


12-2010

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ECOLOGY AND MANAGEMENT OF A HIGH ELEVATION SOUTHERN RANGE
GREATER SAGE-GROUSE POPULATION: VEGETATION MANIPULATION,
EARLY CHICK SURVIVAL, AND HUNTER MOTIVATIONS

by

Michael R. Guttery

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

of

DOCTOR OF PHILOSOPHY

in

Wildlife Biology

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ABSTRACT

Ecology and Management of a High Elevation Southern Range
Greater Sage-Grouse Population: Vegetation Manipulation,
Early Chick Survival, and Hunter Motivations

by

Michael R. Guttery, Doctor of Philosophy

Utah State University, 2010

Major Professors: Dr. Terry A. Messmer and Dr. Roger E. Banner
Department: Wildland Resources

My research provided new information concerning the management, ecology, and conservation of greater sage-grouse (*Centrocercus urophasianus*). I report the results of an experiment using strategic intensive sheep grazing to enhance the quality of greater sage-grouse brood-rearing habitat. Although forb cover, an important component of brood-rearing habitat, responded positively to the grazing treatment, the response of other habitat variables was suppressed because the plots were not protected from domestic and wild herbivores during the years following the treatments. Measurements taken in grazing exclosures confirmed that herbivory by both large and small animals had significant impacts on vegetation. However, despite the suppressed habitat response, sage-grouse preferred the treated plots over the controls.

In another chapter, I modeled survival rates of sage-grouse chicks to 42-days of age. Average chick survival across my study was high (39%). Survival varied across

years and was affected by demographic, behavioral, and habitat factors. The top habitat model indicated that chick survival was positively related to grass cover and was higher in areas dominated by black sagebrush (*Artemisia nova*) than in big sagebrush (*A. tridentata*). The top model with demographic/behavioral factors indicated that survival was affected by interactions between hen age and brood mixing as well as between hatch date and brood mixing.

In my last chapter I report on a survey of Utah sage-grouse hunter motivations and satisfaction. In 2008 and 2009 I surveyed over 600 sage-grouse hunters in Utah to determine why they chose to apply for sage-grouse hunting permits and what factors contributed to a satisfactory hunting experience. Originally, I had hypothesized that the impending Endangered Species Act listing petition for greater sage-grouse motivated hunters to pursue the species before they lost the opportunity. This hypothesis was not supported by the data. The majority of hunters indicated that they chose to hunt sage-grouse because it was a tradition or because it provided an opportunity to spend time outdoors with family. Additionally, Utah sage-grouse hunter satisfaction was influenced by whether or not the hunter was successful in harvesting at least one bird.

ACKNOWLEDGMENTS

The following document represents, for me, much more than four and a half years and three research projects. These pages are in many ways a by-product of one of the most amazing experiences imaginable. The people, places, and ideas I have encountered during this process have shaped my life in ways I could never have anticipated. To the many unnamed friends who have participated in this journey with me, I will be forever indebted.

I thank Dr. Terry Messmer and Dr. Roger Banner for providing me the opportunity to pursue doctoral studies at Utah State University. As my co-advisors they have served very different functions but both have been exceptional mentors in their own ways. I would also like to thank my graduate committee (Dr. Fred Provenza, Dr. Mark Brunson, and Dr. David Koons) for challenging me to think harder and more broadly about my research and life in general.

My dissertation research was completed thanks to the dedicated efforts of many individuals. I am particularly thankful for the contributions of my friends Dr. Dave Dahlgren and Dr. Eric Thacker. Without their guidance and friendship I would not have survived the first few years of my Utah experience. I would also like to thank Jen Anderson, Ben Belisle, Dustin Ingram, Caleb Stratton, Danny Caudill, Gretchen Hochnedel, Chris Wesolek, Talon Redding, Kendal Morris, and Andrew Wiley for being exceptional technicians.

My research on strategic intensive sheep grazing would not have been possible if it were not for the commitment of Andy Taft and his sheep. Andy took a tremendous risk

by entrusting his herd to me for two months. His vision and dedication to responsible land use are truly admirable. Jim Lamb of the Utah Division of Wildlife Resources has been a tremendous ally throughout this entire process. Jim's cooperation has allowed us to go beyond our expectations and his work ethic has inspired us to push through the early mornings and hard times. I would also like to thank Ron Torgerson and Verl Bagley for their assistance and support.

Finally, to my family, and particularly to my parents, I cannot adequately express my love and appreciation for all that you have done for me. Thank you.

Michael R. Guttery

CONTENTS

	Page
ABSTRACT.....	iii
ACKNOWLEDGMENTS	v
LIST OF TABLES.....	ix
LIST OF FIGURES	xi
CHAPTER	
1. INTRODUCTION AND LITERATURE REVIEW	1
POPULATION STATUS	1
THREATS.....	1
Agriculture	2
Energy Development	3
Wildfire.....	3
Livestock Grazing.....	4
Predation	5
Hunting	5
Lack of Information about Juvenile Survival	6
SIGNIFICANCE OF MY RESEARCH	7
LITERATURE CITED.....	8
2. GRAZING SAGEBRUSH WITH SHEEP TO ENHANCE GREATER SAGE- GROUSE BROOD-REARING HABITAT	16
ABSTRACT.....	16
INTRODUCTION	17
METHODS	20
Study Area Description.....	20
Experimental Design.....	21
Statistical Analyses	24
RESULTS	26
Response of Vegetation in Plots	26
Response of Vegetation in Grazing Enclosures.....	28

Response of Sage-Grouse to Grazing Treatments	30
DISCUSSION	30
MANAGEMENT IMPLICATIONS	35
LITERATURE CITED	36
3. EARLY SURVIVAL OF GREATER SAGE-GROUSE CHICKS IN RELATION TO ECOLOGICAL AND DEMOGRAPHIC FACTORS.....	47
ABSTRACT	47
INTRODUCTION	48
STUDY AREA	50
METHODS	51
Data Collection	51
Data analysis	53
RESULTS	56
DISCUSSION	59
Effects of Demographic and Behavioral Factors on Survival	60
Effects of Habitat Factors on Survival.....	63
MANAGEMENT IMPLICATIONS	64
LITERATURE CITED	65
4. MOTIVATIONS AND SATISFACTION OF GREATER SAGE-GROUSE HUNTERS IN UTAH.....	86
ABSTRACT	86
INTRODUCTION	87
METHODS	91
RESULTS	92
DISCUSSION.....	96
MANAGEMENT IMPLICATIONS	99
LITERATURE CITED	100
5. CONCLUSIONS.....	109
LITERATURE CITED	113
CURRICULUM VITAE.....	115

LIST OF TABLES

Table	Page
2-1 Shrub biomass before and after intensive sheep grazing, Parker Mountain, Utah, USA, 2006.	44
3-1 Greater sage-grouse chick capture statistics for Parker Mountain, Utah, USA, 2005-2009.	76
3-2 Demographic and habitat variables used in modeling greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.	76
3-3 Model selection results for all models evaluating the effects of temporal and demographic factors on greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.	77
3-4 Parameter estimates, standard errors and 95% confidence intervals for all terms in the top demographic model used to explain greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.	78
3-5 Survival probabilities to 42 days of age for greater sage-grouse chicks on Parker Mountain, Utah, USA, 2005-2009.	78
3-6 Model selection results for all models evaluating the effects of temporal and habitat factors on greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.	79
3-7 Parameter estimates, standard errors and 95% confidence intervals for all terms in the top habitat model used to explain greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.	80
4-1 Reported levels of hunt satisfaction for successful and unsuccessful greater sage-grouse hunters, Utah, USA, 2008-2009.	107
4-2 Reported reasons for obtaining a greater sage-grouse hunting permit in Utah, USA, 2008.	107
4-3 Percentage of greater sage-grouse permit holders giving specific combinations of primary and secondary reasons for obtaining a hunting permit in Utah, USA, 2008.	107
4-4 Reported reasons for obtaining a greater sage-grouse hunting permit in Utah, USA, 2009.	108

4-5	Percentage of greater sage-grouse permit holders giving specific combinations of primary and secondary reasons for obtaining a hunting permit in Utah, USA, 2008.....	X 108
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LIST OF FIGURES

Figure	Page
2-1 Response of forb cover to sheep grazing treatments, Parker Mountain, Utah, USA, 2006-2009.	44
2-2 Response of forb cover to sheep grazing treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.	45
2-3 Response of cover cover to sheep grazing treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.	45
2-4 Response of grass height to sheep grazing treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.	46
2-5 Response of grass height to pre-treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.	46
3-1 Survivorship curves for greater sage-grouse chicks relative to year classification on Parker Mountain, Utah, USA, 2005-2009.	80
3-2 Survivorship curves for greater sage-grouse chicks relative to brood type and maternal hen age on Parker Mountain, Utah, USA, 2005-2009.	81
3-3 Survivorship curves for greater sage-grouse chicks relative to brood type and hatch date on Parker Mountain, Utah, USA, 2005-2009.	82
3-4 Survivorship curve for greater sage-grouse chicks relative to our top demographic model on Parker Mountain, Utah, USA, 2005-2009.	83
3-5 Survivorship curves for greater sage-grouse chicks relative to grass cover on Parker Mountain, Utah, USA, 2005-2009.	84
3-6 Survivorship curves for greater sage-grouse chicks relative to dominant shrub type on Parker Mountain, Utah, USA, 2005-2009.	85

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

POPULATION STATUS

The long-term status of the greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) is uncertain. Sage-grouse once occurred in at least 16 states in the western United States and in 3 Canadian Provinces (Schroeder et al. 1999). Sage-grouse have been extirpated in 5 states and 1 province, and populations have declined throughout the remaining range (Johnson and Braun 1999, Schroeder et al. 1999). Between 1965 and 2003, sage-grouse populations range-wide declined at an average rate of 2.0 % annually (Connelly et al. 2004). Sage-grouse currently occupy <60% of their presumed distribution prior to EuroAmerican settlement (Schroeder et al. 2004). As a result of declining populations and ongoing habitat loss, at least seven petitions have been filed with the U.S. Fish and Wildlife Service (USFWS) to grant the species protection under the Endangered Species Act (Stiver, *in press*). Overturning a 2005 decision of not warranted, sage-grouse were granted the status of warranted but precluded in 2010.

THREATS

Sage-grouse are a sagebrush (*Artemisia* spp.) obligate species endemic to North America (Wirth and Pyke 2003, Schroeder et al. 2004). The sagebrush ecosystems of western North America are highly variable in relation to vegetation composition, juxtaposition, topography, substrate, weather, management, and frequency of fire (Schroeder et al. 1999). These characteristics make sagebrush ecosystems among the most complex and sensitive systems in North America. The decline of sage-grouse has

largely been an indirect result of their dependence upon sagebrush ecosystems, and less a result of any direct threat to the birds themselves. At least 15 substantial threats to sage-grouse have been identified (see review in Connelly et al. *in press*). Generally, the reduction, fragmentation, and degradation of sagebrush habitats throughout western North America is considered to be the primary cause for their decline (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Wirth and Pyke 2003, Rowland et al. 2006).

Despite the seemingly simple reasons for the general decline of sage-grouse (loss, degradation, and fragmentation of habitat), conservation of the species remains complex (Knick and Connelly *in press*). Although sage-grouse are one of the most extensively studied wildlife species in western North America (J. W. Connelly, Idaho Fish and Game, personal communication), the current challenges facing the species require a level of knowledge not yet attained or, in some cases, not presently attainable.

Agriculture

In areas where soils are suitable for agricultural crops, most sagebrush dominated habitats have been lost or severely fragmented (Wisdom et al. 2000). While much sage-grouse habitat has been converted to cropland, continued agricultural expansion currently poses little threat to remaining habitat because most of the arable land in western North America has already been converted. Concomitantly, little existing cropland is being retired or abandoned (Brown et al. 2005). As a result, few areas previously converted to cropland are available for sage-grouse habitat restoration. Thus, restoring connectivity of habitats fragmented by agricultural development remains difficult.

Energy Development

Habitat fragmentation resulting from energy exploration and development poses a greater threat to the remaining sage-grouse habitat than does loss to agriculture (USFWS 2010). Unlike agriculture, energy development is rapidly expanding throughout the western United States. Greater than 40% of the eastern range sage-grouse habitat with high biological value is currently threatened by energy development (Doherty et al. *in press*). The consequences of energy development for sage-grouse extend beyond the direct fragmentation of habitats due to construction of roads, pipelines, power lines, and well pads (Walker et al. 2007a). Indirect threats include increased availability of perch sites for raptors (Connelly et al. 2000c), introduction and spread of exotic plants (Trombulak and Frissell 2000, Gelbard and Belnap 2003), and increased incidences of West Nile virus (Walker et al. 2004, Walker et al. 2007b). With the global demand for energy predicted to increase by 50 to 60% by 2030 (National Petroleum Council 2007), energy development poses one of the greatest conservation threats to sage-grouse and sagebrush habitats.

Wildfire

Sagebrush ecosystems throughout western North America are under an increasing threat of wildfires (Baker *in press*). Although the length of historical fire return intervals are debated, it is widely accepted that the invasion of cheatgrass (*Bromus tectorum*) into sagebrush steppe ecosystems has increased the frequency and intensity of wildfire (Baker 2006). Fire has long been known to eliminate sagebrush and promote cheatgrass (Pickford 1932), which consequently promotes more frequent wildfire (D'Antonio and

Vitousek 1992). This relationship has resulted in cheatgrass dominating significant proportions of former sagebrush habitat. Although Thacker (2010) documented selection for burned areas by sage-grouse broods, the majority of studies investigating the impact of wildfire on sage-grouse have reported detrimental results (Fischer et al. 1996, Connelly et al. 2000b, Nelle et al. 2000). Effective control of cheatgrass requires simultaneous reduction of seed input and biomass accumulation (Diamond et al. 2009). Most methods for controlling the spread and accumulation of cheatgrass (i.e., fire or herbicides), have significant real and perceived ecological consequences (Vallentine 1989, Brooks 2002).

Livestock Grazing

Livestock grazing is the most ubiquitous land use practice throughout the range of the greater sage-grouse (Fleischner 1994). Thus, it is often cited as a factor contributing to the decline and degradation of sagebrush habitats (Beck and Mitchell 2000). Although negative impacts of livestock on wildlife habitat and ecological processes have been reported in the literature (Fleischner 1994, Noss 1994, Wuerthner 1994), management practices associated with increasing forage availability for livestock may have greater impacts on wildlife habitat than have the livestock themselves (Connelly et al. *in press*). However, there is little doubt that poorly managed livestock can destroy or degrade habitats (Vavra 2005). Unfortunately, few experimental studies of the impacts of livestock grazing on sage-grouse exist. Recently, there has been a realization that existing data provide little information about the direct impacts of grazing on sage-grouse habitats (Connelly and Braun 1997, Connelly et al. *in press*).

Predation

Predation has also been identified as a potential factor limiting sage-grouse populations (Braun 1998). Coates (1997) found that common ravens (*Corvus corax*) were important nest predators in Idaho. Bunnell (2000) found that red fox (*Vulpes vulpes*) were suppressing the Strawberry Valley, Utah population of sage-grouse; however, habitat loss was implicated as the major cause of the initial population decline. In Idaho, Connelly et al. (2000a) reported that more adult sage-grouse were killed by predators than by hunters. Despite relatively high predation rates relative to hunter harvest rates, annual survival was still high leading the authors to conclude that predators were not having a significant impact on the population. It is generally believed that grouse populations can tolerate high predation pressure as long as habitat of sufficient quality and quantity exists (Storch 2000). In a recent review, Hagen (*in press*) concluded that sage-grouse populations restricted to areas with limited or fragmented habitat may experience some benefit from predator control but that no evidence existed to support broad-scale predator management for the benefit of sage-grouse populations. Mezquida et al. (2006) argue that sage-grouse populations could benefit if coyote (*Canis latrans*) populations were allowed to increase due to their impact on mesopredators that prey heavily on sage-grouse.

Hunting

Despite documented population declines, sage-grouse are still hunted throughout much of their range. The 2010 listing of sage-grouse as warranted but precluded under the Endangered Species Act has increased public concern about the impacts of hunting on

sage-grouse populations (J. Robinson, Utah Division of Wildlife Resources, personal communication). Traditional harvest management principles considered most hunting mortality to be compensatory to natural over-winter mortality (Leopold et al. 1943, Errington 1945, Errington 1956). Romesburg (1981) criticized the principle of compensatory mortality as being unsubstantiated dogma. Subsequent studies have cast further skepticism about the role of compensatory mortality in hunted populations (Smith and Willebrand 1999, Williams et al. 2004). Studies of the effects of hunting on sage-grouse populations have yielded mixed results. Johnson and Braun (1999) concluded that sage-grouse harvest in Colorado was likely additive to winter mortality, whereas Sedinger et al. (2010) found no evidence of additive mortality when they analyzed harvest data from Nevada and Colorado. Connelly et al. (2003) reported that sage-grouse populations subjected to low to moderate levels of hunter harvest had lower rates of increase than unharvested populations. The authors concluded that the most appropriate management strategy would combine restricted harvest and habitat conservation measures. Most recently, Connelly et al. (*in press*) suggested that both the social and biological implication of harvest should be taken into consideration when developing conservation strategies for sage-grouse.

Lack of Information about Juvenile Survival

While much is known about the diet and habitat requirements of sage-grouse chicks (Johnson and Boyce 1990, Drut et al. 1994, Aldridge and Brigham 2002, Sveum et al. 1998), far less is known about the factors directly affecting juvenile survival (Crawford et al. 2004). The relative scarcity of survival information for this demographic

is largely a consequence of the lack of radio-transmitters small enough to attach to newly hatched chicks. Recent technological advances have provided the tools needed to monitor individual chicks. While information about factors affecting sage-grouse chick survival does now exist (Gregg and Crawford 2009, Dahlgren et al. 2010), more research is needed in this area.

SIGNIFICANCE OF MY RESEARCH

Despite an impressive body of research pertaining to the biology, ecology, and conservation of greater sage-grouse, questions remain unanswered and the future of the species remains uncertain. This document offers contributions in the areas of habitat management, population ecology, and harvest management. Chapter 2 presents the results of an experiment designed to evaluate the effectiveness of using strategic intensive sheep grazing to manage sage-grouse early brood-rearing habitat. The results of this chapter indicate that sheep can be used to create small patches of high quality brood-rearing habitat. The application of this method is most appropriate for creating a mosaic of habitats across a larger landscape. While this method does offer an opportunity to reconcile a traditional western land-use practice (livestock grazing) with contemporary wildlife conservation needs, appropriate implementation of the method requires a detailed understanding of numerous interacting factors.

Chapter 3 presents the results of the most extensive survival study of individually marked greater sage-grouse chicks to date. Following upon the work of Dahlgren (2009), I modeled chick survival rates across 5 consecutive years as a function of covariates. Overall, chick survival on Parker Mountain was high. My results contribute to the

understanding of the direct impacts of habitat and demographic/behavioral factors on chick survival.

Chapter 4 presents the results of the first known study of the determinants of sage-grouse hunter motivations and satisfaction. Although hunter satisfaction was primarily influenced by whether or not the individual was successful in harvesting sage-grouse, hunters were primarily motivated by a desire to spend time outdoors with family. These results will help managers weigh the biological and social implications of sage-grouse hunting.

