td>
<td>370.60</td>
</tr>
<tr>
<td>lupine</td>
<td>Lupinus spp.</td>
<td>4.49</td>
<td>4.80</td>
<td>62</td>
<td>278.60</td>
</tr>
<tr>
<td>cinquefoil</td>
<td>Potnetilla spp.</td>
<td>2.79</td>
<td>2.18</td>
<td>68</td>
<td>190.00</td>
</tr>
<tr>
<td>penstemen</td>
<td>Penstemon spp.</td>
<td>2.85</td>
<td>2.90</td>
<td>55</td>
<td>156.80</td>
</tr>
<tr>
<td>phlox</td>
<td>Phlox spp.</td>
<td>1.76</td>
<td>1.44</td>
<td>44</td>
<td>77.60</td>
</tr>
<tr>
<td>astragolus</td>
<td>Astragolus spp.</td>
<td>1.55</td>
<td>1.99</td>
<td>41</td>
<td>63.40</td>
</tr>
<tr>
<td>arabis spp</td>
<td>Arabis spp.</td>
<td>1.35</td>
<td>1.06</td>
<td>37</td>
<td>50.00</td>
</tr>
<tr>
<td>groundsmoke</td>
<td>Gayophytum spp.</td>
<td>1.93</td>
<td>1.55</td>
<td>24</td>
<td>46.33</td>
</tr>
<tr>
<td>daisy</td>
<td>Erigeron spp.</td>
<td>1.20</td>
<td>1.15</td>
<td>25</td>
<td>30.00</td>
</tr>
<tr>
<td>buckwheat</td>
<td>Eriogonum spp.</td>
<td>1.25</td>
<td>0.77</td>
<td>13</td>
<td>16.20</td>
</tr>
<tr>
<td>pepperweed</td>
<td>Lepidium spp.</td>
<td>0.84</td>
<td>0.70</td>
<td>19</td>
<td>16.00</td>
</tr>
<tr>
<td>pussytoes</td>
<td>Antennaria spp.</td>
<td>1.63</td>
<td>1.20</td>
<td>7</td>
<td>11.40</td>
</tr>
<tr>
<td>unknown</td>
<td>N/A</td>
<td>0.87</td>
<td>0.56</td>
<td>11</td>
<td>9.60</td>
</tr>
<tr>
<td>clover</td>
<td>Trifolium spp.</td>
<td>1.27</td>
<td>0.94</td>
<td>6</td>
<td>7.60</td>
</tr>
<tr>
<td>GF Keno</td>
<td>Chenopodium spp.</td>
<td>0.60</td>
<td>0.23</td>
<td>4</td>
<td>2.40</td>
</tr>
<tr>
<td>indian</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>paintbrush</td>
<td>Castilleja spp.</td>
<td>1.10</td>
<td>0.71</td>
<td>2</td>
<td>2.20</td>
</tr>
<tr>
<td>scarlet gilia</td>
<td>Gilia spp.</td>
<td>1.00</td>
<td>0.85</td>
<td>2</td>
<td>2.00</td>
</tr>
<tr>
<td>deathcamas</td>
<td>Zigadenus spp.</td>
<td>0.60</td>
<td>N/A</td>
<td>1</td>
<td>0.60</td>
</tr>
<tr>
<td>thistle</td>
<td>Cirsium spp.</td>
<td>0.60</td>
<td>N/A</td>
<td>1</td>
<td>0.60</td>
</tr>
<tr>
<td>Parsely</td>
<td>Lomatium spp.</td>
<td>0.40</td>
<td>N/A</td>
<td>1</td>
<td>0.40</td>
</tr>
</tbody>
</table>

(n=20)

| Total Weight: 1332.33 |

a the number of transects the genus was detected in out of 80 total transects
b the mean % cover multiplied by the frequency, which gives a weighted value as to that genus’s contribution to the vegetative composition of the forb community
c for comparative purposes against other treatment types and control, it is a total of the weights for all genera, this value shows a relative weighted value for forb % cover for each treatment type
Table 3. Dixie Forb data using Daubenmire Frames in June and July 2003 and 2004

