

GREATER SAGE-GROUSE REPRODUCTIVE ECOLOGY  
AND TEBUTHIURON MANIPULATION OF DENSE  
BIG SAGEBRUSH ON PARKER MOUNTAIN

by

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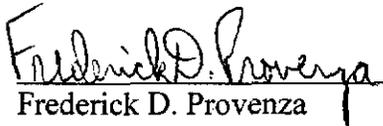
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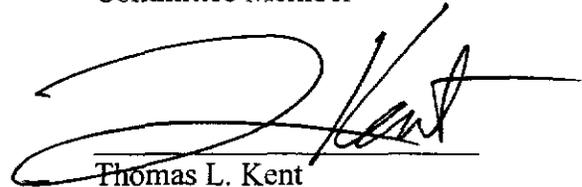
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## ABSTRACT

Greater Sage-Grouse Reproductive Ecology and  
Tebuthiuron Manipulation of Dense Big Sagebrush  
on Parker Mountain

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The greater sage-grouse (*Centrocercus urophasianus*) population on Parker Mountain, in south-central Utah, has been declining over the last 30 years. Studies on the life stages of hens were conducted in 1998-1999 to assess which factors may be constricting the population. Chick survival was positively associated with a higher grass and forb component at brood foraging sites. To supplement the data on breeding ecology and habitat use of sage-grouse hens, I continued to collect data using telemetry from 2000-2002. Nest site and brood-rearing site characteristics were measured and analyzed. To address the potential lack of adequate brood-rearing habitat, I surveyed 324 hectares of sagebrush to determine the general vegetational characteristics of high brood use areas. We observed 19% average grass and forb understory with big sagebrush (*Artemisia tridentata*) canopy cover generally exceeding 30%. I designed a sagebrush manipulation

experiment based on the premise that removal of big sagebrush will increase grasses and forbs for brood-rearing habitat. I identified 8 areas with dense stands of big sagebrush and established 40-hectare experimental vegetation manipulation plots. To decrease the big sagebrush, half of the plots received an herbicide treatment, tebuthiuron. The other 4 plots were untreated. In 2000, pre-treatment data on shrub, grass, and forb components were collected from each plot and the herbicide treatment was applied. From 2002, post-treatment data showed a negative sagebrush response to the herbicide, which was expected. In 2002, there was a drought and most herbaceous vegetation decreased in percent cover in both treatment and control plots. However, in treatment plots, forbs showed a slight increase. The resulting combined grass and forb response in the treatment plots was statistically different than the control plots ( $p = 0.03$ ). Therefore, despite the drought, the treatment was still effective. Tebuthiuron is a useful tool option for managers when trying to decrease high percent canopy cover stands of big sagebrush and increase herbaceous understory vegetation.

(93 pages)

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# CHAPTER 1

## LITERATURE REVIEW

### Introduction

The greater sage-grouse (*Centrocercus urophasianus*) is the largest grouse in North America (Griner 1939, Autenrieth 1981). Of the 9 grouse species located there, greater sage-grouse are most closely related to forest grouse: blue grouse (*Dendragapus obscurus*), sharp-tailed grouse (*Tympanuchus phasianellus*), and the lesser prairie chicken (*Tympanuchus pallidicinctus*) (Johnsgard 1983, Ellsworth et al. 1995, Gutiérrez et al. 2000, Lucchini et al. 2001). Appropriately named, sage-grouse are entirely dependent on sagebrush-steppe habitat (Wallestad et al. 1975, Braun et al. 1976). Therefore, this bird is found only within the distribution of sagebrush in western North America (Johnsgard 1983).

Habitat requirements of sage-grouse necessitate large expanses of sagebrush to provide heterogeneous shrub habitat for wintering, lek and breeding sites, nesting, and brood-rearing (Dalke et al. 1963, Eng and Schladweiler 1972, Connelly et al. 1988). Sagebrush is depended upon for food, microclimate cover for nesting and roosting, and obscurity from predators (Visher 1913, Griner 1939). In addition to the mere presence of sagebrush, the structure of the vegetation community is important. Sage-grouse need horizontal and vertical heterogeneity in the vegetation community (Patterson 1952, Wallestad 1975, Drut et al. 1994). Vertical diversity refers to a diverse herbaceous understory with shrubs varying in size and age. Horizontal diversity is on a larger spatial scale referring to stands of shrubs with varying densities (Payne and Bryant 1998).

Wintering habitat is frequently characterized by a high canopy cover of sagebrush (>20%) (Eng and Schladweiler 1972, Wallestad 1975). Leks tend to be in open areas surrounded by sagebrush to ensure females can see displaying males (Patterson 1952, Wallestad 1975), and nesting generally occurs in sagebrush patches with a higher canopy cover as well as more horizontal ground cover (Wallestad 1975, Wakkinen 1990, Sveum et al. 1998b). Brood-rearing habitat is characterized as having cover and forage availability that are heterogeneous (Klebenow 1969, Dunn and Braun 1986, Sveum et al. 1998a). The importance of species diversity was further supported by a study conducted by Drut et al. (1994) showing chick diet samples containing 34 forb genera and 41 invertebrate families.

Sagebrush composes the majority of winter diet and a portion of the summer diet (Griner 1939, Bean 1941, Patterson 1952, Martin 1970). Additionally, the sagebrush ecosystem provides grasses, forbs, and insects that are important components of adult and chick diets during the summer months (Girard 1937, Rogers 1964, Peterson 1970). For pre-laying hens, forbs and insects are nutritionally important in early spring (Barnett and Crawford 1994). Similarly, chick survival depends heavily on insect consumption for the first 3 weeks after hatching (Johnson and Boyce 1990). As summer progresses, diets of adult and young birds transition to diets with less invertebrate material and more plant material (Rogers 1964, Peterson 1970). Late summer and early fall mark the switch to a sagebrush-dominated diet (Rogers 1964).

## Distribution

The historical distribution of greater sage-grouse once encompassed sagebrush communities throughout most of western North America (Patterson 1952). As a result of westward settlement, sagebrush ecosystems and associated species have been negatively impacted (Griner 1939, Beetle 1960, Braun et al. 1976). Greater sage-grouse population range has declined markedly since the early 1900s (Visher 1913, Patterson 1952, Crawford and Lutz 1985). This decline has mirrored the extensive loss, fragmentation, and deterioration of sagebrush-steppe habitats (Griner 1939, Connelly and Braun 1997, Beck et al. 2003). As a result, sage-grouse populations at the edges of the historical range in the states and provinces have experienced the most striking distributional changes (Schroeder et al. 1999).

Once the most abundant game bird in 9 states (Patterson 1952), sage-grouse have been extirpated from Arizona, New Mexico, Oklahoma, Kansas, Nebraska, and British Columbia (Patterson 1952, Connelly and Braun 1997). Currently, remnant populations exist in southeastern Alberta, southern Saskatchewan, central Washington, east-central California, southeastern North Dakota, and northeastern South Dakota (Schroeder et al. 1999). Larger populations in Oregon, Idaho, Montana, Wyoming, Colorado, and Utah also show declines (Connelly and Braun 1997). In response to the shrinking distribution, all sage-grouse species have been petitioned for listing under the Threatened and Endangered Species Act of 1973 as amended (16 U.S.C. 1531 et seq.).

## **Utah**

Sage-grouse population trends in Utah are similar to those observed in other states; there is an overall decline (Connelly and Braun 1997). Based on historical records, Beck et al. (2003) reported that sage-grouse were found in all 29 counties of Utah before settlement but now occur in only 50% of their historical range. The historical distribution was a mosaic design following the distribution of sagebrush (UDWR 2002). Since settlement of the Intermountain West, sagebrush systems and the corresponding sage-grouse populations have become discontinuous and fragmented (UDWR 2002). Likely in response to this habitat fragmentation, sage-grouse populations in Utah and throughout the West have fluctuated regularly over time with a general pattern of decline (UDWR 2002).

### **Past Habitat Management**

As the West was settled, uninhibited development and resource exploitation occurred. Specifically, livestock grazing pressures, sagebrush eradication, real estate development, and conversion for agricultural purposes have reduced the overall carrying capacity for sage-grouse (Griner 1939, Schneegas 1967, Wallestad and Pyrah 1974).

In addition to the permanent loss of habitat, fragmentation and degradation also have affected remaining sagebrush communities (Schneegas 1967, Braun 1998). In association with human population growth, construction of roads, power lines, and other developments fragmented remaining sagebrush habitat (Braun 1998). Degradation of the herbaceous understory and soils has resulted from past sagebrush eradication efforts for cultivation fields or grazing pasturelands, heavy livestock grazing, and invasion of exotic

plant species (Schneegas 1967, West 1988, Connelly and Braun 1997, Braun 1998).

Overall indications of deterioration include but are not limited to loss of structural diversity, loss of associated plant diversity, loss of meadows, encroachment of non-native flora, soil erosion, and alteration of natural fire cycles (West 1988).

Due to the close ties between sage-grouse and these ecosystems, sage-grouse management relies heavily on an understanding of how to manage sagebrush ecosystems. The sagebrush ecosystems are unique vegetation biomes. Generally, sagebrush-steppe and great basin sagebrush (*Artemisia tridentata ssp. tridentata*) are adapted to relatively arid environments (West 1988). In more xeric sites, smaller, homogenous sagebrush (*A. nova*) dominates (West 1988). In the more mesic sites with deeper soils, big sagebrush (*A. tridentata ssp.*) becomes more prevalent. This species is much larger in stature than *A. nova* and is typically characterized by an understory composed of perennial herbaceous plants in its understory (West 1988). On pristine big sagebrush-grass sites in southern Idaho, Tisdale and others (1965) found as many as 13-24 species in the herbaceous understory.

All plant communities are defined by competitive interactions for water, nutrients, space, and light. The composition of the community is ultimately a function of the outcome of these interactions (Wagner 1977). With natural variation in weather conditions, the advantage may fall in favor of the shrubs or in favor of the herbaceous understory. For example, big sagebrush can start photosynthesizing as soon as the ground thaws and has the ability to sequester moisture from the soil in extremely dry conditions (Caldwell 1979). In contrast, during wet years, the herbaceous understory is better able to utilize surface moisture and nutrients (Caldwell 1979).

Grazing by free-ranging and domestic ungulates can also have a profound influence on the balance of competing plants (Hobbs 1996). Prior to the introduction of domestic ungulates, ranges consisted of a mix of sagebrush and herbaceous understory cover with the latter usually exceeding 80% cover and sometimes reaching 200% cover in more mesic sites (Daubenmire 1975). The herbaceous understory was utilized by many wildlife species [pronghorn antelope (*Antilocapra americana*), sage-grouse, jackrabbits (*Lepus spp.*), Utah prairie dogs (*Cynomys parvidens*)] in warmer months and shrubs were utilized by pronghorn antelope, sage-grouse, jackrabbits, mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*) during wintering months. Herbivore utilization of both shrubs and herbaceous understory mediated competition between the shrubs and the herbaceous understory.