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CHAPTER 2

GRAZING SAGEBRUSH WITH SHEEP TO ENHANCE GREATER SAGE-GROUSE
BROOD-REARING HABITAT**ABSTRACT**

Greater sage-grouse (*Centrocercus urophasianus*) populations experienced significant declines during the twentieth century. Although many factors have been implicated in this decline, the most ubiquitous cause has been the loss and degradation of habitats. Brood-rearing habitat has been found to be limiting for some sage-grouse populations. Fire, herbicides, and mechanical treatments have been previously used in attempts to improve brood-rearing habitat. I evaluated the use of strategic intensive sheep grazing as an alternative means for managing sage-grouse brood-rearing habitat. Grazing treatments were applied in the fall of 2006 and the response of vegetation and sage-grouse was monitored yearly through 2009. Mountain big sagebrush cover was significantly reduced as a result of grazing treatments. Grasses and forbs exhibited significant positive responses in areas where livestock and wildlife grazing were excluded after sheep grazing treatments. When grazing was not excluded in the years following the treatments, none of the habitat variables monitored differed although disproportionate use by large ungulates would indicate that herbage production and herbivory were indeed higher on treated areas. Two separate measures of sage-grouse use confirmed higher use in the sheep grazing treatments than control plots. My results indicate that strategic intensive sheep grazing was effective at managing sage-grouse brood-rearing habitat at small scales in high elevation habitats. If plots treated using this

technique were rested for at least one growing season, the vegetation and sage-grouse response may have been magnified. I recommend the use of this method in combination with managed grazing incorporating protection from large herbivore use to annually treat small acreages of degraded brood-rearing habitat to create a mosaic of small habitat patches.

INTRODUCTION

The status of greater sage-grouse (*Centrocercus urophasianus*, hereafter sage-grouse) is well documented (Connelly and Braun 1997; Schroeder et al. 2004). The decline of sage-grouse populations throughout their range has commonly been attributed to the general loss, degradation, or fragmentation of sagebrush (*Artemisia* sp.) habitats across western North America (Braun et al. 1977; Connelly and Braun 1997; Braun 1998; Schroeder et al. 2004). A number of factors have contributed to the reduction and degradation of sagebrush habitats, including energy and urban development, wildfire, spread of invasive species and poorly managed livestock grazing.

Range conservationists have developed and applied various management techniques for sagebrush steppe ecosystems. However, most traditional approaches to “range improvement” have focused on decreasing sagebrush cover and increasing forage production for domestic livestock (Vale 1974). Management actions designed to reduce sagebrush cover can be detrimental to wildlife species that depend upon sagebrush habitats for all or part of their life cycle (Vale 1974; Baker et al. 1976; Wiens and Rotenberry 1985; Swenson et al. 1987). Additionally, inappropriate livestock grazing

may also have detrimental effects on sagebrush steppe habitats utilized by sage-grouse (Vale 1975; Beck and Mitchell 2000; Connelly et al. 2000; Jones 2000).

Although sage-grouse rely on sagebrush habitats throughout their annual cycle, specific habitat requirements vary considerably depending upon time of year (Schroeder et al. 1999; Connelly et al. 2000). Numerous studies have evaluated the habitat requirements for sage-grouse broods (Klebenow and Gray 1968; Peterson 1970; Wallestad 1971), and the availability of quality brood-rearing habitat may be a limiting factor for some sage-grouse populations (Robinson 2007; Smith 2009).

Brood-rearing habitat is generally characterized by relatively low percent cover of sagebrush (Martin 1970; Wallestad 1971; Hagen et al. 2007) with high percent cover and diversity of forbs and grasses (Sveum et al. 1998; Lyon 2000; Hagen et al. 2007). These conditions are often restricted to more mesic areas within sagebrush steppe such as riparian zones. These habitats provide important food resources for sage-grouse hens and chicks, as well as foraging opportunities for other wildlife and domestic livestock. As such, these habitats may be particularly susceptible to degradation from poor grazing management.

While several studies have reported on the effects of fire, both prescribed and wild, on sage-grouse habitat (Martin 1990; Fischer et al. 1996; Nelle et al. 2000), few studies have attempted to experimentally evaluate the relative effectiveness of other sagebrush habitat improvement practices relative to their effects on sage-grouse habitat. Research conducted on Parker Mountain, Utah reported on the effects of chemical (Tebuthiuron) and mechanical (Dixie-harrow and Lawson aerator) treatments on sage-grouse brood-rearing habitat (Chi 2004; Dahlgren 2006; Dahlgren et al. 2006). While

both chemical and mechanical treatments can reduce sagebrush cover and increase forb cover (Dahlgren et al. 2006) to within the levels suggested in the brood-rearing habitat guidelines (Connelly et al. 2000), concerns have been raised about the longevity, environmental impacts, social acceptance and fossil fuel dependency of these methods (T. Messmer, Utah State University, personal communication).

One possible alternative, though somewhat controversial, method of managing sagebrush ecosystems is through carefully managed grazing by livestock (Provenza et al. 2003; Vavra 2005). When improperly applied, grazing can suppress succession and alter community composition and ecosystem structure and function (Archer 1989; Laycock 1991; Fleischner 1994; Weiss 1999; Vavra 2005). These principles are often manifested in poorly managed rangelands where livestock are allowed to exclusively consume preferred forage (usually forbs or grasses) and as a result shrub cover is allowed to increase. As shrub cover increases, forbs and grasses are outcompeted for vital resources. Properly managed grazing systems can have 4 generally beneficial impacts on landscapes. These benefits are: 1) alteration of the composition of the plant community, 2) increased productivity of selected species, 3) increased nutritive quality of the forage, and 4) increased habitat diversity through altering structure (Vavra 2005).

The objective of this study was to evaluate the viability of strategically timed, high intensity, sheep grazing to improve sage-grouse brood rearing habitat. I report the results of a controlled, randomized and spatially replicated experiment. I predicted that sheep grazing could be managed to decrease cover of sagebrush, increase cover of forbs and grasses, and subsequently increase use of treated plots by sage-grouse.

METHODS

Study Area Description

The study was conducted during 2006-2009 on Parker Mountain in south central Utah (lat 38°16'57.4"N, long 111°51'21.1"W). This area consisted of approximately 107,478 ha with ownership split between the U.S. Forest Service (20%), the U.S. Bureau of Land Management (34%), the Utah School and Institutional Trust Lands Administration (41%), and private landowners (5%). Parker Mountain lies at the southern edge of the range of greater sage-grouse. The area is atypical sage-grouse habitat in that the mountain is a high elevation plateau comprised of a matrix of black sagebrush (*A. nova*) and big sagebrush (*A. tridentata* ssp. *wyomingensis* and *A. t.* ssp. *vaseyana*) with a very sparse understory of forbs and grasses. The area hosts one of the largest contiguous tracts of sagebrush remaining in Utah as well as one of the largest and most stable sage-grouse populations in the state (Beck et al. 2003).

Annual precipitation across the site ranges from 40-51 cm (Dahlgren et al. 2006). Precipitation in this area exhibits a generally bi-modal pattern with most precipitation occurring either as rain during the seasonal monsoonal period in late summer and early autumn or as snow during winter.

The predominant land use on Parker Mountain is livestock grazing at a stocking rate of 1.46 haAUM⁻¹. The site is divided into 3 pastures according to elevation. Cattle are released into the lowest elevation pasture in May. Herds are gradually moved to higher elevation pastures as vegetation at low elevations desiccates and vegetation at higher elevations matures. However, large groups of cattle are often found in high

elevation pastures earlier than planned. Predators, primarily coyotes (*Canis latrans*), are intensively controlled by USDA Wildlife Services, ranchers, and sportsmen to protect livestock and for sport. Winter conditions have traditionally limited use of the mountain by red fox (*Vulpes vulpes*) to low elevations. However, an increasing number of red fox have been observed at higher elevations in recent years (Jim Lamb, Utah Division of Wildlife Resources, personal communications).

Experimental Design

I identified 8 paired-plot locations (1 paired-plot = 1 treatment plot and 1 control plot) on similar ecological sites using geographical information system (GIS) software. All plots were dominated by mountain big sagebrush with rare occurrences of black sagebrush and silver sagebrush (*A. cana*). Four paired-plots were located in areas treated in 2001 with a single-pass Dixie harrow (DH) operation. The other 4 paired-plots were located to the south of the Dixie harrow treatment in areas where no vegetation management had been conducted (unmanipulated, UM). Each plot was approximately 3.2-ha in size. Where possible, plots were elongated to increase edge/area ratios. Once each paired-plot was identified using a GIS, each of the individual plots was randomly assigned to the grazing treatments of graze or control. Within each plot, 4 randomly located 10-m vegetation transects were permanently established.

Initial vegetation measurements were conducted in mid-July 2006 during peak plant production. Parameters measured included shrub species composition and cover (line-intercept (Canfield 1941)), and understory cover (rock, bare, litter, forb, grass) and height. Understory cover was estimated using the Daubenmire frame method

(Daubenmire 1959). Once vegetation measurements were completed on all plots, sage-grouse pellet counts (at each end of each vegetation transect, 1-m radius) were conducted in each plot.

Prior to beginning the grazing treatments, shrub biomass was sampled at five randomly located points in each plot. At each point, the mountain big sagebrush plant nearest to the point was harvested at ground level. Shrub biomass samples were dried at 80 degrees Celsius for 48 hours, and weighed. Sampling was repeated in grazed plots immediately after grazing to determine how much shrub biomass was removed by the sheep.

An electric fence was built around each plot randomly chosen to receive the grazing treatment. Fences were constructed in October 2006 once all cattle were removed from the area. Waiting until cattle were removed helped insure that there were no preexisting differences in vegetation resulting from some plots being protected from cattle grazing. Plots were grazed using local sheep familiar with the vegetation on Parker Mountain. Approximately 1,000 sheep were used in the experiment. Prior to moving sheep into the plots, the animals were temporarily staged at a nearby area for 1 week. This provided a period of conditioning to the electric fence and supplemental feed. The supplement consisted of alfalfa meal (45%), ground corn (30%), dried beet pulp (20%), and soybean meal (5%).

Sheep were not moved onto the experimental plots until there had been at least 1 killing frost. Waiting to begin grazing until after killing frost insured that most grasses and forbs had gone dormant and were therefore not negatively affected by grazing. Waiting until after frost also resulted in reduced monoterpene levels in sagebrush (Kelsey

et al. 1982), thereby decreasing negative post-ingestive feedback from monoterpenes and increasing the acceptability of sagebrush as forage by sheep.

Once the sheep were sufficiently well conditioned to the fence and feed, the flock was divided into two groups of approximately 500 sheep each. Each of the two groups was moved onto a different plot, one in the DH pre-treatment area and one in the UM pre-treatment area, resulting in stocking densities of approximately 155 sheep per hectare in each plot. The protein and energy supplement was provided inside the plots at a rate of approximately 1.35 kg/head/day to increase use of sagebrush by the sheep (Dziba et al. 2007). Sheep were taken to water once per day unless sufficient snow was available for their consumption. Plots were grazed until an adequate level of utilization had been achieved (typically 7-10 days).

Immediately after sheep were removed from each plot a series of three levels of herbivore exclosures were established to assess the impact of different guilds of herbivores on vegetation. The three levels of herbivore exclosure were: open to all herbivores, exclusion of large herbivores (cattle [*Bos taurus*], pronghorn antelope [*Antilocapra americana*], mule deer [*Odocoileus hemionus*], elk [*Cervus canadensis*]), and total exclusion (insects and some very small rodents were still able to access the area but lagomorphs were excluded). The exclosures were randomly located within the plots and exclosures were abutted against one another. Each herbivore exclosure was approximately 2.45-m square. Beginning in the summer of 2007, vegetation in exclosures was measured using the Daubenmire frame method for understory cover, species composition, and height.

Beginning in mid-June 2007, once most sage-grouse chicks were able to fly, walking surveys were conducted in each plot. These surveys consisted of four people spaced approximately 20-m apart (20-m outside plot, edge of plot, 20-m inside plot, and 40-m inside plot). Plots were surveyed for sage-grouse by walking along one of the long sides of the roughly rectangular plot and then walking back along the opposite side. A second walking survey was conducted in mid-July. During walking surveys, all grouse flushed from within or around plots were counted and recorded as male, female, juvenile or unknown. Sage-grouse pellet counts, walking surveys, plot vegetation measurements, and exclosure vegetation measurements were repeated annually through 2009.

Statistical Analyses

I analyzed vegetation response variables using an analysis of variance of a 3-way factorial in a split plot design with repeated measures (PROC MIXED, SAS System for Windows, v9.1). The grazing treatment, year, and pre-treatment status of plots (Dixie-harrowed or unmanipulated) were treated as fixed effects. All three fixed effects were allowed to interact in the analysis. Random effects included plot nested within pre-treatment (plot(pretrt)) and the interaction of the grazing treatment with plots nested within pre-treatments (treatment*plot(pretrt)). The whole plot unit was the plot, with pre-treatment status serving as the whole plot factor. The subplot unit was (grazing treatment x plot) and the subplot factor was the grazing treatment. Measurements were repeated across years at the subplot level. Denominator degrees of freedom were calculated using the Kenward-Roger method. The most appropriate covariance structure for repeated measures was determined for each response variable by comparing Akaike information

criterion (AIC_c) values (Burnham and Anderson 2002). The parametric assumptions of normality and homoscedasticity were checked and deviations from these assumptions were corrected using non-linear transformations of the response variables. Analysis of vegetation responses in the grazing exclosures was conducted in the same way except that the level of exclosure was also included as a fixed effect. This addition resulted in a 4-way factorial split-split plot design with exclosure level being the sub-subplot factor.

Both measures of sage-grouse use of plots resulted in high proportions of zeros, making traditional parametric analytical methods inappropriate. Therefore, I analyzed these data using a negative binomial distribution (PROC GLIMMIX, SAS System for Windows, v9.2) with maximum likelihood estimation based on the Laplace approximation. For walking surveys, the response was the sum of the hens, chicks, and unidentifiable grouse flushed per plot in each year. The response for the pellet count analysis was the total number of pellets counted per plot per year.

Rather than setting a fixed alpha level and referring to p-values as either “significant” or “non-significant” as has been common in applied ecological research I chose to adopt the “neoFisherian” approach to interpreting analytic results (Hurlbert and Lombardi 2009). In addition to rejecting fixed values of alpha and references to “significant” or “non-significant” p-values, this approach promotes the application of the “three-valued logic” of Cox (1958) and Harris (1997) when interpreting significance tests and advocates the presentation of exact p-values as well as effect sizes and measures of variation (Hurlbert and Lombardi 2009). According to Fisher (1958), “tests of significance [should be] used as an aid to judgment, and should not be confused with automatic acceptance tests or ‘decision functions’.” Although this approach can be seen

as producing “fuzzy” results, it in fact provides the reader with the opportunity to reach their own conclusions about the data in the absence of arbitrary statements of significance. I present results from only those factors and interactions found to be statistically and/or biologically meaningful.

RESULTS

Response of Vegetation in Plots

Prior to beginning the grazing treatments, sheep body condition was assessed. Once all plots had been grazed, body condition was reassessed and found to have improved slightly (C. K. Chapman, Utah State University Extension Animal Scientist, unpublished data). Shrub biomass sampling conducted immediately after the completion of grazing treatments showed an average decrease in shrub biomass of 69% (Table 2-1). Duration of grazing per plot ranged from 7 to 10 days (median = 9 days).

Initial shrub cover values (mean \pm 1 SE) were similar for plots in both pre-treatment areas (DH = 24.2% \pm 1.4, UM = 29.7% \pm 2.2, $t_{5,15} = -1.57$, $P = 0.1751$) and for plots randomly selected to receive grazing (27.6% \pm 2.6) and control treatments (26.5% \pm 1.5, $t_{8,45} = 0.26$, $P = 0.7982$). Overall, the pre-treatment status of the sites did not influence how shrub cover responded to the treatments. Measurements taken during the summer following the grazing treatments showed a substantial decline in shrub cover in treated plot (8.8% \pm 3.2). Shrub cover in control plots gradually increased in each subsequent year of the study (2007 = 27.0% \pm 1.9, 2008 = 28.0% \pm 1.4, 2009 = 32.9% \pm 2.6). Following the decline in shrub cover for grazed plots in 2007, cover increased at an average rate of 4.1% per year.

Initial forb cover in 2006 was nominally greater in DH plots ($13.6\% \pm 2.2$) than in UM plots ($10.4\% \pm 1.4$, $t_{26,2} = 1.27$, $P = 0.2136$). Additionally, plots randomly selected as controls had higher forb cover ($13.9\% \pm 2.0$, Fig. 2-1) in 2006 than did plots slated to be grazed ($10.0\% \pm 1.5$, $t_{26,2} = -1.55$, $P = 0.1336$). Following 2006, forb cover relative to the pre-treatment status of plots did not differ. Forb cover in both grazed and control plots declined in 2007 (7.9% and 7.1% , respectively, Fig. 2-1). Forb cover increased for all plots in 2008; however, cover in grazed plots ($13.9\% \pm 2.3$) increased more than in control plots ($9.2\% \pm 1.1$, $t_{26,2} = 1.86$, $P = 0.0744$). Cover also increased in 2009, and again cover was greater in grazed plots ($15.2\% \pm 2.7$) than in control plots ($13.3\% \pm 1.9$, $t_{26,2} = 0.77$, $P = 0.4459$), although the difference was small. Overall, forb height differed slightly between grazed ($5.1 \text{ cm} \pm 0.35$) and control plots ($6.5 \text{ cm} \pm 0.41$, $F_{1,6} = 6.98$, $P = 0.0385$). No differences were observed between DH ($6.0 \text{ cm} \pm 0.44$) and UM plots ($5.6 \text{ cm} \pm 0.36$, $F_{1,6} = 0.05$, $P = 0.8340$) and no difference in the effect of the grazing treatment was observed relative to the pre-treatment status of the plots ($F_{1,6} = 0.33$, $P = 0.5859$).

Grass cover was marginally influenced by the grazing treatments (grazed = $11.6\% \pm 0.87$, control = $9.7\% \pm 0.51$, $F_{1,12} = 1.32$, $P = 0.2730$) and the pre-treatment status of plots (DH = $11.6\% \pm 0.65$, UM = $9.7\% \pm 0.78$, $F_{1,12} = 3.27$, $P = 0.0955$). Differences were observed across years ($F_{3,36} = 15.41$, $P < 0.0001$). Grass cover followed the same general trend as forb cover, decreasing below initial levels (2006 = $10.6\% \pm 0.84$) in 2007 ($8.1\% \pm 0.61$) and then increasing in both 2008 ($9.6\% \pm 0.72$) and 2009 ($14.3\% \pm 1.22$). Grass height did not differ due to grazing treatments (grazed = $9.5 \text{ cm} \pm 0.59$, control = $9.4 \text{ cm} \pm 0.54$, $F_{1,11.5} = 0.01$, $P = 0.9147$) or pre-treatment status (DH = $9.4 \text{ cm} \pm 0.54$,

UM = 9.5 cm \pm 0.59, $F_{1,11.5} = 0.02$, $P = 0.8924$), but did vary across years (2006 = 8.5% \pm 0.37, 2007 = 8.5% \pm 0.31, 2008 = 7.2% \pm 0.37, 2009 = 13.5 \pm 0.84, $F_{3,17.8} = 17.58$, $P < 0.0001$).

Response of Vegetation in Grazing Exclosures

Forb cover was influenced by the interaction between grazing treatment and level of exclosure (Fig. 2-2, $F_{2,24} = 2.60$, $P = 0.0952$). Cover in open areas was identical between grazed and control plots (Grazed = 10.6% \pm 1.38, Control = 10.6% \pm 1.46, $t_{24.8} = 0.16$, $P = 0.8731$). Forb cover was also similar between the 2 treatments for areas where large herbivores were excluded (Grazed = 12.6% \pm 1.35, Control = 13.4% \pm 1.95, $t_{24.8} = -0.03$, $P = 0.9730$). When all herbivores were excluded, forb cover increased in grazed plots (16.9% \pm 1.40) relative to other exclosure levels whereas forb cover in control plots declined to an intermediate level (11.6% \pm 1.70, for grazed versus control $t_{24.8} = 2.08$, $P = 0.0481$).