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Genus</th>
<th>Mean % Cover</th>
<th>Stddev</th>
<th>^aFreq.</th>
<th>^bWeight</th>
</tr>
</thead>
<tbody>
<tr>
<td>phlox</td>
<td>Phlox spp.</td>
<td>5.10</td>
<td>3.20</td>
<td>48</td>
<td>245.00</td>
</tr>
<tr>
<td>Cinquefoil</td>
<td>Potnetilla spp.</td>
<td>2.91</td>
<td>2.33</td>
<td>54</td>
<td>157.20</td>
</tr>
<tr>
<td>dandelion</td>
<td>Taraxacum spp.</td>
<td>2.45</td>
<td>3.59</td>
<td>48</td>
<td>117.60</td>
</tr>
<tr>
<td>lupine</td>
<td>Lupinus spp.</td>
<td>2.47</td>
<td>2.70</td>
<td>38</td>
<td>94.00</td>
</tr>
<tr>
<td>penstemon</td>
<td>Penstemon spp.</td>
<td>2.30</td>
<td>2.41</td>
<td>40</td>
<td>91.80</td>
</tr>
<tr>
<td>daisy</td>
<td>Erigeron spp.</td>
<td>1.49</td>
<td>1.18</td>
<td>46</td>
<td>68.40</td>
</tr>
<tr>
<td>pussytoes</td>
<td>Antennaria spp.</td>
<td>2.64</td>
<td>2.45</td>
<td>19</td>
<td>50.20</td>
</tr>
<tr>
<td>astragolus</td>
<td>Astragolus spp.</td>
<td>0.96</td>
<td>0.63</td>
<td>34</td>
<td>32.60</td>
</tr>
<tr>
<td>groundsmoke</td>
<td>Gayophytum spp.</td>
<td>1.87</td>
<td>1.69</td>
<td>12</td>
<td>22.40</td>
</tr>
<tr>
<td>buckwheat</td>
<td>Eriogonum spp.</td>
<td>1.06</td>
<td>0.79</td>
<td>21</td>
<td>22.20</td>
</tr>
<tr>
<td>thistle</td>
<td>Cirsium spp.</td>
<td>1.88</td>
<td>1.52</td>
<td>8</td>
<td>15.00</td>
</tr>
<tr>
<td>pepperweed</td>
<td>Lepidium spp.</td>
<td>0.54</td>
<td>0.33</td>
<td>18</td>
<td>9.80</td>
</tr>
<tr>
<td>unknown</td>
<td>N/A</td>
<td>1.08</td>
<td>1.10</td>
<td>8</td>
<td>8.60</td>
</tr>
<tr>
<td>GF Keno</td>
<td>Chenopodium spp.</td>
<td>2.67</td>
<td>2.89</td>
<td>3</td>
<td>8.00</td>
</tr>
<tr>
<td>flax</td>
<td>Linum spp.</td>
<td>2.80</td>
<td>0.57</td>
<td>2</td>
<td>5.60</td>
</tr>
<tr>
<td>hymenoxy</td>
<td>Actinea spp.</td>
<td>2.10</td>
<td>0.42</td>
<td>2</td>
<td>4.20</td>
</tr>
<tr>
<td>Parsley</td>
<td>Lomatium spp.</td>
<td>1.70</td>
<td>2.12</td>
<td>2</td>
<td>3.40</td>
</tr>
<tr>
<td>groundsel</td>
<td>Senecio spp.</td>
<td>1.40</td>
<td>1.41</td>
<td>2</td>
<td>2.80</td>
</tr>
<tr>
<td>Aster</td>
<td>Aster spp.</td>
<td>1.20</td>
<td>N/A</td>
<td>1</td>
<td>1.20</td>
</tr>
<tr>
<td>clover</td>
<td>Trifolium spp.</td>
<td>0.80</td>
<td>N/A</td>
<td>1</td>
<td>0.80</td>
</tr>
<tr>
<td>alunroot</td>
<td>Heuchera spp.</td>
<td>0.30</td>
<td>0.14</td>
<td>2</td>
<td>0.60</td>
</tr>
<tr>
<td>arabis spp.</td>
<td>Arabis spp.</td>
<td>0.40</td>
<td>N/A</td>
<td>1</td>
<td>0.40</td>
</tr>
<tr>
<td>corydalis</td>
<td>Corydalis spp.</td>
<td>0.40</td>
<td>N/A</td>
<td>1</td>
<td>0.40</td>
</tr>
<tr>
<td>phlox</td>
<td>Phlox spp.</td>
<td>0.40</td>
<td>N/A</td>
<td>1</td>
<td>0.40</td>
</tr>
</tbody>
</table>

^a the number of transects the genus was detected in out of 80 total transects

^b the mean % cover multiplied by the frequency, which gives a weighted value as to that genus’s contribution to the vegetative composition of the forb community

^c for comparative purposes against other treatment types and control, it is a total of the weights for all genera, this value shows a relative weighted value for forb % cover for each treatment type

|   |   | Total Weight: 962.60 |   |   |   |
Table 4. Lawson Forb data using Daubenmire Frames in June and July 2003 and 2004

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Genus</th>
<th>Mean % Cover</th>
<th>Stddev</th>
<th>aFreq.</th>
<th>bWeight</th>
</tr>
</thead>
<tbody>
<tr>
<td>phlox</td>
<td><em>Phlox</em> spp.</td>
<td>3.65</td>
<td>3.20</td>
<td>43</td>
<td>157.00</td>
</tr>
<tr>
<td>lupine</td>
<td><em>Lupinus</em> spp.</td>
<td>2.91</td>
<td>2.82</td>
<td>43</td>
<td>125.20</td>
</tr>
<tr>
<td>dandelion</td>
<td><em>Taraxacum</em> spp.</td>
<td>1.64</td>
<td>3.28</td>
<td>44</td>
<td>72.20</td>
</tr>
<tr>
<td>Cinquefoil</td>
<td><em>Potnetilla</em> spp.</td>
<td>2.08</td>
<td>2.00</td>
<td>34</td>
<td>70.80</td>
</tr>
<tr>
<td>penstemon</td>
<td><em>Penstemon</em> spp.</td>
<td>1.67</td>
<td>1.89</td>
<td>41</td>
<td>68.60</td>
</tr>
<tr>
<td>astragolus</td>
<td><em>Astragalus</em> spp.</td>
<td>1.28</td>
<td>0.84</td>
<td>46</td>
<td>59.00</td>
</tr>
<tr>
<td>daisy</td>
<td><em>Erigeron</em> spp.</td>
<td>1.02</td>
<td>0.91</td>
<td>30</td>
<td>30.60</td>
</tr>
<tr>
<td>buckwheat</td>
<td><em>Eriogonum</em> spp.</td>
<td>0.99</td>
<td>0.72</td>
<td>26</td>
<td>25.80</td>
</tr>
<tr>
<td>pussytoes</td>
<td><em>Antennaria</em> spp.</td>
<td>2.88</td>
<td>3.32</td>
<td>8</td>
<td>23.00</td>
</tr>
<tr>
<td>pepperweed</td>
<td><em>Lepidium</em> spp.</td>
<td>0.99</td>
<td>0.69</td>
<td>23</td>
<td>22.80</td>
</tr>
<tr>
<td>groundsmoke</td>
<td>spp.</td>
<td>1.66</td>
<td>1.24</td>
<td>10</td>
<td>16.60</td>
</tr>
<tr>
<td>unknown</td>
<td><em>N/A</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>groundsel</td>
<td><em>Senecio</em> spp.</td>
<td>1.75</td>
<td>0.77</td>
<td>4</td>
<td>7.00</td>
</tr>
<tr>
<td>Parsely</td>
<td><em>Lomatium</em> spp.</td>
<td>1.03</td>
<td>0.57</td>
<td>6</td>
<td>6.20</td>
</tr>
<tr>
<td>corydalis</td>
<td><em>Corydalis</em> spp.</td>
<td>1.16</td>
<td>0.83</td>
<td>5</td>
<td>5.80</td>
</tr>
<tr>
<td>indian</td>
<td><em>Castilleja</em> spp.</td>
<td>5.20</td>
<td>N/A</td>
<td>1</td>
<td>5.20</td>
</tr>
<tr>
<td>paintbrush</td>
<td><em>Chenopodium</em></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GF Keno</td>
<td>spp.</td>
<td>0.85</td>
<td>0.90</td>
<td>4</td>
<td>3.40</td>
</tr>
<tr>
<td>clover</td>
<td><em>Trifolium</em> spp.</td>
<td>2.60</td>
<td>N/A</td>
<td>1</td>
<td>2.60</td>
</tr>
<tr>
<td>thistle</td>
<td><em>Cirsium</em> spp.</td>
<td>2.20</td>
<td>N/A</td>
<td>1</td>
<td>2.20</td>
</tr>
<tr>
<td>arabis spp</td>
<td><em>Arabis</em> spp.</td>
<td>0.80</td>
<td>0.57</td>
<td>2</td>
<td>1.60</td>
</tr>
<tr>
<td>hymenoxys</td>
<td><em>Actenia</em> spp.</td>
<td>1.60</td>
<td>N/A</td>
<td>1</td>
<td>1.60</td>
</tr>
<tr>
<td>scarlet gilia</td>
<td><em>Gilia</em> spp.</td>
<td>1.00</td>
<td>N/A</td>
<td>1</td>
<td>1.00</td>
</tr>
<tr>
<td>phlox</td>
<td><em>Phlox</em> spp.</td>
<td>0.40</td>
<td>N/A</td>
<td>1</td>
<td>0.40</td>
</tr>
</tbody>
</table>