Introduction of domestic livestock grazing in the mid-1800s increased pressure on the grasses and forbs (Schneegas 1967). With repeated grazing on the herbaceous understory, sagebrush gained a competitive advantage (Harniss and Wright 1982, West 1996). As a result, the canopy cover of sagebrush increased at the expense of the understory (Young and Evans 1978, Tisdale et al. 1965). Further, in some cases, erosion has occurred in some areas from loss of ground cover (Young 2000). This habitat degradation has negatively impacted sage-grouse on numerous levels. Decreases in herbaceous understory have decreased the amount of vegetation to conceal nests, to conceal birds from predators, and to provide for favorable brood forage habitat (Autenrieth 1981, Gregg 1991, Dobkin 1995).

## Purpose

The purpose of my thesis is to 1) describe and understand the reproductive ecology of greater sage-grouse on Parker Mountain, Utah, and 2) to evaluate the effectiveness of using tebuthiuron to thin dense stands of big sagebrush and increase understory vegetation abundance in high elevation sagebrush ecosystems. To meet these objectives, I resumed monitoring the reproductive ecology of greater sage-grouse on Parker Mountain that was initiated in 1998. From 2000-2002, I collected data on the reproductive ecology of greater sage-grouse hens using telemetry. This study will augment the limited information known about the productivity of this large sage-grouse population and will result in 5 consecutive years of data on Parker Mountain sage-grouse reproduction. Such long term data will provide local and state managers with a better understanding of important variables affecting regional populations and hence, better enable them to make informed and appropriate management decisions. I present and discuss the implications the telemetry reproductive monitoring data in Chapter 2.

I also set up a replicated experimental design to test the efficacy of using tebuthiuron, an herbicide, to improve sage-grouse brood-rearing habitat. I hypothesized that application of tebuthiuron would decrease big sagebrush canopy cover allowing for an increase in the abundance and diversity of herbaceous perennials in the understory. The results of this experiment are presented in Chapter 3.

All research conducted on Parker Mountain has been done in cooperation with Parker Mountain Adaptive Resources Management working group (PARM). PARM is a community-based working group established to address local resource management issues by coordinating knowledge, efforts, and resources.

## Style

The Abstract, Acknowledgements, Contents, and Chapters 1, 3, and 4 are written using the editorial guidelines of the Wildlife Society Bulletin. Chapter 2 is written using the editorial guidelines for Journal of Wildlife Management.

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## CHAPTER 2

### GREATER SAGE-GROUSE REPRODUCTIVE ECOLOGY: NESTING, BROOD-REARING, MOVEMENTS, AND MORTALITY

**Abstract:** As regional population viability of greater sage-grouse (*Centrocercus urophasianus*) comes into question, information on large sage-grouse populations and status is necessary. To determine spatial and temporal use patterns of breeding hens, I collected 3 years of telemetry data on Parker Mountain, Utah. Nest initiation rates and nest success rates were higher than in other states. These data explain the 30-year high lek counts recorded in 2001 and 2002. Longitudinal reproductive data on the Parker Mountain greater sage-grouse population, during high population years, assists managers in determining comprehensive habitat use when populations are large.

#### INTRODUCTION

Greater sage-grouse were once considered one of the most abundant upland game birds in western North America (Patterson 1952:12). However, populations have declined markedly throughout their range since the species was first recognized in the early 1800s (Griner 1939, Patterson 1952:3, Aldrich 1963). This decline appears to be a result of human encroachment as there is an inverse relationship between western settlement in sagebrush (*Artemisia spp.*) vegetation communities and greater sage-grouse population changes (Griner 1939). Montana and Wyoming, states with the lowest human populations and largest areas of sagebrush, support the largest remaining greater sage-grouse populations (Table 2.1, Braun 1998). Most researchers attribute population declines to the loss, fragmentation, and degradation of sagebrush-steppe ecosystems.

The greater sage-grouse evolved within the sagebrush landscape. They possess a unique digestive system that enables them to glean nutrients from terpene-rich sagebrush (Patterson 1952:21). In addition, their soft gizzard can only process soft plant and insect material (Wallestad 1975). They survive almost entirely on sagebrush during winter and use available herbaceous and insect material the rest of the year (Griner 1939, Wallestad 1975, Wallestad et al. 1975, Martin 1976). Because of this dependence on sagebrush, the historical range of greater sage-grouse closely matched the distribution of sagebrush throughout western North America (Rasmussen and Griner 1938).

Distributions of both the sagebrush ecosystem and greater sage-grouse have declined by up to 50% throughout the West (Crawford and Lutz 1985, Braun 1995, Beck et al. 2003). The greater sage-grouse has been extirpated from 1 Canadian province and 5 states (Braun 1998). In the states where the species is still found, the breeding populations have experienced an estimated 33% decline (Connelly and Braun 1997).

The conversion of vast areas of sagebrush has been cited as the cause of sage-grouse population decline (Patterson 1952:12, Wallestad 1975, Braun et al. 1977). The most productive and accessible sagebrush lands were converted to pasturelands (Carr and Glover 1970, Martin 1970), crops (Yocom 1956), reservoirs (Griner 1939, Braun 1998), and urban sites (Griner 1939). More recently, fragmentation and degradation have compromised the quality of the remaining sagebrush habitat and have had a negative impact on remaining greater sage-grouse populations (Braun 1998).

The construction of roads, powerlines, fences, mineral developments, and urban developments has fragmented the sagebrush landscape by creating unnatural barriers, predator perches, and general disturbance (Braun 1998). Furthermore, heavy grazing by

domestic livestock has also contributed to degradation of the sagebrush ecosystem (Pickford 1932). Past heavy grazing within intact sagebrush habitat has altered the composition and abundance of the vegetation community contributing to increased erosion and loss of topsoil (Young 2000). The resulting deterioration of the herbaceous understory and increased density of sagebrush heavily impacted the quality of sage-grouse nesting and brood-rearing habitat (West 1988, Johnson and Boyce 1990, Gregg et al. 1994). Johnson and Boyce (1990) and Barnett and Crawford (1994) reported that forbs and insects are critical to greater sage-grouse in the egg-laying stage and the early survival of young broods. The lower reproductive success alone may explain much of the population variation occurring throughout the greater sage-grouse range (Bergerud 1988).

#### **Status of Greater sage-grouse populations on Parker Mountain**

*Past research.*--The Utah Division of Wildlife Resources (UDWR) conducted the first detailed study of greater sage-grouse on Parker Mountain (Jarvis 1973). The purpose of the study was to increase managers' knowledge of vegetation types and distribution, greater sage-grouse population trends, seasonal habitat use, fecundity, and mortality factors (direct and indirect). Hunter harvest rates also were analyzed to assess recruitment rates relative to lek count data.

*Current research.*--Lek censuses have been conducted on Parker Mountain since 1967. From 1967-1997, the population has exhibited a general decline of male attendance that concerned local, state, and federal interests (Fig. 2.1). The growing concerns culminated in the establishment of the Parker Mountain Adaptive Resources

Management working group (PARM). The objective of this community-based consortium was to pool efforts, knowledge, and resources to address natural resource issues of concern on Parker Mountain, including the status of the greater sage-grouse population. PARM aimed to conduct research on the Parker Mountain greater sage-grouse population to determine the cause of the population declines. Upon determining the reasons for population declines, steps would be made to rehabilitate the population and produce a conservation plan for future management of the species and the ecosystem.

The objectives of my research were to supplement knowledge of the Parker Mountain greater sage-grouse population trends, reproductive ecology, and mortality. As a result, I will be able to validate past information and use the data as a guide for future management recommendations.

## **STUDY AREA**

Parker Mountain is a high-elevation sagebrush and aspen ecosystem spanning both the Aquarius and Awapa plateaus in south-central Utah. These plateaus, encompassing approximately 105,171 ha, constitute the largest contiguous area of sagebrush steppe ecosystem in Utah. Elevation ranges between 2,134 - 3,018 meters and increases in a general northeast to southwest direction. Most of the study area is located in Wayne County with the western and southern edges falling within Garfield and Piute counties. Precipitation varies with elevation, ranging between 25 - 51 cm annually. Most of the precipitation falls during the winter as snow and as rain during the summer monsoon season from July to September (Jarvis 1974). Springs and shallow lakes occur above 2,621 meters elevation. In addition, over 80 livestock water developments provide

seasonal water sources on the plateau (R. Torgerson, Utah State Institutional Trust Lands Administration, personal communication).

The State of Utah School and Institutional Trust Lands Administration (SITLA) manages 43,863 ha on the western portion of Parker Mountain. The U.S. Forest Service manages 21,685 ha on the southern edge of the study area. The eastern portion of the sagebrush plateau (36,398 ha) is managed by the Bureau of Land Management (BLM), and 5,532 ha are privately owned.

There are 10 grazing allotments on Parker Mountain ranging in size from 302 to 2475 ha (Jaynes 1982). The plateau has maintained cattle and sheep herbivory for at least a century. Sheep and cattle still graze the area at 3.6 acres per animal unit month (AUM) (R. Torgerson, Utah State Institutional Trust Lands Administration, personal communication). In addition, the area is used for hunting, motorized vehicle use, hiking, camping, and sightseeing. Consequently, there are numerous dirt and gravel roads. Because the area is largely uninhabited, there are no powerlines.

### **Vegetation**

Black sagebrush (*Artemisia nova*) is the dominant vegetation type at the lower elevations and on exposed slopes and ridges. Draws and drainages are dominated by Wyoming big sagebrush (*A. tridentata wyomingensis*). At the higher elevations, mountain big sagebrush (*A. tridentata vaseyana*) is more prevalent in the drainages giving way to silver sagebrush in the wetter drainages (*A. cana*). In addition, stands of quaking aspen (*Populus tremuloides*) become more abundant at the higher elevations. The aspen are interspersed with the sagebrush, a mosaic frequently located on the north-facing slopes. The associated grasses and forbs include Indian ricegrass (*Oryzopsis*

*hymenoides*), blue grama (*Bouteloua gracilis*), western wheatgrass (*Agropyron smithii*), bluebunch wheatgrass (*Agropyron spicatum*), squirreltail (*Sitanion hystrix*), needle and thread grasses (*Stipa comata*), phlox spp. (*Phlox spp.*), fleabane spp. (*Erigeron spp.*), cinquefoil (*Potentilla spp.*), lupine spp. (*Lupinus spp.*), groundsel spp. (*Senecio spp.*), pussytoes (*Antennaria rosea*), dandelion (*Taraxacum officinale*), buckwheat spp. (*Eriogonum spp.*), and penstemon spp. (*Penstemon spp.*) (Jarvis 1974, BLM 1979).