The response of forb height was best explained by examining the influence of the 3 levels of herbivore exclosure. Forbs in areas open to all herbivores were short (5.6 cm \pm 0.35). When large herbivores were excluded, forb height increased considerably relative to open areas (8.5 cm \pm 0.57, $t_{26.5} = -4.69$, $P < 0.0001$). Excluding all herbivores resulted in only a small increase in forb height (9.1 cm \pm 0.52) relative to areas where large herbivores were excluded ($t_{26.5} = -1.09$, $P = 0.2847$).

Grass cover was influenced by the interaction between the grazing treatments, level of exclosure, and year ($F_{4,72} = 2.69$, $P = 0.0377$). Areas open to all herbivores consistently had the lowest coverage of grass and cover varied little across years or

between grazing treatments (range = 7.3% to 9.6%, mean = 8.3%, Fig. 2-3). When large herbivores were excluded, there were substantial differences in grass cover between control (12.1%) and grazed plots (21.5%). Grass cover was relatively constant across years when large herbivores were excluded in control plots (range = 9.2% to 14.9%). Conversely, grass cover increased markedly with time (2007 = 12.1%, 2008 = 23.5%, 2009 = 28.8%) in grazed plots. Excluding all herbivores in control plots resulted in a steady increase in grass cover across years (2007 = 9.2%, 2008 = 12.9%, 2009 = 16.4%). Grass cover exhibited a different trend when all herbivores were excluded from grazed plots. Cover was initially low (2007 = 8.6%), but increased dramatically in 2008 (25.2%) and then remained the same in 2009 (24.8%).

Grass height increased in each subsequent year of the study ($F_{2,35} = 50.66$, $P < 0.001$). The rate of increase was similar for all treatment combinations. When years were combined, grass height was influenced by interactions between the grazing treatments and level of exclosure ($F_{2,23.7} = 5.57$, $P = 0.0104$, Fig. 2-4) and pre-treatment status and level of exclosure ($F_{2,23.7} = 5.67$, $P = 0.0097$, Fig. 2-5). Regardless of the interaction being considered, grass height was always lowest in areas open to all herbivores and highest in plots having received a sage-brush reduction treatment (DH or sheep grazing). When herbivores were not excluded, the difference in grass height between grazed and control plots was negligible ($7.7 \text{ cm} \pm 0.6$ and $8.9 \text{ cm} \pm 0.7$, respectively, $t_{31.4} = -0.97$, $P = 0.3387$, Fig. 2-4). This difference was also small relative to pre-treatment status (DH = $9.2 \text{ cm} \pm 0.7$, UM = $7.3 \text{ cm} \pm 0.6$, $t_{31.4} = 1.47$, $P = 0.1528$, Fig. 2-5). When all herbivores were excluded, grazed and ungrazed plots again had similar but much greater grass height ($14.8 \text{ cm} \pm 1.2$ and $13.6 \text{ cm} \pm 0.9$, respectively, $t_{31.4} = 0.88$,

$P = 0.3877$). This same trend was observed for the 2 levels of pre-treatment (DH = $14.6 \text{ cm} \pm 1.1$, UM = $13.8 \text{ cm} \pm 1.1$, $t_{31.4} = 0.57$, $P = 0.5705$). Interestingly, these trends did not hold when only large herbivores were excluded. At this level of exclusion, grass height was greater for plots having received the grazing treatment ($15.2 \text{ cm} \pm 1.5$) than for control plots ($11.5 \text{ cm} \pm 1.2$, $t_{31.4} = 2.87$, $P = 0.0073$). Grass height was also considerably greater in plots having received the DH pre-treatment ($16.2 \text{ cm} \pm 1.5$) than in UM plots ($10.6 \text{ cm} \pm 1.0$, $t_{31.4} = 4.28$, $P = 0.0002$).

Response of Sage-Grouse to Grazing Treatments

Analysis of pellet count data showed that plots receiving the two levels of the grazing treatment differed in the number of grouse pellets found ($F_{1,6} = 11.06$, $P = 0.0159$). On average, grazed plots had 0.86 pellets (± 0.36), whereas control plots had only 0.02 pellets (± 0.39). The walking surveys also indicated that grouse used grazed and control plots at different levels ($F_{1,6} = 4.22$, $P = 0.0857$) and that use of the plots varied across years ($F_{2,24} = 6.42$, $P = 0.0059$). More grouse were flushed from grazed plots (1.4 ± 0.36) than control plots (0.5 ± 0.38). Overall use of plots was relatively high in 2007 (1.6 ± 0.34). The number of grouse flushed declined to 0.5 (± 0.37) in 2008 and then increased slightly to 0.7 (± 0.38) in 2009.

DISCUSSION

Little experimental evidence exists to support the notion that sage-grouse can benefit from the removal of sagebrush (Schroeder et al. 2006; but see Dahlgren et al. 2006). Additionally, livestock grazing has been cited as a factor contributing to the

degradation of sage-grouse habitat (Schroeder et al. 1999; Beck and Mitchell 2000).

However, I demonstrate that many characteristics of high quality brood-rearing habitat (Connelly et al. 2000; Hagen et al. 2007) can be achieved through the use of intensively managed sheep grazing.

The guidelines for sage-grouse habitat management state that early brood-rearing habitats should have a relatively open shrub canopy and high coverage of forbs and grasses (Connelly et al. 2000). Hagen et al. (2007) provided support for these statements while also showing the importance of tall grasses in early brood-rearing habitat. Sheep grazing treatments reduced shrub cover to within the range considered optimal for sage-grouse broods. Unlike other shrub control methods, sheep grazing does not kill all shrubs. Instead intensive grazing can result in most shrubs being pruned back such that cover is significantly reduced while retaining live brush. Other studies have shown decreases in sagebrush cover and increases in grass and forb production following intensively managed sheep grazing (Woodland 2007). I conclude that strategic intensive sheep grazing, as described above, has the potential to be a useful tool for managing sage-grouse brood-rearing habitat. However, growing season grazing must be properly managed in order to realize the full benefit of this method.

The response of forbs and grasses to grazing treatments was negligible. Forb and grass cover were greater in grazed plots but the magnitude of the treatment effect was slight. Grass height did not differ between grazed and control plots, but forb height was greater in control plots. However, forb cover in grazed plots was greater than reported by Dahlgren et al. (2006) for plots receiving chemical or mechanical brush control treatments.

Despite the fact that forbs and grasses exhibited a minimal response to grazing treatments, sage-grouse showed a positive response to the treatments. Although the habitat metrics I measured did not differ between grazed and control plots, there may have been notable differences in nutritive quality of forage due to inputs from sheep urine and feces. Sage-grouse are capable of selecting forage based on protein content (Remington and Braun 1985). Recent research has shown that nutrition and body condition may be important determinants of sage-grouse survival and reproduction (Dunbar et al. 2005; Gregg 2006).

The general lack of a positive response by herbaceous vegetation to the grazing treatment may have been a result of preferential use of grazed plots by domestic and wild herbivores in the years following the treatments. Throughout the study, observations were made of pronghorn antelope, mule deer, and cattle preferentially using grazed plots. In 2009, large herbivores (wild and domestic) were tallied as part of the sage-grouse walking surveys. I counted 33 cows and five mule deer in grazed plots and six cows and three mule deer in control plots. Although surveys were not explicitly designed to quantify use of plots by large grazers, these field observations indicated that plots having received the sheep grazing treatment were clearly preferred by cattle. As a result, interpretation of herbaceous response variables is complicated by the fact that in each of the three years following the sheep grazing treatments all plots were used extensively by domestic and wild herbivores. This confounding factor was anticipated during the design phase of this research. However, because much of the rangeland currently occupied by sage-grouse is subjected to grazing by large herbivores, we chose not to protect plots from grazers to determine if sheep grazing treatments could improve brood-rearing

habitat under commonly applied grazing practices. Additionally, this also allowed us to quantify the level to which large and small herbivores impact the herbaceous layer through the use of herbivore exclosures.

Forb cover increased when large herbivores were excluded on both grazed and control plots. Differences in forb cover between grazed and control plots became apparent when all herbivores were excluded, implying that forb cover may be regulated by small mammals. In general, forb cover across the site was within the range considered suitable for sage-grouse broods (Connelly et al. 2000). Forb heights in exclosures did not differ between grazed and control plots. Both levels of herbivore exclusion resulted in increased forb height when compared to areas open to herbivores. This observation suggests that grazing by large herbivores may be the primary factor limiting the height of forbs. However, height of forbs is not typically considered an important metric for brood-rearing habitat (Hagen et al. 2007).

Exclusion of herbivores increased grass cover in grazed plots relative to control plots. Cover increased with time for both grazed and control plots with the increase being more dramatic in the grazed plots. Only minor differences in cover were observed between large herbivore exclosures and total exclosures. These results indicated that the influence of the grazing treatments extends over multiple years and that grass cover is primarily regulated by large herbivores.

Grass height varied unexpectedly in relation to shrub management (both grazing and DH treatments) and level of herbivore exclusion. I contend that lagomorphs were selecting for areas with greater shrub cover, which is why shrub management resulted in greater grass height when large herbivores were excluded but not when all herbivores

were excluded. Decreased shrub cover in treated areas may have increased the susceptibility of rabbits to predation. If rabbits avoided areas with shrub treatments, then exclusion of large herbivores in these areas would be analogous to total exclusion of herbivores. Grass height was similar for areas with shrub control and either total herbivore exclusion or large herbivore exclusion. In plots without shrub control, total herbivore exclusion resulted in considerably taller grass than large herbivore exclusion. From this I conclude that large herbivores are having some impact on grass height but the impact of rabbit herbivory on grass height is much greater.

Forb cover and grass height, both important components of sage-grouse brood-rearing habitat (Hagen et al. 2007), appear to be affected by small herbivores. Land and wildlife managers may find it difficult, expensive, or even ethically unacceptable to reduce lagomorph and rodent populations to improve habitat conditions for sage-grouse. However, it is widely accepted that livestock grazing must be managed in order to be compatible with wildlife conservation. All measures of herbaceous vegetation increased when large herbivores were excluded. The livestock grazing plan for the study site called for grazing to begin in low elevation pastures and proceed to higher elevation pastures throughout the summer (Terry Messmer, USU Extension, personal communication). Thorough implementation of this plan would result in cattle not reaching the majority of the brood-rearing habitat on the site until late in the brood-rearing period. Unfortunately, cattle were often able to reach high elevation habitats much earlier than planned. The ultimate impacts of livestock grazing on sage-grouse habitat are fiercely debated. Poorly managed livestock grazing can undoubtedly be detrimental to sage-grouse. However, removal of livestock may also have detrimental impacts on habitat such as decreases in

increased shrub cover and decreased plant species richness (Manier and Hobbs 2007).

Livestock grazing is not necessarily incompatible with sage-grouse habitat as long as proper grazing management strategies are applied (Holechek et al. 1982).

MANAGEMENT IMPLICATIONS

There are no simple solutions to habitat loss and degradation. Strategic intensive sheep grazing provides a new tool for managing sage-grouse brood-rearing habitat but the application of this method demands careful consideration and may require changes in current land use practices. Cattle grazing on the study site likely suppressed the response of forbs and grasses to the sheep-grazing treatments. It would be informative to evaluate this management technique in areas with other cattle management regimes. In addition, herbivory by rabbits and rodents appears to have significantly impacted some habitat metrics. Although cessation of predator control programs has been proposed to be potentially beneficial to sage-grouse, to my knowledge this hypothesis has not been formally tested. This method for managing brood-rearing habitat through strategic intensive sheep grazing needs to be evaluated at sites where the confounding effects of uncontrolled herbivory are not present. However, it is important to note that sage-grouse responded positively to grazing treatments despite the impact of herbivory by wildlife and livestock in the years following the sheep grazing treatments.

Ultimately, the most important factors influencing the successful application of this management strategy lie in identifying the appropriate grazing strategy and intensity by the most appropriate species. Application of this method to non-brood-rearing habitats (i.e. nesting habitat) could be highly detrimental to sage-grouse populations.

Failure to achieve adequate utilization of sagebrush may result in little to no positive effect on the habitat. Additionally, grazing must be conducted at the time of year that is most conducive to achieving the specific goals of improving brood-rearing habitat (Mosley and Brewer 2006).

Finally, the species used in grazing treatments may drastically effect the time needed to complete treatments and their success (Walker et al. 2006). While cows are capable of consuming sagebrush (Chuck Peterson, USDA NRCS, unpublished data), sheep and goats may be better suited in terms of physiology and morphology. Unlike other sagebrush control methods, strategic intensive grazing cannot be easily applied to large acreages in a single year. Large scale sagebrush treatments have repeatedly been shown to be detrimental to sage-grouse (Martin 1970; Swenson et al. 1987; Connelly et al. 2000*b*). Strategic intensive grazing should be applied yearly in order to create a mosaic of small patch habitats within the greater extent of brood-rearing habitat on a site.

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Table 2-1. Shrub biomass before and after intensive sheep grazing, Parker Mountain, Utah, USA, 2006.

Grazing	Mean	Std. Dev.	Lower 95% CL	Upper 95% CL
Pre	466	171	323	608
Post	146	131	36	255

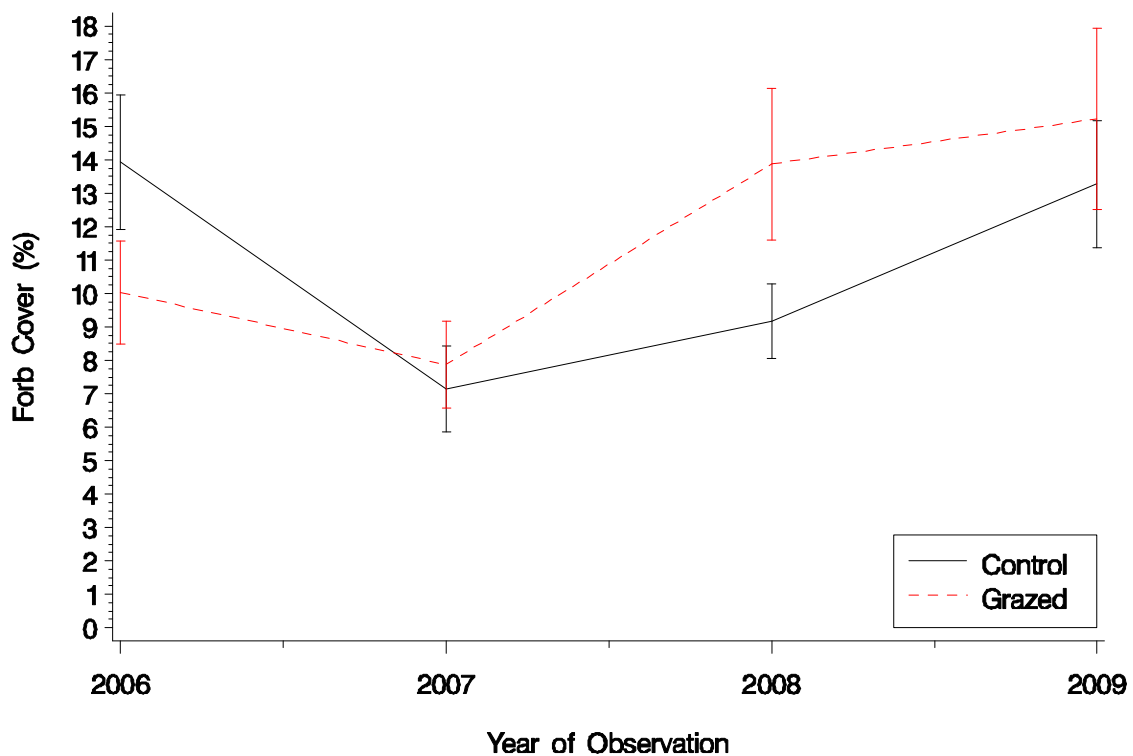


Figure 2-1. Response of forb cover to sheep grazing treatments, Parker Mountain, Utah, USA, 2006-2009.

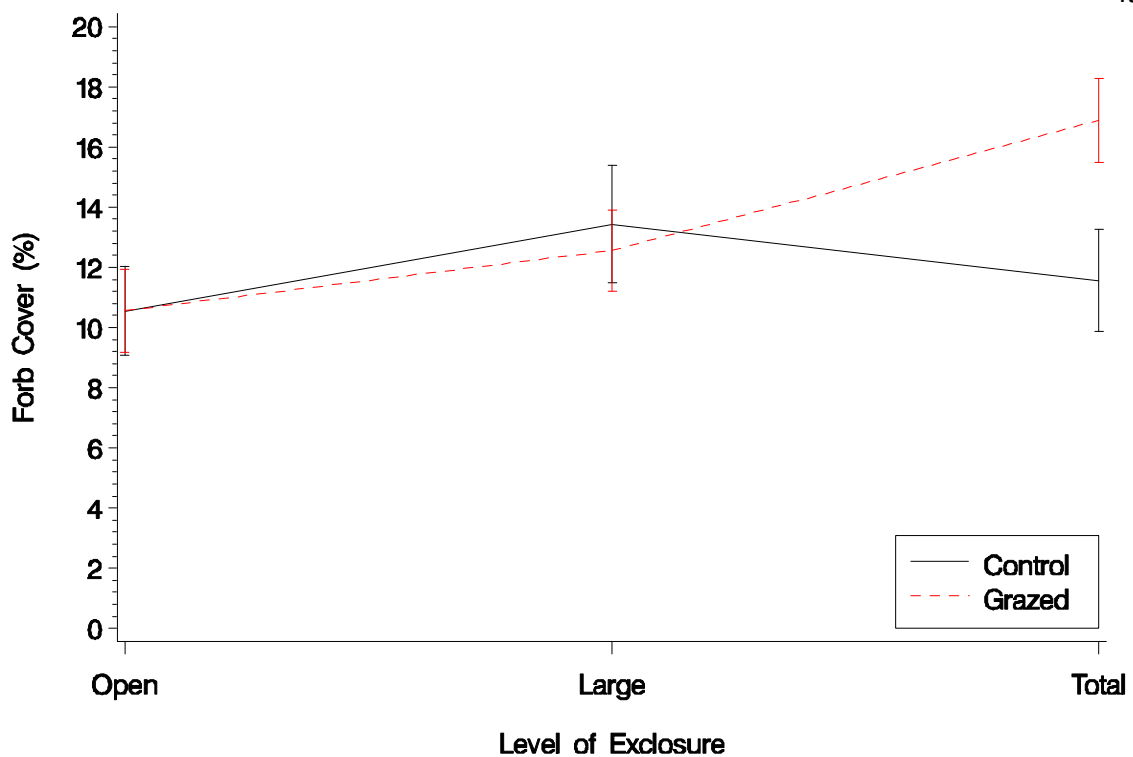


Figure 2-2. Response of forb cover to sheep grazing treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.