\( ^a \) the number of transects the genus was detected in out of 80 total transects

\( ^b \) the mean % cover multiplied by the frequency, which gives a weighted value as to that genus’s contribution to the vegetative composition of the forb community

\( ^c \) for comparative purposes against other treatment types and control, it is a total of the weights for all genera, this value shows a relative weighted value for forb % cover for each treatment type

\( ^{Total Weight:} \) 717.40
CHAPTER 4

GREATER SAGE-GROUSE ECOLOGY IN A HIGH ELEVATION SAGEBRUSH ECOSYSTEM

Abstract: Greater sage-grouse ecology has been described for many sagebrush ranges throughout the West. Most of these populations occur at lower elevations (< 2200 m) and share similar environmental conditions. Little has been published regarding the ecology of populations in the Intermountain West that inhabit higher elevations. We studied the ecology of greater sage-grouse that inhabit Parker Mountain located in south-central Utah to provide management with information that could be used to conserve this population. The results reported are a continuation of work started in 1998. In 2003 and 2004 nest initiation rates were 95% and 56%, nest success was 50% and 80%, and mortality was 36% and 22%, respectively. Preferred nest and brood sites exhibited vegetation characteristics similar to those reported in previous studies, though forb cover was consistently lower. Nest sites exhibited on average of 9.3% herbaceous and 13.2% shrub cover, although nest bush diameter and height averaged 97.5 cm and 64.4 cm, respectively. Brood sites on average exhibited 20.1% shrub and 16.5% herbaceous cover. Additionally, these sites exhibited 2.6% forb cover. During this study greater sage-grouse populations were increasing. Continued monitoring of the Parker Mountain sage-grouse population will provide managers with better information regarding the management of higher elevation sagebrush communities to benefit sage-grouse.

Introduction

Greater sage-grouse (*Centrocercus urophasianus*) are sagebrush obligates that inhabit sagebrush ecosystems throughout the West (Patterson 1952, Schroeder 2004).
Sage-grouse populations throughout much of this range have been declining. These declines have been attributed to habitat loss and/or deterioration (Braun et al. 1977, Connelly and Braun 1997).


Radio telemetry allows researchers to follow sage-grouse from breeding habitats to brood-rearing habitats. Nests can then be monitored for fate, and nest site characteristics can be measured. Following hatch, sage-grouse broods can be followed through the summer to determine brood fate and gather vegetation characteristics of brood sites. The reproductive effort of various populations can be assessed throughout the sage-grouse’s range.

Status of the greater sage-grouse population on Parker Mountain.--The Utah Division of Wildlife Resources (UDWR) in the early 1970’s sponsored the first study of
greater sage-grouse on Parker Mountain (Jarvis 1974). The purpose of this work was to determine seasonal distribution and habitat preferences, movements, productivity, mortality, and chick food habits. Jarvis (1974) reported the major factor limiting the Parker Mountain sage-grouse population was the lack adequate forb cover in brood habitats. He noted that this factor became extremely limiting during dry years.

Lek counts of male sage-grouse were initiated in 1967. Lek count data are highly variable showing large fluctuations in the population over time. Although some of the past variation may be related to methodology, more recent data suggests the population is increasing (Figure 1). Concerns over the mid 1990’s low counts led to the organization of the Parker Mountain Adaptive Resource Management (PARM) working group.

PARM is a private-public partnership that was specifically established to address concerns about the declining sage-grouse population. More recently that group has expanded their focus to include other resource management issues. The group initiated a study to determine the ecology of greater sage-grouse populations on the mountain in 1998 as a means of obtaining information that could be used to guide management actions. The group has subsequently used information from these studies to design and implement management projects (Chapter 2 and 3).