### **Wildlife**

Parker Mountain hosts a diversity of wildlife species. The most common of these are: Pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), coyotes (*Canis latrans*), badgers (*Taxidea taxus*), whitetail jackrabbit (*Lepus townsendii*), blacktail rabbit (*Lepus californicus*), desert cottontail (*Sylvilagus auduboni*), yellow-bellied marmots (*Marmota flaviventris*), and Utah prairie dog (*Cynomys parvidens*). Common avian species include: Golden eagles (*Aquila chrysaetos*), Northern harrier (*Circus cyaneus*), American kestrels (*Falco sparverius*), Great horned owls (*Bubo virginianus*), Northern flicker (*Colaptes auratus*), Vesper sparrow (*Pooecetes gramineus*), Sage sparrow (*Amphispiza belli*), Brewer's sparrow (*Spizella breweri*), and Horned lark (*Eremophila alpestris*).

### **Predator management**

The Parker Mountain Grazing Association provides support for the U.S.D.A. Wildlife Services (WS) to reduce livestock depredation with predator removal throughout the year. Between 2000 and 2002, WS removed 268 coyotes, 6 red fox (*Vulpes vulpes*),

and 2 bobcats (*Lynx rufus*, Wildlife Services 2003). In addition, Wayne County has a countywide bounty on coyotes that resulted in the removal of a total of 690 coyotes from 2001 to 2002 (personal communication, Wayne County Auditor 2003). Some may have been removed from the study area and may have contributed to the predator control on Parker Mountain. Due to increased raven populations and their propensity to predate on sage-grouse nests, raven population control has been attempted using an avicide, DRC-1339 eggs (Maestrelli and Butchko 1990).

## **METHODS**

Parker Mountain leks occur primarily between elevations of 2,438 – 2,682 meters. Thirteen lek sites, historical and presently active have been identified. During the last week in March to the end of April, lek sites were counted at least once a week. The males were counted on the leks using a combination of the techniques described by Patterson (1952:91), Beck and Braun (1980), and Jenni and Hartzler (1978). I arrived at the first lek site ½ hour before sunrise and parked off the edge of the strutting ground. Using binoculars, the visible males were counted three times over the course of 30 minutes. The largest of the three counts was recorded. This was repeated with the subsequent 2 or 3 lek sites. A maximum of 4 lek sites were surveyed each morning. Knowledge of male departure patterns on each lek aided us in determining the appropriate times to count each lek.

### **Radio-telemetry**

Hens were trapped at roost sites on or near leks beginning in late March when males began to strut. Trapping continued until either 25 hens were collared or they were

no longer attending the leks. Most of the hens in 2000-2001 were trapped near Bull Roost lek. This is the largest lek on Parker Mountain with as many as 300 hens and 200 males using the lek on a single morning. In 2002, due to the drought, there was low hen attendance at the Bull Roost lek a low lek. Therefore, trapping occurred around higher elevation leks located between Cedar Peak and Burnt Knoll, leks reporting higher than usual hen attendance.

Hens were located by spotlighting from a truck or ATV and captured with long-handled nets (Giesen et al. 1982). Each hen was fitted with a 16.5 gram, programmed (mortality signal and 5 hours off, 19 hours on) ATSTM collar (150.000 - 151.000 MHz). Each hen was weighed in a mesh sack suspended from a Pesola™ 2500-gram spring scale. Hens were categorized as a yearling or adult based on the condition of the 8th, 9th and 10th primary feathers (Dalke et al. 1963). Global positioning satellite (GPS) units using Universal Transverse Mercator (UTM) in WGS84 were used to record coordinate location where each hen was trapped (Patterson 1952).

Radio-collared birds were located using Telonics™ receivers (TR-2), hand-held H antennas (RA-2A), and vehicle-mounted omni antennas (RA-5A). Collared hens with broods were located at least every 3 days and those without broods every 5 to 7 days. At each bird location I recorded the GPS coordinates, vegetation present, slope, aspect, wind speed, wind direction, temperature, and cloud cover.

### **Nest monitoring**

Hen locations were recorded every 4 - 5 days until nest initiation. Nest initiation was suspected when a hen was found in the same location on  $\geq 2$  occasions and a steady

signal was recorded. The investigator confirmed nest initiation by approaching within 20 m of the signal on 2 consecutive days, and circling the location without flushing the hen. Nests were relocated using natural features near the nest and a marker was placed on an adjacent road.

The nests were checked every 1 - 2 days to determine their status and fate. A nest was deemed "successful" if  $\geq 1$  eggshell with loose membranes was present (Girard 1939). Any unhatched eggs were opened to determine whether they were infertile or partially developed. For each depredated nest, identification of predator type (mammalian or avian) was based upon the presence of eggshells, scat, tracks, and hair (Patterson 1952:106, Rasmussen and Griner 1938). Eggs in abandoned nests were opened to determine stage of egg development at the time of abandonment. Nest initiation dates were estimated using a 27-day incubation period plus a day for each egg present (Schroeder 1997, Aldridge 2000). Clutch sizes were determined using techniques described by Schroeder (1997).

#### **Nest site characteristics**

At each nest site, vegetation measurements were taken in 4 cardinal directions (every 90° starting with a randomly chosen direction). Percent cover of shrubs, grasses, forbs, litter, and bare ground were determined by using the line-intercept method with a 15-meter tape (Canfield 1941). Vertical visual obstruction was measured at each nest site with a Robel pole (Robel et al. 1970).

### **Brood site vegetation**

A few days after the brood left the area, shrub cover and herbaceous understory cover at each site were measured. Visual obstruction (Robel et al. 1970) was measured using the Robel pole and shrub canopy cover was measured using line-intercept method (with a 10-meter tape) (Canfield 1941). Percent cover of herbaceous understory was determined using a series of Daubenmire frames spaced at every 2.5 meters along the 10-meter tape (Daubenmire 1959).

### **Brood movements**

I calculated distances between UTM coordinates to determine site-to-site movements and nest to late brood-rearing movements. In determining the distance between nest and late brood-rearing habitat, I only included hens with “successful” broods. Movements of hens without broods were monitored by measuring the distances traveled between mid-May through late-July.

### **Adult mortality**

I determined sites of hen mortality, examined these areas, and recorded the vegetation association. I examined the remains (including feathers) for signs indicating the cause of death (fresh blood) and the type of predator (talon, claw, or teeth marks). The immediate area was searched for presence of hair, feathers, tracks, and scat.

### **Data analysis**

Nest and brood-rearing site vegetation data were analyzed using the Multi-Response Permutation Procedure (MRPP) with the Blossom statistical program (Mielke and Berry 2001) and P-values were set at 0.05 level of significance. The brood-rearing

sites were separated into “successful” versus “unsuccessful” categories. A brood was deemed “successful” if observed  $\geq 50$  days or “unsuccessful” if  $< 50$  days. I tested the null hypothesis that vegetation attributes at “successful” brood site were not different from “unsuccessful” ones.

One-way analysis of variance (ANOVA) was used to test the null hypothesis that the weights of yearling and adult hens were similar when trapped, P-value was set at 0.05 level of significance.

Descriptive statistics were applied to all data regarding the leks, including the number of nests initiated, nest initiation dates, clutch size, nest success, nest sites characteristics, and movements of hens and broods. Nest aspect was categorized as north, northeast, east, southeast, south, southwest, west, or northwest by dividing the directions into increments of  $22.5^\circ$  on either side of the exact degree (e.g., easterly ranges between  $67^\circ$  and  $112^\circ$ ).

## **RESULTS**

### **Hen capture rates and characteristics**

Forty-four hens were trapped during the study. In 2000, 11 yearlings were fitted with radio collars between 24 March and 13 April. The total trapping time amounted to 33.5 hours, with a mean of 3 hours per captured hen. In 2001, 16 yearling and 4 adult hens were fitted with radio collars between April 8 and 10. In 2001, 13.5 hours were spent trapping, with a mean of 0.7 hours trapping per hen. In 2002, 14 yearling hens were trapped between 29 March and 11 April in 29.5 hours or 2.1 hours per trapped hen (Table 2.2). With the addition of hens previously captured by Joel Flory in 1999, I

monitored a total of 59 hens (762 ground locations), 13 of which were monitored for more than one year (see Appendix). The trapped hens' weights ranged between 1125 and 1650 g ( $\bar{x} \pm \text{SE} = 1432.5 \pm 16.5$ ). Adult mean weights ( $n = 4$ ,  $\bar{x} = 1545 \pm 20.5$  g [SE]) and yearling mean weights ( $n = 41$ ,  $\bar{x} = 1426 \pm 17.2$  g [SE]) were statistically different ( $p = 0.03$ ).

### **Leks**

Each lek was surveyed an average of 4 times ( $\bar{x} = 4.8 \pm 0.4$ ) each spring. Peak lek visitation occurred during the second week of April in 2000 and 2001 (Fig. 2.2). In 2002, the peak male lek attendance occurred during the third week of April. The highest lek counts for 2000, 2001, and 2002 were 425, 543, and 613 strutting males, respectively.

In 2002, although the cumulative lek counts were higher than any year except 2001 (Fig. 2.1), attendance at the largest lek, Bull Roost, was much lower than past years. Simultaneously, the lek counts on the higher elevation leks (Hare and Cedar Peak) were higher than previously recorded (Fig. 2.3).

### **Nest initiation**

During 2000, 2001, and 2002, I actively monitored nest sites of 20, 22, and 23 hens, respectively. Eighty percent of all captured hens initiated nests. More adult hens appeared to have initiated nests ( $n = 29$ , 90%) than yearling hens ( $n = 36$ , 72%). Yearlings consistently appeared to have initiated fewer nests across all years (Fig. 2.4).

The years 2000 and 2002 were characterized by dry, warm springs that emerged from winters with below average precipitation. Winter precipitation in 2001 was comparable to the 63-year precipitation mean reported for the Koosharem weather station

at 7.6 cm for November through March (Logan Climate Center 2003). Nest initiation periods during these 2 dry years were 13-30 April in 2000 and 16 April - 11 May in 2002. During 2001, when snow remained on the ground later into the spring, nest initiation occurred between 22 April and 11 May (Fig. 2.5). During the study, only 2 of 59 hens successfully nested > 1 year. Both hens initiated nesting approximately 2 weeks later in 2001 (wet spring) than in 2000 (dry spring). During 2001, 1 hen again initiated nesting the same time as during the previous year.

### **Clutch size and nest success**

Clutch size ranged between 4 and 9 eggs ( $\bar{x} = 6.5 \pm 0.2$  eggs (SE),  $n = 39$ ). Mean clutch size for yearling hens was comparable ( $\bar{x} = 6.7 \pm 0.2$  eggs,  $n = 20$ ) to the adult mean clutch size ( $\bar{x} = 6.4 \pm 0.3$  eggs,  $n = 19$ ). During the study, 4 nests contained eggs that did not hatch. In 2000, 1 nest had a single infertile egg that did not hatch. In 2002, 3 nests had partial hatching success. One nest had 3 infertile eggs, 1 nest had 1 fertile egg, and 1 nest had 1 infertile egg.