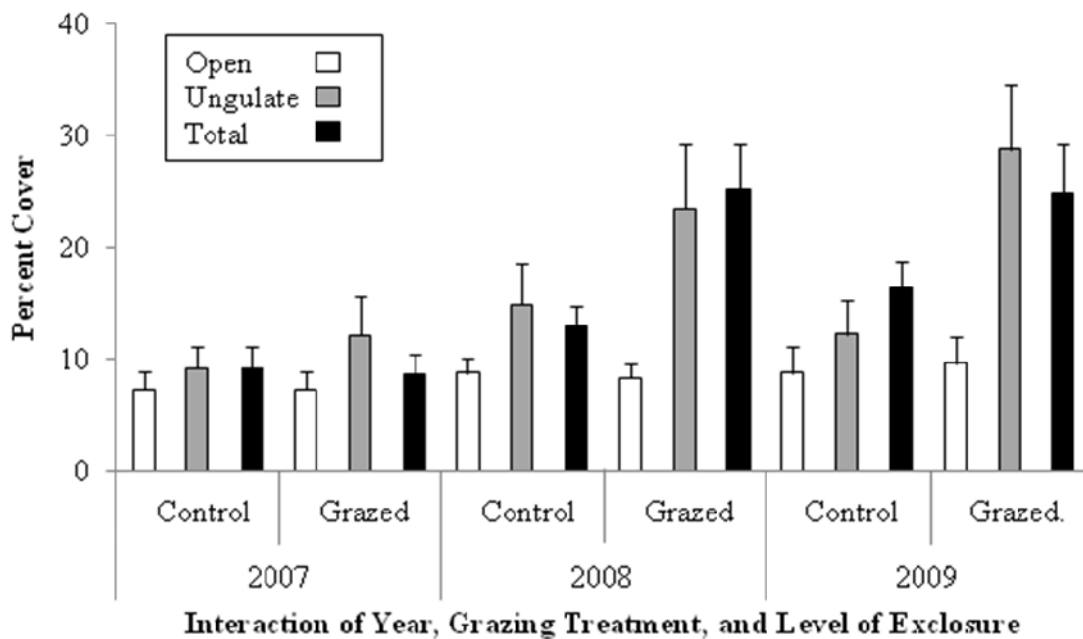


Figure 2-3. Response of cover cover to sheep grazing treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.

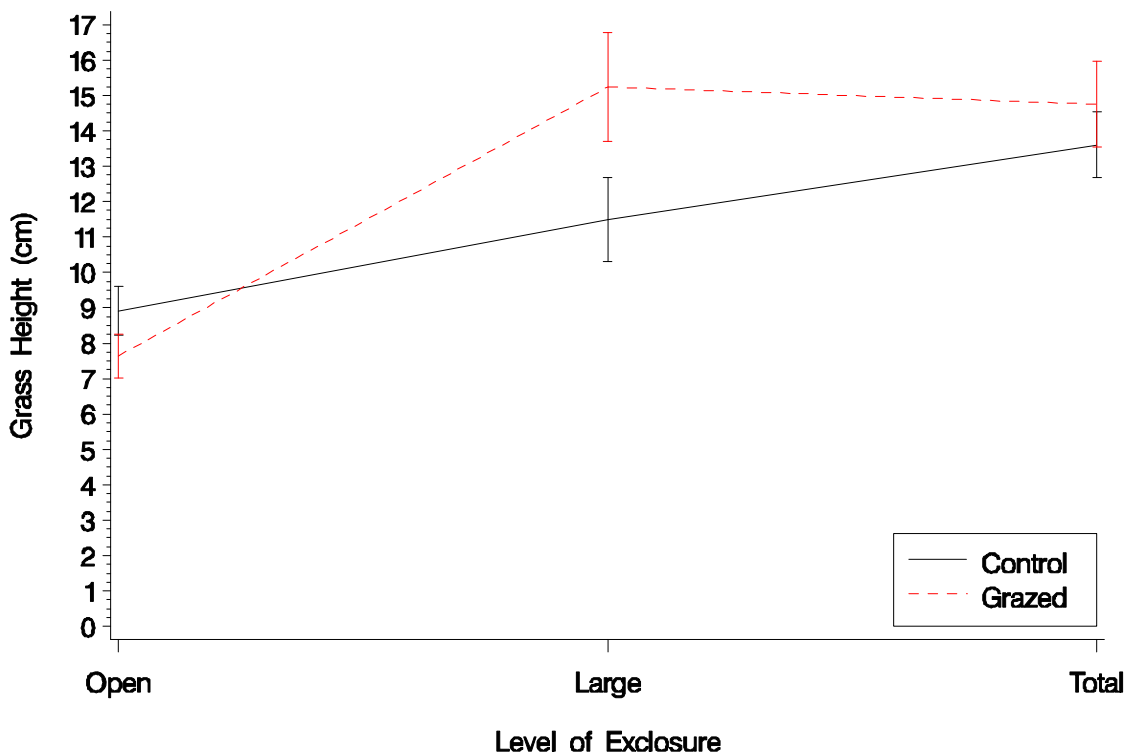


Figure 2-4. Response of grass height to sheep grazing treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.

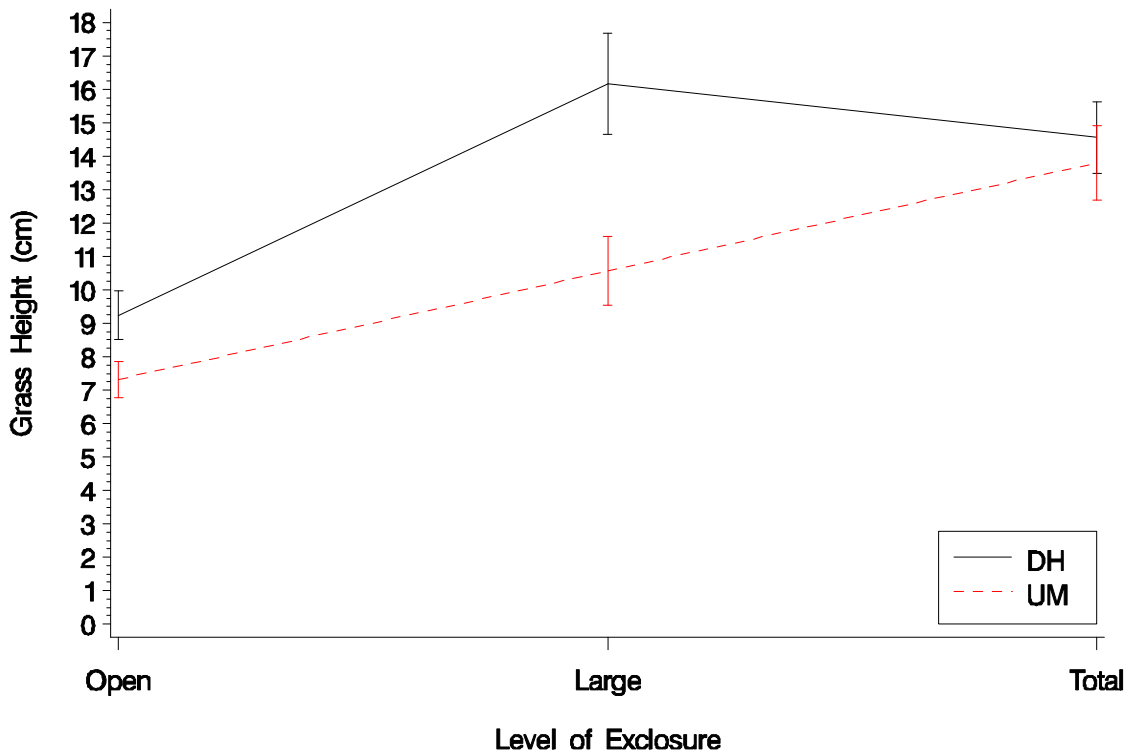


Figure 2-5. Response of grass height to pre-treatments and herbivore exclosures, Parker Mountain, Utah, USA, 2006-2009.

CHAPTER 3

EARLY SURVIVAL OF GREATER SAGE-GROUSE CHICKS IN RELATION TO
ECOLOGICAL AND DEMOGRAPHIC FACTORS**ABSTRACT**

Greater sage-grouse (*Centrocercus urophasianus*) populations declined range-wide in the past century. Low juvenile survival and recruitment rates have been identified as factors contributing to observed declines, yet little is known about the ecological and behavioral processes that affect these demographic parameters. To help address these needs, we modeled chick survival to 42 days of age as a function of parental traits, phenology, behavior, and habitat for the Parker Mountain, Utah sage-grouse population from 2005-2009. We monitored fates of 335 individual chicks from 76 broods that were marked with 1.5 g suture-style radio transmitters. The overall average survival rate was 0.385 (95% CL = 0.247-0.625). We observed higher rates of brood-mixing than have been reported in other sage-grouse populations. Our best model indicated that survival was highest for chicks hatched to yearling hens that remained with their natal brood and for chicks that hatched early in the season and then engaged in brood-mixing regardless of hen age. Our best model including habitat variables indicated that chick survival was positively associated with grass cover and was higher in black sagebrush (*Artemisia nova*) habitats than big sagebrush (*A. tridentata*) habitats. Because adult hens in this population have higher nest initiation and success rates, and survival of their offspring is not significantly affected by brood-mixing, protecting this segment of the population should be the highest conservation priority. Grass cover can be increased

in big sagebrush habitats through appropriate sagebrush control methods and improved livestock management could increase grass cover in both big sagebrush and black sagebrush habitats.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*, hereafter sage-grouse) are obligates of the sagebrush (*Artemisia* spp.) dominated ecosystems of western North America (Hornaday 1916, Schroeder et al. 1999, Schroeder et al. 2004). Sage-grouse populations and their distribution have declined range wide over the past century (Connelly and Braun 1997, Schroeder et al. 2004). As with most imperiled species in the United States (Wilcove et al. 1998, Storch 2000), habitat loss and degradation are often cited as the primary factors leading to the decline of sage-grouse. Other factors implicated in the decline of sage-grouse include disease (Naugle et al. 2005), exploitation (Connelly et al. 2003), and predation (Connelly et al. 2000b). To better manage these threats, more information is needed regarding the ecological and behavioral processes that may affect population dynamics.

Survival of individuals of various age classes is an essential component of understanding the viability of any population (Boyce 1992). Although somewhat variable, annual survival rates of breeding age sage-grouse are typically high (Johnson and Braun 1999, Connelly et al. 2000a, Crawford et al. 2004). Conversely, estimates of juvenile survival are typically low (Schroeder 1997, Aldridge and Brigham 2001). However, chick survival estimates derived from brood flush counts may be biased low due to the tendency of sage-grouse chicks to avoid flying when disturbed (Dahlgren et al.

2010b) and to engage in post-hatch brood amalgamation (i.e. brood-mixing; Gregg and Crawford 2009, Dahlgren et al. 2010a).

Although well documented in numerous waterfowl species (Beauchamp 1997), little is known about the prevalence of brood-mixing in gallinaceous species or its adaptive significance (Faircloth et al. 2005). Several authors have reported the occurrence of brood-mixing in galliforms; however, these reports have largely been based on anecdotal evidence (Burger et al. 1995, Lott and Mastrup 1999). Within the waterfowl literature several hypotheses have been posed to explain the evolutionary role of brood-mixing (Eadie et al. 1988, Nastase and Sherry 1997, Kalmbach et al. 2005, Kalmbach 2006) and the factors that contribute to its occurrence (Beauchamp 1997). Among the explanations of why brood-mixing occurs are: accidental mixing prior to development of mother-offspring bonds (Williams 1974, Monro and Bedard 1977), and inability of the mother to care for offspring due to limited habitat (Eadie and Keast 1982), energetic limitations (Lack 1968) and lack of experience (Aldrich and Raveling 1983)

Development of radio-transmitters small enough to be carried by newly hatched chicks has enabled direct field studies of this age-class (Burkepile et al. 2002). Published survival rates of individually marked chicks have generally been low. Aldridge (2005) reported a survival rate at 56 days post-hatch of 12.3% whereas Gregg and Crawford (2009) report survival at 28 days post-hatch of 39.2 %. However, Dahlgren et al. (2010a) reported a survival rate of 60% at 42 days post hatch. Estimates of individual chick survival are further complicated by the fact that the fates of chicks within a brood cannot be assumed to be independent (Flint et al. 1995a). The lack of independence among brood mates results in overdispersion and leads to reduced variance of parameter

estimates and biased model selection (Anderson et al. 1994, Gruebler and Naef-Daenzer 2010). The analytical approach developed by Manly and Schmutz (2001) and employed by Dahlgren et al. (2010a) accounts for this potential lack of independence through the use of a quasi-likelihood model with a normal approximation to a binomial variance multiplied by a constant dispersion factor.

Studies of sage-grouse broods have provided detailed descriptions of brood-rearing habitat. The importance of arthropods as a food source during the first 3 weeks post-hatch has been well established (Klebenow and Gray 1968, Johnson and Boyce 1990, Dahlgren 2009, Gregg and Crawford 2009). Wet meadows and other areas with high forb abundance/cover and relatively low sagebrush cover are commonly reported as being critical habitat for sage-grouse chicks later in the brood-rearing period (Braun et al. 1977, Drut et al. 1994, Sveum et al. 1998, Connelly et al. 2000a, Hagen et al. 2007). However, considerably less information exists concerning the influence of ecological, demographic and behavioral factors on sage-grouse chick survival (but see Dahlgren 2009 and Gregg and Crawford 2009).

STUDY AREA

This research was conducted on Parker Mountain in south-central Utah (38°17'N, 111°51'W). The area encompassed 107,478 ha and was administered by the Utah School and Institutional Trust Lands Administration (40.8%), the United States Forest Service (20.2%), the United States Bureau of Land Management (33.9%), and private ownership (5.1%). Parker Mountain is a sagebrush-dominated plateau at the southern edge of the sage-grouse range. It is one of the few areas remaining in Utah with relatively stable

numbers of sage-grouse and it includes some of the largest contiguous tracts of sagebrush in the state (Beck et al. 2003). The area receives between 40 and 51 cm of precipitation annually, which generally exhibits a bi-modal pattern, occurring either as rain during the seasonal monsoonal period from late summer and early autumn or as snow during winter.

The predominant land use on the mountain is grazing by domestic livestock at a stocking rate of 1.46 ha per animal unit month (Dahlgren et al. 2006). Sheep and cattle are moved seasonally through 10 grazing pastures beginning in lower elevation pastures in June. As vegetation in these pastures desiccates, livestock are sequentially herded into more mesic higher elevation pastures. Most nesting and brood-rearing activities occur at elevations ranging from 2,500 m to 3,000 m.

The area is dominated by big sagebrush (*A. tridentata*) and black sagebrush (*A. nova*). Common grass species across the site include wheatgrass (*Elymus* spp.), bluegrass (*Poa* spp.), grama grass (*Bouteloua* spp.), squirreltail grass (*Elymus elymoides*), needlegrass (*Hesperostipa* spp.) and June grass (*Koeleria* spp.). Common forb species include cinquefoil (*Potentilla* spp.), phlox (*Phlox* spp.), dandelion (*Taraxacum* spp.), lupine (*Lupinus* spp.), daisy (*Erigeron* spp.), penstemon (*Penstemon* spp.), milkvetch (*Astragalus* spp.), agoseris (*Agoseris* spp.), pussytoes (*Antennaria* spp.), and buckwheat (*Eriogonum* spp.).

METHODS

Data Collection

We captured adult and yearling female sage-grouse on and around leks using spotlights and long handled nets (Giesen et al. 1982) during April 2005-2009. Birds were

fitted with 15-19 g necklace style radio-transmitters (Holohil Systems, Carp, Ontario, Canada). Marked hens were located using telemetry 2+ times during April and May to determine if they initiated a nest. Nesting was confirmed visually but hens were never intentionally flushed from their nest due to the tendency of females in this population to abandon their nest if disturbed (Chi 2004). Nesting hens were visually monitored every 2 days to determine nest fate. Nests were monitored daily as the anticipated hatch date approached.

We captured broods of radio-marked hens by locating hens using telemetry equipment shortly after sunset or just before sunrise. During capture events, the brood hen was flushed and all chicks captured by hand and placed in an insulated container with a bottle of warm water to help maintain body temperature of the chicks. We captured most broods within 48 hours of hatching with all broods being captured within 1 week of hatching. All captured chicks were weighed to the nearest 1.0 gram, then marked with a 1.5 g backpack style radio-transmitter (Advanced Telemetry Systems, Insanti, MN in 2005, Holohil Systems, Carp, Ontario, Canada in 2006-2008, and American Wildlife Enterprises, Monticello, FL in 2009) attached with 2 sutures (Burkepile et al. 2002). Chicks found dead in the immediate vicinity of the capture site were considered to have died as a result of handling. In most years we marked all chicks within a brood, but in 2006 we randomly selected 3 chicks from each captured brood to mark with transmitters.

We attempted to monitor marked chicks every other day until they reached 42 days of age; however, some monitoring intervals were longer than 2 days due to difficulties in locating broods. Chicks found within a 30-m radius of the hen were considered alive, and extensive efforts were made to find any chicks missing from a

brood. We occasionally recovered chick transmitters with no chick remains or signs of predation. We treated these recoveries as mortalities although it is possible that transmitters may have been lost for reasons other than chick death. Due to the difficulty of distinguishing predation from scavenging, we did not assign specific causes of mortality. Grouse capture and transmitter attachment procedures were approved under the Utah State University Institutional Animal Care and Use Committee permit #945R and #942.

Habitat characteristics were measured along 2 perpendicular 20-m transects at approximately one-third of all brood locations. We established the initial transect at each site by taking a random compass bearing. Shrub cover and height were measured by species using the line intercept method (Canfield 1941). The dominant shrub species at each sampling location was also classified as either big sagebrush or other shrub cover (primarily black sagebrush). Coverage of forbs and grasses was estimated in eight 20×50 cm Daubenmire frames along each transect (Daubenmire 1959).

Data Analysis

We use the term “brood-mixing” to refer to the phenomenon described by Eadie et al. (1988) as “post-hatch brood amalgamation.” As per Eadie et al. (1988), we defined brood-mixing as occurring when “a female incubates and hatches her own young, but the young mix with the brood of another female after hatching.” Brood mixing occurred in each of the 5 years of this study. When we confirmed that a marked chick had mixed into the brood of an unmarked hen, that chick was right censored from its original brood and considered to be part of a new brood. Additionally, we right censored all missing chicks

whose fate could not be determined (i.e. removed from the dataset after the last date of telemetry observation). Alternatively, we could have assumed that missing chicks were either dead or alive but our approach likely provides the most realistic estimate of chick survival since only chicks with known fate were allowed to influence daily survival rates (Dahlgren et al. 2010a).

Using these definitions of brood-mixing and right censoring, we modeled sage-grouse chick survival from hatch to 42-days of age using the maximum likelihood estimator developed by Manly and Schmutz (2001) and extended by Fondell et al. (2008). This modeling framework is most appropriate because it allows for variable observation intervals, changes in brood size due to adopted or missing chicks, and accounts for lack of independence in fates amongst chicks within a brood by using a quasi-likelihood approach (Manly and Schmutz 2001, Fondell et al. 2008, Dahlgren et al. 2010a). The quasi-likelihood model uses a normal approximation to a binomial variance multiplied by a constant dispersion factor to account for correlation in survival of brood mates. To model survival as a function of covariates, we used a logit-link function and the 'OPTIM' function in R 2.6.1 (R Development Core Team 2005) to attain maximum likelihood estimates of all parameters. We ran 1,000 bootstraps of our dataset to attain 95% confidence intervals for model parameters (Dixon 1993).

To examine processes affecting chick survival in our population, we first developed models that included alternative parameterizations of chick-age and inter-annual variation. For example, we created models with categorical age classes (whereby the categories were based in biological development of the chicks, such as pre- versus post-flight ages or early ages when the diet consists primarily of insects versus later ages

when forbs become important) as well as linear and quadratic models of age treated as a continuous variable. Furthermore, we considered continuous and categorical Year effects (year categories were created by combining years with similar survival), as well as a model with no Year effect (intercept only). Competing models of the various chick-age and Year-effect parameterizations were ranked using the quasi-likelihood version of Akaike's Information Criterion adjusted for sample size (QAIC_c: Akaike 1973, Burnham and Anderson 2002). Models with $\Delta\text{QAIC}_c \leq 2$ were considered to be equally supported by the data, and when this occurred we based our inference on the model with the fewest parameters using the principles of parsimony (Hamel et al. 2010). We evaluated model goodness-of-fit using the method of proportional reduction in deviance (Zheng 2000, Adler and HilleRisLambers 2008).