The objectives of my research were to monitor the ecology of greater sage-grouse on Parker Mountain to add to the group’s current knowledge. More specifically my research was designed to increase the group’s knowledge of nesting and brood-rearing ecology for application to management.
Study Area

The Parker Mountain study area (PSA) is located in Garfield, Sevier, Piute, and Wayne counties of Utah. The study area encompasses both the Aquarius and Awapa Plateaus (Figure 2). Awapa Plateau (Parker Mountain) lies on an east/west interface, the elevation increasing gradually from east to west and north to south, and meets the Aquarius plateau to the south. Although it shares some of the vegetation characteristics of other sagebrush-steppe zones, its high elevation and unique weather patterns create a distinctive environment. The elevation of the PSA ranges from 2,134 to 3018 meters.

The PSA consists of ~ 107,478 hectares; 21,685 ha managed by the U.S. Forest Service (USFS), 36,398 ha by Bureau of Land Management (BLM), 43,863 ha by Utah School and Institutional Trust Lands Administration (SITLA), and 5,532 ha is in private ownership. The predominant land use in the area is grazing by domestic livestock. The sagebrush habitat on the Parker Mountain is one of the largest contiguous tracts in Utah. Because of its high elevation and remoteness the area has escaped many of the development pressures that have impacted lower elevation sagebrush communities. Subsequently, Parker Mountain continues to be one of the few areas remaining in Utah exhibiting relatively high densities of greater sage-grouse (Beck et al. 2003).

Annual precipitation on Parker Mountain varies by elevational gradient. Higher elevations (> 2700 m) may receive up to 40 to 51 cm/year. Lower elevations receive 25 to 40 cm/year. Precipitation comes mostly in winter in the form of snow and in late summer monsoonal patterns (Figure 3). There are a small number of natural springs located at higher elevations (> 2700 m). Over 80 man-made water developments are
scattered throughout the mountain. These provide seasonal water for both wildlife and livestock.

Livestock stocking densities are 1.46 ha per animal unit month (AUM) (Ron Torgerson, SITLA Biologist, personal communication). The area is grazed by sheep and cattle that are rotated through 10 grazing allotments. Grazing is initiated at lower elevations in June. The livestock are subsequently herded to higher elevation allotments as the desired utilization is achieved (Ron Torgerson, SITLA, personal communication). Additionally, the PSA is used for hunting, off highway vehicles (OHV), camping, and other recreational activities.

Vegetation.--The majority of the Awapa plateau is dominated by black sagebrush (A. nova), or a hybrid of black and mountain big sagebrush as elevation increases (Jim Davis, UDWR, personal communication). Lower lying draws and higher elevation areas on the western edge of the Awapa plateau are dominated by mountain big sagebrush (Artemesia tridentata vaseyana). Some silver sage (A. cana) occurs in the more mesic bottoms and dominates uplands at the very highest elevations where the southern border of the Awapa Plateau meets the Aquarius Plateau. Common forb species include cinquefoil (Potentilla spp.), phlox (Phlox spp.), dandelion (Taraxacum spp.), lupine (Lupinus spp.), daisy (Erigeron spp.), penstemon (Penstemon spp.), and milkvetch (Astragalus spp.). Common grass species include wheatgrass (Agropyron spp.), bluegrass (Poa spp.), gramma grass (Bouteloua spp.), squirrel tail grass (Hordeum spp.), and June grass (Koeleria spp.). Also dry land sedge (Carex siccata) is common on Parker Mountain uplands.
Wildlife.--A variety of wildlife species inhabit the PSA. Common mammal species include mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), pronghorn (*Antilocapra Americana*), jack rabbits (*Lepus* spp.), mountain cottontail (*Sylvilagus nuttallii*), coyote (*Canis latrans*), and badger (*Taxidea taxus*). Common avian species include horned lark (*Eremophila alpestris*), red-tailed hawk (*Buteo jamaicensus*), American kestrel (*Falco sparverius*), golden eagle (*Aquila chrysaetos*), prairie falcon (*Falco mexicanus*), American robin (*Turdus migratorius*), sage sparrow (*Amphispiza belli*), sage thrasher (*Oreoscoptes montanus*), Brewer’s sparrow (*Spizella breweri*), northern flicker (*Copates auratus*), and common raven (*Corvus corax*). Greater short-horned lizards (*Phrynosoma hernandesi*) are common in black sagebrush habitat. State sensitive species that have been recorded on the PSA include the burrowing owl (*Anthene cunicularia*), ferruginous hawk (*Buteo regalis*), pygmy rabbit (*Brachylagus idahoensis*), and greater sage-grouse. The only federally listed species that inhabits the study area is the Utah prairie dog (*Cynomis parvidens*).

Predator management.-- Because of the presence of livestock on the study area, technicians employed by the United States Department of Agriculture (USDA) Wildlife Services (WS) conduct predator control operations on Parker Mountain (K. Dustin, WS, personal communication). Coyotes are common mammalian predators. This work is also conducted under an agreement with the UDWR to increase pronghorn fawn survival. Because of concerns about the impact of common ravens on sage-grouse nests, the contract was expanded to include raven control. Ravens are controlled with an avicide, DRC-1339, injected into chicken eggs.
Methods

*Radio-telemetry.*--Greater sage-grouse hens were trapped at roost sites near leks beginning in late March, 2003. Hens were handled according to protocol approved by the Institutional Animal Care and Use Committee (IACUC) at Utah State University, protocol file # 942, and with a certificate of registration (COR) from the Utah Division of Wildlife Resources (UDWR), COR number 5BAND3969. Hens were located with a spotlight from a truck or ATV and then a dip net was used to capture the bird (Geisen et al. 1982). Hens were weighed with a Pesola™ 2500-gram spring scale. Hens were aged based on the condition of the outer primaries along with weight (Dalke et al. 1963). A 16.5 gram ATSTM necklace radio (150.000 – 151.000) was attached. A Global Positioning System (GPS) unit was used to record the capture location in Universal Transverse Mercator (UTM) units. Telonics™ and ICOM™ receivers, hand held H antennae (RA-2A), 3-element Yagi antennae, and vehicle mounted omni antennae (RA-5A) were used to locate radio-collared hens.

