

GREATER SAGE-GROUSE REPRODUCTIVE ECOLOGY AND RESPONSE TO
EXPERIMENTAL MANAGEMENT OF MOUNTAIN BIG SAGEBRUSH ON
PARKER MOUNTAIN, UTAH

by

David K. Dahlgren

A thesis submitted in partial fulfillment
of the requirements for the degree

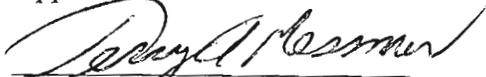
of

MASTER OF SCIENCE

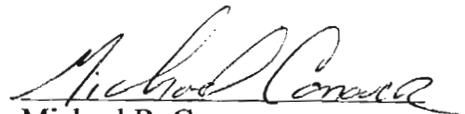
in

Wildlife Biology

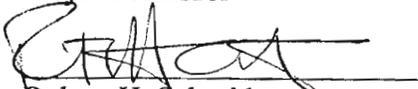
Approved:



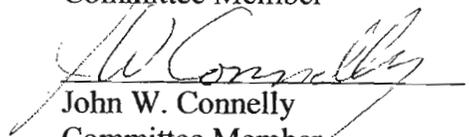
Terry A. Messmer
Major Professor



Michael R. Conover
Committee Member



Robert H. Schmidt
Committee Member



John W. Connelly
Committee Member



Byron R. Burnham
Dean of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2006

Copyright © David Dahlgren 2006

All Rights Reserved

ABSTRACT

Greater Sage-grouse Reproductive Ecology and Response to Experimental Management
of Mountain Big Sagebrush on Parker Mountain, Utah

by

David K. Dahlgren, Master of Science

Utah State University, 2006

Major Professor: Dr. Terry A. Messmer
Department: Forestry, Range, and Wildlife Science

I evaluated the effects of 2 mechanical treatments that may be used to manage greater sage-grouse (*C. urophasianus*) habitat. Dixie harrow and Lawson aerator treatments were conducted in replicated plots that contained (> 38% canopy cover) stands of mountain big sagebrush (*Artemisia tridentata vaseyana*). I monitored shrub and herbaceous vegetation response. Both treatments effectively reduced shrub canopy to guidelines for sage-grouse brood-rearing habitat (10 - 25%). Dixie harrow responded with an increase in herbaceous cover. Additionally, I added Tebuthiuron plots and monitored sage-grouse use within all plots. Sage-grouse, and broods specifically, preferred Tebuthiuron plots compared to mechanical or control. I monitored sage-grouse hens during their reproductive efforts in 2003 and 2004 (n = 25 and 9, respectively). In 2003 and 2004, nest initiation rates were 95% and 56%, nest success was 50% and 80%,

and mortality was 36% and 22%, respectively. Brood sites exhibited 20.1% shrub and 16.5% herbaceous cover.

(117 pages)

ACKNOWLEDGMENTS

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 throughout this research.

I would like to thank the Parker Mountain Adaptive Resource Management partnership for their organization and assistance. 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. 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. I would also like to thank in particular the Utah Division of Wildlife Resources for the field vehicle and all associated expenses.

I would like to thank members of my committee, Dr. Mike Conover, Dr. Robert Schmidt, and Dr. John (Jack) Connelly, for their input and support. Additionally, I thank Susan Durham for her statistical expertise and her ability to help me through the analyses of my data. Also, I thank Russell Norvell for his help with program DISTANCE.

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.

I give special thanks to Renee Chi who assisted in my transformation into a graduate student. Her mentoring and training are greatly appreciated as I learned how to collect data worthy of analysis. Additionally, her work ethic set a precedence that carried through my research. She also assisted in some of the data collection and trapping for my work, for which I am grateful.

I would like to thank Dwayne Elmore as well. His many hours of data collection on my behalf are greatly appreciated. His advice, counsel, and moral support throughout this research effort have been tremendous.

The trapping of sage-grouse hens is very taxing work. I thank all who volunteered their time in this activity for this research.

Special thanks to my family and friends who provided the needed moral support in my life to keep my head above water. Thanks to my grandfather, Robert Dahlgren, who inspired my career choice. Also, many of my family members volunteered their time to collect data. In particular, I thank my mother who took every opportunity I gave her to assist in collecting vegetation data, and stayed excited about it to the end. Thanks for helping me measure the “grass” Mom.

David K. Dahlgren

CONTENTS

	Page
ABSTRACT	iii
ACKNOWLEDGMENTS	v
LIST OF TABLES	x
LIST OF FIGURES	xi
CHAPTER	
1. INTRODUCTION AND LITERATURE REVIEW	1
Description	1
General Habitat Requirements	1
Wintering Habitat.....	2
Pre-laying Habitat	2
Lekking Habitat	2
Nesting Habitat	3
Brood-rearing Habitat	4
Factors Impacting Sage-grouse Populations	5
Sage-grouse in Utah	8
Sage-grouse Management Techniques	9
Fire Management	9
Biological Management	10
Chemical Management	11
Mechanical Treatment	12
Purpose.....	13
Literature Cited	14
2. EFFECTS OF MECHANICAL TREATMENT ON SAGE-GROUSE BROOD- REARING HABITAT IN MOUNTAIN BIG SAGEBRUSH.....	23
Introduction.....	24
Study Area	26
Methods.....	28
Results.....	31

Pre-treatment Vegetation Characteristics	31
Post-Treatment Vegetation Response	31
Time Period Comparisons.....	32
Discussion.....	33
Conclusions.....	34
Literature Cited.....	35
3. GREATER SAGE-GROUSE USE OF MOUNTAIN BIG SAGEBRUSH HABITAT TREATMENTS	45
Introduction.....	46
Study Area	48
Methods.....	50
Results.....	53
Discussion.....	55
Conclusions.....	57
Management Implications.....	57
Literature Cited.....	60
4. GREATER SAGE-GROUSE REPRODUCTIVE ECOLOGY IN A HIGH ELEVATION SAGEBRUSH ECOSYSTEM	74
Introduction.....	75
Study Area	77
Vegetation.....	78
Wildlife	79
Methods.....	80
Population Status	80
Monitoring Nesting and Brooding Ecology.....	80
Nest and Brood Site Vegetation.....	82
Adult Mortality	83
Data Analysis	83
Results.....	84
Population Status	84
Monitoring Nesting and Brooding Ecology.....	84
Nest and Brood Site Vegetation.....	86
Adult Mortality	86
Discussion.....	87

Conclusions.....	89
Literature Cited.....	91
5. CONCLUSIONS.....	100
Future Research Possibilities	103
Community-based Conservation.....	105
Literature Cited	106
APPENDIX A: The seed mixture for Dixie harrow plots.....	109
APPENDIX B: Distance-to-edge Histograms of Pellet Count Data.....	110
APPENDIX C: Relative Forb Cover Abundance.....	114

LIST OF TABLES

Table	Page
2-1. Vegetation cover responses for treatment and control by time periods, Parker Mountain, Utah, 2000 – 2003.....	38
3-1. Pellet count probability of detection and cluster densities, Parker Mountain, Utah, 2003-2004.....	64
3-2. Comparison of treatment types for cluster density and probability of detection, Parker Mountain, Utah, 2003 – 2004.....	64
3-3. Birddog survey flush counts, Parker Mountain, Utah 2003 and 2004.....	64
3-4. Birddog survey comparisons of treatment type for total grouse and broods flushed, Parker Mountain, Utah, 2003-2004.....	75
3-5. 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.....	65
4-1. 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).....	96
Appendix A The seed mixture for Dixie harrow plots, Parker Mountain, Utah, 2001.....	109
Appendix C Control forb data using Daubenmire frames in June and July 2003 and 2004.....	114
Appendix C Tebuthiuron forb data using Daubenmire frames in June and July 2003 and 2004.....	115
Appendix C Dixie forb data using Daubenmire frames in June and July 2003 and 2004.....	116
Appendix C Lawson forb data using Daubenmire frames in June and July 2003 and 2004.....	117

LIST OF FIGURES

Figure	Page
2-1. Parker Mountain Study Area, Utah, 2000 – 2003.....	39
2-2. Monthly Precipitation (Utah Climate Center data, climate.usurf.usu.edu), Koosheram (~15 km from PLP), Utah, 2000-2004.....	40
2-3. Parker Lake Pasture within Parker Mountain Study Area, Utah, 2000 – 2003.....	41
2-4. Photo of Dixie harrow.....	42
2-5. Photo of Lawson aerator.....	42
2-6. Shrub canopy cover, Parker Mountain, Utah, 2001 – 2003.....	43
2-7. Total herbaceous cover, Parker Mountain, Utah, 2000 – 2003.....	43
2-8. Grass cover, Parker Mountain, Utah, 2000 – 2003.....	44
2-9. Forb cover, Parker Mountain, Utah, 2000 – 2003.....	44
3-1. Parker Mountain Study Area, Utah, 2002 – 2004.....	66
3-2. Monthly Precipitation (Utah Climate Center data, climate.usurf.usu.edu), Koosheram (~15 km from PLP), Utah, 2000-2004.....	67
3-3. Parker Lake Pasture, Parker Mountain, Utah, 2002 – 2004.....	68
3-4. Plots and treatment type within Parker Lake Pasture, Parker Mountain, Utah, 2002-2004.....	69
3-5. Sage-grouse pellet cluster density by treatment, Parker Mountain, Utah, 2003 and 2004.....	70
3-6. Sage-grouse pellet count probability of detection [p(d)], Parker Mountain, Utah, 2003 and 2004.....	70
3-7. Total sage-grouse flushed with birddogs by treatment (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.....	71

3-8. Sage-grouse broods flushed with birddogs by treatment (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.....	71
3-9. Total sage-grouse flushed with birddogs by year (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.....	72
3-10. Sage-grouse broods flushed with birddogs by year (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.....	72
3-11. Shrub canopy cover in PLP for 2003 and 2004 June and July.....	73
4-1. Sage-grouse lek counts (UDWR data) 1967 – 2004, Parker Mountain, Utah.....	97
4-2. Parker Mountain study area, 2003 – 2004.....	98
4-3. Monthly Precipitation (Utah Climate Center data, climate.usurf.usu.edu), Koosheram (~15 km from PLP), Utah, 2000-2004.....	99
4-4. Slope aspects of greater sage-grouse nests, Parker Mountain, 2003 and 2004.....	99
Appendix B Dixie UTRA Histogram for Distance to Edge, Parker Mountain, Utah, 2003-2004.....	110
Appendix B Dixie TRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.....	110
Appendix B Lawson UTRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.....	111
Appendix B Lawson TRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.....	111
Appendix B Spike UTRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.....	112
Appendix B Spike TRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.....	112
Appendix B Control UTRA Histogram of Distance to Edge, Parker Mountain, Utah, 2003-2004.....	113

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

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 are considered sagebrush (*Artemisia* spp.) 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, Nebraska, and British Columbia (Schroeder et al. 2004).

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.

Wintering 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 (*A. tridentata*), low (*A. arebuscula*), and black (*A. nova*) sagebrush are important as they provide thermal cover, escape cover, and food for sage-grouse (Connelly et al. 2000a). 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).

Pre-laying Habitat

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).

Lekking Habitat

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

(Patterson 1952). Sage-grouse may take advantage of disturbances that provide this habitat type if sparsely vegetated areas are scarce (Connelly et al. 1981).

Nesting Habitat

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. 1998). Sage-grouse hens can renest following nest failure. Schroeder (1997) reported an unusually high (87%) renesting effort by hens in central Washington, while Connelly et al. (1993) observed much lower rates (15% average for yearlings and adults). 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.

Sagebrush communities that exhibit an abundant herbaceous understory are important for brood-rearing habitat (Connelly et al. 2000a). Direct intervention within

brood-rearing areas, especially areas where shrub canopy cover may be limiting the understory, could possibly benefit sage-grouse, though little information is available. Consequently, it is important to identify management practices that could create more suitable brood-rearing habitat, and experimentally test their effect on sage-grouse.

Factors Impacting 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, Krueger et al. 2002).

Braun et al. (1976, 1977) and Connelly and Braun (1997) 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 by livestock in the late 1800s and early 1900s led to decreased sagebrush distribution, degradation, and change in plant species composition (Krueger et al. 2002). Increased concern that public rangeland

was being degraded across the western United States led to the passage of the Taylor Grazing Act 1934. 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 (Heady 1975). 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 of 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*) became a monoculture in many areas (Shown et al. 1969). Though livestock usually benefited from such treatments, in many cases those species that required diverse sagebrush communities for part or all of their life cycle were impacted. Crested wheatgrass provides poor sage-grouse habitat (Reynolds and Trost 1980, Ritchie et al. 1994).

European settlement also interrupted fire intervals. Fire helped maintain the co dominance 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). Fire suppression and overgrazing also led

to pinyon-juniper (*Pinus edulis*, *Juniperus* spp.) woodland encroachment into sagebrush habitat which further impacted 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 also aided 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). Knick and Rotenberry (1997) documented cheatgrass invasion causing increased fragmentation, and with increased fire frequency, eventual conversion to an annual-dominated system. Annual-dominated communities may be considered a separate steady state (Laycock 1991). These communities displace 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 has declined (Connelly et al. 2004). 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 (UDWR 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 (> 500 breeding sage-grouse moving average from 1996-2000) 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 abundant 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) (UDWR 1998). To address these declines, UDWR prepared the Utah Strategic Management Plan for sage-grouse (UDWR 2002). This plan, approved by the Utah Wildlife Board in 2002, identified 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 (T. Messmer, Utah State University, personal communication).

Because of concerns about 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 (K. Kritz, USFWS, 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, Salt Lake City, Utah, personal communication). Local working groups and their sage-grouse habitat recovery plans will most likely play a major role in 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 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

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. Nelle et al. (2000) reported a prescribed burning program along with wildfires within a mountain big sagebrush dominated area negatively impacted nesting and brood-rearing habitat. However, Pyle and Crawford (1996) reported that greater sage-grouse use of mesic sagebrush habitat increased after small areas were burned. Fire may have limited use as a management tool, especially in areas where invasive plant species, such as cheatgrass, occur.

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 season of use by livestock.

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 likely with fall grazing (Bork et al. 1998).

Van Pollen and Lacey (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 commonly were 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) suggested 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, K. Rasmussen, USFS, unpublished data). Connelly et al. (2000a) recommended mechanical treatment in 4 to 8m wide strips in areas with $\geq 35\%$ 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 (K. Rasmussen, USFS, 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 patterns 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 rarely has 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 conjunction with this research I continued to monitor sage-grouse reproductive efforts and conducted surveys of sage-grouse use in treatments (Dixie harrow, Lawson aerator, and tebuhturon) and control. This thesis is written in a multiple paper format following the *Wildlife Society Bulletin* and The Journal of Wildlife Management 2006 unified style guidelines (Messmer and Morison 2006).

Literature Cited

- Apa, A. D. 1998. Habitat use and movements of sympatric sage and Columbian sharp-tailed grouse in southeastern Idaho. Dissertation, University of Idaho, Moscow, USA.
- Autenrieth, R. E. 1981. Sage grouse management in Idaho. Idaho Department of Fish and Game, Wildlife Bulletin 9, Boise, Idaho, USA.
- Barnett, J. K., and J. A. Crawford. 1994. Pre-laying nutrition of sage-grouse hens in Oregon. *Journal of Range Management* 47:114-118.
- Beck, J. L., and D. L. Mitchell. 2000. Influences of livestock grazing on sage grouse habitat. *Wildlife Society Bulletin* 28:993-1002.
- Beck, J. L., D. L. Mitchell, and B. D. Maxfield. 2003. Changes in the distribution and status of sage-grouse in Utah. *Western North American Naturalist* 63:203-214.
- Beck, T. D. I., and C. B. Braun. 1978. Weights of Colorado sage-grouse. *Condor* 80:241-243.
- Bork, E. W., N. E. West, and J. W. Walker. 1998. Cover components on long-term seasonal sheep grazing treatments in three-tip sagebrush steppe. *Journal of Range Management* 51:293-300.
- Braun, C. E. 1987. Current issues in sage grouse management. *Proceedings of the Western Association of Fish and Wildlife Agencies* 67:134-144.
- Braun, C. E. 1998. Sage-grouse declines in western North America: what are the problems? *Proceedings of the Western Association of State Fish and Wildlife Agencies* 78:139-156.

- Braun, C. E., M. F. Baker, R. L. Eng, J. W. Gashwiler, and M. H. Schroeder. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. *Wilson Bulletin* 88:165-171.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. *Wildlife Society Bulletin* 5:99-106.
- Bunting, S. C., B. M. Kilgore, and C. L. Bushey. 1987. Guidelines for prescribed burning sagebrush-grass rangelands in the northern Great Basin. General Technical Report INT-231, United States Department of Agriculture, Forest Service, Ogden, UT. 33 pages.
- Burkhardt, J. W., and E. W. Tisdale. 1976. Causes of juniper invasion in southwestern Idaho. *Ecology* 76:472-484.
- Commons, M. L., R. K. Baydack, and C. E. Braun. 1999. Sage-grouse response to pinyon-juniper management. *USDA Forest Service Proceedings RMRS-P-9*. pages 238-239.
- Connelly, J. W., W. J. Arthur, O. D. Markham. 1981. Sage grouse leks on recently disturbed sites. *Journal of Range Management* 34:153-154.
- Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. *Wildlife Biology* 3/4: 123-128.
- Connelly, J. W., R. A. Fischer, A. D. Apa, K. P. Reese, and W. L. Wakkinen. 1993. Renesting by sage grouse in South Eastern Idaho. *The Condor* 95:1041-1043.
- Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. *Western*

Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming.

Connelly, J. W., K. P. Reese, R. A. Fischer, and W. L. Wakkinen. 2000b. Response of sage grouse breeding population to fire in southeastern Idaho. *Wildlife Society Bulletin* 28:90-96.

Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000a. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.

Connelly, J. W., W. L. Wakkinen, A. P. Apa, and K. P. Reese. 1991. Sage-grouse use of nest sites in southeastern Idaho. *Journal of Wildlife Management* 55:521-524.

Cottam, W. P., and G. Stewart. 1940. Plant succession as a result of grazing and of meadow desiccation by erosion since settlement in 1862. *Journal of Forestry* 38:613-626.