Upon identifying the best parameterization of chick-age and year-effects, we then considered the addition of brood type (mixed or not), hatch date (calendar date standardized to have a minimum value of 1), and hen age (adult or yearling). Since very little is known about the effect of these variables on sage-grouse chick survival, we chose to evaluate each factor independently as well as combinations of all 3 variables. Models were ranked using the QAIC_c approach described above.

To evaluate the influence of habitat variables on chick survival, we conducted a separate analysis on a reduced dataset ($n = 450$ survival periods as opposed to 1,261 for the previous analysis) where habitat measurements were taken. Habitat covariates used in this analysis included: dominant shrub cover (big sagebrush or other), percent shrub cover, average shrub height, percent forb cover, average forb height, percent grass cover, and average grass height. Additionally, we conducted a principal components analysis of

the habitat parameters and used the first 2 principle components as covariates in our modeling exercise. Models of variation in sage-grouse chick survival across different habitat variables were again ranked using the QAIC_c approach described above.

RESULTS

Most hens had only one brood. Of the 76 hens in the study, 17 had broods during more than one year. Peak hatch date ranged from 25 May to 7 June across the years. We did not document renesting in any year of the study. Across the 5 years, we attached radio transmitters to 335 chicks from 76 broods, resulting in 8,096 chick exposure days. Chick age at the time of capture ranged from 1 to 8 days with an average of 2.7 days. Chick weight at capture ranged from 22-58 g with an average of 33.3 g (SE=0.366). Table 3-1 presents a detailed summary of chick captures by year. We determined that 10 chicks died as a result of capture injury or transmitter attachment, and these chicks were not included in survival analyses. A total of 95 chicks (29.2%) went missing during the course of the study. We censored all missing chicks from the dataset after the last date of telemetry observation.

Brood-mixing occurred in 25 of the 76 broods (32.9%). Brood mixing was most prevalent in 2005 and 2006 with 67% of the brood-mixing events occurred during these 2 years. We documented mixing in 44% (8 of 18) of yearling hen broods as compared to only 29% (17 of 58) of adult hen broods. However, this difference was not statistically significant across the course of the study ($\chi^2_1 = 1.4253$, $P = 0.2325$). Multiple brood-mixing events were documented in 5 broods. Fifty percent of brood-mixing events involved more than one chick being adopted into the brood of an unmarked hen at the

same time. We documented brood-mixing as early as the first week after hatch and as late as the end of the sixth week after hatch. However, most brood-mixing events (83%) occurred during weeks 2-4. We could not determine the ultimate fate of 46% (26/56) of brood-mixed chicks due to the increased difficulty of locating chicks without a marked hen. Documenting the adoption of unmarked chicks into marked broods was not possible because we did not flush chicks when locating broods. However, when capturing broods we occasionally found chicks that were clearly older than natal chicks based on weight and development of primary feathers. This indicates that brood mixing may occur almost immediately after hatch.

Our best temporal model of chick survival included a linear effect of age and the 5 study years separated in 3 categories (years with high: 2005 and 2008-2009, moderate: 2006, and low survival: 2007). This model was used as the basis for further model development. Table 3-2 presents all variables considered in models of chick survival along with variable codes and descriptions. Models that were too complex for the dataset were identified with failure of the OPTIM algorithms to converge on maximum-likelihood estimates of the parameters, and were subsequently excluded from the model-comparison analysis.

Of the 20 demographic/behavioral models for which parameter convergence occurred, 2 were strongly supported by our data (see Table 3-3). Of these 2 models, the top-ranked model was more parsimonious (i.e. contained fewer parameters), and thus we based inference on it alone. There was evidence of mild over-dispersion in the data. Estimated variance in survival within a brood was 1.491 times the expected binomial variance; 95% CL = 1.180-2.422. This suggests that the correlation between the

probabilities of survival of chicks within the same brood was fairly low, but of importance. Survival rates were strongly impacted by year classification (Fig. 3-1). Probability of survival in poor years was 0.108 (95% CL = 0.034-0.280), compared to 0.296 (95% CL = 0.209-0.486) for moderate years and 0.516 (95% CL = 0.392-0.715) for good years. The selected model also included interactions between brood type and hen age (bt × ha) as well as brood type and hatch date (bt × hd, Table 3-4). Survival probabilities varied drastically as a result of the interaction between brood type and hen age (Fig. 3-2). Survival of chicks hatched to adult hens was fairly constant and was estimated with high precision regardless of brood type relative to chicks hatched to yearling hens (Table 3-5). Probability of survival decreased as hatch date increased for both mixed and normal broods; however, the magnitude of the effect was much greater for mixed broods (Fig. 3-3). Survival rates were estimated with much greater precision for chicks not engaging in brood-mixing (Table 3-5). When all effects were held at a constant average value, the probability of survival to 42 days was estimated to be 0.385 (95% CL = 0.247-0.625, Fig. 3-4).

We evaluated 21 models for the habitat dataset (Table 3-6). The temporal model resulted in 10% less reduction in deviance for the reduced habitat dataset (28.81%, Table 3-6) than for the full dataset used in the previous analysis (38.85%, Table 3-3). Three models were equally supported by the data. The model selected for interpretation had 6 parameters being estimated whereas the other 2 models each had 7 parameters. The top model contained effects of grass cover (GC) and dominant shrub type (DST) in addition to the base temporal model (Table 3-7). The probability of survival to 42 days was positively associated with grass cover ($\beta = 0.063$, 95% CL = -0.038 to 0.270).

Probability of survival in habitats with high grass cover was 0.526 (95% CL = 0.346-0.902). Moderate grass cover resulted in a survival probability of 0.447 (95% CL = 0.301-0.826) whereas survival was 0.379 (95% CL= 0.169-0.770) when grass cover was sparse (Fig. 3-5). Big sagebrush dominated habitats had low survival rates (0.294, 95% CL = 0.139-0.502) compared to areas dominated by other shrubs (0.519, 95% CL =0.305-0.932, Fig. 3-6), primarily black sagebrush.

DISCUSSION

Dahlgren et al. (2010a) analyzed years 2005 and 2006 of this dataset and found that chick survival was high (0.50). Our inclusion of 3 additional years of chick survival data resulted in a reduction in the overall average survival rate of chicks in this population. However, the probability of survival as estimated by our best model still exceeds all other published survival estimates from studies monitoring individually marked greater sage-grouse chicks (Aldridge and Boyce 2007, Gregg and Crawford 2009). Additionally, the duration of our study exceeds that of any other study of individually marked sage-grouse chicks to date.

The temporal trends in chick survival that we observed are common in the avian juvenile survival literature. Increases in daily survival rates with age have been documented for numerous species (Fields et al. 2006, Wiens et al. 2006, Fondell et al. 2008). Survival is also often found to vary across years (Flint et al. 1995b, Hannon and Martin 2006, Fondell et al. 2008). Additionally, offspring survival has been shown to be affected by hen age (Fields et al. 2006), hatch date (Anderson et al. 2001), and brood-

mixing (Nastase and Sherry 1997). Our results are unique in that they show that these factors may interact to produce unexpected patterns in chick survival.

Effects of Demographic and Behavioral Factors on Survival

Juvenile survival typically exhibits a positive relationship with hen age (Crawford 1977, Blus and Keahey 1978, Middleton 1979, Martin 1995, Fields et al. 2006). The ultimate causes of this relationship vary according to life history (Martin 1995), but common proximate mechanisms are related to foraging ability/efficiency (Lack 1968, Wheelwright and Schultz 1994), physiological maturation (Robertson et al. 1994), acquisition of quality sites/mates (Ainley 1987, Wheelwright and Schultz 1994), social rank (Cristol 1995), and parental competence (Forslund and Larsson 1992).

The influence of brood-mixing on juvenile survival is not well understood. Engaging in brood-mixing is generally considered to be advantageous relative to not being associated with a brood (Maxson 1978); however, the benefits of mixing versus remaining in the natal brood are questionable (Eadie et al. 1988). We found that the interaction between hen age and brood type (mixed or not) influenced how these 2 factors affect sage-grouse chick survival. Unlike most studies of the effects of hen age on offspring survival, we found that survival was highest for chicks hatched to yearling hens that remained with their natal brood (Fig. 3-2). However, chicks hatched to yearling hens who engaged in brood-mixing were almost certain to die (Fig. 3-2). The influence of brood-mixing on chicks hatched to older hens was negligible. We interpret this as evidence of heterogeneity within the population of yearling hens (Vaupel and Yashin 1985). Dahlgren (2009) found that annual survival did not differ for yearling and adult

hens in the Parker Mountain population; however, nest initiation and nest success rates did differ between the 2 groups.

We hypothesize that only the most fit yearling hens were initiating nests and that only the very best nesters were successfully hatching a brood. Yearling hens that nest successfully are likely a highly superior sub-population. As a result, the offspring of these hens have an unexpected survival advantage. The exceptionally low survival rate for chicks hatched to yearling hen that engage in brood-mixing may be largely due to the small number of chicks that fall into this category (note the extremely wide confidence interval for this group, Table 3-5). Lower survival for chicks hatched to adult hens, regardless of brood-mixing status, may be the result of unobserved heterogeneity in the adult hen population. Heterogeneity at this level could be the result of some adult hens not having previous brood-rearing experience (Forsslund and Pärt 1995, Lewis et al. 2006) or reproductive senescence (Holmes et al. 2001).

Offspring survival is often found to be negatively associated with hatching date (Lack 1968, Rotella and Ratti 1992, Norris 1993, Wiggins et al. 1994, Riley et al. 1998). We found this to be the case both for chicks who remained with their natal brood and for those that engaged in brood-mixing. Increased survival among early hatching chicks may be the result of higher forage abundance and/or quality early in the brooding season (Lindholm et al. 1994). We found that coverage of forbs, an important component of sage-grouse chick diets (Klebenow and Gray 1968), increased throughout the brood-rearing period (unpublished data). This observation suggests that hatching early did not increase access to forage on our study site. Negative relationships between offspring survival and hatch date for some species are actually a function of differences in the

quality of the parents, with increasing quality leading to earlier nesting (Verhulst et al. 1995).

Our only surrogate measure of hen quality was weight at the time of capture. A linear regression analysis of 27 hens that successfully nested the year they were captured showed no evidence of heavier hens having earlier hatch dates ($P = 0.4759$). However, it should be noted that weight alone is likely not a sufficient measure of individual quality. Gregg et al. (2008) reported that nutrition of preincubating sage-grouse hens was related to consumption of forbs high in calcium, phosphorus and crude protein. Additionally, Dunbar et al. (2005) report that several blood parameters, including total plasma protein and calcium : phosphorus ratio, are directly related to reproductive success in sage-grouse. While we cannot rule out the possibility that higher quality hens nested earlier, we suspect that decreased survival rates for later hatching chicks may be the result of predators switching from alternative prey sources as the density of sage-grouse broods increased with time (Murdoch 1969). This effect may be exaggerated on our study area because most broods from across the site eventually converged along the western rim of the mountain resulting in high brood density in this relatively small area.

We found that survival was highest for chicks that hatched early and then engaged in brood mixing (Fig. 3-3). Survival decreased drastically for later hatching chicks that brood-mixed. Chicks that remained with their natal brood also showed lower survival with later hatch dates, but the magnitude of the effect was much smaller as compared to brood-mixed chicks. Since most brood-mixing events occur 2-4 weeks post-hatch, we suspect that brood-mixing may be advantageous for early hatching chicks because it likely results in the chicks being the oldest and most experienced individuals in their new

brood. These older chicks likely benefit as a result of their younger naïve brood mates being more susceptible to predation (Berger et al. 2001). Conversely, late hatching chicks have a higher probability of mixing into a brood of older more experienced chicks, resulting in the brood-mixing chicks being more susceptible to threats.

Effect of Habitat Factors on Survival

Gregg and Crawford (2009) and Dahlgren et al. (2010a) reported relationships between food availability and sage-grouse chick survival. We hypothesized that percent forb cover, a metric commonly reported to be selected for by sage-grouse broods (Drut et al. 1994, Connelly et al. 2000a, Hagen et al. 2007), would be positively associated with chick survival. However, our top habitat model indicated that grass cover and dominant shrub type were the most important determinants of chick survival (Table 3-6). Percent grass cover was positively associated with probability of survival to 42 days (Table 3-7, Fig. 3-5). Gregg and Crawford (2009) report a similar finding. Interestingly, we found survival to be negatively associated with big sagebrush dominated habitats (Fig. 3-6). Black sagebrush, which dominated most areas not dominated by big sagebrush, is important winter forage for some sage-grouse populations (Dalke et al. 1963, Beck 1977, Thacker 2010); however, it is not commonly reported to be used by sage-grouse broods. Despite lower chick survival, big sagebrush habitats had greater coverage of forbs than did black sagebrush habitats (10.5% and 5.3% respectively, $t_{418} = -9.66$, $P < 0.0001$).

Dahlgren et al. (2010a) and Gregg and Crawford (2009) found that sage-grouse chick survival was positively related to the availability of arthropods in the orders Orthoptera and Lepidoptera. Abundance of Orthopterans was greater in black sagebrush

habitats than in big sagebrush habitats in our study site ($t_{103} = 2.06$, $P = 0.0423$), although there was no difference in abundance of Lepidopterans between the 2 habitat types ($t_{158} = 0.05$, $P = 0.9565$, unpublished data). This suggests that sage-grouse chicks may be benefiting from increased availability of Orthopterans in black sagebrush habitats. Additionally, we suggest that sage-grouse chicks may benefit from the low stature and dense structure of black sagebrush. The low height of black sagebrush would facilitate early detection of avian and mammalian predators while the dense structure would provide ample cover for a sage-grouse chick (see Aldridge 2005 and Gregg and Crawford 2009 for related arguments on sage-grouse brood habitat selection).

MANAGEMENT IMPLICATIONS

Our results demonstrate that brood-mixing can have drastic and surprising effects on sage-grouse chick survival. We suspect that the high rate of brood-mixing on Parker Mountain is largely the result of high brood densities in our core brood-rearing habitats. At this time we cannot determine if brood-mixing is hen initiated, chick initiated, or simply a consequence of other factors (i.e. disruption of broods during predation events). Despite survival being higher for chicks hatched to yearling hens who remain with their natal brood, we suggest that management strategies that result in greater protection of adult hens will be of greatest benefit to overall population growth. Adult hens on Parker Mountain have higher nest initiation and nest success rates and their chicks do not appear to be affected significantly by brood-mixing.

We provide additional evidence of the importance of grass cover for sage-grouse chicks. Dahlgren et al. (2006) and Guttery (Chapter 2 of this document) have

demonstrated that grass cover can be increased through sagebrush management. However, these studies were conducted in big sagebrush habitats. We found chick survival to be higher in black sagebrush habitats than in big sagebrush habitats. The sagebrush management treatments that have been tested on Parker Mountain would not necessarily have the same results if they were applied to black sagebrush. We suggest that improved livestock management in brood-rearing habitats would be the best approach for increasing grass cover in big and black sagebrush habitats.

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Table 3-1. Greater sage-grouse chick capture statistics for Parker Mountain, Utah, USA, 2005-2009. For hen age, 'A' indicates adult hens whereas 'Y' indicates yearling hens.

Year	Broods Marked	Chicks Marked	Capture Mortalities	Hen Ages	Avg. Chicks Marked
2005	21	89	3	10 A, 11 Y	4.23
2006	21	61	1	21 A, 0 Y	2.90
2007	12	55	2	8 A, 4 Y	4.67
2008	11	66	3	9 A, 2 Y	6.00
2009	11	64	1	10 A, 1 Y	5.82
Total	76	335	10	58 A, 18 Y	4.41

Table 3-2. Demographic, behavioral, and habitat variables used in modeling greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.

Code	Factor	Factor Description
	Linear	Linear effect of age
	Year	Year class (high, medium, and low survival)
bt	Brood Type	Mixed or normal brood
ha	Hen Age	Yearling or adult
hd	Hatch Date	Calendar date adjusted to minimum value of 1
DST	Dominant Shrub Type	Either <i>Artemisia tridentata</i> or other shrub type
SC	Shrub Cover	Percent shrub cover
SH	Shrub Height	Mean shrub height
FC	Forb Cover	Visual estimate of percent forb cover
FH	Forb Height	Mean forb height
GC	Grass Cover	Visual estimate of percent grass cover
GH	Grass Height	Mean grass height

Table 3-3. Model selection results for all models evaluating the effects of temporal and demographic/behavior factors on greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009. Models were developed in 3 stages. First the best age model was determined. Various combinations of year effects were then added to the best age model to produce an overall best temporal effects model. Finally, demographic effects were added to the best temporal model. All models were evaluated using the Quasi-Akaike's Information Criterion (QAIC). K = no. of parameters. Wt = model weight (i.e. the likelihood of a particular model being the best model). %RD = percent reduction of deviance relative to the intercept only model. The full model did not converge.

Model	K	$\Delta QAIC_c$	Wt	%RD
*bt + ha + hd + (bt × ha) + (bt × hd)	9	0.00	0.518	61.89
*bt + ha + hd + (bt × ha) + (bt × hd) + (ha × hd)	10	0.15	0.481	62.32
*bt + ha + hd + (ha × hd) + (bt × ha)	9	18.74	0.000	57.65
*bt + ha + hd + (bt × ha)	8	19.08	0.000	57.12
*bt + ha + hd	7	27.16	0.000	54.83
*bt + ha + hd + (bt × hd)	8	28.11	0.000	55.08
*bt + ha + hd + (ha × hd)	8	29.07	0.000	54.86
*bt + ha + hd + (ha × hd) + (bt × hd)	9	30.13	0.000	55.08
*ha + hd + (ha × hd)	7	39.17	0.000	52.12
*ha + hd	6	40.68	0.000	51.32
*bt + hd	6	42.52	0.000	50.90
*bt + hd + (bt × hd)	7	43.55	0.000	51.13
*hd	5	49.31	0.000	48.91
*bt + ha	6	80.56	0.000	42.30
*bt + ha + (bt × ha)	7	82.21	0.000	42.39
*ha	5	82.65	0.000	41.37
*bt	5	91.56	0.000	39.36
Intercept + Linear + Year (*)	4	91.77	0.000	38.85
Intercept + Linear	3	196.22	0.000	14.78
Intercept	2	259.57	0.000	0.00
Full Model	11	NA	NA	NA

Table 3-4. Parameter estimates, standard errors and 95% confidence intervals for all terms in the top demographic/behavior model used to explain greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.

Parameter	Beta	SE	Lower CI	Upper CI
D	1.491	0.369	1.180	2.422
Intercept	3.321	0.486	2.431	4.490
Linear Age Trend	0.035	0.015	0.009	0.075
Year Effect	0.617	0.173	0.331	1.002
Brood Type	-0.733	0.770	-2.247	0.704
Hen Age	-0.610	0.457	-1.568	0.135
Hatch Date	-0.040	0.020	-0.082	-0.008
Brood Type × Hen Age	2.799	1.750	-1.779	5.204
Brood Type × Hatch Date	-0.214	0.142	-0.363	0.161

Table 3-5. Survival probabilities to 42 days of age for greater sage-grouse chicks on Parker Mountain, Utah, USA, 2005-2009.