In 2003 and 2004, 25 and 9 hens were monitored, respectively. Hens were located at least every 5 days prior to nesting if possible. For both field seasons (2003 and 2004), we were not able to begin following birds closely until the first of May. By this time, some hens had initiated nesting.

*Nest monitoring.*-- During the nest initiation period collared hens were approached cautiously to allow observers to get within ~ 10 m of the nest site. At this point we were able to obtain a visual location of the hen using binoculars. Hens located under the same bush within a 2-day period were assumed to be nesting. Nests were approached every other day and a positive visual of the hen was made to determine status
Nest initiation dates were estimated using a 27-day incubation period while adding a day for each egg present (Schroeder 1997). Clutch sizes were determined using methods by Schroeder (1997). Rock piles were used to mark paths to each nest to avoid using florescent flagging.

A successful nest had $\geq 1$ eggshell with loose membranes present (Girard 1939). If nests were depredated, sign (scat, tracks, hair, feathers, eggshells) was assessed to determine the possible predator. If eggs were completely removed with no eggshell sign, mammal tracks, or hair found in close proximity, the nest was assumed to be predated by a raven. Predator type was assigned either mammalian or avian.

*Nest site vegetation.*—Vegetation transects were used at each nest site to describe cover characteristics. To establish these transects a center pole was place directly in the middle of the nest with four 15 m transects radiating in 4 directions (starting with a random direction, then 90 degrees for each consecutive transect). Percent cover for shrubs, grasses, forbs, litter, and bare ground were measured on these transects using the line-intercept method (Canfield 1941). Vertical visual obstruction was measured using Robel poles along each transect looking to and from the nest (Robel et al. 1970). Nest bush species, maximum height, and maximum diameter were also measured. Aspect of nests were separated into 45 degree categories (north, northeast, east, southeast, south, southwest, west, and northwest) beginning 22.5 degrees each side of north.

*Brood monitoring.*—Hens with broods were located every 3 days and those without broods every 5 to 7 days. Brood hens were approached cautiously, and usually could be observed without flushing the hen. Binoculars were used in the early brood-rearing stages to locate the hen, while most hens flushed as chicks grew and began to fly.
proficiently. Broods were considered successful if at least 1 chick survived to ≥ 50 days and unsuccessful if no chicks survived ≥ 50 days. At each collared hen location GPS coordinates, major shrub type, slope, aspect, wind speed, wind direction, temperature, cloud cover, and number of total grouse flushed were recorded.

*Brood site vegetation.*--Brood site vegetation characteristics were measured ~ 3 days following location. To measure site vegetation, a center pole was placed as close as possible to the hen’s former location, with four 10 m transects radiating at 90 degree angles after the first random direction. Shrub cover was measured using the line intercept method (Canfield 1941). Ground cover (grasses, forbs, litter, bare ground, and rock) was measured using Daubenmire frames (n = 4) every 2.5 meters along each transect (Daubenmire 1959).

*Adult mortality.*--We recorded location, habitat, and possible predator sign of hen mortalities. The carcass and remains were inspected for talon, teeth, or claw marks. In some cases it was difficult to assign predator type to adult hens because of scavengers. Scavenger activity increased if more than a couple days had passed since mortality occurred. Generally if bones were left intact we assumed avian predation. If bones were missing or chewed we recorded mammalian predation. For those mortalities where just the collar had been chewed on it was impossible to determine if a mammal caused the mortality or just scavenged the carcass.

**Data Analyses**

Nest vegetation data were analyzed using logistic regression to compare successful to unsuccessful nests (P = 0.05). Descriptive statistics were used to compare brood site vegetation, nest initiation, nest initiation dates, clutch size, and nest success.
Results

*Lek Counts.*—Lek counts have been increasing since the PARM was established (Figure 1). Total male counts have been the highest since they began on Parker Mountain, though males per lek numbers are lower. Additionally, we’ve counted more leks per year in recent years (Figure 1). In 2002 researchers observed a lek that had not previously been counted. It was not in clear sight of a road, and was most likely active prior to discovery. In 2004, multiple historical leks that had not been active for many years became active. Additionally, two new leks were discovered in 2004. One was not in view of a road, and might have been active prior to discovery, though the other was definitely new. None of the new leks discovered in 2004 were included in the lek count data presented in Figure 1.

*Hen captures.*—Fifteen hens (2 adults, 13 yearlings) were trapped from late March to mid-April in 2003. Hens were trapped near Bull Roost or Black Point leks. No hens were trapped in 2004. Hen weights ranged between 900 and 1580 grams. Adult mean weights (n=2, $\bar{x} = 1513 \pm 62.5$ [SE]) and yearling mean weights (n=13, $\bar{x} = 1427 \pm 49.33$ [SE]) were not different ($p = 0.28$). In addition to hens trapped in 2003, we monitored 3 and 12 hens which were trapped in 2001 and 2002, respectively (Chi 2004).

*Nest initiation.*—Of the 25 hens monitored in 2003, 6 died prior to nest initiation. In 2003 and 2004, 18 (95%) and 5 (56%) of the hens monitored initiated nests, respectively. Nests were initiated in both years from mid-April through mid-May.