The overall nest success (not including observer caused nest abandonment) was 69% ( $n = 48$ ). Hatching success for yearling nests was 66% ( $n = 24$ ) in comparison to 70% ( $n = 24$ ) for adult hens (Fig. 2.6). In 2001, 3 nests were abandoned, 2 of which were observer caused. In 2002, 4 nests were abandoned; 2 of them were abandoned because of the observer and 2 were incubated beyond the typical 25-28 days ( $\geq 33$  and 45 days).

### **Nest vegetation and elevation**

There was no difference in vegetation characteristics between successful ( $n = 33$ ) and unsuccessful nests ( $n = 15$ ) across years ( $p = 0.54$ ). All nests were located under

shrubs. Twenty-five nests were located under black sagebrush, 19 under big sagebrush, 2 under rabbitbrush, 1 under a combination of rabbitbrush and black sagebrush, 1 under big sagebrush and bitterbrush (*Purshia tridentata*), and 1 under a big sagebrush/snowberry (*Symphoricarpos oreophilus*) combination. The mean shrub height was  $\bar{x} = 51 \pm 2.2$  cm (SE) for all nests. Successful versus unsuccessful nest shrub height was  $\bar{x} = 52.9 \pm 3.4$  cm and  $\bar{x} = 44.1 \pm 3.3$  cm, respectively. Mean shrub canopy cover for successful and unsuccessful nest sites was similar ( $\bar{x} = 32.1 \pm 1.0$  %). Nest sites had a mean grass cover percentage of  $\bar{x} = 6.09 \pm 0.49$  % and a mean forb cover percentage of  $\bar{x} = 2.26 \pm 0.45$  %. There was no significant difference in forb and grass cover at successful versus unsuccessful nests.

Nests were located between the elevations of 2450 and 2850 m. The slopes of all nest sites ranged between 0 and 26 with a mean of  $\bar{x} = 6 \pm 0.8$  (SE). Forty-eight percent of the nests ( $n = 25$ ) were on slopes with an easterly aspect, 40% ( $n = 21$ ) with a northerly aspect, 35% ( $n = 18$ ) with a westerly aspect and 27 % ( $n = 14$ ) with a southerly aspect (Fig. 2.7).

Hens nesting > 1 year ( $n = 7$ ) were found to nest within close proximity to the previous year's nest, showing nest fidelity to nesting locations. The minimum and maximum distances between one year's nest site and the following year's nest site are 144 m and 5200 m, respectively. The mean distance from first year's nest sites to the following year's nest sites is  $\bar{x} = 1379 \pm 0.45$  m (SE). Hen 174 nested for three consecutive years with the second and third year's nests 454 and 486 m from the first year's nest site.

### **Brood-rearing sites**

Thirty broods and 267 associated brood-rearing locations were monitored. In 2000, 2001, and 2002, the percent of broods that survived beyond 40 days was 73% (n = 11), 88% (n = 8), and 55% (n = 11), respectively. Correspondingly, 111 brood-rearing sites were monitored in 2000, 68 in 2001, and 88 in 2002.

There was no difference in brood site vegetation characteristics between the short-lived and the longer-lived broods during 2000 ( $p = 0.12$ ) and 2001 ( $p = 0.08$ ); although, in 2002 “successful” brood sites contained more forbs (64%) and less shrub canopy cover (12%,  $p = 0.02$ ) than “unsuccessful” brood sites (Table 2.3).

### **Hen movements**

Most of the hens moved up in elevation as summer progressed. Movements between consecutive brood locations ranged between 0.007 and 19.993 km ( $\bar{x} = 1.664 \pm 0.245$  km [SE],  $n = 268$ ). Direct distances between nesting and late brood-rearing habitat ranged between 0.515 and 38.532 km ( $\bar{x} = 12.417 \pm 2.242$  km,  $n = 16$ ). Hens that traveled short distances between nest and brood-rearing sites tended to have nests at higher elevations than the rest. Hens monitored for > 1 year showed fidelity to specific movement patterns from spring lek attendance to late summer habitat areas.

### **Adult hen mortality**

There were 23 (39%) confirmed mortalities of grouse (Fig. 2.8). I could not definitively ascertain the causes of most of the mortalities. Twenty (34%) radio-collars were not heard again. I assumed the collars ceased transmitting (old or malfunction) or

the hens were no longer on the field site. Radio-collared hens without transmitting collars were observed on 4 occasions.

## **DISCUSSION**

Historic anecdotal information and systematic greater sage-grouse lek surveys conducted in western states suggest a general decline in greater sage-grouse populations (Hanf et al. 1994, Braun 1995, Beck and Mitchell 1997). In contrast, surveys on Parker Mountain in 2001 and 2002 recorded the highest lek counts since initiation of surveys on Parker Mountain in 1967. Fluctuations in the population are natural but the general downward trend of greater sage-grouse populations throughout their range has alarmed ranchers and conservationists alike (UDWR 2002). The Parker Mountain population represents one of few stable populations in Utah (UDWR 2002).

It is difficult to identify a single factor that is primarily responsible for recent lek count increases observed on Parker Mountain. The expansive sagebrush land on Parker Mountain has undergone little change in management and development practices in the last 30 years. Weather patterns have been stochastic (Logan Climate Center 2003). Information on when, where, and how much precipitation is received would help determine the effects on the system, but there is no weather station on Parker Mountain. In addition, surveys of other species' populations and assessments of their relationships with sage-grouse have not been determined in this study or other studies conducted on Parker Mountain.

Parker Mountain 80% nest initiation rate is comparable only to Washington, the highest of all other reported state nest initiation rates (Sveum 1995, Schroeder et al. 1999). The 69% nest success rate is higher than Oregon, Washington, and Wyoming nest

success rates (Schroeder et al. 1999). Nest success rate was higher than reported for Parker hens by Jarvis (1973). Nesting area fidelity was demonstrated by 7 hens, as was reported from research conducted by Berry and Eng (1985) and Fischer and others (1993). Nests were located an average of 1379 m from preceding year's nest sites, comparable to distances found in Idaho (Fischer et al. 1993).

Although the sample size is small, most breeding and brood-rearing site characteristics were consistent with those found in the literature (Schroeder et al. 1999, Connelly et al. 2000). Vegetation data collected at brood sites were consistent with past research on Parker Mountain and general mean grass and forb cover was consistent with suggested percentages for productive greater sage-grouse habitat (Jarvis 1973, Connelly et al. 2000). Fidelity to seasonal movement patterns from spring to late summer habitats was demonstrated by hens, with or without broods, similar to research conducted in Wyoming (Berry and Eng 1985).

## **MANAGEMENT IMPLICATIONS**

Lek counts conducted on Parker Mountain from 1999-2002 indicate the population is higher than it has been in 30 years. Concurrently, nest initiation rates and nest success rates were higher than most other states' sage-grouse populations. Mortality rates on Parker were conservatively estimated and found to be similar to other states. Land use and management did not drastically change over the course of the last 30 years. The year-around removal of mammalian predators likely contributes to the high nest success rate on Parker. Based on the information collected from radio-collared hens on Parker, present management is resulting in a productive, growing sage-grouse population.

All sage-grouse research conducted on Parker Mountain has occurred during high periods in the population cycle. Productivity measurements need to be collected during ebbing population cycles to understand the limiting factors when the populations are not increasing. In conjunction with those research efforts, data need to be collected on invertebrate abundance, alternative prey populations (small mammals), predator populations, and grazing utilization to fill the gaps of knowledge in the dynamic system in which greater sage-grouse participates. With more information about the ecosystem, managers will be better equipped with the tools of knowledge to properly manage all the facets of sagebrush systems and their inhabitants.

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Table 2.1. Comparison of state human populations, growth from 1960-2000, human population density, Greater sage-grouse population estimates, and 1960 estimates of hectares of sagebrush for Wyoming, Montana, Idaho, Nevada, Utah, Oregon, Colorado and California. The largest remaining sage-grouse populations occur in the Montana and Wyoming, the states with the lowest populations, population growth and persons per kilometer.

State	2000 Human population census (a)	1960-2000 % population growth (a)	Persons/km <sup>2</sup> (b)	Greater sage-grouse breeding populations (c)	Sagebrush acreage (millions of ha) (d)
Wyoming	493,782	50	13.2	> 20,000	15.1
Montana	902,195	34	16.0	> 20,000	14.0
Idaho	1,293,953	94	40.4	< 20,000	15.0
Nevada	1,998,253	600	47.1	< 15,000	10.9
Utah	2,233,169	140	70.5	< 5,000	10.7
Oregon	3,421,399	93	92.2	< 20,000	10.9
Colorado	4,301,261	145	107.5	< 15,000	7.8
California	33,871,648	115	562.6	< 5,000	7.3

(a) Source: <http://censusscope.org>

(b) Source: <http://quickfacts.census.gov>

(c) Source: Braun, C. E. 1998. Sage grouse declines in western North America: What are the problems? Proceedings of the Western Association of Fish and Wildlife Agencies 78:139-156.

(d) Source: Beetle, A. A. 1960. A study of sagebrush. The section Tridentatae of *Artemisia*. University of Wyoming, Agricultural Experiment Station, Bulletin 368, Laramie, Wyoming, USA.

Table 2.2. Trapping days, the number of Greater sage-grouse hens fitted with radio collars, the number of yearlings and adults trapped, the mean hours spent trapping each hen and the mean weight of trapped hens on Parker Mountain, Utah, 2000-2002.

Year	Trapping Days	# Hens	Yearling	Adult	Trapping Hrs/hen	Mean Weight (g)
2000	9	11	11	0	3	1444
2001	3	20	16	4	0.7	1420
2002	8	14	14	0	2.1	1453

Table 2.3. Mean percent vegetation cover (SE) at successful and unsuccessful brood-rearing sites on Parker Mountain, Utah, 2000-2002.

Year	Brood Status	Mean percent cover		
		forbs	grasses	shrubs
2000	Successful	7.0 (1.0)	11.1 (0.7)	28.1 (1.8)
	Unsuccessful	3.0 (0.8)	9.6 (1.7)	28.9 (2.7)
2001	Successful	9.5 (1.4)	9.3 (0.6)	27.6 (1.8)
	Unsuccessful	12.4 (2.8)	11.2 (2.3)	19.5 (3.4)
2002 <sup>a</sup>	Successful	8.7 (0.9)	11.6 (0.7)	25.6 (1.0)
	Unsuccessful	6.0 (1.0)	11.4 (1.6)	28.9 (2.2)

<sup>a</sup> Vegetation characteristics differ between successful and unsuccessful ( $P < 0.05$ ) according to the multi-response permutation process (MRPP).