Drut, M. S., W. H. Pyle, and J. A. Crawford. 1994. Technical note: diets and food selection of sage-grouse chicks in Oregon. *Journal of Range Management* 47:90-93.

Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996. An investigation on fire effects within xeric sage grouse brood habitat. *Journal of Range Management* 49:194-198.

Fischer, R. A., K. P. Reese, and J. W. Connelly. 1997. Effects of prescribed fire on movements of female sage grouse from breeding to summer ranges. *Wilson Bulletin* 109:82-91.

- Gregg, M. A., J. A. Crawford, M. S. Drut, and A. K. Delong. 1994. Vegetation cover and predation of sage-grouse nests in Oregon. *Journal of Wildlife Management* 58:162-166.
- Hart, R. C. 2000. Mechanical brush control: monitoring brush dynamics following land treatment with the Lawson Aerator.
<http://farwest.tamu.edu/rangemgt/pdfs/00bookme.pdf> Accessed on 4-15-03.
- Heady, H. F. 1975. *Rangeland management*. McGraw-Hill Book Company, New York, New York, USA.
- Hupp, J. W., and C. E. Braun. 1989. Topographic distribution of sage-grouse foraging in winter. *Journal of Wildlife Management* 53:823-829.
- Johnson, K. H., R. A. Olson, and T. D. Whitson. 1996. Composition and diversity of plant and small mammal communities in tebuthiuron-treated big sagebrush (*Artemisia tridentata*). *Weed Technology* 10:404-416.
- Klebenow, D. A., and G. M. Gray. 1968. The food habits of juvenile sage-grouse. *Journal of Range Management* 21:80-83.
- Klebenow, D. A. 1969. Sage-grouse nesting and brood habitat in Idaho. *Journal of Wildlife Management* 33:649-662.
- Klebenow, D. A. 1970. Sage grouse versus sagebrush control in Idaho. *Journal of Range Management* 23:396-400.
- Knick, S. T., and J. T. Rotenberry. 1997. Landscape characteristics of disturbed shrub steppe habitats in southwestern Idaho (USA). *Landscape Ecology* 12:287-297.

- Krueger, W. C., M. A. Sanderson, J. B. Cropper, M. Miller-Goodman, C. E. Kelley, R. D. Pieper, P L. Shaver, and M. J. Trlica. 2002. Environmental impacts of livestock on US grazing lands. Council for Agricultural Science and Technology, Issue Paper No. 22. CAST, 4420 West Lincoln Way, Ames IA 50014. 16 pages.
- Laycock, W. A. 1979. Management of sagebrush. *Rangelands* 1:207-210.
- Laycock, W. A. 1991. Stable states and thresholds of range condition on North America rangelands: a viewpoint. *Journal of Range Management* 44:427-433.
- Martin, N. S. 1970. Sagebrush control related to habitat and sage grouse occurrence. *Journal of Wildlife Management* 34:313-320.
- Messmer, T. A. and F. A. Rowher. 1998. Issues and problems in predation management to enhance avian recruitment. *Transactions of the North American Wildlife and Natural Resources Conference* 61:25-30.
- Messmer, T. A., and M. L. Morison. 2006. Unified manuscript guidelines for Wildlife Society peer-reviewed publications. *Wildlife Society Bulletin* 34:252-268.
- Miller, R. F., T. J. Svejcar, and N. E. West. 1994. Implications of livestock grazing in the Intermountain sagebrush region: plant composition. Pages 101-146 *in* M. Vavra, W. A. Laycock, and R. D. Pieper, editors. *Ecological implications of livestock herbivory in the West*. Society for Range Management, Denver, Colorado, USA.

- Montana Extension Service. 2001. Powder River County pasture and range aerator demonstration. animalrangeextension.montana.edu/Natural/GLCI/Projects/2001/PwdrRvr%20Range%20Renov.htm. Accessed on 4-14-03.
- Nelle, P. J., K. P. Reese, and J. W. Connelly. 2000. The long-term effect of fire on sage grouse nesting and brood-rearing habitats on the Upper Snake River Plain. *Journal of Range Management* 53:586-591.
- Olson, R. A., T. D. Whitson. 2002. Restoring structure in late-successional sagebrush communities by thinning with tebuthiuron. *Restoration Ecology* 10:146-155.
- Patterson, R. L. 1952. *The sage grouse in Wyoming*. Sage Books, Denver, Colorado, USA.
- Peterson, J. G. 1970. The food habits and summer distribution of juvenile sage grouse in central Montana. *Journal of Wildlife Management* 34:147-155.
- Pyle, W. H., and J. A. Crawford. 1996. Availability of foods of sage grouse chicks following prescribed fire in sagebrush-bitterbrush. *Journal of Range Management* 49:320-324.
- 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, Montana, USA.
- Reynolds, T. D., and C. H. Trost. 1980. The response of native vertebrate populations to crested wheatgrass planting and grazing by sheep. *Journal of Range Management* 33:122-125.
- Riggs, R. A., and P. J. Urness. 1989. Effects of goat browsing on Gambel oak communities in northern Utah. *Journal of Range Management* 42:354-360.

- Ritchie, M. E., M. L. Wolfe, and R. Danvir. 1994. Predation of artificial sage grouse nests in treated and untreated sagebrush. *Great Basin Naturalist* 54:122-129.
- Schroeder, M. A. 1997. Unusually high reproductive effort by sage-grouse in a fragmented habitat in north-central Washington. *The Condor* 99:933-941.
- Schroeder, M. A., and R. K. Baydack. 2001. Predation and the management of prairie grouse. *Wildlife Society Bulletin* 29:24-32.
- Schroeder, M. A., C. L. Adridge, A. D. Apa, J. R. Bohne, C. E. Braun, S. D. Bunnell, J. W. Connelly, P. A. Deibert, S. C. Gardner, M. A. Hillard, G. D. Kobriger, S. M. McAdam, C. W. McCarthy, J. J. McCarthy, D. L. Mitchell, E. V. Rickerson, and S. J. Stiver. 2004. Distribution of sage-grouse in North America. *The Condor* 106:363-376.
- Sharrow, S. H., W. C. Leninger, and B. Rhodes. 1989. Sheep grazing as a sivicultural tool to suppress brush. *Journal of Range Management* 42:2-4.
- Shown, L. M., R. F. Miller, and F. A. Branson. 1969. Sagebrush conversion to grassland as affected by precipitation, soil, and cultural practices. *Journal of Range Management* 22:303-311.
- Stewart, G., and A. C. Hull. 1949. Cheatgrass (*Bromus tectorum* L.)--an ecological intruder in southern Idaho. *Ecology* 30:58-74.
- Sveum, C. M., W. D. Edge, and J. A. Crawford. 1998. Nesting habitat selection by sage-grouse in southcentral Washington. *Journal of Range Management* 51:265-269.

- Swenson, J. E., C. A. Simmons, and C. D. Eustace. 1987. Decrease of sage grouse *Centrocercus urophasianus* after plowing of sagebrush steppe. *Biological Conservation* 41:125-132.
- Vale, T. R. 1974. Sagebrush conversion projects: an element of contemporary environmental change in the western United States. *Biological Conservation* 6:274-284.
- Van Poolen, H. W., and J. R. Lacey. 1979. Herbage response to grazing systems and stocking intensities. *Journal of Range Management* 32:250-253.
- Wakkinen, W. L., K. P. Reese, and J. W. Connelly. 1992. Sage-grouse nest locations in relation to leks. *Journal of Wildlife Management* 56:381-383.
- Wallestad, R. O. and D. B. Pyrah. 1974. Movement and nesting of sage-grouse hens in central Montana. *Journal of Wildlife Management*. 38:630-633.
- Wambolt, C.L., and G.F. Payne. 1986. An 18-year comparison of control methods for Wyoming big sagebrush in southwestern Montana. *Journal of Range Management* 39:314-319.
- Watts, M. J., and C. L. Wambolt. 1996. Long-term recovery of Wyoming big sagebrush after four treatments. *Journal of Environmental Management* 46:95-102.
- West, N. E. 1983. Temperate deserts and semi-deserts. Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.
- West, N. E., F. D. Provenza, P. S. Johnson, and M. K. Owens. 1984. Vegetation changes after 13 years of livestock grazing exclusion on sagebrush semidesert in west central Utah. *Journal of Range Management* 37:262-264.

West, N. E., and J. A. Young. 2000. Intermountain valleys and lower mountain slopes. Pages 255-284 in M. G. Barbour and W. D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, Cambridge, U. K.

Wisdom, M. J., R. S. Holthausen, D. C. Lee, B. D. Wales, W. J. Murphy, M. R. Eames, C. D. Hargis, V. A. Saab, T. D. Rich, F. B. Samson, D. A. Newhouse, and N. Warren. 2000. Source habitats for terrestrial vertebrates of focus in the Interior Columbia Basin: Broad-scale trends and management implications. U. S. Department of Agriculture, Forest Service, Pacific Northwest Resource State General Technical Report PNW-GTR-485, Portland, OR.

Young, J. A., and F. L. Allen. 1997. Cheatgrass and range science: 1930-1950. *Journal of Range Management* 50:530-535.

CHAPTER 2

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

Abstract: In 1999 the Western Association of Fish and Wildlife Agencies (WAFWA) signed a Memorandum of Understanding (MOU) calling for the adoption of a range-wide sage-grouse (*Centrocercus* spp.) conservation plan. In this MOU, 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 I 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 (cattle). 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%, $P = 0.02$). 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, Krueger et al. 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, Connelly et al. 2004). 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 (~10 to 25%) shrub canopy cover (Martin 1970, Wallestad 1971, Connelly et al. 2000) 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).

In 1999 the Western Association of Fish and Wildlife Agencies (WAFWA) signed a Memorandum of Understanding (MOU) calling for the adoption of a range-wide sage-grouse conservation plan. In this MOU, WAFWA identified a need to determine the effect of management practices on sage-grouse and sagebrush ecosystems under different environmental conditions (WAFWA 1999). 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. Rasmussen, 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, and the sage-grouse response to treatment. 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, in Garfield, Sevier, Piute, and Wayne counties, Utah and encompasses both the Aquarius and Awapa Plateaus (Figure 2-1). 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 (cattle and sheep). Stocking rates are 1.46 ha per animal unit month (AUM) (personal communication, R. Torgerson, SITLA biologist). 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.

Sheep are grazed in the more southern pastures and continuously herded. Sheep are not currently grazed in Parker Lake Pasture (PLP). Cattle are grazed throughout the mountain. In addition to livestock, a large herd of pronghorn (*Antilocarpa americana*) graze the mountain throughout the year.

The sagebrush habitat on 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 2-2). 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 PLP, was selected for this study (Figure 2-3).

The PLP contains lower lying draws that are dominated by mountain big sagebrush with some silver sage (*A. cana*) in the more mesic bottoms. Hillsides 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 I identified 12 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 2-4). The plots were flagged to ensure accuracy during treatment. Five random 20 m vegetation transects were placed within each plot. Transects were placed randomly by partitioning plots into 100 squares, randomly selecting a square, and placing the transect at the center of the square. 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 2-4). To mimic actual contracting operations, the contractors who conducted the work were directed to stay within flagged areas for treatment. The contractors were not told the actual location of the vegetation transects. Thus, within each plot, some of the pre-treatment vegetation transects were not treated. This allowed me 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. I sampled a total of 160 independent transects within the treated plots (97 treated, 63 untreated).

Shrub canopy (all shrub species) 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 (Figure 2-5). 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, where the harrow was dragged over the treatment area in one direction and again in the opposite direction. 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 2-4). (Note: The seed mixture failed to germinate within the two years after application. 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 (Figure 2-6). 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 2-4). No seeding took place following the Lawson aerator treatment.

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.

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). Separate analyses were run for each of 4 variables: 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 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, $P = <0.01$) plots compared to control plots ($\bar{x} = 32.8\%$, SE = 2.5). There was no difference in shrub canopy between Dixie harrow and Lawson aerator plots ($P = 0.36$). 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 between treatments ($P = 0.45$). Forb cover increased with Dixie harrow ($\bar{x} = 10.4\%$, $SE = 1.8$, $P = <0.01$) compared to control ($\bar{x} = 6.3\%$, $SE = 1.8$) and Lawson aerator ($\bar{x} = 8.1\%$, $SE = 1.8$, $P = 0.01$), but did not differ between control and Lawson aerator ($P = 0.41$). Total herbaceous cover increased with Dixie harrow ($\bar{x} = 23.9\%$, $SE = 1.4$, $P = <0.01$), 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 between treatments ($P = 0.07$).

Time Period Comparisons

Time period comparisons are contained in Table 2-1. 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 Lawson aerator differed from control June to July 2003 ($P = 0.01$), and July 2002 to July 2003 ($P = 0.01$), and Dixie harrow differed from control July 2002 to July 2003 ($P = 0.01$) and July 2000 to August 2001 ($P = 0.01$). 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 between Dixie harrow and Lawson aerator 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 reduced shrub canopy cover (Figure 2-7). All plots started with an average shrub canopy cover of ~ 38% (Figure 2-7). Connelly et al. (2000) recommended shrub canopy of 10 to 25% for brood-rearing areas. Mountain big sagebrush in PLP had become dense stands, which is not optimal brood-rearing habitat for sage-grouse. Dixie harrow and Lawson aerator treatments opened up the dense shrub canopy cover on average to percentages within habitat guidelines for brood-rearing habitat (Connelly et al. 2000, Figure 2-7).

Dixie harrow was the most effective treatment at increasing herbaceous cover by reducing shrub canopy. Mean percent grass and forb cover within control plots decreased between pre- to post-treatment sampling periods, but increased on Dixie harrow plots. However, the percent increase in grass and forb components for Dixie harrow plots were < 3% . Dixie harrow moderately increased all herbaceous components and specifically forb cover (Figures 2-8, 2-9, and 2-10). Forb cover is the most important herbaceous component for sage-grouse broods (Connelly et al. 2000). 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 2-1).

In the summer of 2002 southern Utah was impacted by a severe drought (Figure 2-2). Therefore, the measured grass response to sagebrush treatment may have helped to alleviate the impact of the drought conditions on the herbaceous component, though the percent change in was small. Comparisons from July 2002 to June 2003 showed the greatest increase in herbaceous cover for both Dixie harrow and

Lawson aerator (Figures 2-8, 2-9, and 2-10), which is most likely due to an increase in precipitation in 2003 (Figure 2-2).

Though treatment and control plots were assigned randomly, control plots were clumped in the north end of the pasture (Figure 2-4). The PLP does decrease slightly in elevation north to south. Thus, clumping did not create a confounding effect because vegetation within all plots was similar pretreatment.

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 cover, though the increase was comparatively small. Dixie harrow can be used to improve and restore shrub canopy cover within mountain big sagebrush areas to meet sage-grouse brood-rearing habitat guidelines when shrub canopy exceeds 25%, and possibly increase herbaceous components. Though the change was moderate, Dixie harrow was the only treatment that increased forb cover within the first 2 years post-treatment. Jarvis (1973) reported the limiting factor of the Parker Mountain sage-grouse population was the lack of 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

generate the anticipated increase in herbaceous understory. This response may have been both a consequence 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

- Apa, A. D. 1998. Habitat use and movements of sympatric sage and Columbian sharp-tailed grouse in southeastern Idaho. Dissertation, University of Idaho, Moscow, USA.
- Autenrieth, R. E. 1981. Sage grouse management in Idaho. Idaho Department of Fish and Game, Wildlife Bulletin 9, Boise, Idaho, USA.
- Beck, J. L., and D. L. Mitchell. 2000. Influences of livestock grazing on sage grouse habitat. *Wildlife Society Bulletin* 28:993-1002.
- Beck, J. L., D. L. Mitchell, and B. D. Maxfield. 2003. Changes in the distribution and status of sage-grouse in Utah. *Western North American Naturalist* 63:203-214.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. *Wildlife Society Bulletin* 5:99-106.
- Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. *Western*

- Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming, USA.
- Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.
- Dunn, P. O., and C. E. Braun. 1986. Summer habitat use by adult female and juvenile sage-grouse. *Journal of Wildlife Management* 50:228-235.
- Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996. An investigation on fire effects within xeric sage-grouse brood habitat. *Journal of Range Management* 49:194-198.
- Jarvis, J.M. 1974. Sage grouse population studies on the Parker Mountain in south central Utah. Fed. Aid Wildl. Restor. Proj. W-65-R, Job c-1. Utah Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, UT, USA.
- Johnson, K. H., R. A. Olson, and T. D. Whitson. 1996. Composition and diversity of plant and small mammal communities in tebuthiuron-treated big sagebrush (*Artemisia tridentata*). *Weed Technology* 10:404-416.
- Klebenow, D. A. 1969. Sage-grouse nesting and brood habitat in Idaho. *Journal of Wildlife Management* 33:649-661.
- Krueger, W. C., M. A. Sanderson, J. B. Cropper, M. Miller-Goodman, C. E. Kelley, R. D. Pieper, P L. Shaver, and M. J. Trlica. 2002. Environmental impacts of livestock on US grazing lands. Council for Agricultural Science and Technology, Issue Paper No. 22. Ames, IA, USA.

- Levy, E. B., and E. A. Madden. 1933. The point method for pasture analysis. *New Zealand Journal of Agriculture* 46:267-269.
- Martin, N. S. 1970. Sagebrush control related to habitat and sage-grouse occurrence. *Journal of Wildlife Management* 34:313-320.
- Miller, R. F., T. J. Svejcar, and N. E. West. 1994. Implications of livestock grazing in the Intermountain sagebrush region: plant composition. Pages 101-146 in M. Vavra, W. A. Laycock, and R. D. Pieper, editors. *Ecological implications of livestock herbivory in the West*. Society for Range Management, Denver, Colorado, USA.
- Patterson, R. L. 1952. *The sage grouse in Wyoming*. Sage Books, Denver, Colorado, USA.
- Sveum, C. M., J. A. Crawford, and W. D. Edge. 1998. Use and selection of brood-rearing habitat by sage-grouse in south-central Washington. *Great Basin Naturalist* 58:344-351.
- Underwood, A. J. 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. *Ecological Applications* 4:3-15.
- Wallestad, R. O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. *Journal of Wildlife Management* 35:126-136.
- West, N. E. 1983. *Temperate deserts and semi-deserts*. Elsevier Scientific Publishing Company, Amsterdam, The Netherlands.