Interaction Effect	Survival	95% CL
Brood Type × Hen Age		
Normal, Yearling	0.613	(0.370-0.839)
Normal, Adult	0.409	(0.306-0.579)
Mixed, Yearling	0.0004	(0.000-0.787)
Mixed, Adult	0.383	(0.070-0.812)
Brood Type × Hatch Date		
Normal, Early	0.544	(0.409-0.728)
Normal, Mid	0.462	(0.357-0.627)
Normal, Late	0.376	(0.266-0.538)
Mixed, Early	0.697	(0.060-0.924)
Mixed, Mid	0.193	(0.049-0.642)
Mixed, Late	0.001	(0.000-0.539)

Table 3-6. Model selection results for all models evaluating the effects of temporal and habitat factors on greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009. Models were developed in 2 stages. First the best temporal effects model from the demographic effects analysis was applied to the habitat data set. Second, habitat effects were added to the best temporal model. All models were evaluated using the Quasi-Akaike's Information Criterion (QAIC). K = no. of parameters estimated. Wt = model weight (i.e. the likelihood of a particular model being the best model). %RD = percent reduction of deviance relative to the intercept only model.

Model	K	$\Delta QAIC_c$	Wt	%RD
*DST + GH + (DST \times GH)	7	0.00	0.377	63.00
*DST + GC	6	0.26	0.331	61.16
*DST + GC + (DST \times GC)	7	0.92	0.238	62.27
*FC + GC + SC	7	4.72	0.036	59.26
*FC + GC	6	6.13	0.018	56.51
*PC1 + PC2 + (PC1 \times PC2)	7	15.72	0.000	50.56
*GC	5	15.87	0.000	47.18
*DST + FC + (DST \times FC)	7	16.47	0.000	49.96
*DST + FC	6	20.86	0.000	44.86
*SC + FC	6	20.92	0.000	44.80
*DST	5	21.45	0.000	42.76
*DST + GH	6	23.31	0.000	42.91
*PC2	5	25.98	0.000	39.18
*SC	5	28.29	0.000	37.35
*PC1	5	28.99	0.000	36.80
*FH + GH + SH	7	30.19	0.000	39.11
*FC	5	33.17	0.000	33.49
*SH	5	33.85	0.000	32.95
*FH + GH	6	36.31	0.000	32.63
Intercept + Linear + Year (*)	4	37.04	0.000	28.81
*GH	5	37.68	0.000	29.92
*FH	5	38.75	0.000	29.07
Intercept + Linear	3	54.14	0.000	13.66
Intercept	2	69.38	0.000	0.00

Table 3-7. Parameter estimates, standard errors and 95% confidence intervals for all terms in the top habitat model used to explain greater sage-grouse chick survival on Parker Mountain, Utah, USA, 2005-2009.

Parameter	Beta	SE	Lower CI	Upper CI
D	1.260	0.590	1.008	3.148
Intercept	2.348	1.517	-1.296	5.486
Linear Age Trend	0.046	0.043	-0.010	0.151
Year Effect	0.261	0.457	-1.028	1.072
Dominant Shrub Type	-0.631	0.771	-3.195	0.219
Grass Cover	0.063	0.084	-0.038	0.270

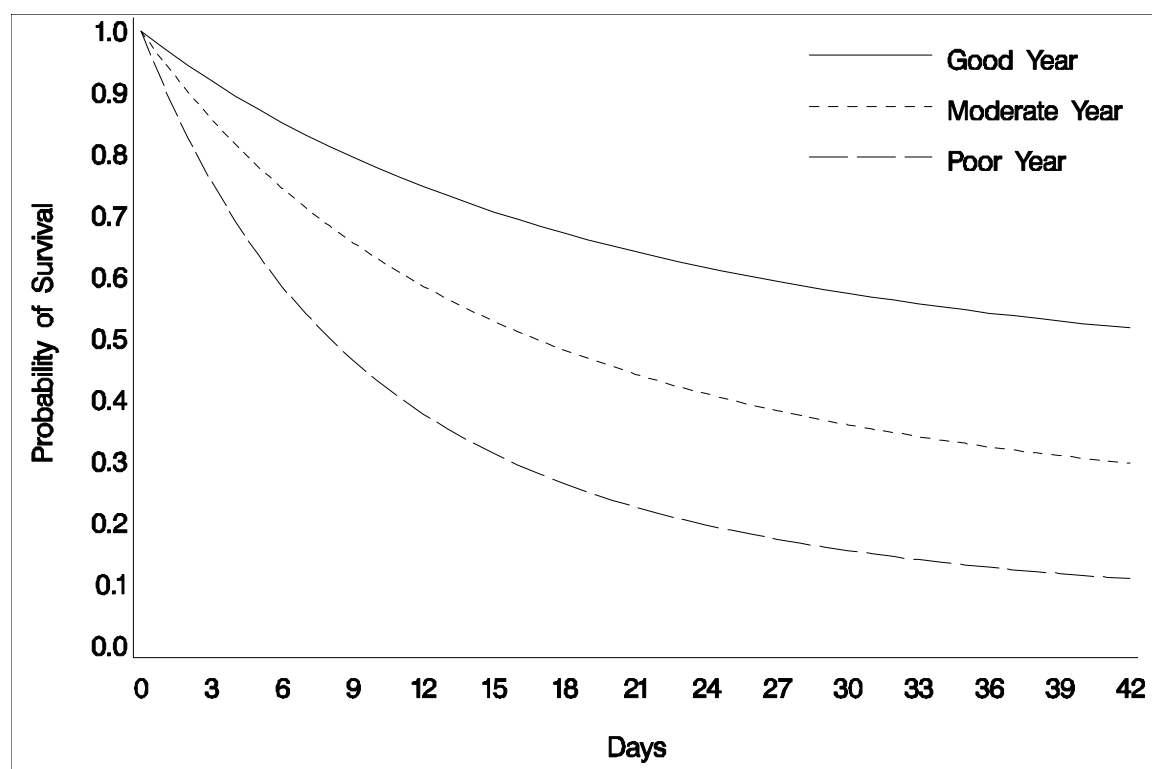


Figure 3-1. Survivorship curves for greater sage-grouse chicks relative to year classification on Parker Mountain, Utah, USA, 2005-2009. All other effects were held constant at their mean values (median hatch date was used).

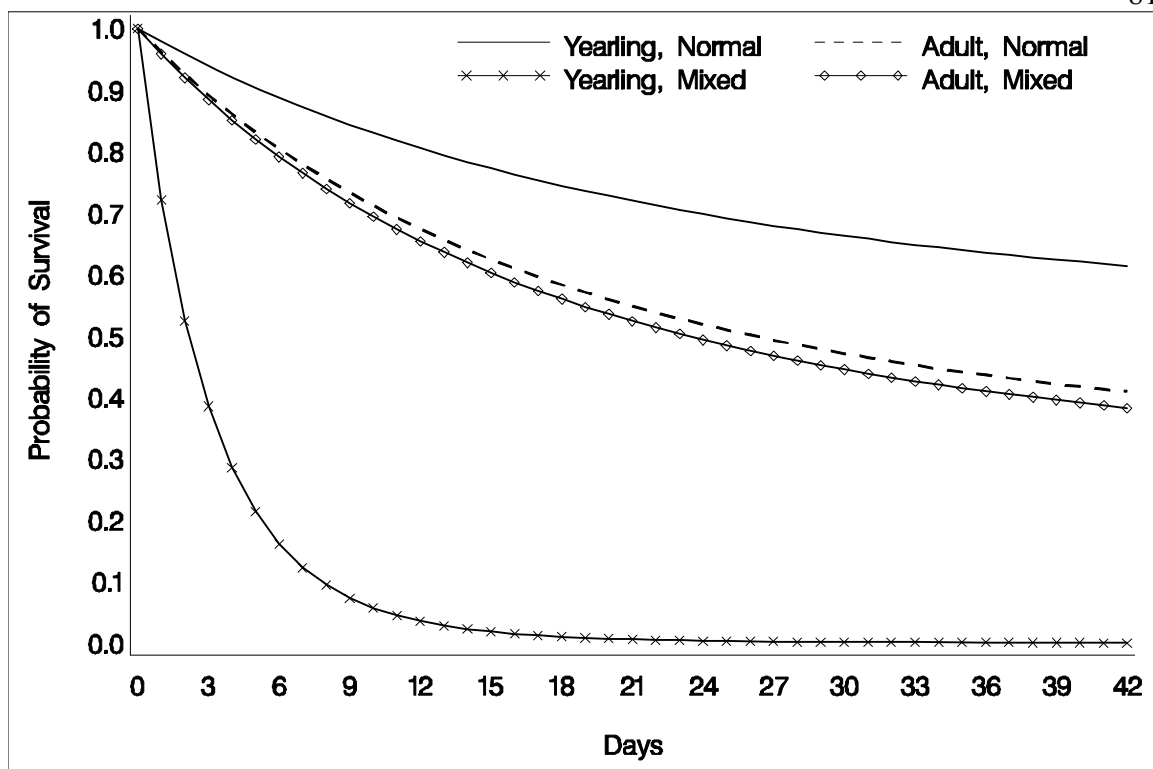


Figure 3-2. Survivorship curves for greater sage-grouse chicks relative to brood type and maternal hen age on Parker Mountain, Utah, USA, 2005-2009. All other effects were held constant at their mean values (median hatch date was used).

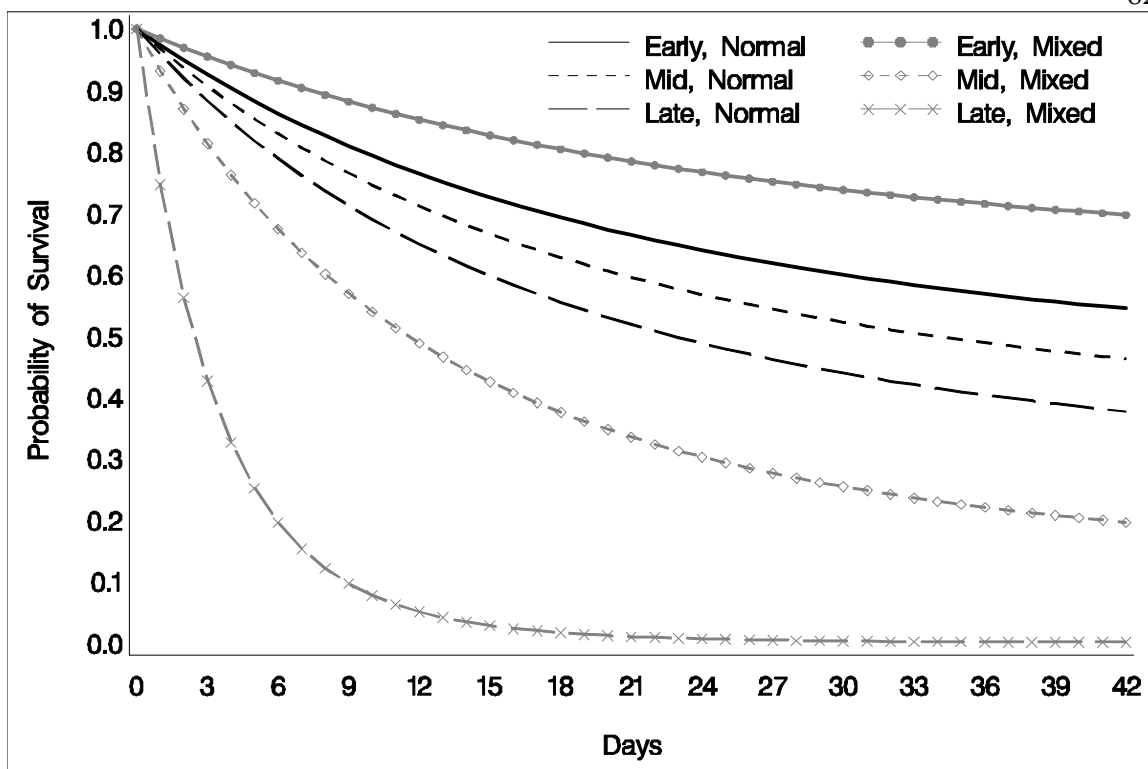


Figure 3-3. Survivorship curves for greater sage-grouse chicks relative to brood type and hatch date on Parker Mountain, Utah, USA, 2005-2009. All other effects were held constant at their mean values.

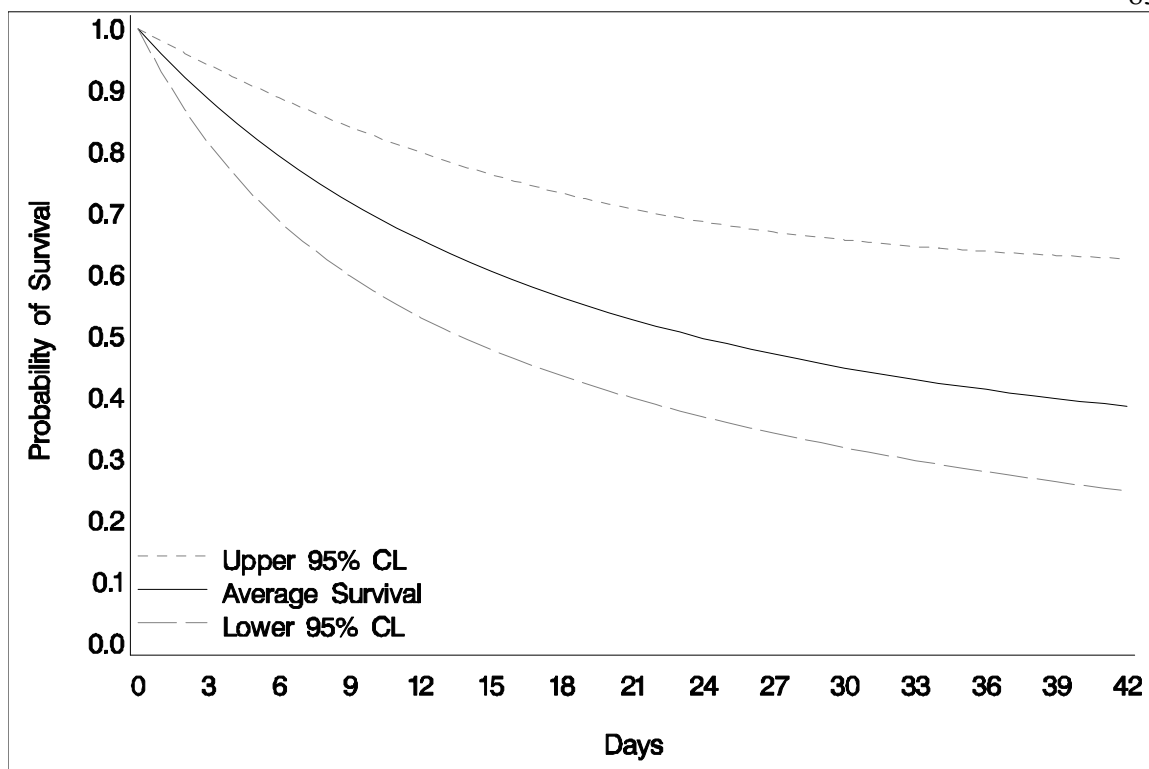


Figure 3-4. Survivorship curve for greater sage-grouse chicks based on our top demographic/behavior model on Parker Mountain, Utah, USA, 2005-2009. All effects were held constant at their mean values (median hatch date was used).

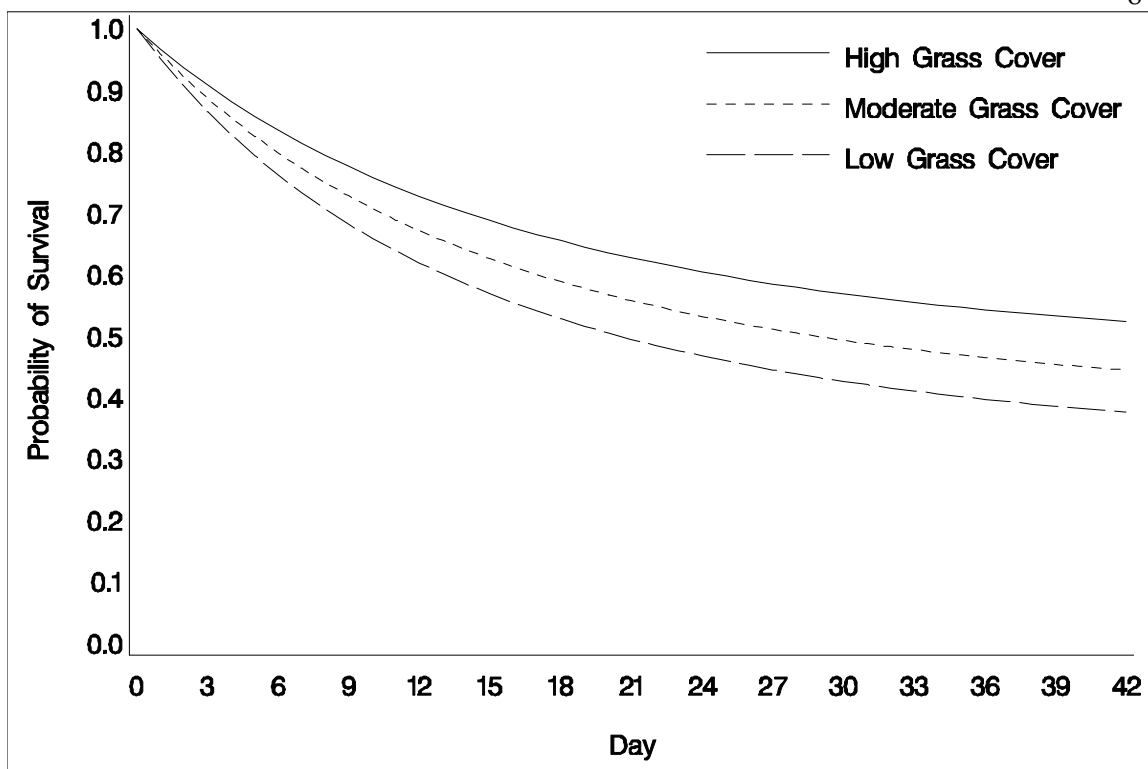


Figure 3-5. Survivorship curves for greater sage-grouse chicks relative to grass cover on Parker Mountain, Utah, USA, 2005-2009. All other effects were held constant at their mean values.