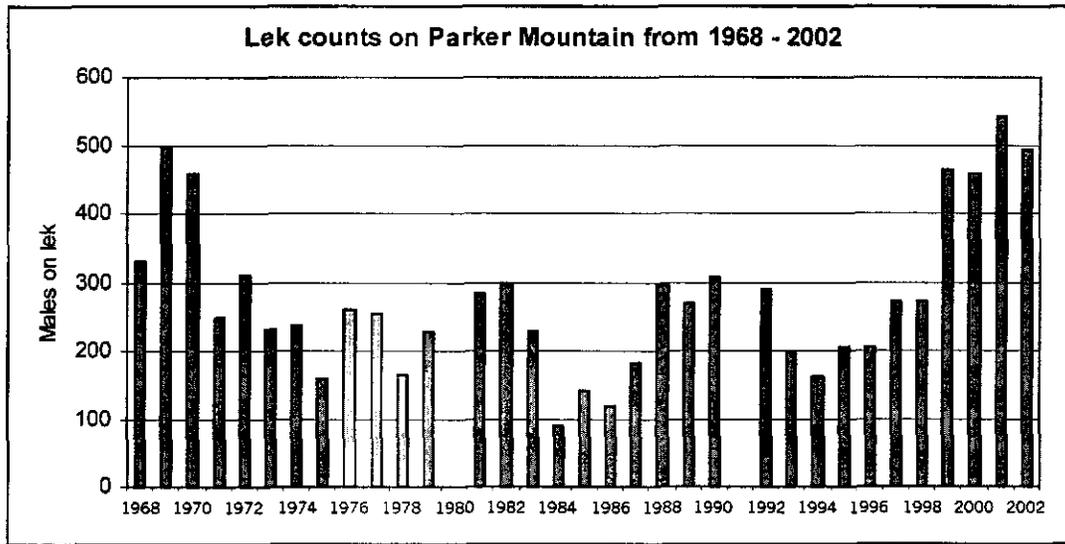


Fig. 2.1. Lek surveys assessing male Greater sage-grouse attendance on Parker Mountain, Utah, 1967-2002. 1980 and 1991 were years when lek surveys were not conducted due to weather.

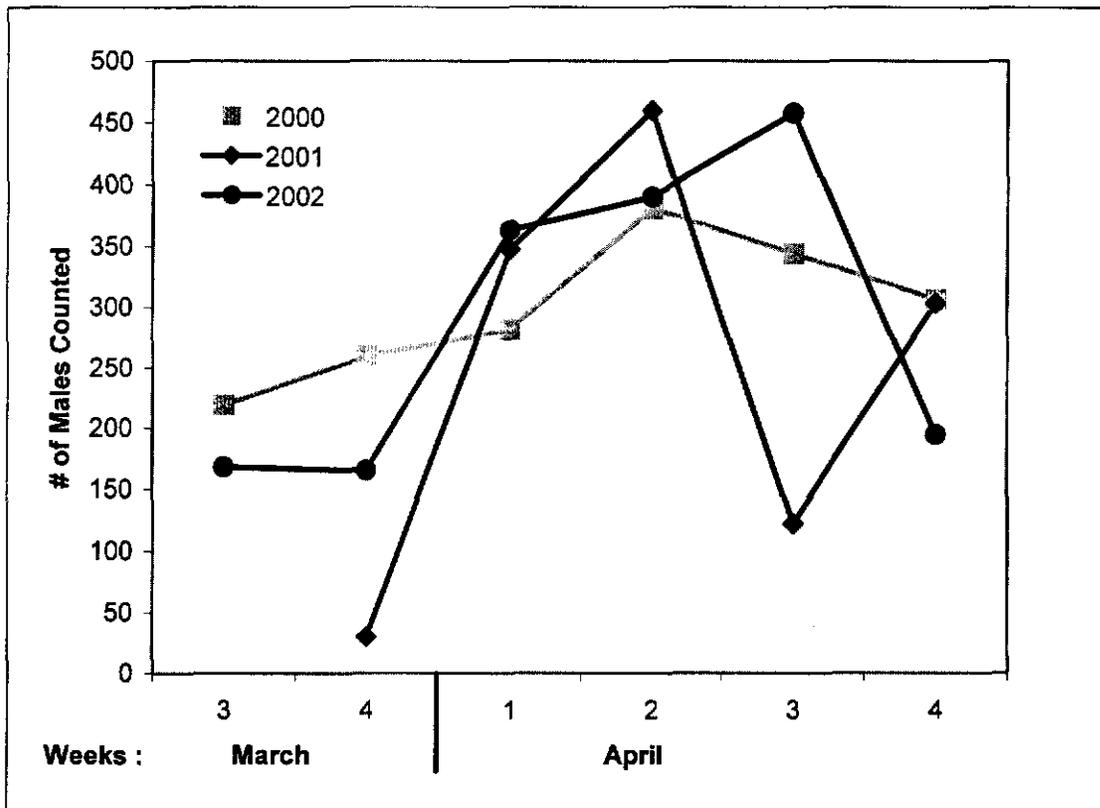


Fig. 2.2. Comparison of greater sage-grouse male lek counts, Parker Mountain, Utah, 2000-2002.

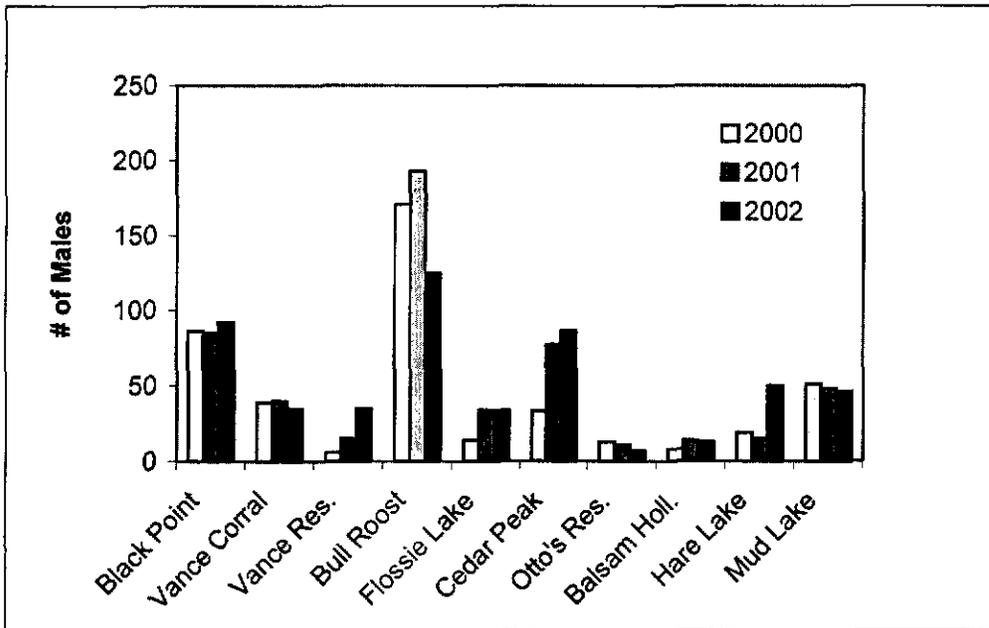


Fig. 2.3. Peak greater sage-grouse male lek counts on different leks, Parker Mountain, Utah, 2000-2002.

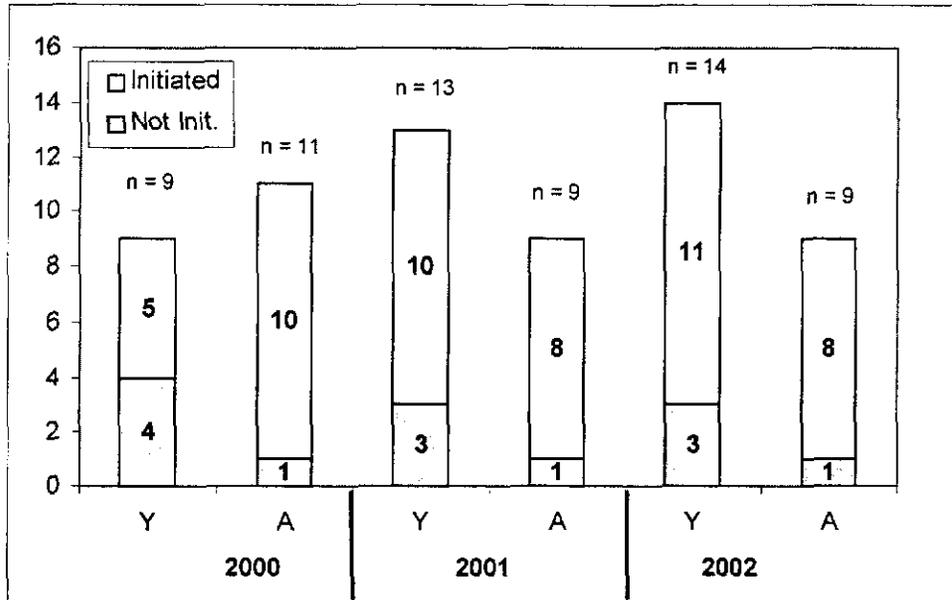


Fig. 2.4. Nest initiation for yearling and adult greater sage-grouse hens on Parker Mountain, Utah, 2000-2002.



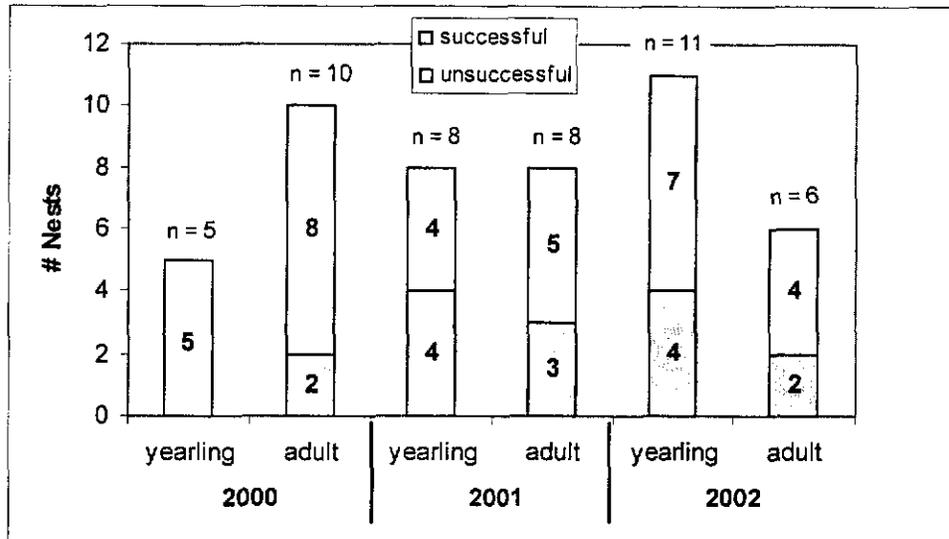


Fig. 2.6. Yearling and adult greater sage-grouse hen nest success on Parker Mountain, Utah, 2000-2002.