Table 2-1. Vegetation cover responses for treatment and control by time periods, Parker Mountain, Utah, 2000 – 2003.

	Shrub Canopy Cover			Total Herbaceous Cover		
	Est.	SE	<i>P</i>	Est.	SE	<i>P</i>
C v D x Before treatment	N/A	N/A	N/A	0.01	0.05	0.01
C v L x Before treatment	N/A	N/A	N/A	0.02	0.05	0.08
D v L x Before treatment	N/A	N/A	N/A	0.01	0.05	0.07
C v D x 2002 (June to July)	0.07	0.04	0.05	0.09	0.05	0.92
C v L x 2002 (June to July)	0.06	0.04	0.10	0.15	0.05	0.72
D v L x 2002 (June to July)	-0.01	0.04	0.75	0.06	0.05	0.80
C v D x 2003 (June to July)	0.01	0.04	0.96	-0.02	0.05	0.06
C v L x 2003 (June to July)	0.06	0.04	0.10	-0.04	0.05	0.01
D v L x 2003 (June to July)	0.06	0.04	0.11	-0.02	0.05	0.21
C v D x June (2002 to 2003)	-0.03	0.04	0.47	0.15	0.05	0.71
C v L x June (2002 to 2003)	-0.01	0.04	0.69	0.20	0.05	0.40
D v L x June (2002 to 2003)	0.01	0.04	0.74	0.05	0.05	0.63
C v D x July (2002 to 2003)	-0.01	0.04	0.01	0.04	0.05	0.01
C v L x July (2002 to 2003)	-0.02	0.04	0.67	0.01	0.05	0.01
D v L x July (2002 to 2003)	0.08	0.04	0.03	-0.03	0.05	0.27
	Grass Cover			Forb Cover		
	Est.	SE	<i>P</i>	Est.	SE	<i>P</i>
C v D x Before treatment	0.03	0.04	0.52	-0.03	0.02	0.21
C v L x Before treatment	-0.01	0.04	0.92	0.02	0.02	0.47
D v L x Before treatment	-0.03	0.04	0.46	0.05	0.02	0.05
C v D x 2002 (June to July)	0.08	0.04	0.05	0.02	0.02	0.49
C v L x 2002 (June to July)	0.12	0.04	0.01	0.03	0.02	0.15
D v L x 2002 (June to July)	0.04	0.04	0.26	0.02	0.02	0.44
C v D x 2003 (June to July)	-0.01	0.04	0.83	-0.01	0.02	0.68
C v L x 2003 (June to July)	-0.05	0.04	0.18	0.01	0.02	0.64
D v L x 2003 (June to July)	-0.04	0.04	0.26	0.02	0.02	0.38
C v D x June (2002 to 2003)	0.11	0.04	0.01	0.04	0.02	0.08
C v L x June (2002 to 2003)	0.16	0.04	0.01	0.04	0.02	0.08
D v L x June (2002 to 2003)	0.05	0.04	0.16	0.01	0.02	1.00
C v D x July (2002 to 2003)	0.02	0.04	0.53	0.02	0.02	0.51
C v L x July (2002 to 2003)	-0.01	0.04	0.80	0.02	0.02	0.44
D v L x July (2002 to 2003)	-0.03	0.04	0.38	0.01	0.02	0.91

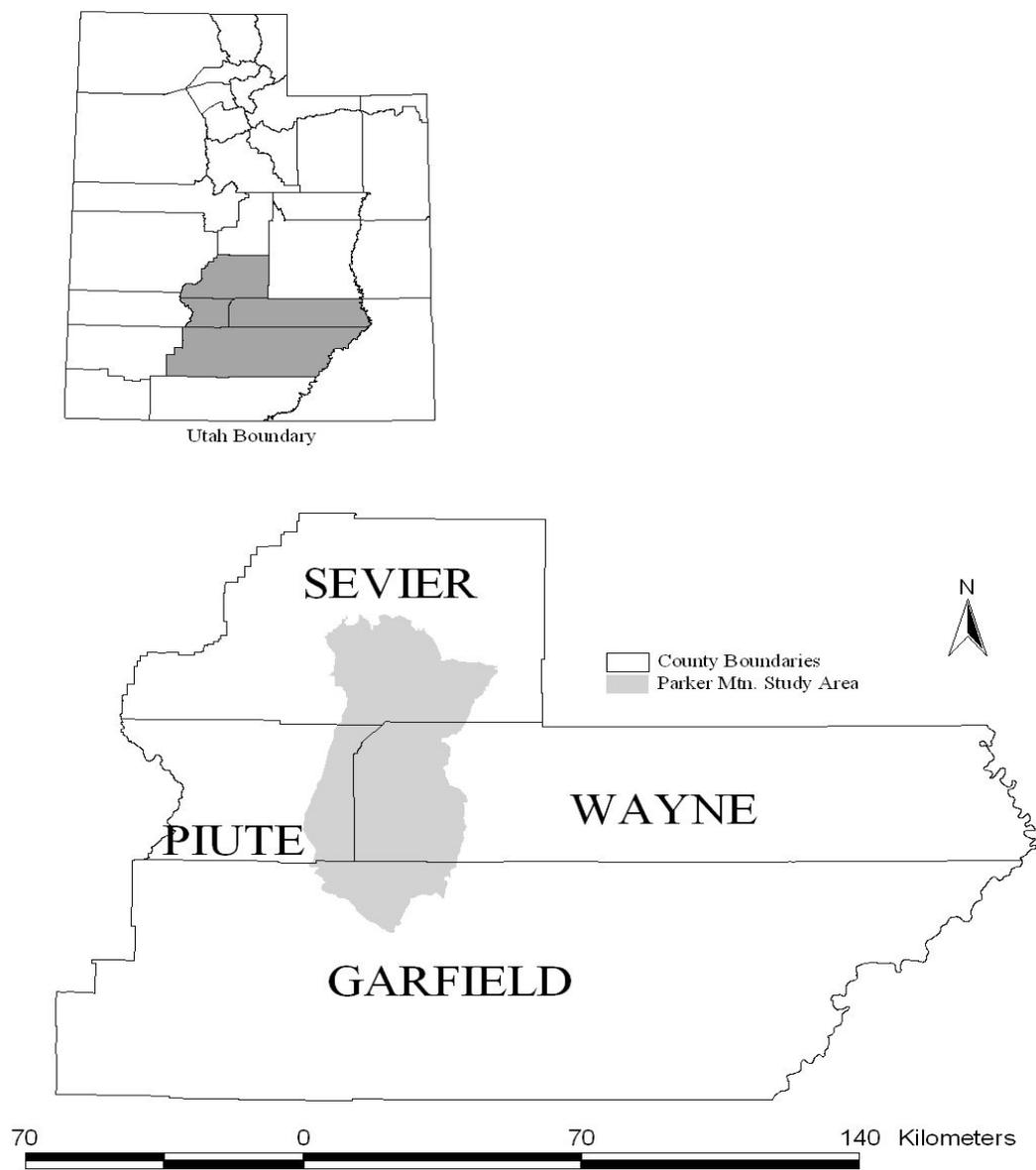


Figure 2-1. Parker Mountain Study Area, Utah, 2001-2003.

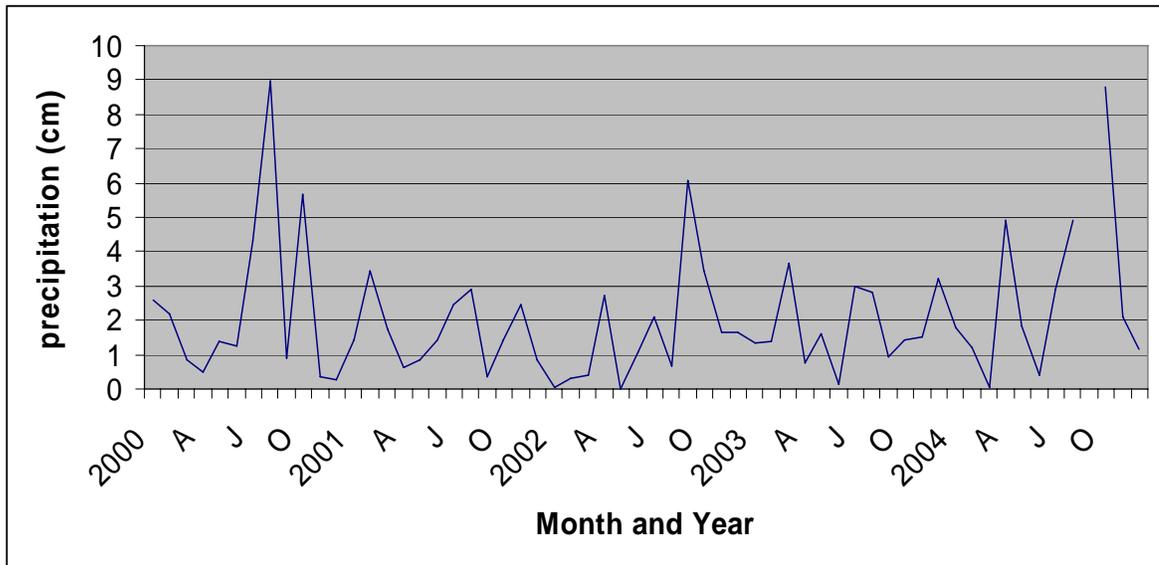


Figure 2-2. Monthly precipitation (Utah Climate Center data, climate.usurf.usu.edu), Koosheram (~ 15 km from PLP), Utah, 2000-2004.

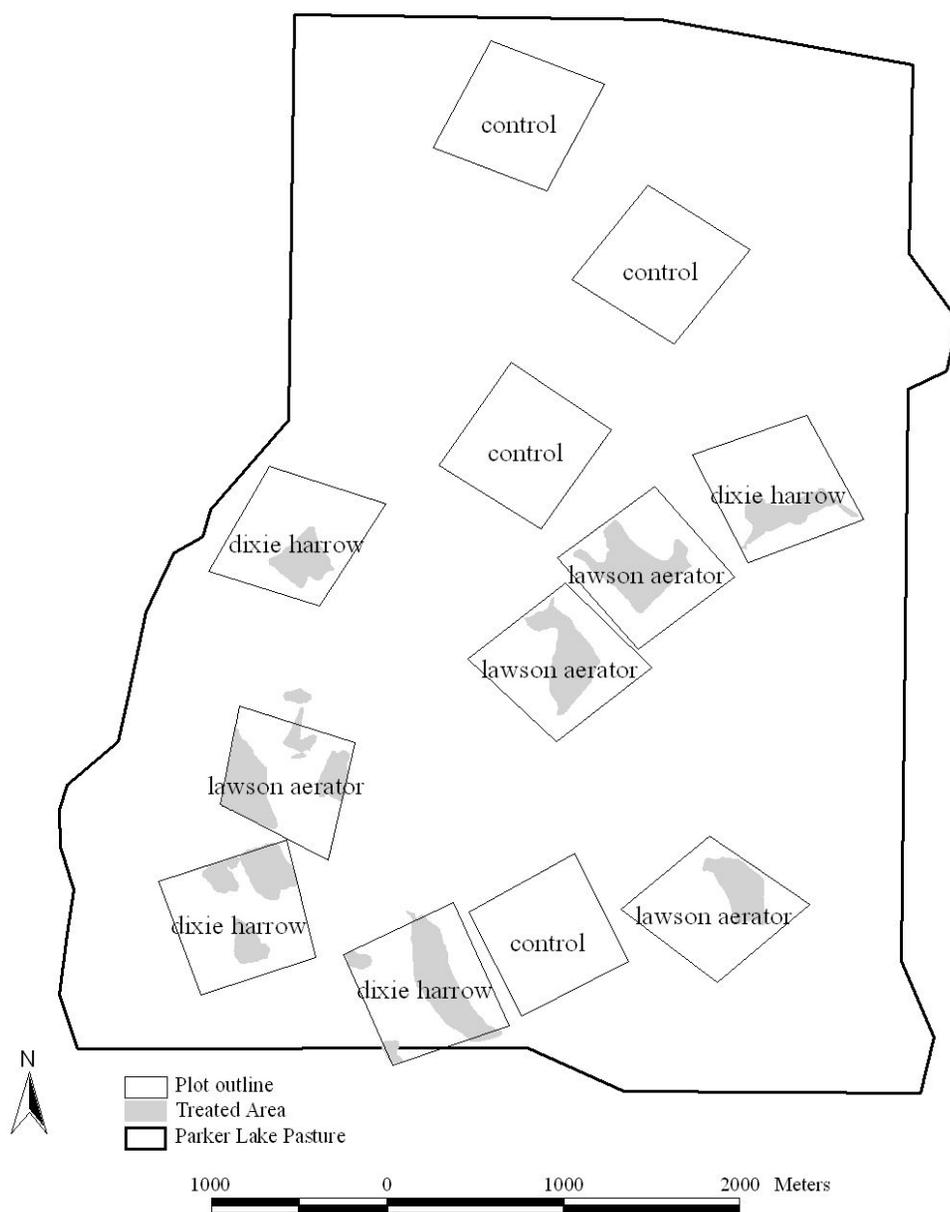


Figure 2-3. Parker Lake Pasture within Parker Mountain Study Area, Utah, 2000 – 2003.



Figure 2-4. Dixie harrow photo, <http://reveg-catalog.tamu.edu/07-Site%20Preparation.htm> accessed on 3-10-06.



Figure 2-5. Lawson aerator photo, <http://reveg-catalog.tamu.edu/07-Site%20Preparation.htm> accessed on 3-10-06.

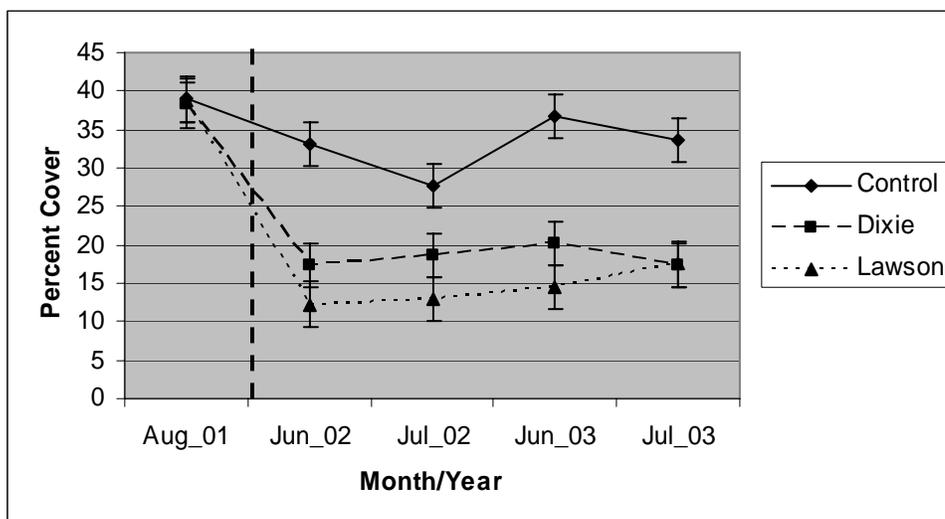


Figure 2-6. Shrub Canopy Cover, Parker Mountain, Utah, 2001-2003.

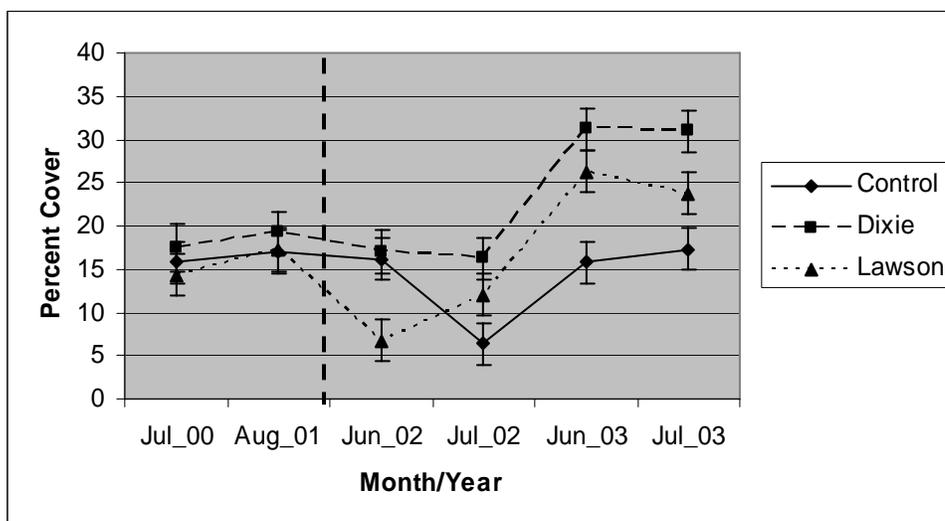


Figure 2-7. Total Herbaceous Cover, Parker Mountain, Utah, 2000-2003.

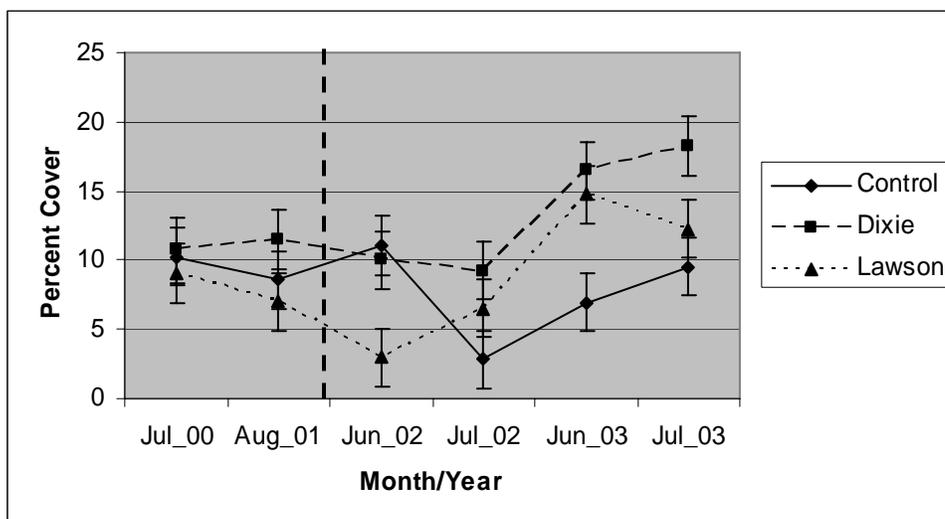


Figure 2-8. Grass Cover, Parker Mountain, Utah, 2000-2003.