*Nest success.*—In 2003 there were 9 (50%) successful nests, 7 (39%) unsuccessful nests, and 2 (11%) abandoned nests. In 2003 one nest was abandoned due to observer influence. In 2004 there were 4 (80%) successful nests and 1 (20%) unsuccessful nest.
Clutch size.--Clutch size ranged between 4 and 8 eggs, and averaged 5 and 6.6 for 2003 and 2004, respectively. No infertile eggs were detected during 2003 and 2004.

Nest Vegetation.--Nest characteristics (forb cover, shrub cover, grass cover, number of forb species, slope, nest bush height, nest bush diameter, and Robel measurements in and out) did not differ for successful (n=15) and unsuccessful (n=8) nests (Table 1). Though not statistically significant, increased grass cover, nest bush height, nest bush diameter, and higher Robel pole readings were positively correlated with nest success. Nests were located under mountain big sagebrush (n=16), black sagebrush (n=4), rabbit brush (n=2), and an Indian rice grass clump (n=1). Aspect of nests was mostly east and southeast (Figure 4).

Brood success and site vegetation.--In 2003 we monitored 9 broods. One hen died within 3 days following hatching, thus no brood site vegetation was measured for this hen. Another hen died ~ 21 days following hatching. A third hen’s collar was beginning to fail and her last brood location was found ~ 42 days following hatch. All other broods had at least one chick survive ≥ 50 days (successful).

In 2004 we monitored 3 broods. One hen’s collar failed within 3 days following hatch, thus we were not able to collect any data on vegetation at her brood site. One hen lost her brood within ~14 days (unsuccessful) following hatch, and joined other adult birds. At least one chick in the other 2 broods survived ≥ 50 days (successful).

Brood site vegetation averaged the following: forbs 2.58% (SE = 0.10); grasses 13.88% (SE = 0.53); total herbaceous 16.46% (SE = 0.56); and shrub cover 20.06% (SE = 5.56). Because of the low sample size of unsuccessful broods we were not able to statistically compare vegetation characteristics at successful and unsuccessful brood sites.
Adult hen mortality.--In 2003 and 2004 we documented 9 (36%) and 2 (22%) mortalities, respectively. Although it was impossible to determine the exact predator, we were able to collect enough information to estimate the type of predator. For the 11 mortalities we concluded 8 were caused by avian predators and 2 mammalian, while one bird was legally harvested. Jarvis (1974) determined that golden eagles were the main predator of adult sage-grouse on Parker Mountain. My observations would concur with his findings.

In 2004 we lost contact with 5 birds during the post-brood rearing period because their radio batteries failed. These birds had been monitored for at least 2 nesting seasons.

Discussion

Lek counts of male sage-grouse may be a good indicator of population trends (Connelly and Braun 1997). Recent PSA lek counts have been the highest recorded counts since 1967 (Figure 1). However, limited data from the late 1960’s indicate that the population may have been higher then. The discovery of leks not previously counted, may be the result of increased monitoring efforts. However, the new leks and increased use of historic leks indicate the population is increasing. Although there are many factors (weather, percentage of male sage-grouse attendance, timing of counts with peak male attendance, and consistency and intensity of search effort for new leks) which might affect overall lek counts, we believe this data indicates a population growth trend.

Sage-grouse nesting and brood-rearing activities continue to be the most important factor in sage-grouse population dynamics (Connelly et al. 2000). Nest initiation rates and nest success on Parker Mountain are some of the highest in comparison to other populations (Schroeder et al. 1999). Brood-rearing vegetation
characteristics, except forb cover, were comparable to other studies (Connelly et al. 2000a). Forb cover in general on Parker Mountain may be low due to an overall dryer environment compared to higher latitude sagebrush ecosystems, a general lack of deep rich soil types, and an over abundance of shrub canopy cover, especially in mountain big sagebrush dominated draws (Chapter 2). Additionally, moisture on Parker Mountain comes in the winter in the form of snow, favoring shrubs, and during late summer monsoons, favoring warm season grasses. Very little moisture comes during the early to mid summer, when many forb species would benefit.

Nest success, including Chi (2004), was similar from 2000 – 2004, and averaged 67%, which is higher than most other studies (Schroeder et al. 1999). Similar to my findings, Chi (2004) found no statistical difference in vegetation characteristics when comparing successful versus unsuccessful nests for Parker Mountain sage-grouse in 2000 - 2002, though nest bush height was higher for successful versus unsuccessful nests. Shrub cover (32.10 %, Chi 2004) in 2000 to 2002 at nest sites was higher than in 2003 to 2004 (13.22 %), though my sample size was considerably lower.

Chi (2004) compared brood sites of successful versus unsuccessful broods and found a difference in 2002 where successful brood sites had more forb cover. Chi (2004) measured slightly higher average forb cover at all brood sites than I did, but averaged only 7.76 %. Wallestad (1971) and Klott and Lindzey (1990) averaged forb cover of 22 and 16.6% for brood sites, respectively, much higher than Parker Mountain brood sites. Forb cover may be the limiting factor for brood survival on Parker Mountain.
Conclusions

The Parker Mountain sage-grouse population trend may be due to many factors. Availability of nesting habitat and high nest success compared to other populations may account for some of this increase. Predator management may impact population trends. Raven control has been initiated in recent years, and may increase nest success. Coyote control has been very consistent over the last few decades. Though the area has been in a drought, mild winters may have assisted in the survival of adults. Additionally, shrub treatment targeting mountain big sagebrush to increase herbaceous cover has increased within brood-rearing habitats on the western rim of the PSA (Chapter 2).

Forb cover within brood-rearing habitats is lower than other areas within sage-grouse range. Additionally, brood-rearing habitat at higher elevations on the western rim of the Awapa Plateau have dense stands of mountain big sagebrush, which exceed recommended shrub canopy cover (Connelly et al. 2000). These areas could be treated in a manner that would benefit sage-grouse.