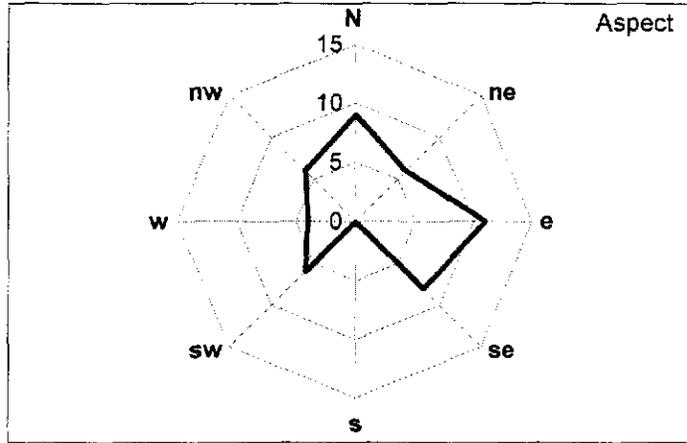
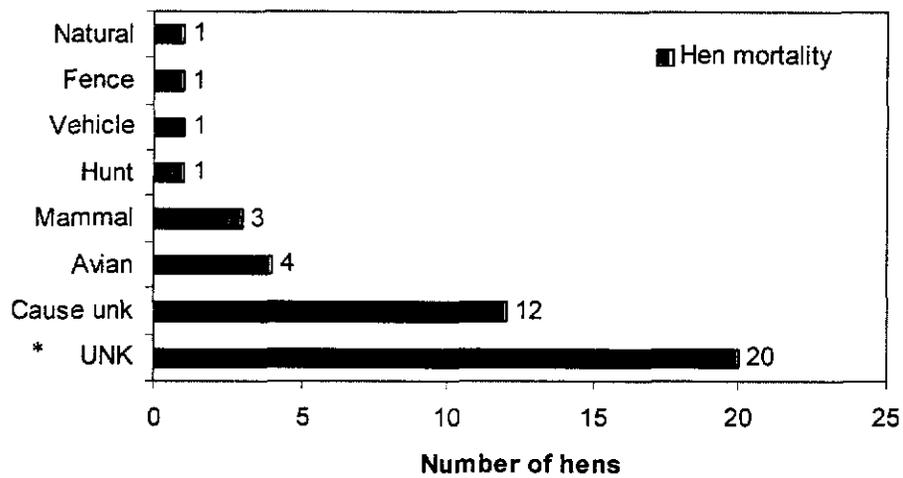


Fig. 2.7. Slope aspects of greater sage-grouse nests on Parker Mountain, Utah, 2000-2002.



\* Denotes collars not functioning or disappearance from the area.

Fig. 2.8. Probable causes of greater sage-grouse hen mortalities on Parker Mountain, Utah, 2000-2002.

EFFECTIVENESS OF USING TEBUTHIURON ON DENSE BIG SAGEBRUSH TO  
INCREASE HERBACEOUS UNDERSTORY VEGETATION  
FOR SAGE-GROUSE BROOD HABITAT

**Abstract** The greater sage-grouse (*Centrocercus urophasianus*) population on Parker Mountain located in south-central Utah has been declining over the last 30 years due to an inadequate quantity of grasses and forbs for chicks to survive. Therefore, under the premise that removal of big sagebrush will increase grasses and forbs for brood-rearing habitat, I designed a sagebrush manipulation experiment by establishing 8 plots each 40 ha in size and treated half with the herbicide, tebuthiuron. After herbicide treatment, the percent cover of most plant species declined due to drought. Nevertheless, an herbicide effect was evident with a decrease in shrub cover and an increase in grass and forb cover in treatment plots compared to control plots. Although increased survival of broods was not directly assessed, broods need grasses, forbs, and insects. Therefore, broods utilizing treated areas will be in better physical condition than broods in non-treated areas.

### Introduction

Studies conducted on sage-grouse (*Centrocercus spp.*) population dynamics suggest that sage-grouse populations have declined by up to 47% range-wide (Connelly and Braun 1997). The primary factors cited as potential causes are habitat loss, fragmentation, and degradation (Patterson 1952:281, Wallestad 1975a, Braun 1998). Since the settling of the West by Europeans, humans have destroyed sagebrush (*Artemisia spp.*) communities, as much as 50% in some states (Braun 1998). Increased

fragmentation has occurred as a result of increasing human population densities (i.e., roads, development, power lines). Habitat degradation has resulted from non-native plant introductions, changes in disturbance regimes, and heavy livestock use. In most cases, restoring degraded sagebrush habitat is more economically feasible than recreating sagebrush ecosystems from converted lands or dismantling of the source of fragmentation.

Grazing by domestic livestock, a source of degradation, has been of particular concern in many sagebrush-steppe ecosystems (Pickford 1932, Wagner 1977, Beck et al. 2003). The introduction of domestic livestock to the arid West in the mid-1800s augmented herbivory by wild ungulates on grasses and forbs (Schneegas 1967). Repeated overgrazing on the herbaceous understory was a contributing factor in reducing the vigor of herbaceous understory vegetation (Pickford 1932, Wagner 1977). Therefore, the additional herbivory on the herbaceous understory gave sagebrush a competitive advantage (West 1996). Consequently, sagebrush has become increasingly dominant as the herbaceous understory decreased (Pickford 1932).

In response to increasing sagebrush density, sage-grouse and other sagebrush obligate species increased in abundance throughout the West (Schneegas 1967). Initially, increased sagebrush abundance may have been beneficial for sagebrush-obligate species (Schneegas 1967). However, continuous herbivory on herbaceous vegetation interacting with drought has had negative ramifications to these species due to a decline in the herbaceous understory in the sagebrush-steppe systems (Pickford 1932, Patterson 1952:14, Johnsgard 1983:112).

### **Sagebrush and sage-grouse**

During winter, sage-grouse depend on sagebrush almost entirely for sustenance (Wallestad 1975a). Sagebrush also provides critical cover throughout their life cycle (thermal cover, breeding, nesting, and brood-rearing) (Girard 1937). Grasses and forbs associated with sagebrush communities provide critical food and cover (Peterson 1970a, Gregg 1991). Associated insects provide important sources of protein for breeding hens and young chicks (Johnson and Boyce 1990). As sagebrush communities have deteriorated, sage-grouse populations have declined (Klebenow 1970, Martin 1970, Eng and Schladweiler 1972).

In response to these declining sage-grouse populations, petitions have been filed with the U. S. Fish and Wildlife Service to list the Gunnison (*Centrocercus minimus*) and the Greater sage-grouse (*Centrocercus urophasianus*) species under the Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1531 et seq.). Due to the widespread distribution of Greater sage-grouse on public lands in the West, a listing under ESA would dramatically affect future land use decisions throughout its range (Knick et al. 2003).

### **Greater sage-grouse conservation strategies**

In the past, fire, chemical and mechanical vegetation manipulation techniques were used in sagebrush-steppe ecosystems to enhance forage production for livestock and decrease sagebrush density (Pyrah 1971, Connelly et al. 2000b). Generally, these techniques focused on removal of vegetation, particularly sagebrush, with the intent of increasing the abundance of herbaceous vegetation for livestock (Carr and Glover 1970, Wallestad 1971, Braun 1998). Although an increase in herbaceous understory vegetation

is beneficial for sage-grouse, historic sagebrush removal projects may have negatively impacted sage-grouse because too much sagebrush was removed (Martin 1970, Peterson 1970*b*, Wallestad 1975*a, b*).

More recently, there has been renewed interest in restoring sagebrush-steppe ecosystems by modifying the use of prior range improvement techniques to benefit sage-grouse and other sagebrush obligate species (Dobkin 1995). This interest has incited sage-grouse habitat improvement projects to decrease the density and cover but not eliminate sagebrush rather than completely eliminate it. For management purposes, finding a technique that efficiently decreases sagebrush density and cover and increases herbaceous understory cover is one of the first steps towards developing efficient methods for improving sage-grouse habitat.

Of range improvement techniques, use of herbicides is the most controversial and least evaluated with respect to efficacy and effects (Radosevich et al. 1997). Tebuthiuron, an herbicide typically applied to control brush, was used in the late 1970s (Scifres et al. 1979). Tebuthiuron did not appear to detrimentally affect forbs to the same degree that 2,4-D (2,4-dichlorophenoxy) did (Blaisdell and Mueggler 1956, Carr and Glover 1970, Martin 1970, Britton and Sneva 1983). Scifres and Mutz (1978) research suggests that moderate use of tebuthiuron can thin dense sagebrush stands, while stimulating an understory response. In this way, sagebrush communities would be pushed back to earlier successional states dominated by herbaceous understory (Beetle 1960).

Replicated sagebrush manipulation experiments using tebuthiuron to improve sage-grouse habitat are not well documented in the literature. In addition, results from

past projects may have management significance only in areas with similar site characteristics (e.g., climate, elevation, soils). The objective of this study was to assess the effectiveness of using tebuthiuron to decrease dense stands of sagebrush and increase herbaceous understory vegetation in high elevation big sagebrush communities and thereby improve brood-rearing habitat for sage-grouse.

## Methods

### Study area

The study site is located on Parker Mountain, south central Utah, on the Aquarius and Awapa plateaus (Fig 3.1). It is a contiguous high-elevation sagebrush steppe plateau between 2,134 – 3,018 m. Bounded by an escarpment on the west side and Rabbit Valley on the east, the plateau consists of 103,603 ha and is located in Wayne, Garfield, Piute and Sevier counties. The study area is a patchwork of different land ownerships: Utah State Institutional Trust Lands Administration manages 43,863 ha, Bureau of Land Management owns 36,398 ha, U.S. Forest Service owns 21,685 ha, and 5532 ha are privately owned.

Annual precipitation on Parker Mountain ranges from 25 - 51 cm, varying by elevation. Springs and shallow lakes exist above 2,621 m elevation. More than 80 livestock water developments provide other seasonal water sources across the plateau (R. Torgerson, SITLA, personal communication).

Historically, the primary use of Parker Mountain was domestic livestock grazing. The area was heavily grazed during the 1930s especially after the passage of the Taylor Grazing Act (Jarvis 1973). Sheep and cattle are still grazed (at much lower stocking

rates) at 3.6 ha per animal unit per month (AUM) (R. Torgerson, SITLA, personal communication). Currently, there are 10 grazing allotments on Parker Mountain ranging in size from 2300 to 18,000 ha (R. Torgerson, Utah State Institutional Trust Lands Administration, personal communication). In addition, the area is used for hunting, motorized vehicles, hiking, camping, and sight-seeing. Consequently, there are numerous dirt and gravel roads.

The experimental plots are located in Parker Lake grazing pasture. This pasture was selected due to its large size and its extensive sage-grouse brood use. The Parker Lake pasture is located on the southwest portion of Parker Mountain. It is approximately 2030 ha and ranges from 2712 to 2804 m in elevation.

### **Experimental design**

To identify possible study plots, I analyzed aerial photography of the Parker Lake pasture to locate areas that had greater than 30 % sagebrush canopy cover. I created a grid of 40.5 ha square plots within the pasture that met this criteria. Nineteen possible plots within the pasture were identified. Of these, I randomly selected 8 plots to use in this study (Fig. 3.2). Treatments were randomly assigned to plots.