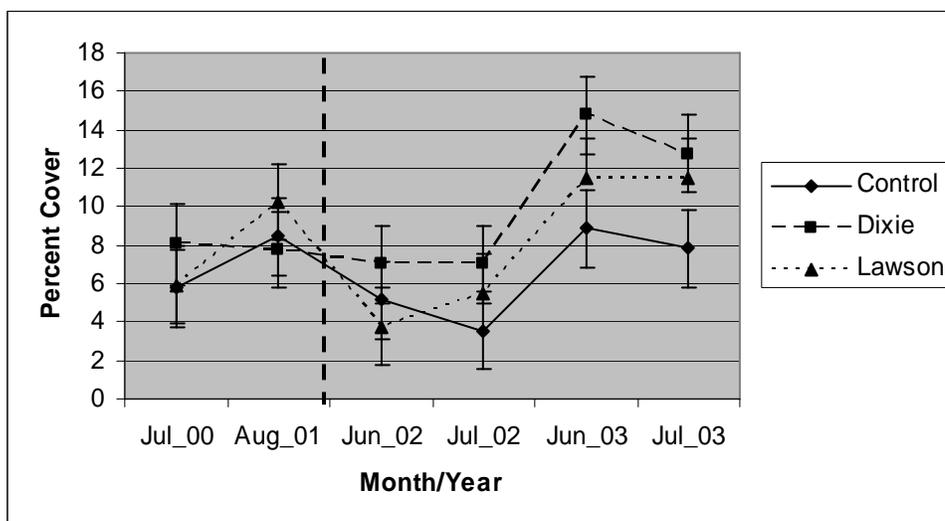


Figure 2-9. Forb Cover, Parker Mountain, Utah, 2000-2003.

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. In 1999 the Western Association of Fish and Wildlife Agencies (WAFWA) signed a Memorandum of Understanding (MOU) calling for the adoption of a range-wide sage-grouse (*Centrocercus* spp.) conservation plan. In this MOU, WAFWA identified a need to determine the effect of management practices on sage-grouse and sagebrush (*Artemisia* spp.) ecosystems under different environmental conditions. 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 the herbicide Tebuthiuron on sage-grouse habitat use in a mountain big sagebrush communities, we treated sixteen 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 bird dog 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 compared to control. 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 sage-brush 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 (*Artemisia* 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. 1994, Krueger et al. 2002).

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 techniques 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 (first two weeks) 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 (third week until chick dispersal or brood integrity ceases) 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 et al. (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 includes both the Aquarius and Awapa Plateaus (Figure 3-1). 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 are privately owned (Figure 3-1). The predominant land use in the area is grazing by domestic livestock (cattle and sheep). Sagebrush habitat on the Parker Mountain comprises one of the largest contiguous tracts of sagebrush in Utah. Because of its remoteness, Parker Mountain has escaped development and land use pressures occurring at lower elevations, and 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 3-2). A few natural springs occur at higher elevations (> 2700 m). These springs have been augmented by > 80 water developments that have increased livestock distribution during the grazing season and provided seasonal water sources for wildlife.

The Parker Lake Pasture (PLP) was selected as an experimental study area. PLP consists of ~ 2000 ha (Figure 3-3) and is between 2700 m and 2900 m elevation. This area generally receives more precipitation (~ 40 to 51 cm/yr) than lower elevation areas. 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 3-4). The plots exhibited ~ 38% sagebrush canopy cover (Chapter 2), and were randomly assigned to treatment and control groups. Treatments included Dixie harrow and Lawson aerator (mechanical) and Tebuthiuron (chemical). The Tebuthiuron (1.6 kg/ha at 0.3 active ingredient, 20P, N-[5-(1,1-dimethylethyl)-[5-¹⁴C]-1,3,4-thiadiazol-2-yl]-N,N'-dimethylurea, Dow AgroSciences 9330 Zionsville Road, Indianapolis, IN, USA) 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 resulted in a partial kill of sagebrush and the herbicide pellets were applied over the entire plot, I was not able to determine the exact area affected. Tebuthiuron may also have a delayed effect because the herbicide has a soil half life of 12 to 15 months with 102 to 152 cm of precipitation per year (Extension Toxicology Network 1993). The half life of Tebuthiuron on the plots is probably longer because PLP receives much less precipitation (40 to 51 cm/yr).

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 crossing the entire plot was placed within each third. Transects were walked very slowly while researchers (7 individuals over a 2-year period) 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 (> 10 pellets in very close proximity usually with a cecal dropping) 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. In 2004 the first survey was done using the same 1 of 2 dogs, while the second was conducted by 16 dogs (1 in each plot), covering all 16 plots during the same time period (0800 to 0930). Due to the close proximity of plots (Figure 3-4), and surveying different plots on different days, there was a risk of double sampling. To assess this risk Utah Chukar Foundation members volunteered their time and most experienced dogs for the second 2004 survey. I used 1 of 2 German shorthaired pointers (GSP) for all surveys, except in the last survey of 2004, where pointers, English setters, GSP's,

Brittanies, and German wirehaired pointers were used. Grouse were flushed and classified as juvenile, hen, male, or unknown. Sex was determined by size, where adult males nearly double the size of hens. Juveniles were also determined by size, most being considerably smaller than adult hens. An explanation of the differences between juvenile, adult male, and adult female was given to all observers, and each was asked if they were comfortable classifying grouse flushed. All answered to the affirmative. The vast majority had experience with observing sage-grouse prior to the survey. Broods were counted as a hen with any number of chicks. If more than 1 hen flushed with multiple chicks, the number of broods equaled the number of hens. The survey effort was the same 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 (Canfield 1941) for percent shrub cover (all shrub species). 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.

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 3-1 and 3-2). Lawson aerator and Dixie harrow treatments pellet counts were higher than control plots (Table 3-1), but did not differ statistically (Table 3-2 and Figure 3-5). Probability of detection was highest in Lawson aerator plots (Table 3-1, Table 3-2, and Figure 3-6). Detection probabilities were similar for all plots, and ranged between 24.8 to 31.2% (Table 3-2).

For distance-to-edge frequency data, the Dixie harrow treated sagebrush within plots (TRA) and untreated sagebrush within plots (UTRA) exhibited a marked drop off between ~ 20 and 30 meters (Appendix B). 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 B). Tebuthiuron TRA showed a drop off between ~ 40 and 50m, though it wasn't as dramatic (Appendix B). Tebuthiuron

UTRA showed a drop off between ~ 20 and 30 m, similar to other untreated areas (Appendix B). Interestingly, in the control areas, the grouse were still using mountain big sagebrush habitat within 30 m of the edge (Appendix B).

During birddog surveys, more grouse overall and broods specifically were flushed in the Tebuthiuron plots (Table 3-3 and Figures 3-7 and 3-8). 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 3-3 and 3-4).

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

For the birddog surveys of plots done on multiple days in 2004 I 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 I 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 3-11, Connelly et al. 2000). For forb cover, Tebuthiuron treatments were higher than control and Lawson aerator ($P = 0.0003$, 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 ($P = 0.0160$, 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 (*Taraxacum* spp.) densities and percent cover when compared to the other plots (Appendix C).

Discussion

For pellet counts, detection probabilities differed among 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 3-1, Figure 3-5). 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 classify adults by gender.

Forb response, particularly dandelion (Appendix C), 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, Peterson 1970, Wallestad et al. 1975, Johnson et al. 1996), 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. Most likely the

greatest factor for plot preference was that Tebuthiuron plots exhibited 18 to 25% shrub canopy cover while providing abundant forbs. The 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 (Chi 2004).

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 ~ 100 m.

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.

No pre-treatment sage-grouse use data were collected. The post-treatment sage-grouse use data would have been strengthened if pretreatment data were collected.

Conclusions

Sage-grouse on Parker Mountain preferred the treatment plots, especially Tebuthiuron plots, for brood-rearing. 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 (I used 0.3 active ingredient) of active ingredient that results in partial kill of sagebrush is probably 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. Shrub cover should exceed 25% canopy cover and combined forb and grass cover should be less than 15% cover before treatment should be considered within sage-grouse brood-rearing habitat.

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 B) 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 3-5.

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 (16 40.5 ha plots) in a vast expanse (a ~2000 ha pasture in a ~100,000 ha contiguous tract of sagebrush) 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 treat > 20% of available seasonal habitat in wintering or nesting areas (Connelly et al. 2000).

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

When conducting birddog surveys, the individual dog's abilities must be considered. 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 1 of 2 dogs) used for surveys, and 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 did not 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 did not want to risk a dog catching a chick. Thus my surveys were taken within the late brood-rearing period. If I had completely trained dogs I would have liked to look for broods during the early brood-rearing period as well.

Literature Cited

- Apa, A. D. 1998. Habitat use and movements of sympatric sage and Columbian sharp-tailed grouse in southeastern Idaho. Dissertation, University of Idaho, Moscow, USA.
- Autenrieth, R. E. 1981. Sage grouse management in Idaho. Idaho Department of Fish and Game, Wildlife Bulletin 9, Boise, Idaho, USA.
- Beck, J. L., and D. L. Mitchell. 2000. Influences of livestock grazing on sage grouse habitat. *Wildlife Society Bulletin* 28:993-1002.
- Beck, J. L., and D. L. Mitchell, and B. D. Maxfield. 2003. Changes in the distribution and status of sage-grouse in Utah. *Western North American Naturalist* 63:203-214.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. *Wildlife Society Bulletin* 5:99-106.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: estimating abundance of biological populations. Oxford University Press Inc., Great Clarendon Street, Oxford OX2 6DP, New York, USA.
- Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry* 39:388-394.
- Chi, R. Y. 2004. Greater sage-grouse reproductive ecology and Tebuthiuron manipulation of dense big sagebrush on Parker Mountain. Master Thesis, Utah State University, Logan, Utah, USA.

- Commons, M. L., R. K. Baydack, and C. E. Braun. 1999. Sage-grouse response to pinyon-juniper management. USDA Forest Service Proceedings RMRS-P-9.
- Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.
- Danvir, R. E. 2002. Sage-grouse ecology and management in northern Utah sagebrush-steppe. Wildlife Research Report, Deseret Land and Livestock Inc. Woodruff, Utah, USA.
- Daubenmire, R. F. 1959. A canopy-coverage method of vegetation analysis. *Northwest Science* 33:43-64.
- Dunn, P. O., and C. E. Braun. 1986. Summer habitat use by adult female and juvenile sage-grouse. *Journal of Wildlife Management* 50:228-235.
- Extension Toxicology Network. 1993. Pesticide information profile: Tebuthiuron. <http://pmep.cce.cornell.edu/profiles/extoxnet/pyrehttrins-ziram/tebuthiuron-ext.html>. Accessed on 11-21-2005.
- Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996. An investigation on fire effects within xeric sage-grouse brood habitat. *Journal of Range Management* 49:194-198.
- Johnson, K. H., R. A. Olson, and T. D. Whitson. 1996. Composition and diversity of plant and small mammal communities in Tebuthiuron-treated big sagebrush (*Artemisia tridentata*). *Weed Technology* 10:404-416.
- Klebenow, D. A. 1969. Sage-grouse nesting and brood habitat in Idaho. *Journal of Wildlife Management* 33:649-661.

- Klebenow, D. A., and G. M. Gray. 1968. The food habits of juvenile sage-grouse. *Journal of Range Management* 21:80-83.
- Krueger, W. C., M. A. Sanderson, J. B. Cropper, M. Miller-Goodman, C. E. Kelley, R. D. Pieper, P L. Shaver, and M. J. Trlica. 2002. Environmental impacts of livestock on US grazing lands. Council for Agricultural Science and Technology, Issue Paper No. 22. Ames, Iowa, USA.
- Martin, N. S. 1970. Sagebrush control related to habitat and sage-grouse occurrence. *Journal of Wildlife Management* 34:313-320.
- Miller, R. F., T. J. Svejcar, and N. E. West. 1994. Implications of livestock grazing in the Intermountain sagebrush region: plant composition. Pages 101-146 *in* M. Vavra, W. A. Laycock, and R. D. Pieper, editors. *Ecological implications of livestock herbivory in the West*. Society for Range Management, Denver, Colorado, USA.
- Olson, R. A., and T. D. Whitson. 2002. Restoring structure in late-successional sagebrush communities by thinning with tebuthiuron. *Restoration Ecology* 10:146-155.
- Patterson, R. L. 1952. *The sage grouse in Wyoming*. Sage Books, Denver, Colorado, USA.
- Peterson, J. G. 1970. The food habits and summer distribution of juvenile sage-grouse in central Montana. *Journal of Wildlife Management* 34:147-155.
- Pyle, W. H., and J. A. Crawford. 1996. Availability of foods of sage grouse chicks following prescribed fire in sagebrush-bitterbrush. *Journal of Range Management* 49:320-324.

- Pyrah, D. B. 1972. Effects of chemical and mechanical sagebrush control on sage-grouse. Montana State Dept. of Fish and Game Job Completion report, W-105-R-6. Helena, Montana, USA.
- SAS Institute Inc. 2002-2003. SAS procedures guide, release 9.1 edition. SAS Institute, Cary, North Carolina, USA.
- Sveum, C. M., J. A. Crawford, and W. D. Edge. 1998. Use and selection of brood-rearing habitat by sage-grouse in south-central Washington. *Great Basin Naturalist* 58:344-351.
- Vale, T. R. 1974. Sagebrush conversion projects: An element of contemporary environmental change in the western United States. *Biological Conservation* 6:274-284.
- Wallestad, R. O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. *Journal of Wildlife Management* 35:126-136.
- Wallestad, R. O., J. G. Peterson, and R. L. Eng. 1975. Foods of adult sage-grouse in central Montana. *Journal of Wildlife Management* 38:628-630.

Table 3-1. Pellet count probability of detection and cluster densities, Parker Mountain, Utah, 2003-2004.

Plot Type	Total # of Clusters	Probability of Detection		Clusters	
		^a P(d)	^b SE	^d Ds	^b SE
C	135	0.255	0.0179	23.38	6.46
D	225	0.274	0.0141	36.26	15.13
L	207	0.312	0.0195	29.33	9.04
T	433	0.248	0.0081	77.12	20.71

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

Table 3-2. Comparison of treatment types for cluster density and probability of detection, Parker Mountain, Utah, 2003-2004.

Comparison of Treatments	Cluster Density		Probability of Detection	
	Z value	P value	Z value	P value
C – D	-0.783	0.4336	-0.83383	0.4044
C – L	-0.536	0.5922	-2.15338	0.0312
C – T	-2.477	0.0132	0.356281	0.7216
D – L	0.393	0.6942	-1.57914	0.1144
D – T	-1.593	0.1112	1.598918	0.1098
L – T	-2.115	0.0344	3.030964	0.0024

Table 3-3. Birddog survey flush counts, Parker Mountain, Utah 2003 and 2004.

Treatment or Year	^a Total Grouse			^b Total Broods		
	n	Mean	^c SE	n	Mean	^c SE
C	6	0.75	0.75	1	0.13	0.13
D	79	9.88	4.28	6	0.75	0.41
L	109	13.63	7.85	7	0.88	0.48
T	252	31.5	7.63	38	4.75	1.21
2003	205	12.81	4.54	16	1	0.42
2004	241	15.06	5.31	36	2.25	0.81

^aAny grouse, male, hen, unknown, or chick^bBroods equaled 1 or more chicks with a hen, if more than one hen was flushed with multiple chicks broods equaled the number of hens^cStandard Error

Table 3-4. Birddog survey comparisons of treatment type for total grouse and broods flushed, Parker Mountain, Utah, 2003-2004.

Comparisons of Treatments	^a Total Grouse		^b Total Broods	
	t value	P value	t value	P value
C - D	-1.58	0.1404	-1.09	0.2962
C - L	-1.85	0.0887	-1.39	0.1902
C - T	-4.04	0.0017	-5.41	0.0002
D - L	-0.27	0.7888	-0.30	0.772
D - T	-2.46	0.0302	-4.31	0.001
L - T	-2.18	0.0496	-4.02	0.0017

^aAny grouse, male, hen, unknown, or chick

^bBroods equaled 1 or more chicks with a hen, if more than one hen was flushed with multiple chicks broods equaled the number of hens

Table 3-5. 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.