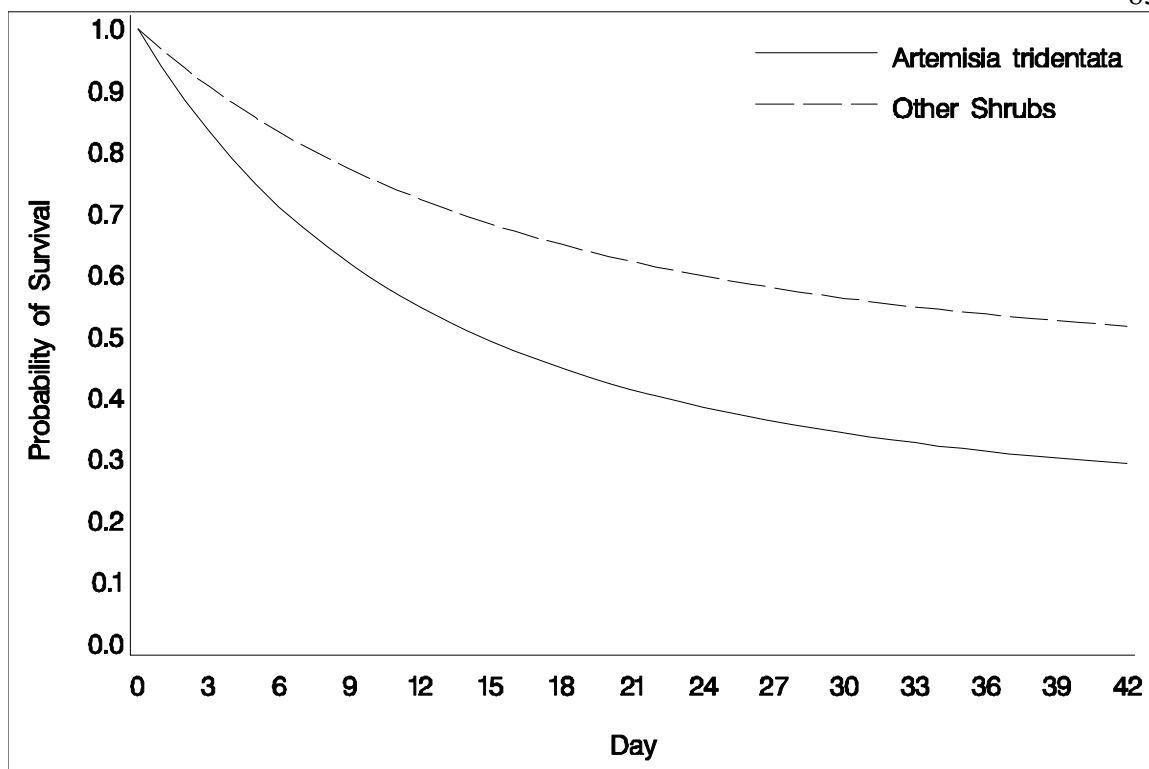


Figure 3-6. Survivorship curves for greater sage-grouse chicks relative to dominant shrub type on Parker Mountain, Utah, USA, 2005-2009. All other effects were held constant at their mean values (median grass cover was used).

CHAPTER 4
MOTIVATIONS AND SATISFACTION OF GREATER
SAGE-GROUSE HUNTERS IN UTAH

ABSTRACT

Greater sage-grouse (*Centrocercus urophasianus*) populations have experienced significant declines during the past century. Stakeholders concerned that the species may be at risk of extinction have filed petitions with the U.S. Fish and Wildlife Service (USFWS) to provide additional protection for the species under the Endangered Species Act (ESA). In 2010, the USFWS designated the species as a candidate for listing. Despite concerns about the long-term viability of this species, the birds are still considered an upland game species and are hunted throughout much of their current range, including four populations in Utah. In 2008, the demand for Utah sage-grouse hunting permits exceeded their availability within hours of being offered through an on-line application process. We hypothesized that the pending ESA listing decision facilitated increased hunter demand. We conducted telephone interviews of randomly selected hunters who obtained permits to hunt sage-grouse in Utah in 2008 (N = 318) and 2009 (N = 288) to determine their motivations for hunting sage-grouse and determinants of hunter satisfaction. Contrary to our hypothesis, few of the hunters interviewed (6.6%) reported obtaining permits because of the pending ESA listing decision. Most hunters reported that they hunted for tradition (31.1%), to spend time outdoors with family (34.7%), or for meat (25.2%). Unlike other studies that have found hunter satisfaction to be a function of multiple factors, our data suggest that Utah sage-grouse hunter

satisfaction is primarily influenced by hunter success. Maintaining conservative bag limits in the future will ensure that hunter densities are low and that harvest success is high, resulting in high hunter satisfaction. The family-orientated nature of sage-grouse hunting in Utah may result in sage-grouse hunting being an effective means of recruiting new hunters and engaging them more fully in the conservation of this hunted candidate species.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*, hereafter sage-grouse) populations have declined during the past century (Schroeder et al. 1999). While many factors have been implicated as potential causal agents in this decline, the general reduction and fragmentation of sagebrush habitats throughout western North America is considered to be the primary factor underlying population declines (Braun et al. 1977, Connelly and Braun 1997, Braun 1998, Wirth and Pyke 2003, Rowland et al. 2006).

The U.S. Fish and Wildlife Service (USFWS) has received seven petitions from concerned stakeholders requesting that sage-grouse be protected under the Endangered Species Act (ESA; Stiver *In Press*). In 2010, the USFWS designated sage-grouse as a candidate species with a “Warranted but Precluded” determination. This designation indicates that sufficient information exists pertaining to the biological vulnerability and threats facing the species to warrant federal protection. However, the species was precluded from protection due to the existence of higher-priority species (Federal Register, 2001(<http://www.fws.gov/endangered/esa-library/pdf/2001NOR.pdf>)). Once a species receives the “Warranted but Precluded” designation, population status must be re-

evaluated annually to determine if the species has recovered and can be declared “Not Warranted” or if populations have continued to decline thereby earning the status of “Warranted.” If sage-grouse are found to warrant full protection under the ESA in the near future, there could be substantial consequences for natural resource uses in the western U.S. The best-known potential impacts are to public land livestock grazing (Schroeder et al. 2006, Spjute 2010), but there could also be consequences for hunting.

Sage-grouse are considered an upland game species in many western states where they occur. As early as 1916, William Hornaday predicted that hunting would lead to the extinction of sage-grouse. Although hunting was not considered to constitute an extinction threat by the USFWS, many stakeholders question why state wildlife agencies continue to allow sage-grouse hunting (J. Robinson, Utah Division of Wildlife Resources, personal communication).

Early research on the effects of hunting on wildlife populations indicated that mortality resulting from hunting compensated for natural over-winter death and did not negatively affect the number of individuals surviving to breed in the following year (Leopold et al. 1943, Errington 1945, Errington 1956). More recent studies of the impact of hunting on sage-grouse have concluded that harvest mortality is likely additive to winter mortality and may result in depressed breeding populations (Johnson and Braun 1999, Connelly et al. 2000, but see Sedinger et al. 2010). Although there was little evidence that hunting caused population declines, Connelly et al. (2003) reported that even moderate hunting may limit the ability of sage-grouse populations to increase. Despite increasing concern about the future of sage-grouse and mounting information

indicating that hunting may prevent populations from achieving their maximum rate of increase, sage-grouse are still hunted in several of the states in which they occur.

To address management concerns, sage-grouse hunting regulations have become increasingly conservative over the past century. For example, in 1916, Utah had a 15 day open season and a daily bag limit of 8 sage-grouse (Hornaday 1916). As of 2008, the sage-grouse hunting season was 16 days but permit numbers were restricted to insure that no more than 10% of the population was harvested. The Utah sage-grouse hunt is fairly unique in that hunters must obtain special permits that allow them to harvest up to two sage-grouse. Prior to the 2009 hunting season, these permits were obtained on a first-come first-served basis. Under this protocol, all permits were typically sold within one week of them being made available to the public (Dave, Olsen, Utah Division of Wildlife Resources, personal communication). However, in 2008 the demand for permits increased dramatically with all permits being sold on the first day they were available. In 2009, the Utah Division of Wildlife Resources (UDWR) adopted a draw system for distributing sage-grouse permits.

The sudden increase in demand for sage-grouse permits in 2008 raised questions regarding sage-grouse hunter motivations and satisfaction. Previous research on hunter motivations and determinants of satisfaction has focused on ubiquitous species such as deer, turkey and waterfowl (Hawn et al. 1987, Hammitt et al. 1990, Heberlein and Kuentzel 2002, Wynveen et al. 2005, Schroeder et al. 2006, Brunke and Hunt 2008). Because one of the basic tenets of harvest management is that only species or populations that are large and robust enough to sustain harvest be hunted (Connelly et al. 2005), few opportunities exist to study hunters of rare, declining, or ESA candidate species.

Much of the research on hunter satisfaction has indicated that the primary determinants of satisfaction are related to successfully seeing and harvesting game (Decker et al. 1980, McCullough and Carmen 1982, Messmer et al. 1998, Gigliotti 2000, Frey et al. 2003), experiencing nature (Hammit et al. 1990, Wynveen et al. 2005, Schroeder et al. 2006), and spending time with friends and family (Decker and Connelly 1989). However, it is unlikely that any single factor is sufficiently capable of predicting hunter satisfaction. As such, a multiple satisfactions approach to hunter management has been proposed (Hendee 1974, Decker et al. 1980).

Manfredo et al. (2004) defined motivation as “a specific force that directs behaviors.” Hunter motivation has not been studied as extensively as hunter satisfaction; however, it appears that most hunters primarily engage in hunting activities for reasons other than harvesting game (Decker and Connelly 1989, Hayslette et al. 2001, Radder and Bech-Larsen 2008). Hunters appear to be motivated by the desire to interact with nature and to socialize with friends and family. However, Decker and Connelly (1989) emphasize that the importance of having a reasonable chance of a successful hunt cannot be underestimated.

No studies have investigated the factors that motivate hunters to pursue sage-grouse or the factors that influence satisfaction. Additionally, we are unaware of any other studies that have surveyed hunters of an ESA candidate species. A better understanding of why hunters hunt sage-grouse and what influences satisfaction may aid in developing a model for retaining, and subsequently recruiting, upland game hunters (Enck et al. 2000) as well as furthering an understanding of interactions between hunting and the Endangered Species Act. The objectives of this study were to: 1) describe sage-

grouse hunters in Utah, 2) determine what factors contribute most to sage-grouse hunter satisfaction, and 3) gain an understanding of why Utah hunters choose to hunt sage-grouse.

METHODS

Because the UDWR requires hunters to obtain a permit to hunt sage-grouse, the identity of each permit holder is known. The UDWR subsequently conducts annual telephone interviews of a random sample of sage-grouse permit holders to determine hunt participation rates, harvest success, number of days hunted, number of birds harvested, and hunter satisfaction. Because of the high demand for permits in 2008, we modified the 2008 survey to include questions concerning motivations for obtaining a permit and factors contributing to hunter satisfaction. Additionally, permit holders were asked questions about their knowledge of the petition to list sage-grouse under the ESA, participation in sage-grouse hunting in Utah since 2002, and their plans to hunt sage-grouse in the future. The survey was modified slightly in 2009 to include questions about anticipated participation in upland game hunting if the sage-grouse hunt were cancelled, whether a hunt could be satisfactory if a limit of sage-grouse were not harvested, and whether a hunt could be satisfactory if no sage-grouse were harvested.

The survey sampling protocol required that a minimum of 25% of the permit holders for each of the 4 hunt areas in the state be contacted. Areas with fewer permits were sampled at a higher rate than areas with relatively more permits. Each permit holder was assigned a permit number and sampling was conducted by randomly selecting numbers. A total of 318 and 288 sage-grouse permit holders were surveyed in 2008 and

2009, respectively. For both years this constituted an approximate 30% sampling effort. If a permit holder could not be reached or refused to participate in the survey, another permittee was randomly selected. We were unable to conduct a test for non-response bias, but have no cause to suspect that such a bias existed (Steinert et al. 1994).

Frequencies were calculated and comparisons of response categories were performed using chi-square tests (PROC FREQ, SAS System for Windows, v9.1). Hunters were clustered into groups depending upon the number of years they had obtained a sage-grouse permit since 2002 using Ward's method for binary cluster analysis (PROC CLUSTER, SAS System for Windows, v9.1). Dissimilarity measures were calculated using the DGOWER method (PROC DISTANCE, SAS System for Windows, v9.1). Hunters were able to choose between 5 levels of satisfaction. Since this constituted an ordinal multinomial response, we used cumulative logit models with backward selection to determine which variables influenced hunter satisfaction (PROC LOGISTIC, SAS System for Windows, v9.1). Explanatory variables included: hunt success, number of days spent hunting, group (from cluster analysis), and primary reason for obtaining a permit. The number of birds harvested was not used because this response was highly correlated with hunt success.

RESULTS

The number of hunters surveyed was similar in 2008 and 2009 (N = 318 and 288, respectively). Seventy-seven percent of surveyed permit holders participated in the sage-grouse hunting. Participation did not differ between years ($Z = -0.6653$, $P = 0.5028$). The median number of days spent hunting sage-grouse was one for both years. In 2008,

61% of permit holders who participated in the sage-grouse hunt were successful in harvesting at least one bird. The percentage of successful hunters increased to 67% in 2009. In both years, 70% of successful hunters bagged their limit of sage-grouse ($n = 2$). In both years, approximately 58% of permit holders reported being aware that sage-grouse had been petitioned for listing under the ESA. In 2008, a greater percentage of permit holders reported that they planned to obtain a sage-grouse permit during the following year than in 2009 (84.6% and 76.0%, respectively).

In 2008, approximately 33% of permit holders reported that the change in sage-grouse hunting season dates that year had affected their interest in pursuing the species. The percentage of respondents who reported that the change in season dates increased their interest was similar to the percentage who reported a decline in interest (15.4% and 17.3%, respectively). Sage-grouse hunting participation rates did not differ between groups who reported an increase or decrease in interest due to changes in season date ($\chi^2 = 0.6303$, $df = 1$, $p = 0.5707$). Additionally, respondents who reported that they were less interested in hunting sage-grouse were no less likely to report intentions of obtaining a sage-grouse permit the following year than were respondents who reported being more interested in pursuing the bird ($\chi^2 = 0.7685$, $df = 2$, $p = 0.6810$).

Only 9% of permit holders surveyed in 2009 reported that they would no longer engage in upland gamebird hunting if the sage-grouse hunt were cancelled. Fifty-nine percent of permit holders reported that their level of participation in upland game hunting would not be affected if they no longer had the option to hunt sage-grouse. The remaining 32% indicated that elimination of the sage-grouse hunting season would result in them hunting upland game less often.

Cluster analyses indicated that sage-grouse hunters constituted two distinct groups based on their regularity of hunting sage-grouse since 2002. We considered up to 5 clusters but ultimately determined that the 2 cluster solution was the most informative. We termed these two groups “Occasional” and “Consistent.” Most occasional hunters had hunted sage-grouse in fewer than 3 years since 2002. Many consistent hunters reported having hunted sage-grouse annually since 2002.

Analysis of the 2008 survey data indicated that reported level of satisfaction was best explained by whether or not a hunter was successful in harvesting at least 1 sage-grouse ($\beta = 1.8431$, $\chi^2 = 49.56$, $df = 1$, $p \leq 0.0001$, $R^2 = 0.2089$). Whether successful or unsuccessful, responses reflected the full range of satisfaction levels from “very unsatisfied” to “very satisfied” (Table 4-1). However, unsuccessful hunters were more likely than successful ones to report all levels of satisfaction except “Very Satisfied” (Table 4-1). Successful hunters were over 40% more likely to report that they were “very satisfied” with their sage-grouse hunting experience than unsuccessful hunters. Analysis of the 2009 survey data revealed the same pattern with hunter success best explaining hunter satisfaction ($\beta = 1.8298$, $\chi^2 = 39.57$, $df = 1$, $p \leq 0.0001$, $R^2 = 0.1919$). Again, unsuccessful hunters were more likely to report all levels of satisfaction except “very satisfied” which was selected over 40% more often by successful hunters (Table 4-1). When permit holders were presented with a hypothetical situation in which they were not successful in harvesting their limit of sage-grouse, over 43% responded that they would still be satisfied with their hunt while over 50% reported that they would be very satisfied. When respondents were presented with a situation in which they were

unsuccessful in harvesting *any* sage-grouse, over 47% reported that they would still be satisfied while over 42% said that they would be very satisfied with their hunt.

In 2008, the most commonly cited primary reason for obtaining a sage-grouse permit was “Tradition” (Table 4-2). The second most common primary reason for obtaining a permit was for “Meat.” Interestingly, “Meat” was the most commonly cited secondary reason followed by “Tradition.” Permit holders who cited “Tradition” as their primary reason for obtaining a permit were most likely to state that their secondary reason was “Meat” (Table 4-3); whereas permit holders who primarily obtained a sage-grouse permit for “Meat” were most likely to say that their secondary reason was “Tradition.” The only other strong dependency of primary and secondary reasons for obtaining a permit was between “New” and “Meat.” Although a small percentage of hunters cited “Other” as their primary or secondary reason for obtaining a permit in 2008, their associated comments indicated that an additional motivation category was needed.

For the 2009 survey, we added the option of “To spend time outdoors with family” to the question of why hunters obtained a sage-grouse permit. This was subsequently the most commonly cited primary and secondary reason selected by survey participants (Table 4-4). “Meat” remained the second most commonly selected primary option. Comparison of all primary/secondary reason combinations showed that respondents were most likely to cite “Family” as their secondary motivation regardless of the primary reason stated (Table 4-5).

DISCUSSION

Hunting participation rates have declined across the United States in recent decades (Heberlein and Thompson 1996, Li et al. 2003, Mehmood et al. 2003, Miller and Vaske 2003). Between 2004 and 2009, participation in the Utah sage-grouse hunt declined at an average rate of 1.6% annually (UDWR, unpublished data). Miller and Vaske (2003) have suggested that declining hunter participation rates are the result of an aging hunting community, lack of time available for hunting, too many regulations, and a lack of available land to hunt. Declines in hunter participation have also been linked to concerns about transmission of disease from wildlife to humans (Bishop 2004, Vaske et al. 2004).

Our methodology does not allow us to determine why participation in sage-grouse hunting has declined in Utah. However, our initial hypothesis reflects a belief that regulatory issues affect hunter behavior and participation rates. We obtained hunters' own predictions about whether further regulation, listing of sage-grouse as a protected species, would foster a decline in upland game bird hunting in general. A majority of respondents said they would participate in the sport just as often if sage-grouse were not available for harvest. While the timing of the season had changed the level of interest in the sage-grouse hunt for about a third of respondents, about equal numbers responded positively as negatively to this regulatory change.

Brunke and Hunt (2008) reported that meeting hunting expectations was an important predictor for whether hunters would engage in hunting activities in subsequent years. Our results showed an inverse relationship between the percentage of successful hunters in a given year and the percentage of hunters who planned to obtain a sage-

grouse permit the following year. This appears to indicate that the most important expectation of Utah sage-grouse hunters was not harvesting sage-grouse.

In 2008, 8.7% of survey respondents reported that none of the options provided for why they chose to obtain a sage-grouse permit applied to them. Respondents in this category were asked to provide a statement explaining their motivation for obtaining a permit. Among these comments provided were statements such as: “We hunt [sage-grouse] as a family” and “Because [hunting sage-grouse is] an enjoyable activity to do with my kids.” Over half of the statements provided referred to spending time with family. In response to these statements we added the option “To spend time outdoors with family” to the 2009 survey.

Our hypothesis that the petition to list sage-grouse under the ESA motivated hunters to obtain a sage-grouse permit was not supported. It is possible that survey respondents chose to strategically avoid reporting that their decision to obtain a permit was influenced by the listing petition and therefore responses were biased. However, Whittaker et al. (1998) suggest that incidences of strategic bias are less common for telephone surveys than mail surveys because respondents do not have time to strategize their response and are more likely to provide an unbiased answer. As has been reported in other studies (Hayslette et al. 2001, Radder and Bech-Larsen 2008), respondents in our study appear to have been strongly influenced by tradition and companionship/socializing when deciding to hunt sage-grouse. Unlike other recent studies, we found that success-based motivations factored heavily into the decision of many Utah hunters to pursue sage-grouse.

Decker and Connelly (1989) suggested that the factors influencing individuals to engage in hunting could be grouped into 3 motivational categories: appreciative, achievement, and affiliative. Appreciative hunters are motivated by the desire to get outdoors and enjoy the natural environment. Achievement hunters seek to achieve a goal such as harvesting animals, whereas affiliative hunters hunt because it provides an opportunity to spend time with friends and family. Subsequent studies have expanded Decker and Connelly's (1989) classifications by adding additional categories (Gigliotti 2000, Backman et al. 2001, Bhandari et al. 2006). Our results suggest that Utah sage-grouse hunters are primarily motivated by affiliative (To spend time outdoors with family) and achievement (For the meat, View them as a trophy game bird) oriented factors. However, while the option "To spend time outdoors with family" is primarily affiliative, it could also be considered to be appreciative (To spend time outdoors).