To determine the effect of tebuthiuron, I compared 4 experimentally treated tebuthiuron plots with 4 untreated (control) plots. Plots were randomly assigned to treatment or control. The former were sprayed with tebuthiuron (20P) at 1.6 kg/ha at 0.3 active ingredient during October 2000 using a fixed-wing aircraft. This application rate was calculated to attain a 60 % sagebrush kill rate (T. Jarmin, Utah Natural Resource Conservation Service, personal communication).

Research has shown livestock selectively graze herbaceous vegetation following a tebuthiuron treatment. To study the interaction of cattle grazing and herbicide treatment on vegetation, cattle were allowed to graze both treated and control plots during 2001. To separate the effects of herbicide from grazing, I located 2 sites each 5 X 5 m squares in each plot and surrounded one of them with a fence sturdy enough to exclude cattle. I then compared vegetation inside the exclosures to the 5 X 5 m sites outside them where cattle were allowed to graze.

### **Vegetation measurements**

*Experiment 1.* To assess the effectiveness of the tebuthiuron treatment, vegetation sampling was conducted in 2000 and 2002. Pre-treatment herbaceous understory vegetation was measured during the 2000 field season to create a baseline set of data against which to compare the effects of the treatment on vegetation composition. To measure the herbaceous understory within each plot, I used a variation of the point-intercept method (Levy and Madden 1933). Big sagebrush stands were mapped within each plot, and 5 points were randomly chosen from which to start each point-intercept transect. Using a global positioning systems (GPS) unit, I obtained Universal Transverses Mercator coordinates (UTM, World Geodetic System 1984) at each point. A 3-meter pole was placed at each randomly chosen point. From the pole, each transect line was set up with a 20-meter tape extended out in a randomly chosen direction (5 within each plot). Sampling was conducted with 1 person lowering a smaller spiked pole at each meter and another recording the cover type contacted (e.g., bare ground, rock, litter, grass, forb). In addition, the 20-meter tape was used for a line-intercept shrub

canopy cover sampling of the study plots. The same point-intercept vegetation sampling methods were used in 2002.

*Experiment 2.* To assess the impacts of grazing on the treatment and control plots in 2001, vegetation sampling was conducted in before and after grazing in 2001. During 2001, I located a series of 12 Daubenmire frames within each enclosure and grazed site to sample the understory vegetation cover types and classify them by percent cover (Daubenmire 1959). Sampling was conducted both before (June) and after (July) livestock grazing.

### **Data analysis**

*Experiment 1.* To assess the effect of the herbicide on vegetation, I determined how the percent cover of grasses, forbs and shrubs changed from 2000 to 2002. I predicted that the herbicide treatment would cause grass, forbs, and grass-forbs combined to increase in percent cover and would cause shrub cover to decline. I tested these predictions using 1-way, unpaired Student's t-tests.

*Experiment 2.* Vegetation data were analyzed looking at the effects of the treatment (treated and control), location (inside and outside of the enclosure), and month (June and July) on percent grass cover and on percent forb cover using an analysis of variance with a three-way factorial in a split-split plot design. The whole plot unit was the unit comprised of two areas: an enclosed plot area and its adjacent outside area; the whole plot factor was treatment. The subplot unit was the area; the subplot unit was location. The sub-subplot unit was the repeated measure on the area; the sub-subplot factor was month. Computations were made using Proc MIXED in SAS/STAT©. The line-

line-intercept vegetation cover data to determine a 2-year post-treatment vegetation response were collected in 2000 and 2002 and analyzed descriptively.

## Results

### Experiment 1

The application of tebuthiuron yielded mixed results (Table 3.1.). Shrub canopy cover declined in treatment and control plots and there was no statistically significant difference between the treatment and control plots ( $p = 0.35$ ). The percent cover of grass ( $p = 0.18$ ) and forbs ( $p = 0.09$ ) individually were also not statistically different in treatment and control plots but the combination of grass and forb together was statistical different ( $p = 0.04$ ).

### Experiment 2

Although the sample size was small, interactions involving either herbicide treatment or month had no significant effects on the percent cover of forbs and grasses in the treatment and control plots (Table 3.2., Table 3.3.). However, the percent cover of forbs and grasses were higher inside the exclosures than in the grazed sites before and after the cattle arrived. Hence what appeared to be a significant grazing effect, analyzing only the after-grazing data, was really an artifact of a biased placement of exclosures located in areas with more vegetation. Exclosure plots were established first, then, adjacent open plots were established.

## Discussion

### Experiment 1

Consistent with other tebuthiuron studies, my herbicide treatment decreased shrub cover in areas treated. Shrub percent cover decreased in most of the control plots. I attribute the decreased shrub cover in control plots to drift of the herbicide from adjacent treatment plots. Numerous areas of dying sagebrush overlapped into control areas and some vegetation sampling within control areas occurred in these areas. The problem of herbicide drift would reduce measured differences between shrub cover in treated and control plots. Despite this, grass and forb cover was still significantly higher in treated plots than control plots.

Another confounding variable was that a drought occurred in 2002. This caused vegetation, especially grass, to decline in all plots. Hence, the main effect of the herbicide application was vegetation in treated plots decreased less than in control plots. Forb cover actually increased in herbicide-treated plots despite the drought but declined substantially in control plots. With the point-intercept sampling technique used to measure herbaceous understory in the plots, the vegetation response was not consistently positive. With more sampling points in each plot or more replicates, the trends I saw may have been more statistically significant.

In Idaho, with an application rate of 0.6 kg/ha, Murray (1988) reduced mean percent canopy cover of mountain big sagebrush by 70%. There was no difference in the amounts of herbaceous understory between the treated and untreated plots during the first 2 years of the treatment. During the third year, however, grasses showed a positive response to the herbicide. In Utah, Clary et al. (1985) found after 3 years at 0.6 kg/ha

active ingredient 20P, the treatment areas exhibited some increase in annual grasses and large reductions in mountain big sagebrush. Big sagebrush reductions were achieved with application rates ranging from 0.3 to 1.1 kg active ingredient/ha. In addition, after 2 years, Western wheatgrass showed an increasing trend with application rates 1.1 kg/ha active ingredient at 20P (Whitson and Alley 1984).

In the past, tebuthiuron has been used primarily as a tool to eradicate brush and increase the abundance of desirable forage species (Scifres et al. 1979). For years, tebuthiuron has successfully been used in Texas to efficiently control mixed brush and increase the grass abundance but has failed to elicit a positive response from the forb component (Scifres and Mutz 1978). The results from this research suggest that use of tebuthiuron in dense stands of mountain big sagebrush can effectively decrease sagebrush canopy cover and increase the herbaceous understory vegetation. Therefore, tebuthiuron is an effective management technique for improving sage-grouse brood habitat.

### **Conclusions**

Improving forage for domestic livestock was the objective of past herbicide sagebrush treatments but did not benefit sage-grouse (Carr and Glover 1970, Klebenow 1970, Martin 1970, Wallestad 1975b). Scifres and Mutz (1978) suggested moderate use of tebuthiuron could selectively remove only a portion of the sagebrush and stimulate the understory. On Parker Mountain, I conducted replicated tebuthiuron experiments were conducted to improve sage-grouse habitat with an application rate 1.6 kg/ha at 20P. The treatment reduced the live mountain big sagebrush canopy cover and slightly increased forb cover.

Limited management recommendations can be made based on my results. Thus, I encourage further experimental research on the effects of tebuthiuron treatments on sage-grouse and their habitats. More research should be conducted following the sage-grouse population and habitat management guidelines (Connelly et al. 2000a). More small-scale, experimental research using tebuthiuron is needed to investigate its efficacy as a management tool for improving sage-grouse habitat (Connelly et al. 2000a). The response of a sagebrush community to tebuthiuron will depend on the individual site characteristics such as: soil type, precipitation, sagebrush type, presence or absence of understory herbaceous cover, and land management. Therefore, before large-scale use of tebuthiuron, small-scale experimental use should be thoroughly assessed in the area to determine if the response meets the desired objectives. Moreover, if a treatment is applied to an area to improve sage-grouse habitat, no livestock grazing should occur the first or second growing season following treatment to allow herbaceous understory establishment (Clary et al. 1985). In general, grazing should be adaptively managed following a treatment, otherwise, grazing can put undo pressure on a range and obliterate the benefits of the treatment (West 1988).

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Table 3.1. Mean percent cover (SE) of herbaceous understory vegetation and shrub canopy cover before and after the herbicide treatment in treatment and control plots and analyzed mean vegetation change in the treatment versus control plots with an unpaired one-tailed t-test on Parker Mountain, Utah, 2000-2002.

	Treatment			Control			t-value	P
	2000	2002	change	2000	2002	change		
Forbs	4.0 (0.7)	6.3 (1.7)	2.3	5.3 (1.0)	3.5 (1.3)	-1.8	1.50	0.09
Grass	9.5 (1.7)	4.0 (1.5)	-5.5	10.5 (2.2)	3.0 (0.6)	-7.5	1.00	0.18
Grass & Forbs	13.5 (2.4)	10.3 (3.0)	-3.2	15.8 (1.6)	6.5 (1.3)	-9.3	2.17	0.04
Shrubs	31.0 (2.0)	18.2 (1.8)	-12.8	37.5 (4.8)	26.8 (1.0)	-10.7	0.39	0.35

Table 3.2. Analysis of variance with a three-way factorial in a split-split plot design to assess a forb response from an interaction of treatment and grazing in the treated and control plots in Parker Lake grazing pasture, Wayne County, Utah, 2001.

Effect	DF	F value	P value
trt	6	0.72	0.43
loc	6	8.38	0.03
trt*loc	6	0.02	0.90
month	12	0.20	0.66
trt*month	12	0.49	0.50
loc*month	12	0.24	0.63
trt*loc*month	12	0.29	0.60

trt = treated or untreated

loc = inside or outside the exclosure

month = before (June) or after (July) grazing

Table 3.3. Analysis of variance with a three-way factorial in a split-split plot design to assess a grass response from an interaction of treatment and grazing in the treated and control plots in Parker Lake grazing pasture, Wayne County, Utah, 2001.