	^a UTRA	^b TRA
Dixie	40-60 m	40-60 m
Lawson	60-80 m	160 m+

^aUTRA-width of intact mountain big sagebrush

^bTRA-width of treatment

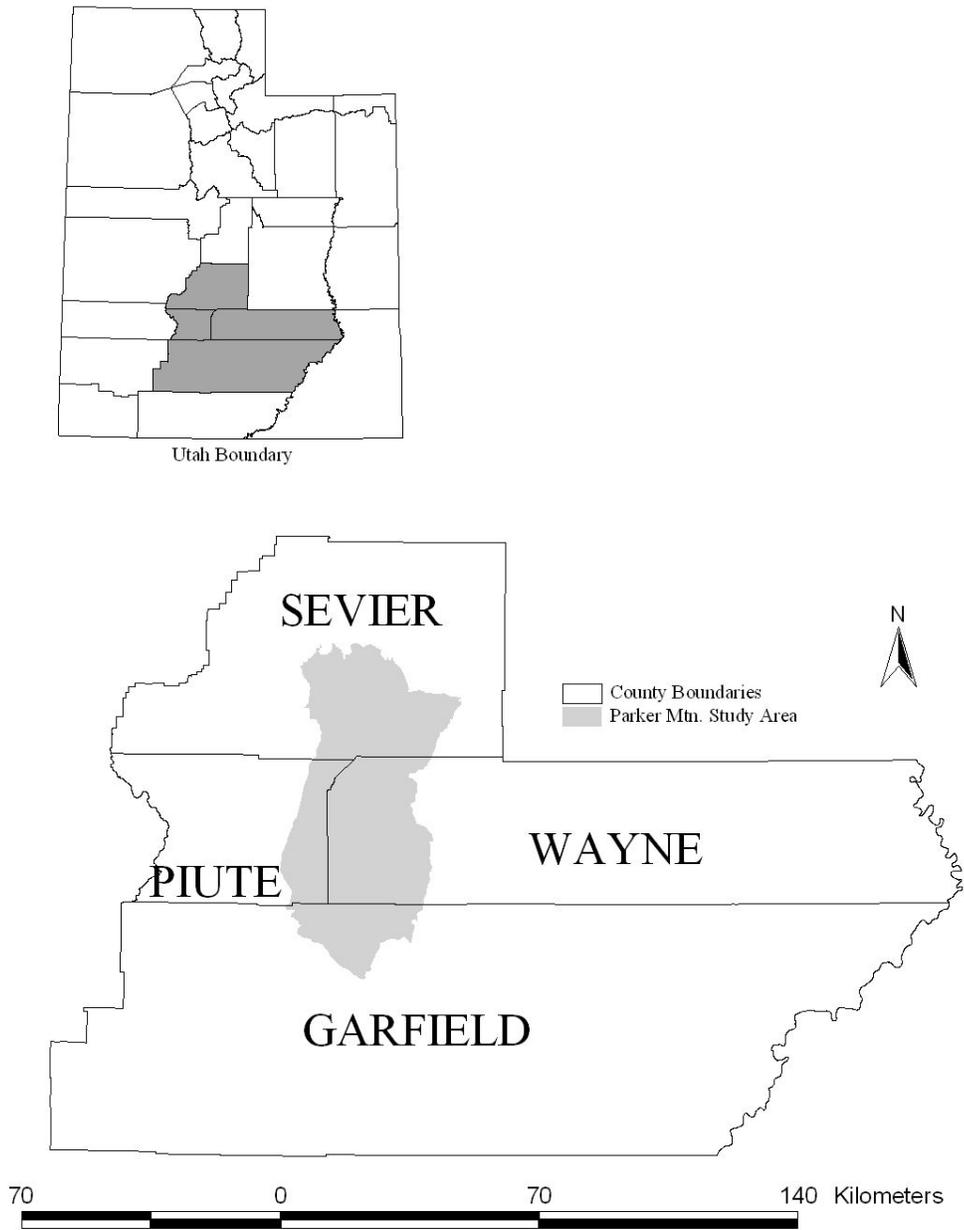


Figure 3-1. Parker Mountain Study Area, Utah, 2002-2004.

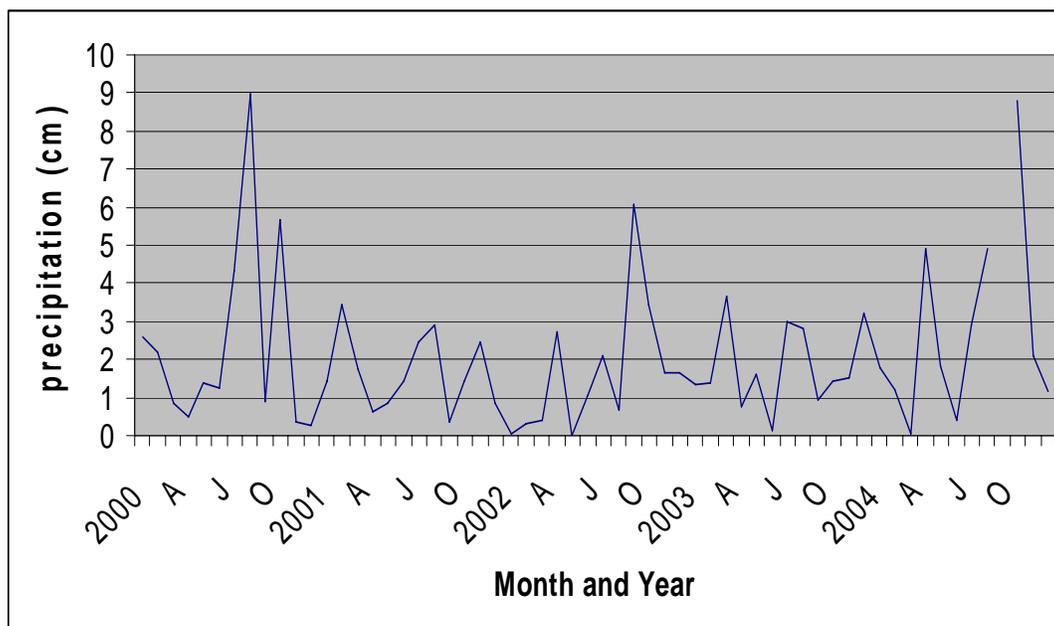


Figure 3-2. Monthly Precipitation (Utah Climate Center data, climate.usurf.usu.edu), Koosheram (~ 15 km from PLP), Utah, 2000-2004.

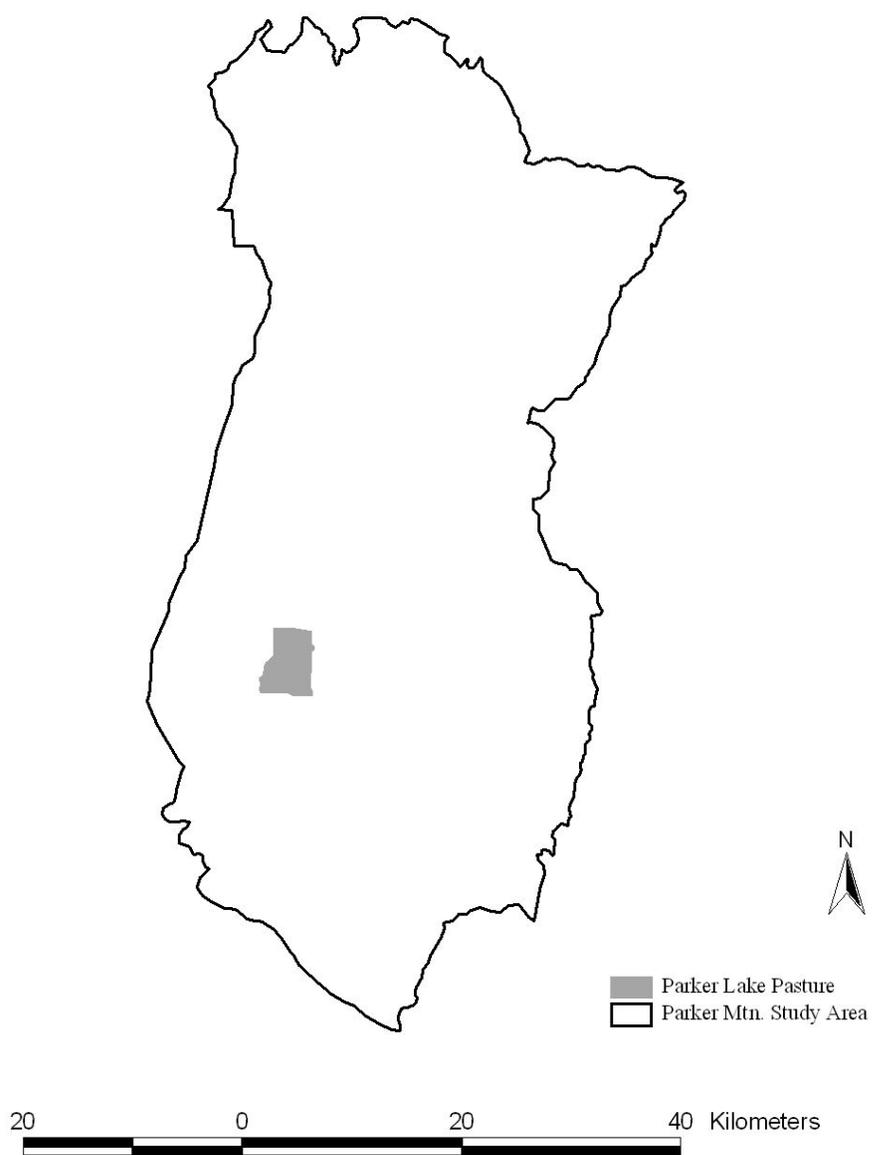


Figure 3-3. Parker Lake Pasture, Parker Mountain, Utah, 2002-2004.

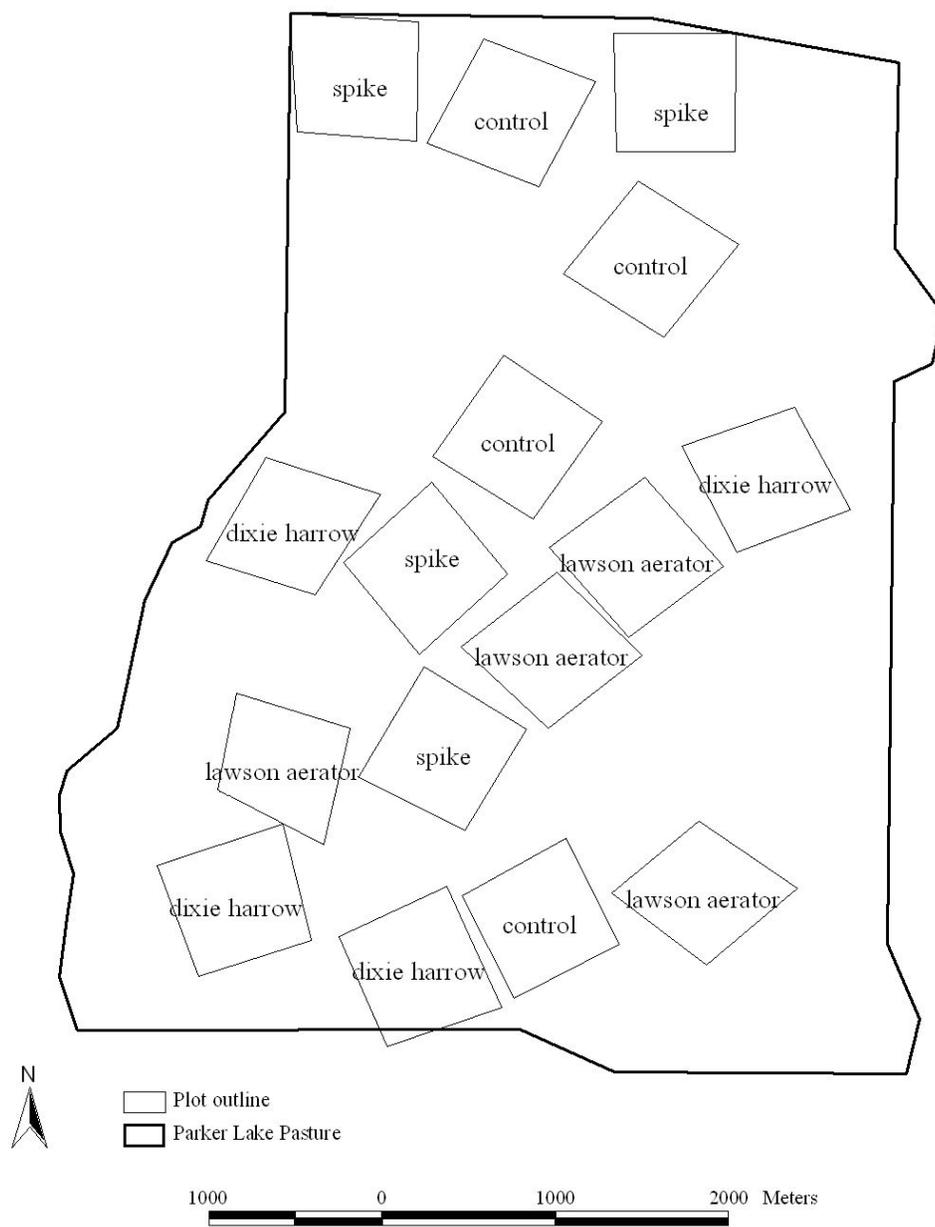


Figure 3-4. Plots and Treatment Type within Parker Lake Pasture, Parker Mountain, Utah, 2002-2004.

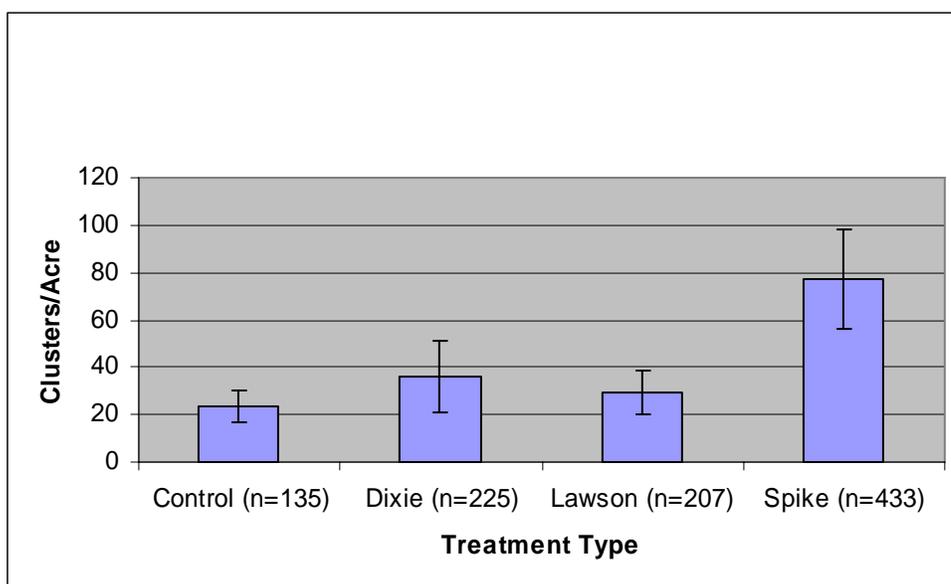


Figure 3-5. Sage-grouse pellet cluster density by treatment, Parker Mountain, Utah, 2003 and 2004.

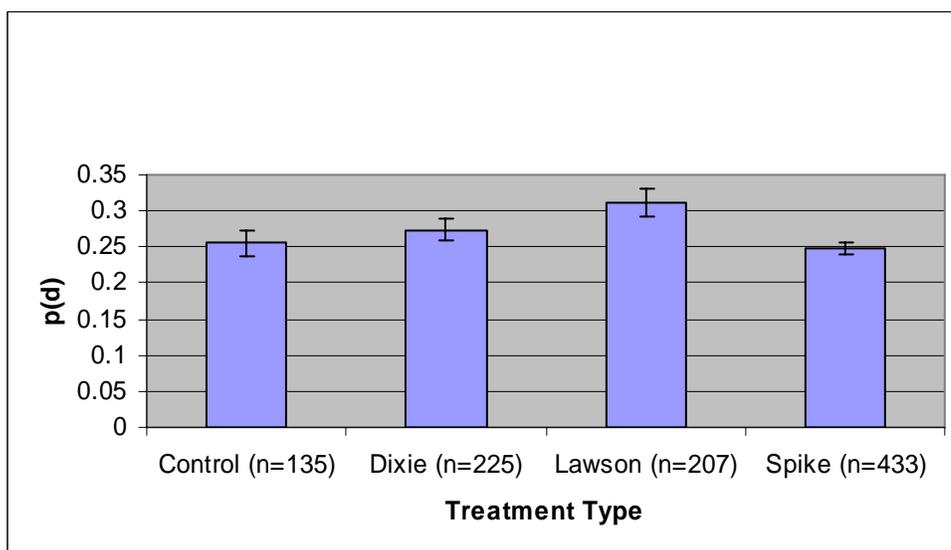


Figure 3-6. Sage-grouse pellet count probability of detection [p(d)], Parker Mountain, Utah, 2003 and 2004.