Most Utah sage-grouse hunters were satisfied with their hunting experience in both 2008 and 2009. Unlike other studies that found that hunter satisfaction was affected by multiple factors (Decker et al. 1980, Hammitt et al. 1990, Gigliotti 2000, Frey et al. 2003), our data suggest that the level of satisfaction was primarily influenced by hunter success. Messmer et al. (1998) reported similar results in a survey of Utah big game hunters.

Early game management philosophy purported that successful hunters were satisfied hunters (Stankey et al. 1973, Woods and Kerr 2010). While our data appear to support this idea, our models explained only 20% of the variation in hunter satisfaction. This suggests that other factors which we did not measure may be better determinants of satisfaction than hunter success. However, our findings do show that having a successful

hunt is important to sage-grouse hunters. This is also implied by the fact that in both years of the study, a large percentage of respondents reported that they hunt for meat. Although other studies have clearly demonstrated that hunter success does not equal hunter satisfaction, we contend that the importance of maintaining sustainable population sizes that provide a reasonable chance of a successful hunt must not be overlooked. This consideration is paramount in developing strategies to managing hunting opportunities for a candidate species.

MANAGEMENT IMPLICATIONS

State wildlife agencies depend heavily upon funds acquired through license sales to supplement their annual budgets. For this reason, it is essential for them to retain current hunters and recruit new hunters. Although it is impossible for wildlife management agencies to manage hunter motivations, it is possible to gain an understanding of why individuals choose to hunt and what factors influence hunter satisfaction. Once these elements are understood, management actions can be developed to help ensure that hunters are able to meet their objectives and have more satisfying hunting experiences.

The percentage of Americans who hunt has been declining in recent decades (Enck et al. 2000). Participation in hunting is partially dependent upon the individual's perceived ability to control their hunting experience (Hrubes et al. 2001). A number of factors (lack of accessible land, too many hunters afield, work obligations) have been found to be associated with hunter dissatisfaction (Duda et al. 1995). While not all of

these factors can be controlled by hunters or by wildlife management agencies, some, such as the lack of areas to hunt, can be addressed to increase hunter retention.

Exposure to hunting as a youth, particularly with fathers, appears to be one of the most important indicators of whether an individual will hunt as an adult (Bissell et al. 1998). As such, increasing hunter retention could subsequently result in increased hunter recruitment. Although sage-grouse hunting in itself may not be an important revenue source for wildlife agencies, it may provide an avenue for families to enjoy an outdoor experience that reinforces youths' interest in hunting and the environment. Numerous studies have found that early life experiences, especially when shared with close friends or family, can have significant impacts on an individual's environmental values as an adult (see review in Chawla 1998). Ultimately, as a species, sage-grouse may benefit from being hunted if the activity results in future generations having a greater interest in the species and its habitats.

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Table 4-1. Reported levels of hunt satisfaction for successful and unsuccessful greater sage-grouse hunters, Utah, USA, 2008-2009.

Year	Successful	Very				Very Satisfied
		Unsatisfied	Unsatisfied	Neutral	Satisfied	
2008	No	12.1	15.7	22.5	29.1	20.5
	Yes	2.1	3.6	8.1	24.2	62.0
2009	No	8.4	8.3	22.9	36.3	24.1
	Yes	1.4	1.7	6.4	24.0	66.5

Table 4-2. Reported reasons for obtaining a greater sage-grouse hunting permit in Utah, USA, 2008.

Reasons for Obtaining a Permit	Primary	Secondary
View them as a trophy game bird (Trophy)	21.7	10.7
Always hunted them (Tradition)	31.1	20.0
Want to harvest one before ESA listing (Listing)	6.6	10.2
New to upland game, giving it a try (New)	11.6	10.7
Hunt them for meat (Meat)	25.2	43.6
Other reasons (Other)	3.8	4.9

Table 4-3. Percentage of greater sage-grouse permit holders giving specific combinations of primary and secondary reasons for obtaining a hunting permit in Utah, USA, 2008.

Primary Reason	Secondary Reason					
	Listing	Meat	New	Other	Tradition	Trophy
Listing	NA	38.9	16.7	11.1	5.6	27.8
Meat	2.0	NA	28.0	4.0	44.0	22.0
New	3.6	82.1	NA	3.6	3.6	7.1
Other	0.0	0.0	0.0	NA	50.0	50.0
Tradition	10.5	77.6	1.5	3.0	NA	7.5
Trophy	23.3	26.7	10.0	6.7	33.3	NA

Table 4-4. Reported reasons for obtaining a greater sage-grouse hunting permit in Utah, USA, 2009.

Reasons for Obtaining a Permit	Primary	Secondary
View them as a trophy game bird (Trophy)	15.3	8.9
Always hunted them (Tradition)	17.0	12.6
Want to harvest one before ESA listing (Listing)	3.5	7.7
New to upland game, giving it a try (New)	8.0	7.3
Hunt them for meat (Meat)	20.5	15.5
To spend time outdoors with family (Family)	34.7	46.3
Other reasons (Other)	1.0	1.6

Table 4-5. Percentage of greater sage-grouse permit holders giving specific combinations of primary and secondary reasons for obtaining a hunting permit in Utah, USA, 2009.

Primary Reason	Secondary Reason						
	Family	Listing	Meat	New	Other	Tradition	Trophy
Family	NA	10.7	29.3	14.7	1.3	25.3	18.7
Listing	60.0	NA	30.0	0.0	0.0	0.0	10.0
Meat	67.9	1.8	NA	8.9	1.8	10.7	8.9
New	73.7	5.3	15.8	NA	0.0	0.0	5.3
Other	0.0	0.0	0.0	0.0	NA	0.0	0.0
Tradition	75.6	6.7	11.1	2.2	2.2	NA	2.2
Trophy	53.7	14.6	12.2	2.4	2.4	14.6	NA

CHAPTER 5

CONCLUSIONS

Although much is known about the seasonal habitat requirements of greater sage-grouse (*Centrocercus urophasianus*; Schroeder et al. 1999, Connelly et al. 2000), surprisingly little is known about the effects of specific habitat management actions on local sage-grouse populations (Connelly et al. 2004). Dahlgren et al. (2006) found that both chemical and mechanical sagebrush treatments can improve brood-rearing habitat. I evaluated whether strategic intensive sheep grazing could be used to create small patches of high quality brood-rearing habitat (see Chapter 2). Relative to other treatment methods, sheep grazing has the advantages of high social acceptance and low fossil fuel dependency. The sheep grazing treatments I evaluated were effective in reducing sagebrush cover. Other habitat parameters measured showed small and highly variable responses to the grazing treatments. Herbivore exclosures constructed after grazing treatments were applied indicated that the response of forbs and grasses was suppressed due to grazing by domestic (cattle) and wild (Pronghorn antelope, mule deer, lagomorphs) herbivores. Despite the limited herbaceous response, sage-grouse selected the grazed plots at a higher rate than reference plots. Unlike more common habitat management approaches (herbicides, mechanical, fire), strategic intensive sheep grazing cannot be easily used to treat large acreages of habitat in a single year. However, when applied across multiple years, this method offers managers an effective means of creating a mosaic of small habitat patches within a greater expanse of brood-rearing habitat. Caution must be taken to not apply this type of habitat treatment in nesting or winter

habitat. Other precautions and requirements for the proper use of this method are described in Chapter 2.

While much is known about the habitat requirements of sage-grouse broods, very little is known about the factors affecting individual chick survival rates (Crawford et al. 2004). This lack of knowledge is primarily a function of the absence of radio-transmitters small enough to attach to newly hatched chicks. Recent technological and methodological advances have provided the tools necessary to study this important demographic (Burkepile et al. 2002). I modeled chick survival from hatch to 42-days of age using two 5-year data sets (2005-2009; Chapter 3). When all effects were held at a constant average value, the probability of survival to 42 days was estimated to be 0.385 (95% CL = 0.247-0.625). Survival exhibited a linear age trend and varied among good, moderate, and poor years. Brood-mixing was found to have a strong effect on chick survival; however, this effect differed with hen age and hatch date. In general, survival was highest for chicks that hatched early and did not engage in brood-mixing. Brood-mixing appears to be occurring at a much higher rate in the Parker Mountain population than in other studied populations and may vary annually. The second analysis indicated that survival was influenced by the dominant shrub type (*Artemisia tridentata* or *A. nova*) and by grass cover. The probability of survival was positively related to increased grass cover. Surprisingly, survival was higher in black sagebrush dominated habitats than in big sagebrush habitats. These results emphasize the importance of understanding the ecology of specific populations when designing and implementing management actions to conserve this species. Black sagebrush habitats are not typically considered to be

important brood-rearing areas, but they appear to be vital to the Parker Mountain population.

While a number of studies have examined the effects of hunter harvest on sage-grouse populations (Connelly et al. 2003, Sedinger et al. 2010), we know little about sage-grouse hunters. With the recent listing of sage-grouse as warranted but precluded under the Endangered Species Act (USFWS 2010), hunting the species has become more contentious. More information is needed about the biological and sociological implications of hunting the bird (Connelly et al. *in press*).

I present the first known study of sage-grouse hunter motivations and determinants of satisfaction (Chapter 4). Unlike other studies that have found hunter satisfaction to be a function of multiple determinants, my analysis showed that hunt success was the single most important factor in determining sage-grouse hunter satisfaction. I initially hypothesized that the proposed listing of sage-grouse under the Endangered Species Act would be an important factor influencing hunters to pursue sage-grouse in Utah. This hypothesis was not supported. Ironically, most hunters reported that their decision to hunt sage-grouse was primarily influenced by the desire to spend time outside with family. The percentage of Americans who participate in hunting has been declining in recent decades (Enck et al. 2000). This trend is concerning for state wildlife management agencies that depend on license sales for a large portion of their annual budgets. The family oriented nature of sage-grouse hunting in Utah may provide a venue for introducing youth to the sport.

In addition to addressing several questions about sage-grouse management, ecology, and conservation, my research raises new questions. Strategic intensive sheep

grazing proved to be a viable method for managing sage-grouse brood-rearing habitat on Parker Mountain. However, the application of this method must be evaluated in other areas to further assess its value for sage-grouse managers. In addition, it will be informative to apply the method in other types of big sagebrush communities as well as in locations with other grazing regimes. Ultimately, the objective of any habitat management tool is to directly influence some population demographic (chick survival in my case), not merely demonstrate preferential use of a habitat. Thus far this has not been done.

My research on sage-grouse chick survival also raised a number of questions. There are a number of reasons why brood-mixing occurs in different species. While the behavior has been documented in multiple sage-grouse populations, no studies have been conducted to determine how it happens (chick initiated, hen initiated, disturbance induced, etc) or the evolutionary role it may play. Numerous studies across multiple species have documented differences in offspring production and survival relative to maternal age. However, recent theoretical research has challenged this relationship (Marshall et al. 2010). Consequently, it may be more appropriate to design conservation actions to protect all females as opposed to distinguishing between yearlings and adults. Finally, it is unclear why sage-grouse chicks on Parker Mountain have higher survival in black sagebrush habitats than in big sagebrush habitats. Although I offer some suggestions about the nature of this relationship, more research will be required to elucidate the actual processes.

Sage-grouse hunting regulations vary considerably by state. While my research provided useful information about sage-grouse hunters in Utah, it will be important to

study hunters in other states to determine if similar patterns exist elsewhere. It would also be informative to survey the general public about their attitudes and perceptions of sage-grouse hunting.

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CURRICULUM VITAE**MICHAEL R. GUTTERY**

Department of Wildland Resources
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Utah State University
Logan, UT 84322

Education**Ph.D.****(IN PROGRESS)**

Utah State University
Major: Wildlife Biology
Current GPA: 3.86/4.0
Advisors: Dr. Terry A. Messmer and Dr. Roger E. Banner
Dissertation Title: Ecology and Management of a High Elevation Southern Range
Greater Sage-Grouse Population: Vegetation Manipulation, Early Chick
Survival, and Hunter Motivations

Master of Science**May 2006**

Mississippi State University
Major: Forestry
Cumulative GPA: 3.78/4.0
Advisor: Dr. Andrew W. Ezell
Thesis Title: Evaluation of Artificial Regeneration of Oaks, Willow Oak Acorn
Production, Light Conditions Following Midstory Control, and the Effects of
Long-Term Annual Flooding on Forest Vegetative Composition in an
Arkansas Greentree Reservoir

Bachelor of Science**December 2003**

University of Tennessee-Martin
Major: Natural Resources Management
Concentration: Wildlife Biology
Cumulative GPA: 3.19/4.0

Professional Experience

Science Advisor for the Parker Mountain Adaptive Resource Management Sage-grouse Working Group, 2006-2010. Advised rancher and state and federal natural resource management professionals on issues concerning sage-grouse and range management.

Graduate Research Assistant at Utah State University, 2006-2010. Conducted grazing and sage-grouse telemetry research, designed and implemented hunter surveys. Interviewed, hired, and supervised >10 research technicians.

Graduate Research Assistant at Mississippi State University, 2004-2006. Conducted research on oak regeneration in artificially flooded timber, evaluated acorn production in relation to natural regeneration and waterfowl forage potential. Supervised several research technicians.

Biological Science Technician at Tennessee National Wildlife Refuge and Cross Creeks National Wildlife Refuge, 2003. Coordinated wood duck banding program, assisted with Canada goose banding program, assisted with MAPS neotropical bird banding, conducted beaver control, collected data from wood duck nest boxes.

Bobwhite Quail Research Technician at the Ames Plantation, 2002. Built, established, and maintained infra-red video camera systems to monitor quail nests, tracked quail daily using radio telemetry, conducted vegetation surveys of quail habitat.

Tree Improvement Program Research Technician at the Ames Plantation, 2001-2002. Collected acorns, walnuts, and persimmons for experimental planting, maintained oak research orchards, assisted with prescribed burns for wildlife habitat.

Professional Certification

Associate Wildlife Biologist

Certification through The Wildlife Society

Certification Date: July 2005

Professional Society Memberships

The Wildlife Society, 2002-present

Student-Professional Working Group, 2008-present

Society for Range Management, 2007-present

Wildlife Habitat Committee, 2008-present

Ecological Society of America, 2008-present

Xi Sigma Pi National Forestry Honor Society, 2005-present

Awards and Honors

Outstanding Student Paper at the 14th Biennial Southern Silvicultural Research Conference, 2007, Athens, Georgia, USA.

Moehring Outstanding Masters Graduate Student in Forestry, 2006, Mississippi State University, Starkville, Mississippi, USA.

Competitive Grants

2006 “Development of a new low altitude photography technique for the assessment of vegetation chance and ground cover” Intermountain Region Digital Image Archive Competitive Student Grant, \$20,000.

2009 “Grazing sagebrush with sheep to enhance greater sage-grouse brood-rearing habitat. NRCS Sage-Grouse Restoration Project, \$25, 700.

Teaching Experience

PSY 1410 Analysis of Behavior: Basic Principles Lab, Utah State University, 3 students, Spring 2008.

WILD 6500 Biometry: Design and Analysis of Ecological Research Lab, Utah State University, 20 students, Spring 2009.

Peer Reviewed Publications

E. T. Thacker, D. Gardner, T. A. Messmer, **M. R. Guttery**, and D. K. Dahlgren. IN REVIEW. Gas chromatography to determine winter diets of sage-grouse. Journal of Wildlife Management.

Dahlgren, D. K., T. A. Messmer, E. T. Thacker, and **M. R. Guttery**. 2010. Evaluation of brood detection techniques: recommendations for estimating greater sage-grouse productivity. Western North American Naturalist 70:233-237.

Guttery, M. R., A. W. Ezell, J. D. Hodges, and A. J. Londo. IN PRESS. Obtaining adequate light for planted bottomland oak (*Quercus* spp.) seedlings: a case study utilizing midstory control. Journal of Sustainable Forestry.

Guttery, M. R., A. W. Ezell, J. D. Hodges, A. J. Londo, and R. P. Maiers. 2010. Production of willow oak acorns in an Arkansas greentree reservoir: an evaluation of regeneration and waterfowl forage potential. P. 455-460 in J. A. Stanturf, editor. Proceedings of the Fourteenth Biennial Southern Silvicultural Research Conference. USDA Forest Service General Technical Report SRS-121.

Guttery, M. R. and A. W. Ezell. 2005. Characteristics of a bottomland hardwood forest under greentree reservoir management in east central Arkansas. P. 409-411 in K. F. Connor, editor. Proceedings of the Thirteenth Biennial Southern Silvicultural Research Conference. USDA Forest Service General Technical Report SRS-92.

Self, A. B., A. W. Ezell, and **M. R. Guttery**. 2005. First-year survival and growth of bottomland oak species following intensive establishment procedures. P. 209-211 in K. F. Connor, editor. Proceedings of the Thirteenth Biennial Southern Silvicultural Research Conference. USDA Forest Service General Technical Report SRS-92.

Technical Reports

Guttery, M. R., D. K. Dahlgren, D. Caudill, G. Hochnedel, T. Black, and T. A. Messmer. 2008. Parker Mountain Adaptive Resource Management Group. 2008 Annual Report. Utah State University. 24pp.

Guttery, M. R., D. K. Dahlgren, M. Monsen, and T. A. Messmer. 2007. Parker Mountain Adaptive Resource Management Group. 2007 Annual Report. Utah State University. 21pp.

Dahlgren, D. K., **M. R. Guttery**, M. Monsen, and T. A. Messmer. 2006. Parker Mountain Adaptive Resource Management Group. 2006 Annual Report. Utah State University. 20pp.

Presentations

Invited symposia at national conferences:

Guttery, M. R., R. E. Banner, and T. A. Messmer. 2008. Sheep, sagebrush and sage-grouse: managing habitats through strategic intensive grazing. Society for Range Management, Louisville, Kentucky.

Contributed papers/posters at state, regional, and national conferences:

Guttery, M. R., D. K. Dahlgren, T. A. Messmer, D. N. Koons. 2010. Influence of demographic and habitat parameters on sage-grouse chick survival. Western Agencies Sage and Columbian Sharp-tailed Grouse Workshop, Twin Falls, Idaho.

Guttery, M. R., T. A. Messmer, and D. N. Koons. 2009. Early survival of greater sage-grouse chicks in a high-elevation southern range population. The Wildlife Society, Monterey, California.

Guttery, M. R., T. A. Messmer, and D. N. Koons. 2009. Early survival of greater sage-grouse chicks on Parker Mountain. Utah Chapter of The Wildlife Society, Bryce Canyon, Utah.

Guttery, M. R., R. A. Banner, and T. A. Messmer. 2008. Sheep, sagebrush and sage-grouse: managing habitats through strategic intensive grazing. Western Agencies Sage and Columbian Sharp-tailed Grouse Workshop, Mammoth Lakes, California.

Dahlgren, D. K., E. Thacker, **M. R. Guttery**, and T. A. Messmer. 2007. Use of bird-dogs in prairie grouse research. Prairie Grouse Technical Committee Meeting, Chamberlain, South Dakota.

Guttery, M. R., and A. W. Ezell. 2007. Production of willow oak acorns in an Arkansas greentree reservoir: an evaluation of regeneration and waterfowl forage potential. Biennial Southern Silvicultural Research Conference, Athens, Georgia.

Guttery, M. R., and A. W. Ezell. 2005. Forest stand composition in an Arkansas greentree reservoir. The Wildlife Society, Madison, Wisconsin.

References

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