Small mosaic sagebrush treatments in large expanses of sagebrush should be treated where mountain big sagebrush occurs within brood-rearing habitat on Parker Mountain. Treatments spread out spatially and temporally would create small “islands” of forb rich habitat for broods, while not destroying nesting habitat in the area. Areas of high nesting density should be delineated and protected before sagebrush treatment is applied.

PARM has proposed future habitat manipulation on Parker Mountain. These projects will be done to benefit wildlife in general and sage-grouse specifically. By conducting radio telemetry studies on sage-grouse we have positively identified habitat
characteristics, as well as locations of those habitat types that sage-grouse are currently using on Parker Mountain. Consequently, future management activities can be targeted to positively impact sage-grouse.

Continued monitoring of sage-grouse on Parker Mountain is needed to assess the effect of management actions. Lek counts, nest monitoring, brood monitoring, and winter habitat use are all important factors to measure for Parker Mountain sage-grouse. With PARM’s assistance these research activities can continue.

**Literature Cited**


Figure 1.
Figure 2. Parker Mountain study area, 2003-2004.
Figure 3. Richfield UT, Precipitation Data October 1998 to Sept 2003 (Data from http://www.ksveradio.com/weather.html)
Table 1. Descriptive statistics for 2003 and 2004 Greater Sage-grouse nests on Parker Mountain, 2003-2004. (note: forb cover and grass cover were assessed with the line intercept method (Canfield 1941), which may not be appropriate for ground cover)

<table>
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<th></th>
<th>Mean</th>
<th>SE</th>
<th>Range</th>
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<td>Forb Cover (%)</td>
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<td>0.21</td>
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<tr>
<td>Grass Cover (%)</td>
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<td>0.96</td>
<td>2.62 - 20.68</td>
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<tr>
<td>Shrub Cover (%)</td>
<td>13.22</td>
<td>1.73</td>
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<tr>
<td>Nest Bush Diameter (cm)</td>
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<td>10.43</td>
<td>25 - 220</td>
</tr>
<tr>
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<td>4.09</td>
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<tr>
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<td>Slope (degrees)</td>
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</table>

Figure 4. Slope aspects of greater sage-grouse nests, Parker Mountain, 2003 and 2004.
CHAPTER 5

CONCLUSIONS

Over the last century, greater sage-grouse (*Centrocercus urophasianus*) populations have been declining (Braun et al. 1977). These declines have been largely attributed to habitat loss and degradation (Braun et al. 1977). Overall sage-grouse populations have declined in Utah (Beck et al. 2003). However, in some areas of the state such as Parker Mountain located in south central Utah, the declines have not been as pronounced (Beck et al. 2003).

Sustaining current population levels and increasing numbers will require an adaptive resource management approach (Connelly et al. 2004). This approach must combine contemporary knowledge of habitat needs of sage-grouse (i.e. lekking, nesting, early and late brood-rearing, and wintering) within sagebrush ecosystems with landscape level experiments that will provide managers with the information needed to increase and reestablish the species and other sagebrush obligates (Connelly et al. 2000, Connelly et al 2004).

Although the ecology of greater sage-grouse has been described for many sagebrush ranges throughout the West, most of these populations occur at lower elevations (< 2200 m) and share similar environmental conditions. Little has been published regarding the ecology of populations in the Intermountain West that inhabit high elevation habitats. To fill this void we used radio telemetry to study the ecology of greater sage-grouse that inhabit Parker Mountain located in south-central Utah. This population had never been studied using radio telemetry techniques. The results reported in this thesis are a continuation of work started in 1998 (Messmer and Flory 2002).
During the 2003-2004 study period, nest initiation rates were 95% and 56%, nest success was 50% and 80%, and mortality was 36% and 22%, respectively. Preferred nest and brood sites exhibited vegetation characteristics similar to other studies, though forb cover was consistently lower. Nest sites averaged 9.28% herbaceous cover and only 13.22% shrub cover, although nest bush diameter and height averaged 97.52 cm and 64.35 cm, respectively. Brood sites averaged 20.06% shrub cover and 16.46% herbaceous cover, though only 2.58% cover was due to forbs. During this study greater sage-grouse populations were most likely increasing.

In 2001 the Western Association of Fish and Wildlife Agencies (WAFWA) adopted a range-wide sage-grouse conservation plan. In this plan WAFWA identified a need to determine the effect of management practices on sage-grouse and sagebrush ecosystems under different environmental conditions. Currently, little information exists regarding the effects of mechanical treatments on high elevation sagebrush communities for use in sage-grouse habitat management.

To address this need, I evaluated the effects of 2 mechanical treatments, the Dixie harrow and Lawson aerator, on mountain big sagebrush communities located on Parker Mountain. This experiment was conducted on twelve 40.5 ha plots that exhibited ~ 38% shrub canopy cover. The plots were located in sage-grouse brood-rearing habitat that is seasonally grazed by domestic livestock. The plots were randomly assigned to treatment or control groups. The mechanical treatments were conducted in the fall of 2001.

The Dixie Harrow and Lawson aerator treatments reduced shrub canopy cover from 38.2% and 38.9% to 18.4% and 14.3%, respectively. Herbaceous cover (grass and forb combined) increased on the Dixie harrow treatments (+ 5.5%, $P = 0.02$).
herbaceous cover did not differ for the Lawson aerator and control post treatment. Post-treatment percent grass and forb cover on the Dixie harrow plots exceeded that of the control plots ($P = 0.02$ and 0.01, respectively). Two years post-treatment, the Dixie harrow generated the greatest herbaceous cover response.

The same experimental design was used to assess the effect of Tebuthiuron treatment on mountain big sagebrush (Chi 2004). Chi found that though change in grass and forb cover individually did not differ from control, total herbaceous cover did differ. I continued to measure vegetation characteristics in Tebuthiuron plots in 2003 and 2004. The Tebuthiuron treatments produced an understory the contained a greater diversity of forb species and abundance than the mechanical treatments or control.