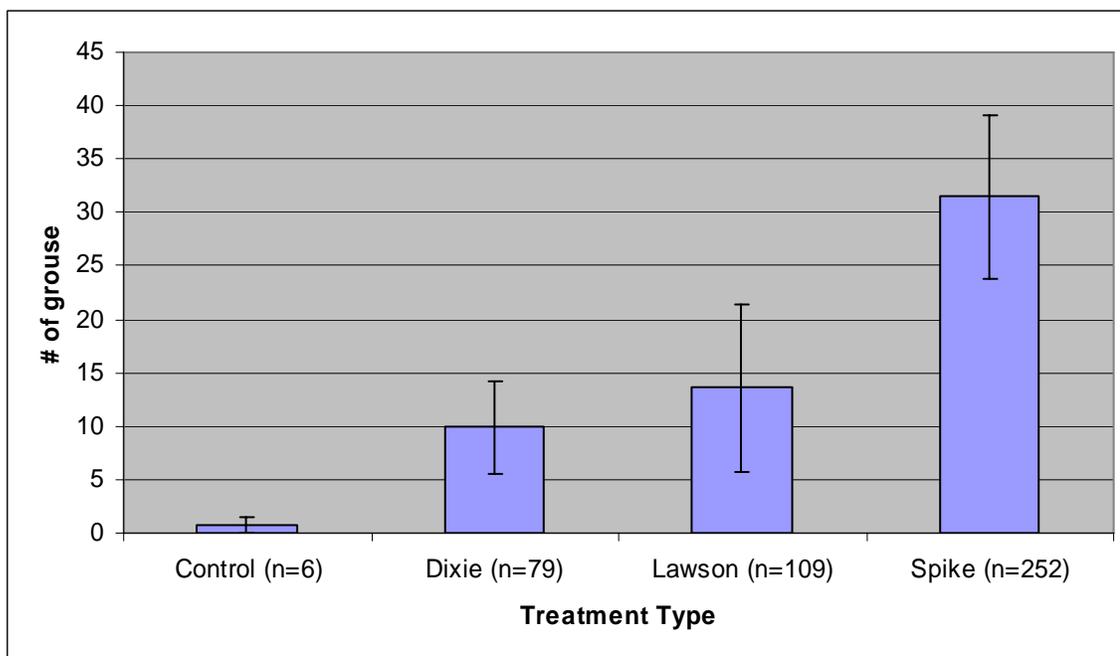


Figure 3-7. Total sage-grouse flushed with bird dogs by treatment (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

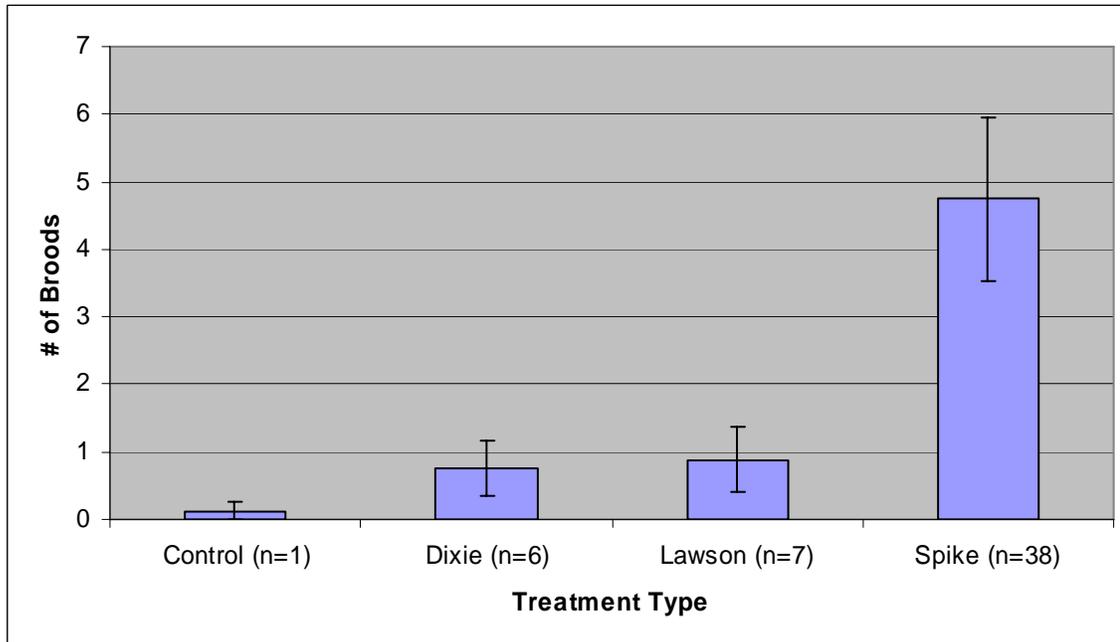


Figure 3-8. Sage-grouse broods flushed with bird dogs by treatment (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

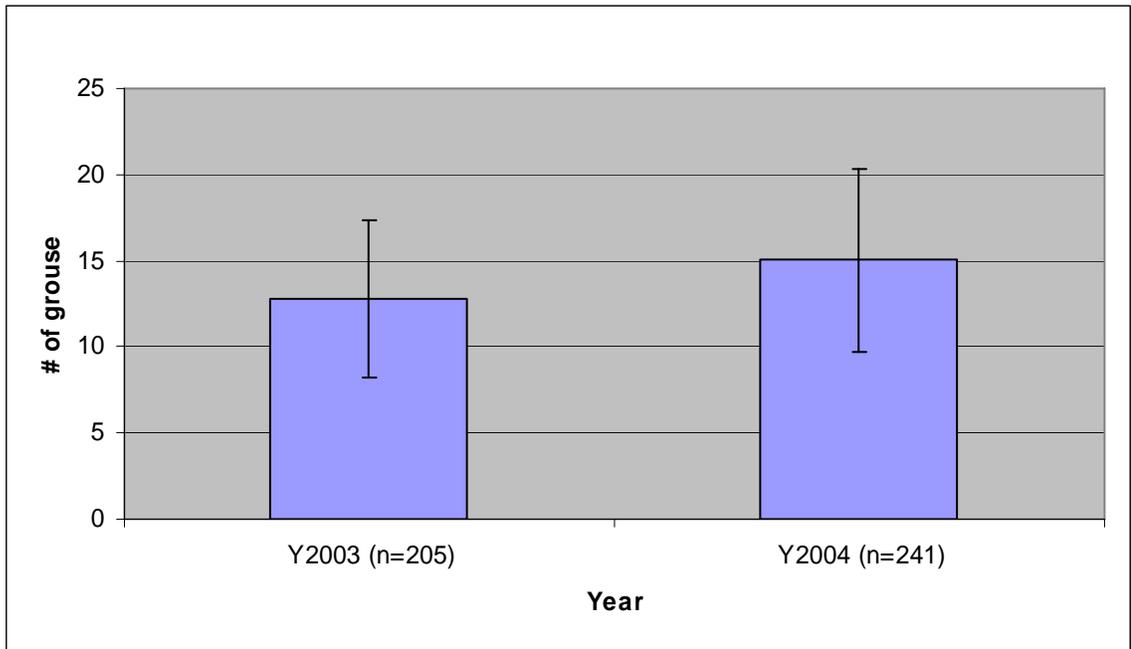


Figure 3-9. Total sage-grouse flushed with birddogs by year (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

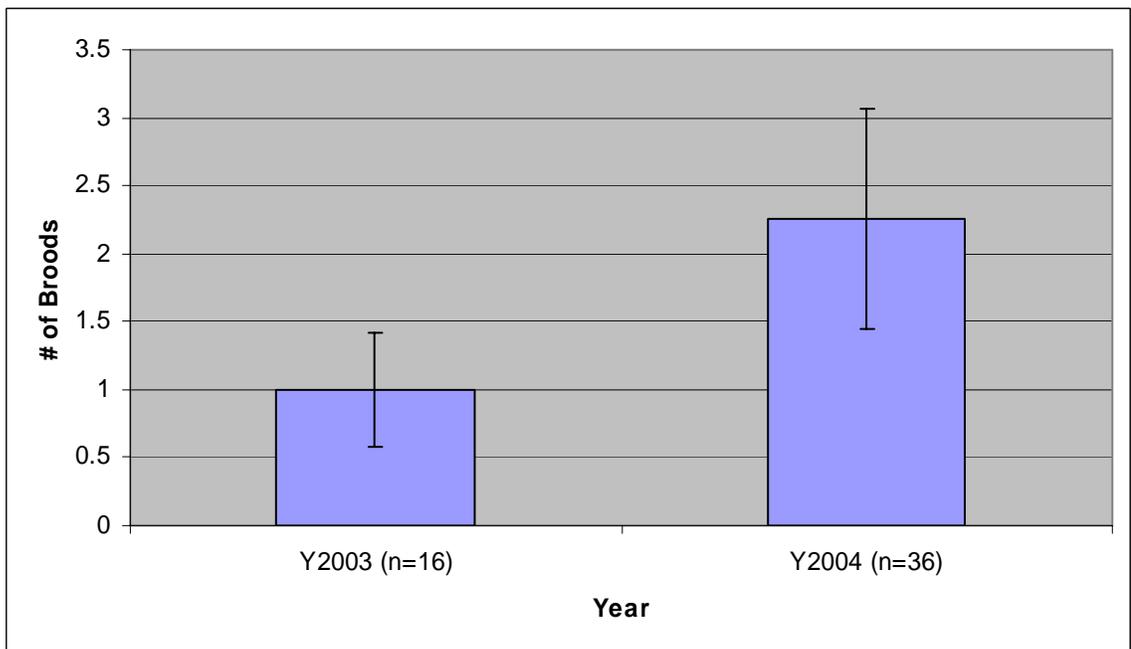


Figure 3-10. Sage-grouse broods flushed with birddogs by year (2 surveys each year combined), Parker Mountain, Utah, 2003 and 2004.

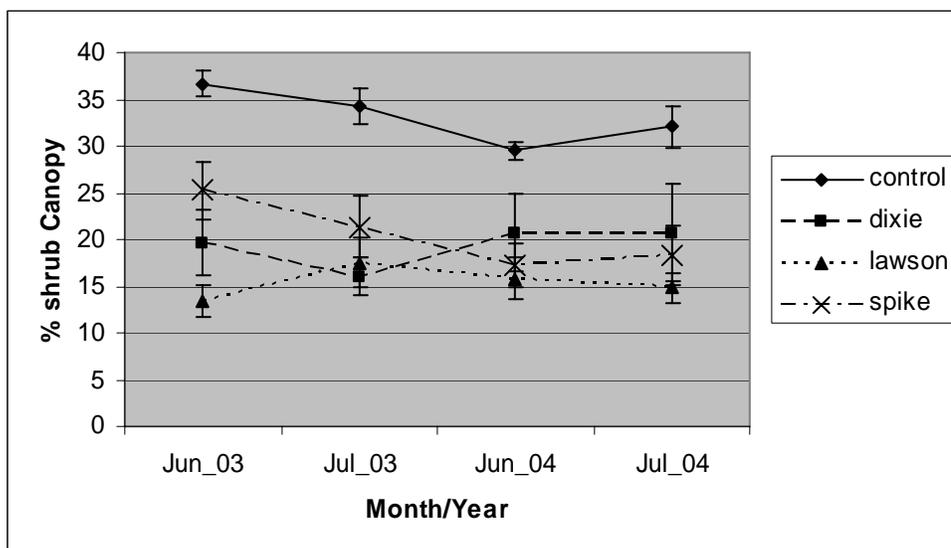


Figure 3-11. Shrub Canopy Cover in PLP June and July 2003 and 2004, Parker Mountain, Utah.

CHAPTER 4

GREATER SAGE-GROUSE REPRODUCTIVE 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. I 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% (n=19) and 56% (n=9), nest success was 61% (n=18) and 80% (n=5), and adult mortality was 36% (n=25) and 22% (n=9), 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 most likely 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 et al. 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).

Many studies have been conducted to determine the ecology of sage-grouse populations for use in management (Patterson 1952, Dalke et al. 1963, Klebenow 1969, Peterson 1970, Wallestad 1971, Eng and Schladweiler 1972, Jarvis 1974, Wallestad and Pyrah 1974, Connelly 1982, Connelly et al. 1988). To better define the contributing factors, more recent studies have focused specifically on describing the reproductive ecology of greater sage-grouse (Dunn and Braun 1986; Klott and Lindsey 1990; Connelly et al. 1991; Wakkinen et al. 1992; Fischer et al. 1993; Barnett and Crawford 1994; Drut et al. 1994; Gregg et al. 1994; Delong et al. 1995; Fischer et al. 1996a,b; Pyle and Crawford 1996; Schroeder 1997; Apa 1998; Sveum et al. 1998a,b; and Connelly et al. 2000b). Most recent studies relied heavily on radio telemetry to monitor sage-grouse hens.

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.

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 of 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 4-1). 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 4-2). 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 (sheep and cattle). 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 4-3). 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*). Lower lying draws and higher elevation areas on the western edge of the Awapa plateau are dominated by mountain big sagebrush (*Artemisia 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 jamaicensis*), 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*).

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

Population Status

Lek counts for male sage-grouse have been conducted since the 1960s. The UDWR collects the data, and in recent years Utah State University has assisted. Counts are made during the lekking season (~ March to May), with each lek being counted one-half-hour before sunrise to one hour after sunrise. Each lek is counted 3 times per year. Data herein represents the high counts of each lek combined yearly for Parker Mountain.

Monitoring Nesting and Brooding Ecology

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 and hens were aged based on the condition of the outer primaries along with weight (Dalke et al. 1963). A 16.5 gram ATS™ 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, handheld 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.

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 within 10m every other day and a positive visual of the hen was made to determine status and fate. 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 ≥ 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. Predator type was assigned either mammalian or avian when possible.

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.

Nest and Brood Site Vegetation

Vegetation transects were used at each nest site to describe cover characteristics. To establish these transects a center pole was placed 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 site vegetation characteristics were measured 3-5 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 Analysis

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

Population Status

The number of strutting males counted during seasonal lek counts have been increasing since the PARM was established (Figure 4-1). Total male counts have been the highest since they began on Parker Mountain, though males per lek numbers are lower. Additionally, we have counted more leks per year in recent years (Figure 4-1). 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, 2 historic leks that had not been active for many years became active. Additionally, 2 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 4-1. In Utah average males/lek for periods 1995 to 1999 and 2000 to 2003 increased from 15 to 21, respectively (Connelly et al. 2004). For Parker Mountain average males/lek, during the same periods, increased from 25 to 31.

Monitoring Nesting and Brooding Ecology

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 versus yearling weights were not compared due to only 2 adults being captured in 2003. 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 and success rates reported

herein may be lower than actual rates because I was not able to begin intense monitoring of hens until the beginning of May both years, and some nests may have been initiated and predated in April of each year. 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.

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 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.

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).

Nest and Brood Site 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 4-1). 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), rabbitbrush (n=2), and an Indian rice grass clump (n=1). Aspect of nests was mostly east and southeast (Figure 4).

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 Mortality

In 2003 and 2004 we documented 9 (36%) and 2 (22%) mortalities, respectively. I used Kaplan – Meier estimation to calculate survivability for adult hens each year from May to September, and survivability was 60 and 59% for 2003 and 2004, respectively (Kaplan and Meier 1958). However, both 2003 and 2004 there were relatively low adult mortality sample sizes. 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.

In 2004 I 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, Connelly et al. 2004). Recent PSA lek counts have been the highest recorded counts since 1967 (Figure 4-1). However, limited data from the late 1960s 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 these data indicate a population growth trend for the Parker Mountain sage-grouse population. This was not surprising because lek counts through out Utah have been stable to increasing since the mid 1980s, with greater increases since the mid 1990s (Connelly et al. 2004). Lek count data for Parker Mountain included maximum male counts for each lek. This method ignores the use of lek complexes by male sage-grouse, and data herein probably resulted in double counting and inflation of

population numbers. However, the method was consistent year to year which still results in a reasonably reliable trend.

Sage-grouse nesting and brood-rearing activities continue to be the most important factor in sage-grouse population dynamics (Connelly et al. 2000a). 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, historic and present grazing regimes, 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 that reported by Chi (2004), ranged from 61.1 to 84.6% from 2000 to 2004 (n= 13, 17, 19, 18, and 5, respectively), 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 to 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.

For Parker Mountain, Jarvis (1974) determined that golden eagles were the main predator of adult sage-grouse on Parker Mountain. My observations concur with his findings.

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. 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), possibly increasing brood survival. Additionally, populations throughout Utah and the rest of greater sage-grouse range have been increasing the last 10+ years (Connelly et al. 2004). For future management, a Parker Mountain lek study measuring inter-lek movement and lek attendance rates would be helpful.

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 has dense stands of mountain big sagebrush, which exceed recommended shrub canopy cover (Connelly et al. 2000a). These areas could be treated in a manner that would benefit sage-grouse (Chapter 3).

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 and winter use 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.

Literature Cited

- Apa, A. D. 1998. Habitat use and movements of sympatric sage and Columbian sharp-tailed grouse in southeastern Idaho. Dissertation, University of Idaho, Moscow, Idaho, USA.
- Barnett, J. F., and J. A. Crawford. 1994. Pre-laying nutrition of sage-grouse hens in Oregon. *Journal of Range Management* 47:114-118.
- Beck, J. L., and D. L. Mitchell, and B. D. Maxfield. 2003. Changes in the distribution and status of sage-grouse in Utah. *Western North American Naturalist* 63:203-214.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. *Wildlife Society Bulletin* 5:99-106.
- Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry* 39:388-394.
- Chi, R. Y. 2004. Greater sage-grouse reproductive ecology and tebuthiuron manipulation of dense big sagebrush on Parker Mountain. Master Thesis, Utah State University, Logan, Utah, USA.
- Connelly, J. W., Jr. 1982. An ecological study of sage-grouse in southeastern Idaho. Dissertation, Washington State University, Pullman, Washington, USA.
- Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage-grouse *Centrocercus urophasianus* populations in western North America. *Wildlife Biology* 3/4:123-128.
- Connelly, J. W., H. W. Browsers, and R. J. Gates. 1988. Seasonal movements of sage-grouse in southeastern Idaho. *Journal of Wildlife Management* 52:116-122.

Connelly, J. W., K. P. Reese, R. A. Fischer, and W. L. Wakkinen. 2000b. Response of sage-grouse breeding population to fire in southeastern Idaho. *Wildlife Society Bulletin* 28:90-96.

Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming, USA.

Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000a. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.

Connelly, J. W., W. L. Wakkinen, A. D. Apa, and K. P. Reese. 1991. Sage-grouse use of nest sites in southeastern Idaho. *Journal of Wildlife Management* 55:521-524.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage-grouse in Idaho. *Journal of Wildlife Management* 27:810-841.

Daubenmire, R. F. 1959. A canopy coverage method of vegetation analysis. *Northwest Science* 33:43-64.

DeLong, A. K., J. A. Crawford, and D. C. DeLong Jr. 1995. Relationships between vegetational structure and predation of artificial sage-grouse nests. *Journal of Wildlife Management* 59:88-92.

Drut, M. S., W. H. Pyle, and J. A. Crawford. 1994. Diets and food selection of sage-grouse chicks in Oregon. *Journal of Range Management* 47:90-93.

- Dunn, P. O., and C. E. Braun. 1986. Summer habitat use by adult female and juvenile sage-grouse. *Journal of Wildlife Management* 50:228-235.
- Eng, R. L., and P. Schladweiler. 1972. Sage-grouse winter movements and habitat use in central Montana. *Journal of Wildlife Management* 36:141-146.
- Fischer, R. A., A. D. Apa, W. L. Wakkinen, K. P. Reese, and J. W. Connelly. 1993. Nesting-area fidelity of sage-grouse in southeastern Idaho. *Condor* 95:1038-1041.
- Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996a. An investigation on fire effects within xeric sage-grouse brood habitat. *Journal of Range Management* 49:194-198.
- Fischer, R. A., K. P. Reese, and J. W. Connelly. 1996b. Influence of vegetal moisture content and nest fate on timing of female sage-grouse migration. *Condor* 98:868-872.
- Geisen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage-grouse in Colorado. *Wildlife Society Bulletin* 10:224-231.
- Girard, G. L. 1939. Life history of the shoveler. *Transactions of the North American Wildlife Conference* 4:364-371.
- Gregg, M. A., J. A. Crawford, M. S. Drut, and A. K. DeLong. 1994. Vegetational cover and predation of sage-grouse nests in Oregon. *Journal of Wildlife Management* 58:162-166.
- Jarvis, J. M. 1974. Sage-grouse population studies on the Parker Mountain in south central Utah. Federal Aid Wildlife Restoration Project W-65-R, Job c-1. Utah

Department of Natural Resources, Division of Wildlife Resources, Salt Lake City, Utah, USA.

- Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. *Journal of the American Statistical Association* 53:457-481.
- Klebenow, D. A. 1969. Sage-grouse nesting and brood habitat in Idaho. *Journal of Wildlife Management* 33:649-661.
- Klott, J. H., and F. G. Lindsey. 1990. Brood habitats of sympatric sage-grouse and Columbian sharp-tailed grouse in Wyoming. *Journal of Wildlife Management* 54:84-88.
- Patterson, R. L. 1952. *The sage grouse in Wyoming*. Sage Books, Denver, Colorado, USA.
- Peterson, J. G. 1970. The food habits and summer distribution of juvenile sage-grouse in central Montana. *Journal of Wildlife Management* 34:147-155.
- Pyle, W. H., and J. A. Crawford. 1996. Availability of foods of sage grouse chicks following prescribed fire in sagebrush-bitterbrush. *Journal of Range Management* 49:320-324.
- Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. *Journal of Range Management* 23:295.
- Schroeder, M. A. 1997. Unusually high reproductive effort by sage-grouse in a fragmented habitat in north-central Washington. *Condor* 99:933-941.
- Schroeder, M. A., C. L. Adridge, A. D. Apa, J. R. Bohne, C. E. Braun, S. D. Bunnell, J. W. Connelly, P. A. Deibert, S. C. Gardner, M. A. Hillard, G. D. Kobriger, S.

- M. McAdam, C. W. McCarthy, J. J. McCarthy, D. L. Mitchell, E. V. Rickerson, and S. J. Stiver. 2004. Distribution of sage-grouse in North America. *The Condor* 106:363-376.
- Schroeder, M. A., J. R. Young, and C. E. Braun. 1999. Sage-grouse (*Centrocercus urophasianus*). Pages 1-28 in A. Poole and F. Gill, editors. *The Birds of North America*, Incorporated, Philadelphia, Pennsylvania, USA.
- Sveum, C. M., J. A. Crawford, and W. D. Edge. 1998a. Use and selection of brood-rearing habitat by sage-grouse in south-central Washington. *Great Basin Naturalist* 58:344-351.
- Sveum, C. M., W. D. Edge, and J. A. Crawford. 1998b. Nesting habitat selection by sage-grouse in south-central Washington. *Journal of Range Management* 51:265-269.
- Wakkinen, W. L., K. P. Reese, and J. W. Connelly. 1992. Sage-grouse nest locations in relation to leks. *Journal of Wildlife Management* 56:381-383.
- Wallestad, R. O. 1971. Summer movements and habitat use by sage grouse broods in central Montana. *Journal of Wildlife Management* 35:126-136.
- Wallestad, R. O., and D. B. Pyrah. 1974. Movement and nesting of sage-grouse hens in central Montana. *Journal of Wildlife Management* 38:630-633.

Table 4-1. 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)

	Mean	SE	Range
Forb Cover (%)	1.04	0.21	0 - 4.80
Grass Cover (%)	8.24	0.96	2.62 - 20.68
Shrub Cover (%)	13.22	1.73	2.91 - 29.17
Nest Bush Height (cm)	64.35	4.85	23 - 112
Nest Bush Diameter (cm)	97.52	10.43	25 - 220
Robel In (cm)	52.84	4.09	19.50 - 90.25
Robel Out (cm)	32.66	4.36	6 - 79.25
Slope (degrees)	4.83	0.83	0 - 17

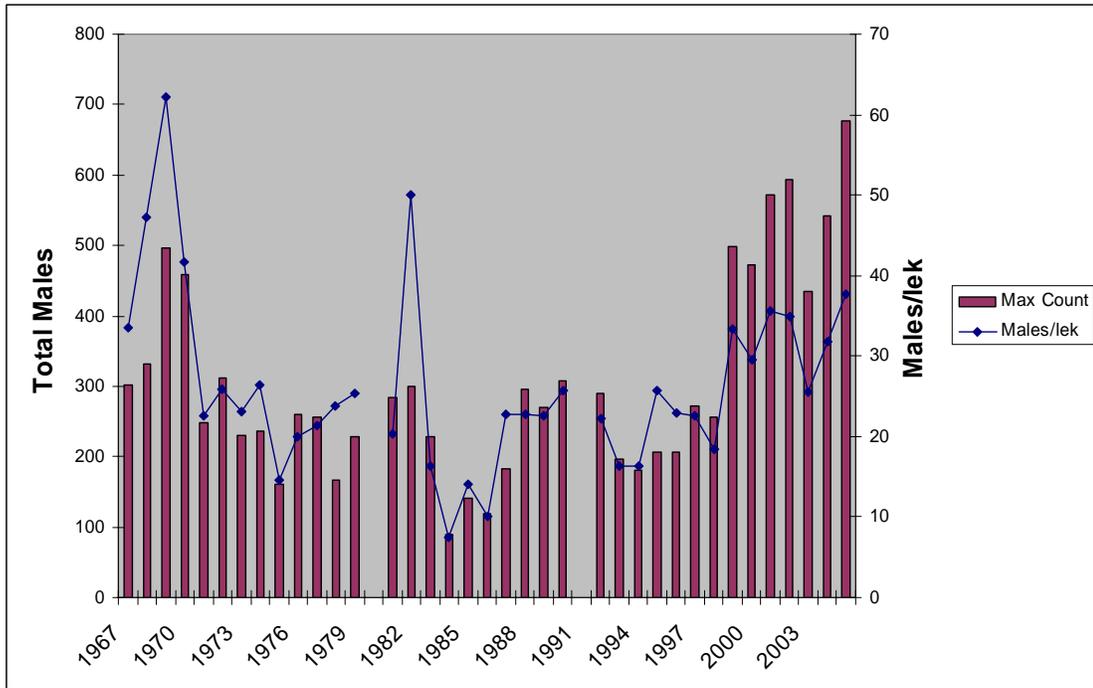


Figure 4-1. Sage-grouse Lek Counts (UDWR data) 1967–2004, Parker Mountain, Utah.

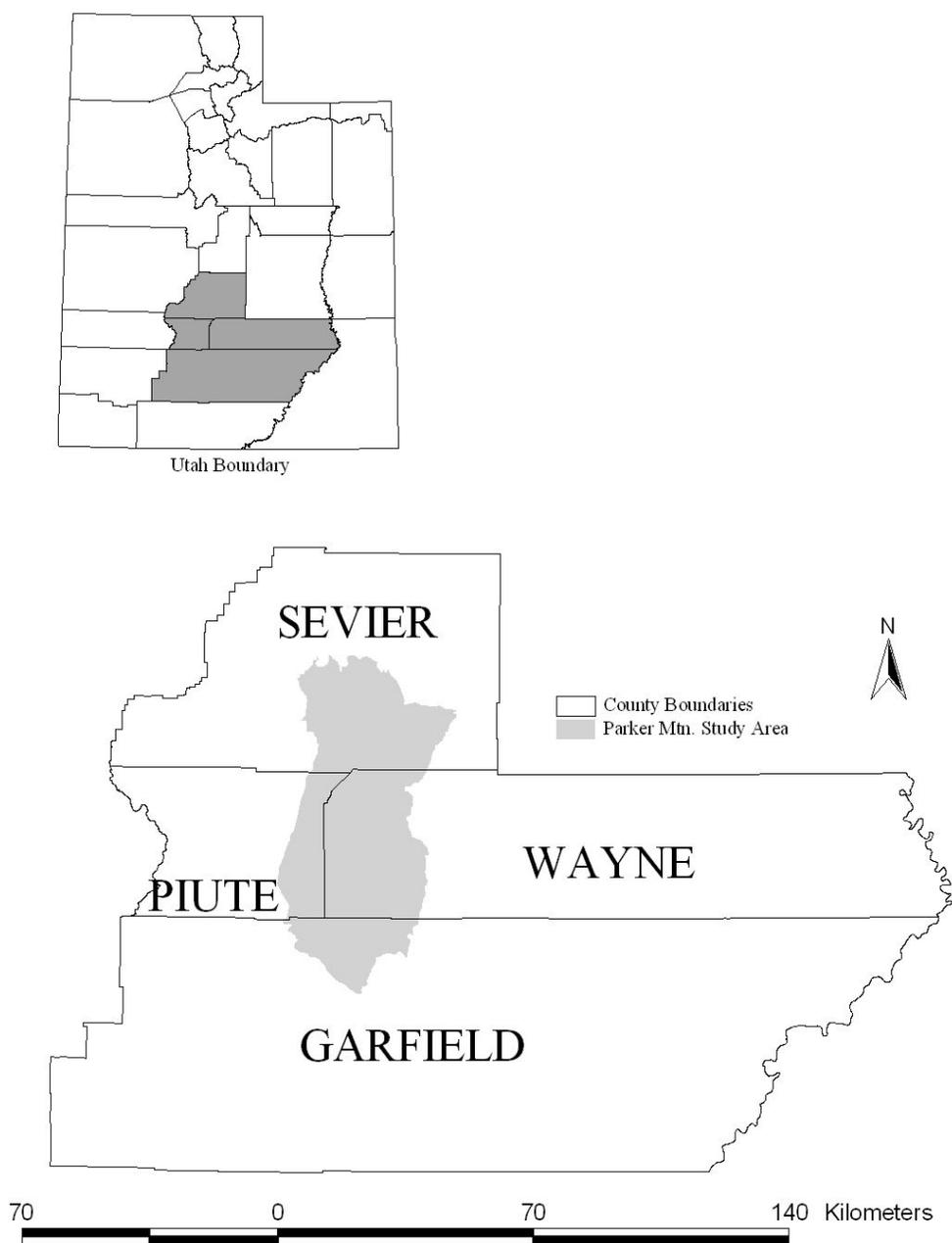


Figure 4-2. Parker Mountain study area, 2003-2004.

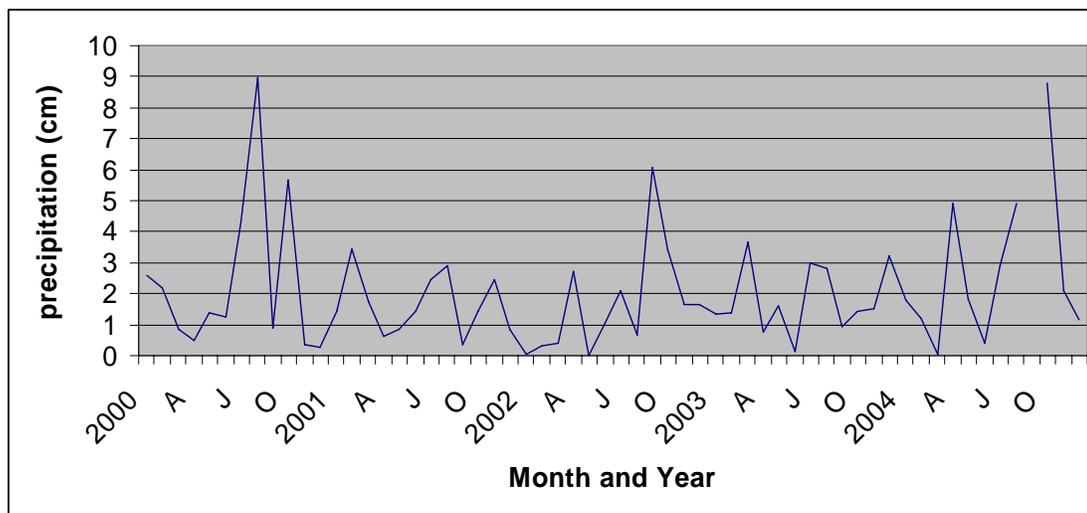


Figure 4-3. Monthly Precipitation (Utah Climate Center data, climate.usurf.usu.edu), Koosheram (~15 km from PLP), Utah, 2000-2004.

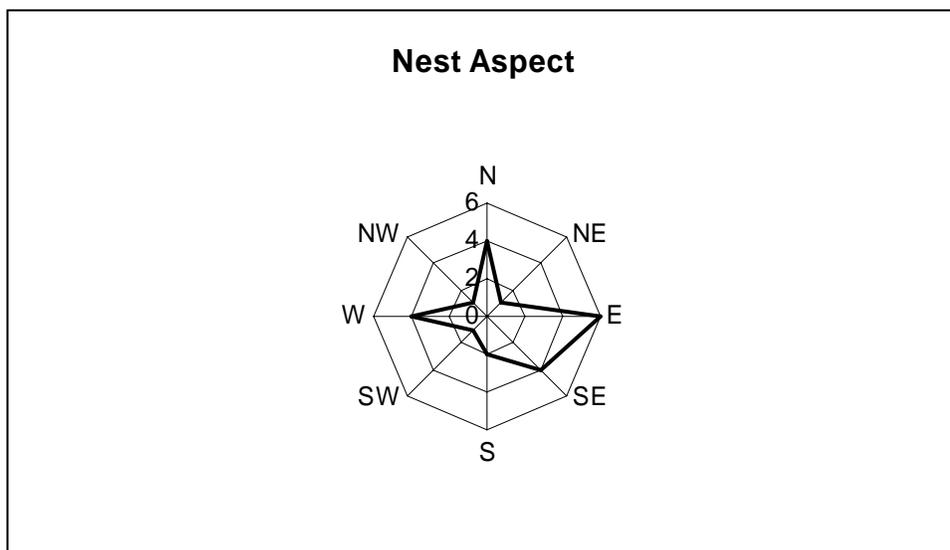


Figure 4-4. Slope aspects of greater sage-grouse nests, Parker Mountain, 2003 and 2004.

CHAPTER 5

CONCLUSIONS

Over the last century, greater sage-grouse (*Centrocercus urophasianus*) populations sharply declined up to the mid 1980's, and since have been steady to moderately increasing (Connelly et al. 2004). Declines have been largely attributed to habitat loss and degradation (Braun et al. 1977, Connelly et al. 2004). Overall sage-grouse populations in Utah have followed the same trend (Beck et al. 2003, Connelly et al. 2004). 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), and in recent years lek counts indicate an increasing population.

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 (*Artemisia* spp.) ecosystems with landscape level experiments, and grazing practices that will provide managers with the information needed to increase and reestablish the species and other sagebrush obligates (Connelly et al. 2000, 2004).

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 1999 the Western Association of Fish and Wildlife Agencies (WAFWA) signed a Memorandum of Understanding (MOU) calling for the adoption of a range-wide sage-grouse (*Centrocercus* spp.) conservation plan. In this MOU, 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 on average 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%, $P = 0.02$). The 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, though it was only moderate for forb and grass (Chapter 2).

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 abundance than the mechanical treatments or control, especially for dandelion cover.

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, these 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 (*A. 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 (D. Mitchell, UDWR Upland Game Coordinator, personal communication). 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. Additionally, a lek study could ascertain male lek movements, and help managers determine appropriate lek complexes to aid in interpreting lek count data. 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 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 State 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 that has been accomplished would not have happened without all the partners' contributions.

Literature Cited

- Beck, T. D. 1977. Sage-grouse flock characteristics and habitat selection in winter. *Journal of Wildlife Management* 41:18-26.
- Beck, J. L., D. L. Mitchell, and B. D. Maxfield. 2003. Changes in the distribution and status of sage-grouse in Utah. *Western North American Naturalist* 63:203-214.
- Braun, C. E., T. Britt, and R. O. Wallestad. 1977. Guidelines for maintenance of sage grouse habitats. *Wildlife Society Bulletin* 5:99-106.
- Burkepile, N. A., J. W. Connelly, D. W. Stanley, and K. P. Reese. 2002. Attachment of 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 manipulation of dense big sagebrush on Parker Mountain. Master Thesis, Utah State University, Logan, Utah, USA.
- Connelly, J. W., and Q. D. Markham. 1983. Movements and radionuclide concentrations of sage-grouse in southeastern Idaho. *Journal of Wildlife Management* 47:169-177.
- Connelly, J. W., H. W. Browsers, and R. J. Gates. 1988. Seasonal movements of sage-grouse in southeastern Idaho. *Journal of Wildlife Management* 52:116-122.

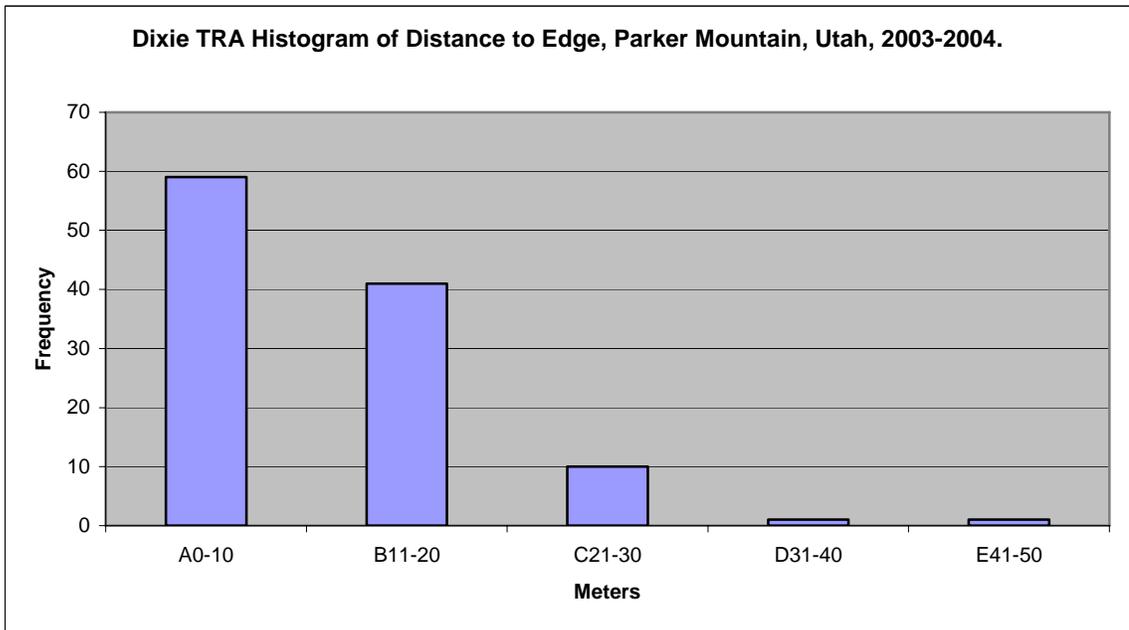
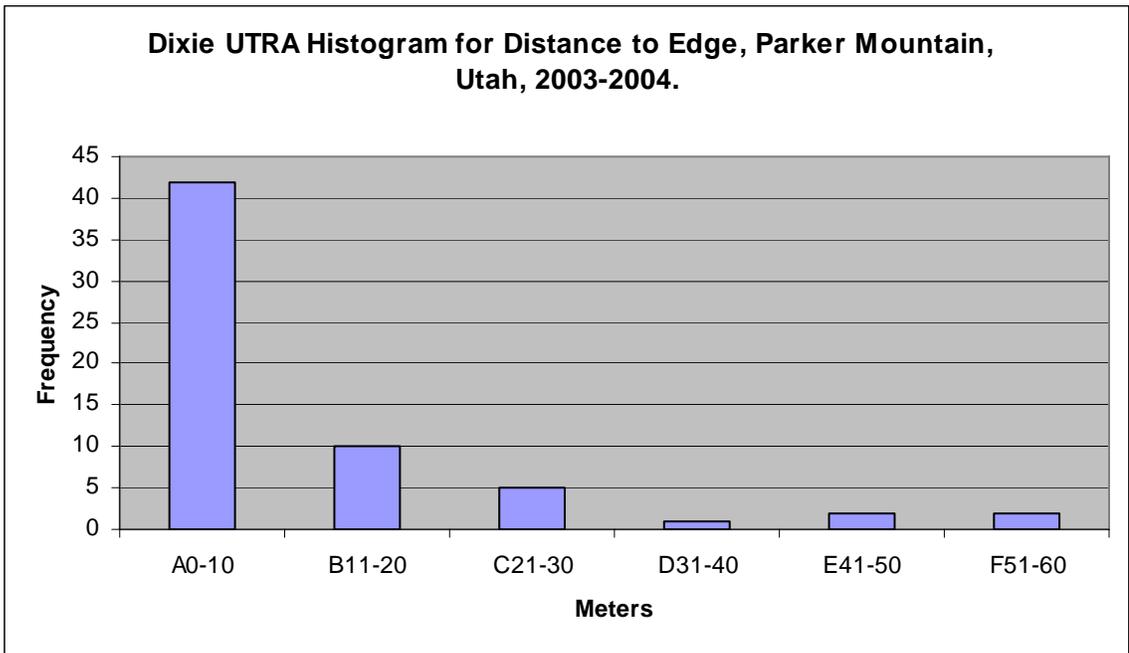
- Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage grouse populations and their habitats. *Wildlife Society Bulletin* 28:967-985.
- Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming, USA.
- Messmer, T. A., and J. Flory. 2002. Parker Mountain Adaptive Management working group Annual Status Report. Utah State University Extension Service, Logan, Utah, USA.
- Schroeder, M. A. 1997. Unusually high reproductive effort by sage-grouse in a fragmented habitat in north-central Washington. *Condor* 99:933-941.

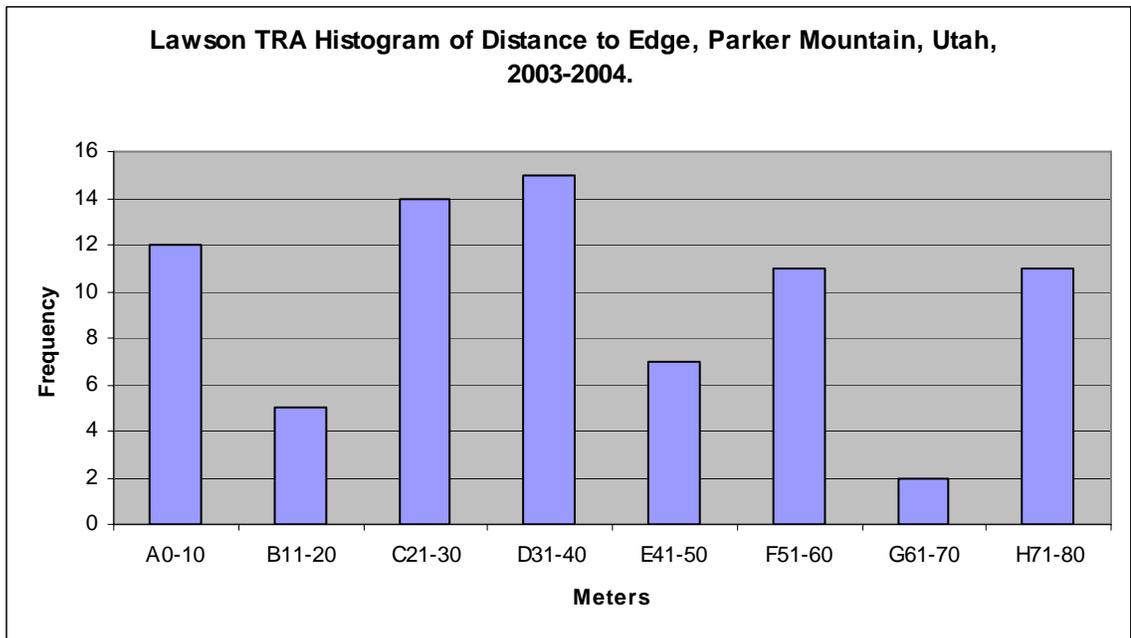
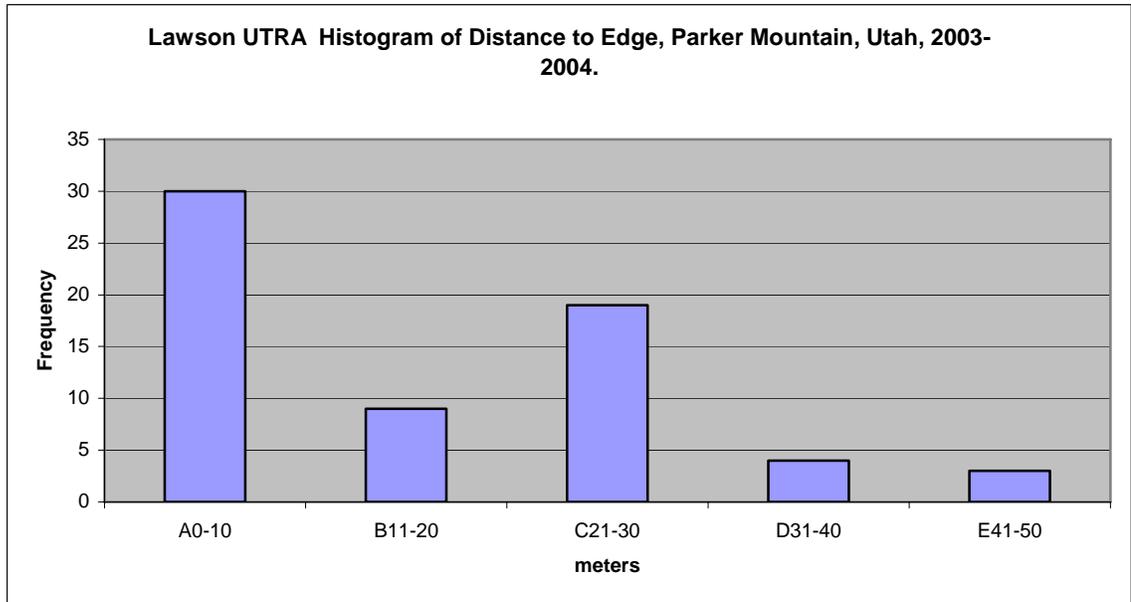
APPENDICES

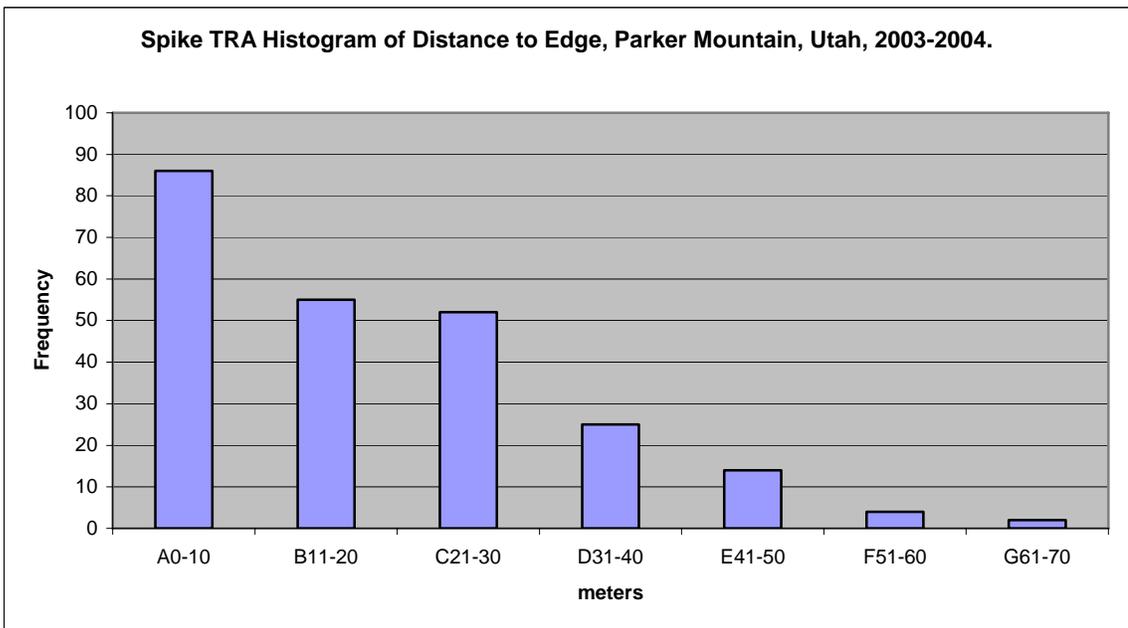
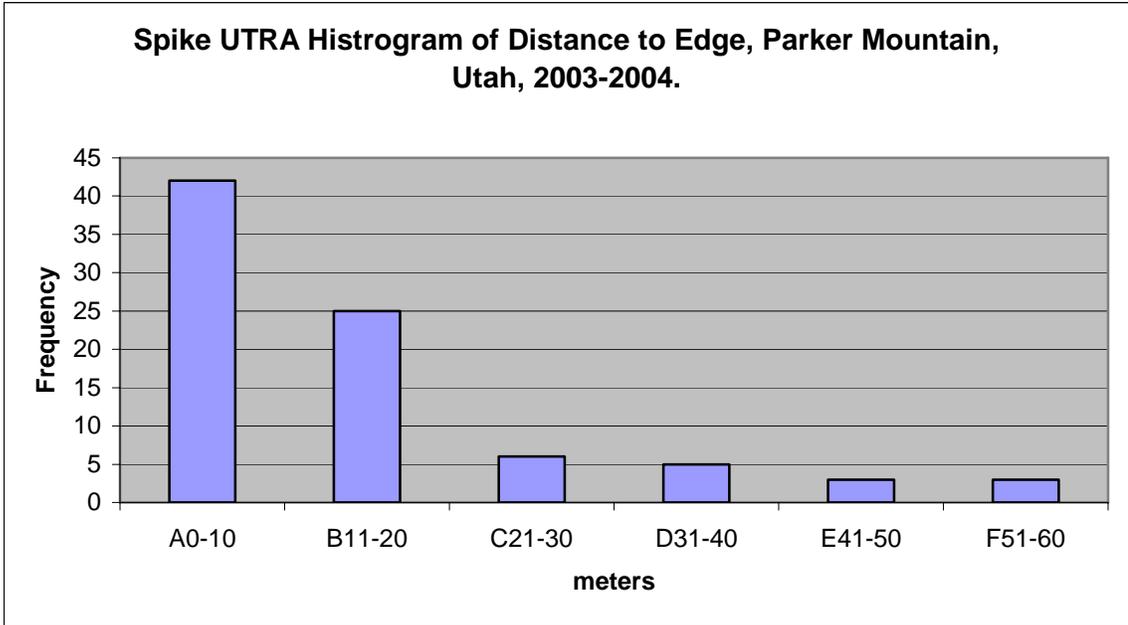
Appendix A: The seed mixture for Dixie harrow plots.

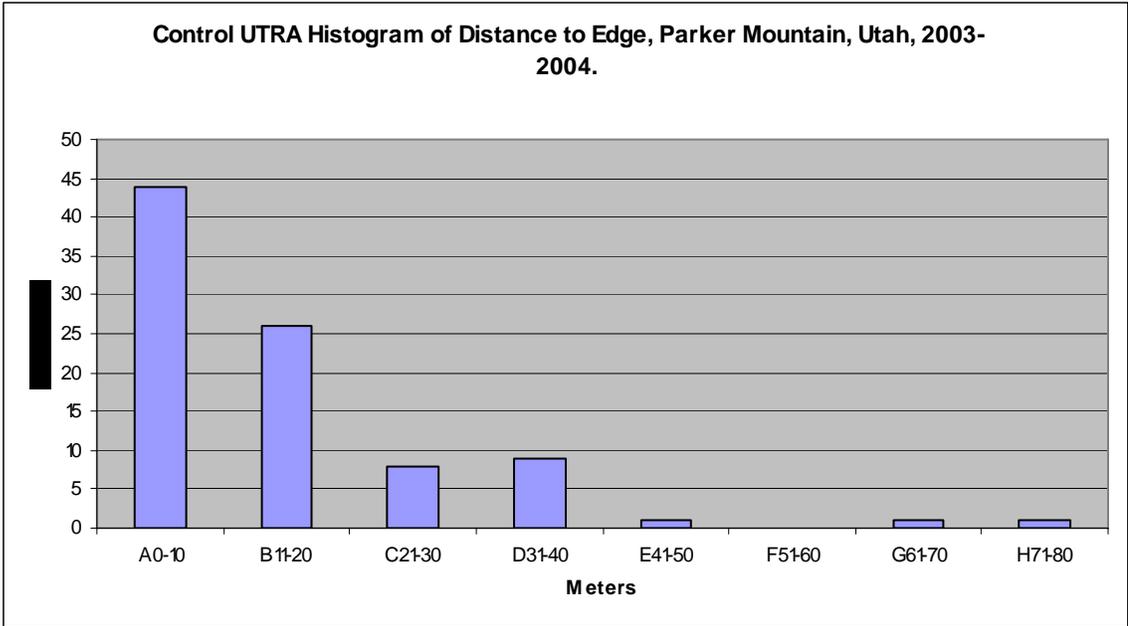
Common Name	Latin Name	lbs/acre
Blue bunch wheatgrass	<i>Agropyron spicatum</i>	1.0
Crested wheatgrass	<i>Agropyron desertorum</i>	0.5
Pubescent wheatgrass	<i>Agropyron trichophorum</i>	1.0
Thick spike grass	<i>Elymus lanceolatus</i>	1.0
Western wheatgrass	<i>Agropyron smithii</i>	1.0
Alfalfa	<i>Medicago spp.</i>	2.5
Western yarrow	<i>Achillea millefolium</i>	1.2
Flax	<i>Linum lewisi</i>	0.25
Sainfoin	<i>Onobrychis viciifolia</i>	0.5
Burnet	<i>Sanguisorba spp.</i>	0.2

Appendix B: Distance-to-edge Histograms of Pellet Count Data









Appendix C: Relative Forb Cover Abundance

Table C1. Control forb data using Daubenmire frames in June and July 2003 and 2004

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

^cTotal

(n=15)

Weight: 723.80

^athe number of transects the genus was detected in out of 80 total transects^bthe 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^cfor 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 C2. Tebuthiuron forb data using Daubenmire frames in June and July 2003 and 2004

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

^cTotal

(n=20)

Weight: 1332.33

^athe number of transects the genus was detected in out of 80 total transects^bthe 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^cfor 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 C3. Dixie forb data using Daubenmire frames in June and July 2003 and 2004

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

^cTotal

Weight: 962.60

^athe number of transects the genus was detected in out of 80 total transects^bthe 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^cfor 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 C4. Lawson forb data using Daubenmire frames in June and July 2003 and 2004

Common Name	Genus	Mean % Cover	Stddev	^a Freq.	^b Weight
phlox	<i>Phlox</i> spp.	3.65	3.20	43	157.00
lupine	<i>Lupinus</i> spp.	2.91	2.82	43	125.20
dandelion	<i>Taraxacum</i> spp.	1.64	3.28	44	72.20
Cinquefoil	<i>Potentilla</i> spp.	2.08	2.00	34	70.80
penstemon	<i>Penstemon</i> spp.	1.67	1.89	41	68.60
astragalus	<i>Astragalus</i> spp.	1.28	0.84	46	59.00
daisy	<i>Erigeron</i> spp.	1.02	0.91	30	30.60
buckwheat	<i>Eriogonum</i> spp.	0.99	0.72	26	25.80
pussytoes	<i>Antennaria</i> spp.	2.88	3.32	8	23.00
pepperweed	<i>Lepidium</i> spp.	0.99	0.69	23	22.80
	<i>Gayophytum</i>				
groundsmoke	spp.	1.66	1.24	10	16.60
unknown	N/A	0.68	0.25	13	8.80
groundsel	<i>Senecio</i> spp.	1.75	0.77	4	7.00
Parsely	<i>Lomatium</i> spp.	1.03	0.57	6	6.20
corydalis	<i>Corydalis</i> spp.	1.16	0.83	5	5.80
indian					
paintbrush	<i>Castilleja</i> spp.	5.20	N/A	1	5.20
	<i>Chenopodium</i>				
GF Keno	spp.	0.85	0.90	4	3.40
clover	<i>Trifolium</i> spp.	2.60	N/A	1	2.60
thistle	<i>Cirsium</i> spp.	2.20	N/A	1	2.20
arabis spp	<i>Arabis</i> spp.	0.80	0.57	2	1.60
hymenoxys	<i>Actenia</i> spp.	1.60	N/A	1	1.60
scarlet gilia	<i>Gilia</i> spp.	1.00	N/A	1	1.00
phlox	<i>Phlox</i> spp.	0.40	N/A	1	0.40

^cTotal

Weight: 717.40

^athe number of transects the genus was detected in out of 80 total transects^bthe 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^cfor 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