To determine if sage-grouse use differed for treatment and control, I conducted pellet counts and birddog flushing surveys. Based on these surveys, sage-grouse use was consistently higher in the Tebuthiuron treatments than all other plots. I believe this increased use is reflective of the differing vegetation responses observed. These results suggest that the use of Tebuthiuron to enhance sage-grouse brooding rearing habitat in big mountain sagebrush communities had a more immediate effect than mechanical treatments.

I also recorded different sage-grouse use patterns within plots. Sage-grouse use within plots was highest within ~ 30 meters along edges whether in treated or untreated sagebrush. These observations suggest that when using these treatments, managers should treat patches in large contiguous stands of sagebrush rather than leaving islands of remnant sagebrush in larger treated areas. Additionally, this data suggest that mosaic or sinuous treatment pattern designed to maximize edge effects should be considered.
Continued monitoring of the Parker Mountain sage-grouse population and these treatments will provide managers with more information regarding the management of higher elevation sagebrush communities to benefit sage-grouse.

**Future Research Possibilities**

A similar sagebrush manipulation experiment assessing vegetation response to sagebrush treatment and subsequent sage-grouse use could be conducted at a lower elevation with a different subspecies of big sagebrush (*Artemesia tridentata*). This would help answer questions concerning precipitation regimes, and may lend information concerning a different herbaceous species composition. Additionally, if sage-grouse use data could be taken pre-treatment, it would strengthen the study design compared to mine.

Currently the UDWR uses maximum male lek counts with the formula of 75 % male lek attendance, along with a 2:1 female to male sex ratio to estimate population size for sage-grouse (personal communication, Dean Mitchell, UDWR Upland Game Coordinator). Research could be conducted on Parker Mountain to ascertain true male lek attendance rates. Males could be collared in the fall or winter, when they are not associated with leks, and then each lek could be monitored during the same mornings on Parker Mountain to measure collared male attendance. This method would assume researchers know the location of and monitor all the leks on Parker Mountain. Results would help managers to more accurately estimate population size based on lek counts for the Parker Mountain population.

The winter ecology of sage-grouse on Parker Mountain has never been studied. Currently, managers are assuming the limiting factor of the Parker Mountain population
takes place during the reproductive (summer) period. Mortality during the winter has not been significant since the beginning (1998) of this study. However, the severity of winters since 1998 has been fairly mild. Beck (1977) found that sage-grouse used only 7% of the total study area during the winter in Colorado. With proposed treatment of sagebrush on Parker Mountain, it would be beneficial to delineate and protect the specific wintering areas Parker Mountain sage-grouse are using. Additionally, more accurate sex ratios may be detected with winter flock characteristics (Beck 1977). More accurate sex ratios combined with better male lek attendance rates would improve population estimates based on lek counts.

Habitat fragmentation has been cited as a major concern for sage-grouse populations in Utah (Beck et al. 2003). The Parker Mountain sage-grouse population may seem isolated upon initial investigation. However, there are leks in Grass Valley, on Monroe Mountain, in Johns Valley, in Panguitch Valley, and near Alton. There are unsuitable habitats that separate these areas, but none are of a greater distance than sage-grouse have been known to move (Connelly and Markham 1983, Connelly et al. 1988). A genetics study with samples taken from each of these areas would lend information concerning the connectivity of sage-grouse populations in southern Utah.

Brood survival is a major concern for sage-grouse population recruitment (Schroeder 1997). Multiple flushes of chicks have been used to assess brood survival, though attempting to flush chicks most likely underestimates survival (Schroeder 1997). Burkepile et al. (2002) successfully attached radios to 1-day old sage-grouse chicks, and was able to monitor survival. Validation and comparison of their findings on Parker Mountain would lend important information. Radio telemetry would enable researchers
to determine the cause of mortality to chicks, whether it be predation, starvation, or weather related. This information along with vegetation characteristics would allow management options which could increase recruitment into the population.

**Community-based Conservation**

Community-based conservation has played an integral role in this project. In 1998 partners from public and private entities gathered to discuss the concerns for the Parker Mountain sage-grouse population, and formed the Parker Mountain Adaptive Resource Management working group (PARM). Federal (USDI Bureau of Land Management, USDA Forest Service, the Natural Resource Conservation Service, USDA Wildlife Services, and US Fish and Wildlife Service), state (UDWR, Farm Bureau Agency, Utah Statue University Extension, Jack H. Berryman Institute), local (Wayne County Commission), and private (Parker Mountain Grazing Association) entities all contributed substantial means and services to this project. In essence, everything we’ve accomplished would not have happened without all the partners’ contributions. PARM has become a model for other community-based conservation groups managing for sage-grouse and other natural resources.

Important principles to PARM’s success include but are not limited to; collaboration, consensus, sacrifice, monetary contributions, communication, humility, respecting differences, commitment, local leadership, relationship development, regular meeting schedules, and individual personalities. I can’t say enough about the individuals who have come from various agencies and backgrounds, and yet have come together for one purpose. All have benefited, including the many natural resources contained within the Parker Mountain ecosystem.
Literature Cited


radio transmitters to one-day-old sage-grouse chicks. Wildlife Society Bulletin 
30:93-96.

Chi, R. Y. 2004. Greater sage-grouse reproductive ecology and tebuthiuron 
State University, Logan, Utah, USA.

concentrations of sage-grouse in southeastern Idaho. Journal of Wildlife 
Management 47:169-177.

Connelly, J. W., H. W. Browers, and R. J. Gates. 1988. Seasonal movements of sage-

manage sage grouse populations and their habitats. Wildlife Society Bulletin 
28:967-985.

assessment of greater sage-grouse and sagebrush habitats. National Sage-grouse
Conservation Planning Framework Team, Western Association of Fish and Wildlife Agencies.