Effect	DF	F value	P value
trt	6	0.36	0.57
loc	6	8.21	0.03
trt*loc	6	0.85	0.39
month	12	0.01	0.93
trt*month	12	0.04	0.84
loc*month	12	0.44	0.52
trt*loc*month	12	1.32	0.27

trt = treated or untreated

loc = inside or outside the enclosure

month = before (June) or after (July) grazing

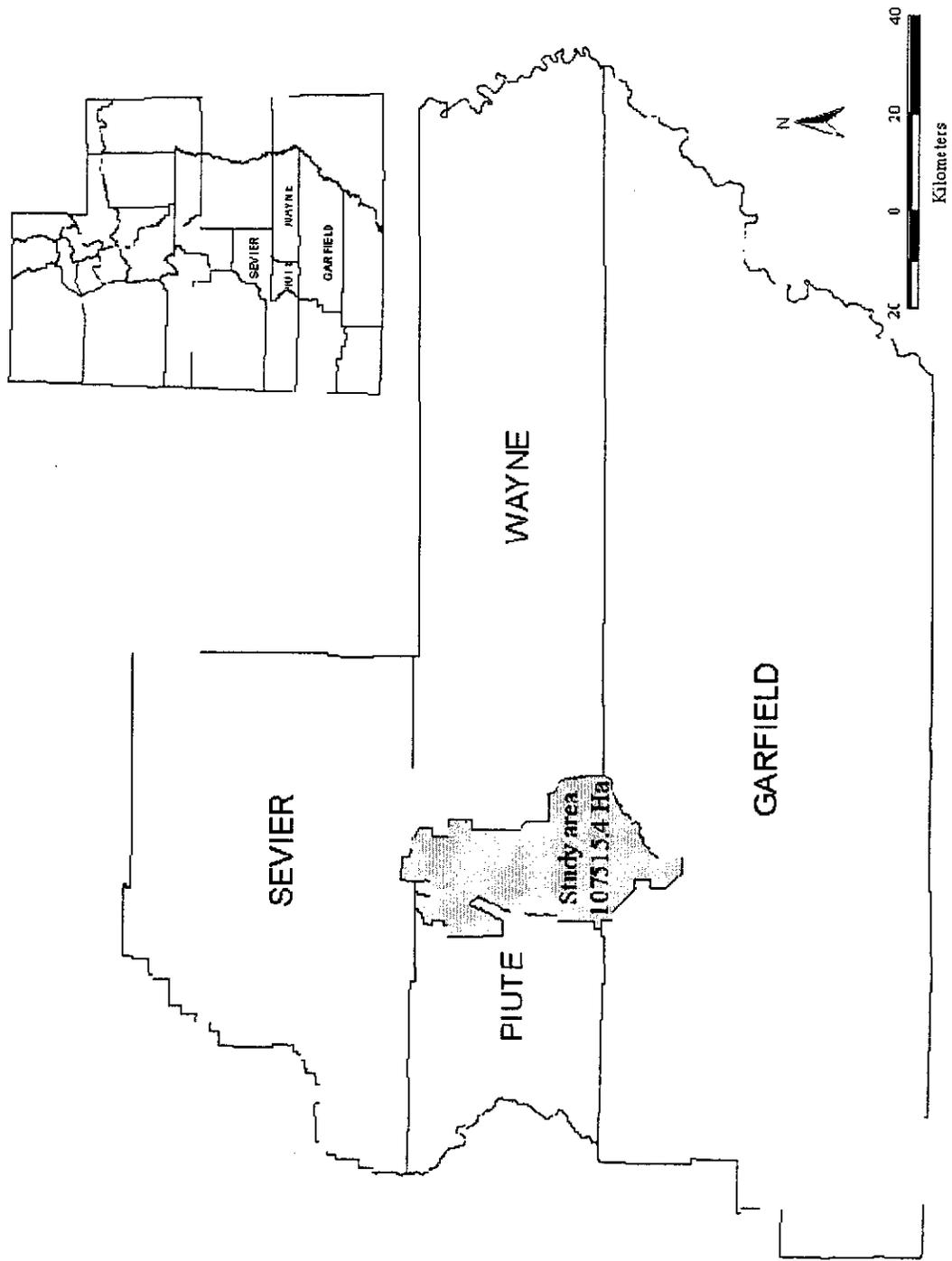


Fig. 3.1. Parker Mountain Study Area.

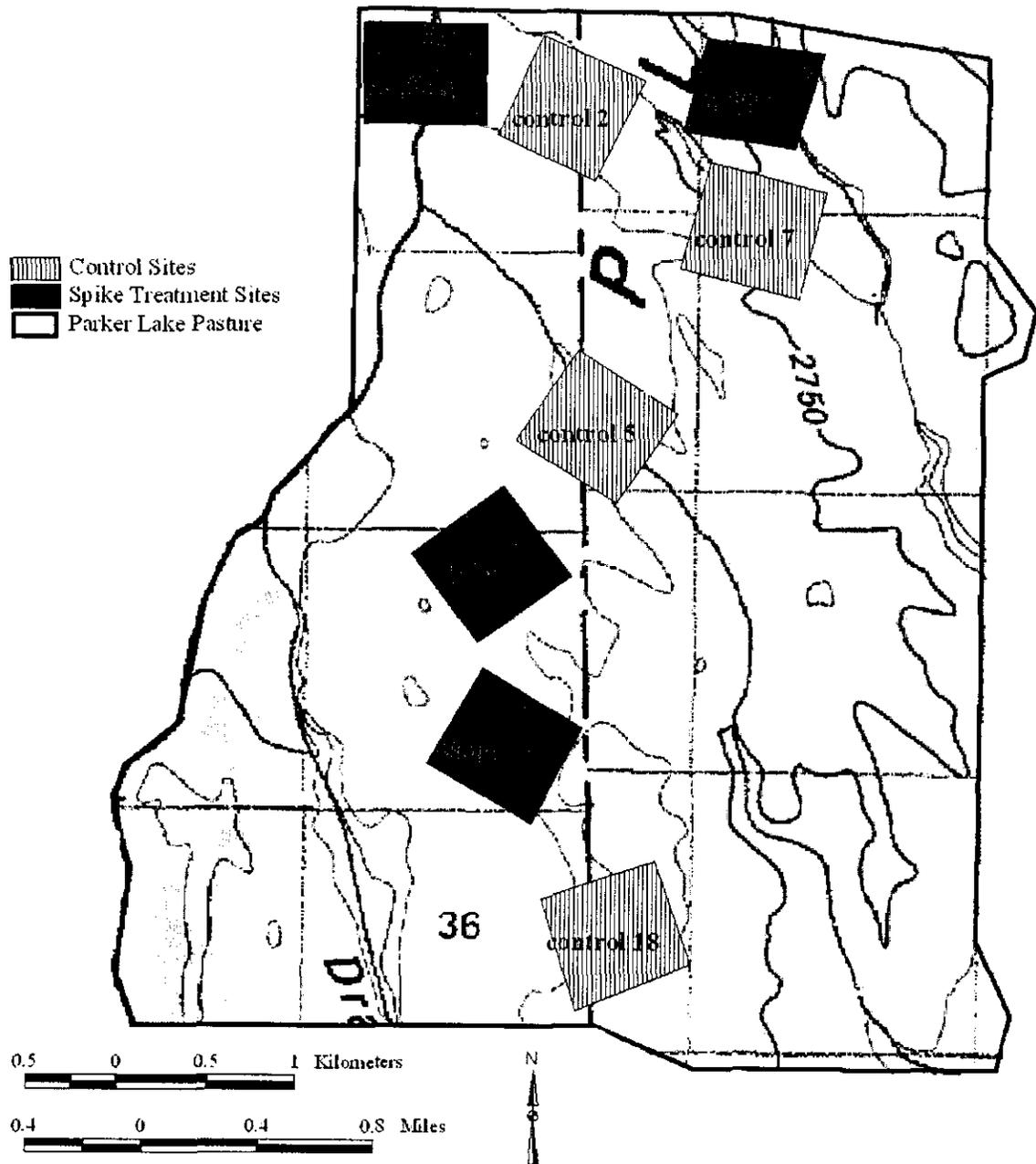


Figure 3.2. Map of treatment and control plots within the Parker Lake pasture, Piute and Wayne Counties, Utah, 2000-2002.

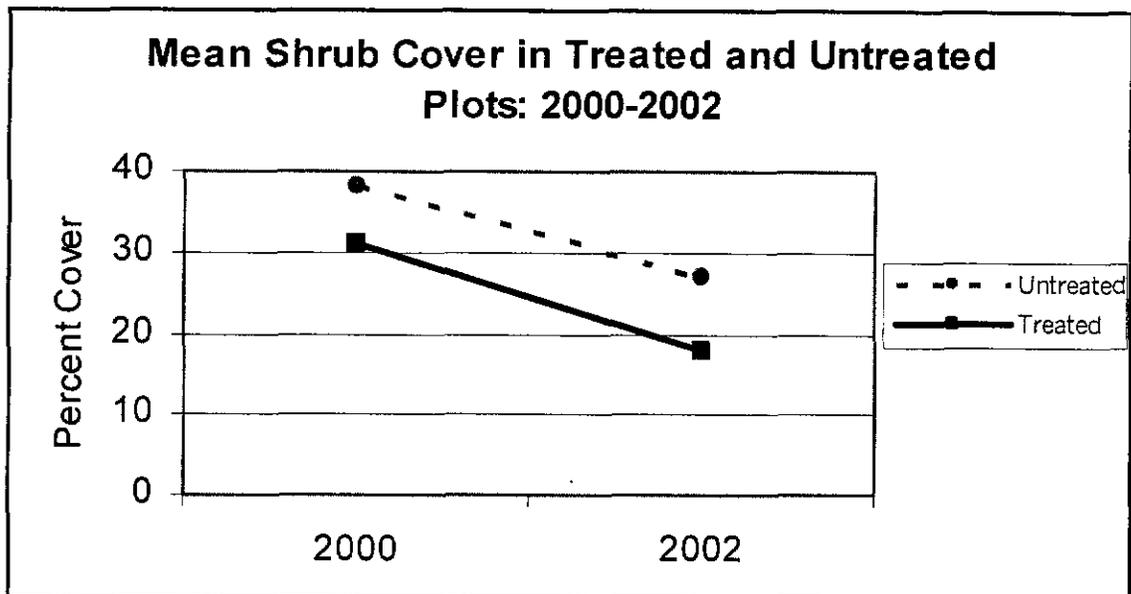


Figure 3.3. Mean changes in percent shrub canopy cover in treated and untreated plots in Parker Lake pasture, Piute and Wayne counties, Utah, 2000-2002.

## CHAPTER 4

### CONCLUSIONS

The greater sage-grouse population on Parker Mountain in south-central Utah is one of the largest sage-grouse populations in the state. On the Awapa and Aquarius plateaus, the Parker Mountain sagebrush ecosystem represents a unique area from a human and natural resource perspective. First, the area is one of the last remaining contiguous sagebrush systems remaining in Utah. The high plateau supports sagebrush at elevations up to 3050 m. Contrasting other sagebrush systems throughout the West, Parker lacks invasions of non-native mammalian and terrestrial vegetation species that have plagued the natural processes of other sagebrush ecosystems (Braun 1998). Lastly, human use is minimal on Parker Mountain largely due to its geographical remoteness.

Until 1997, little research had been conducted on the Parker Mountain sage-grouse population. In 1998, as a result of growing concerns with low sage-grouse lek counts on Parker Mountain, the Parker Mountain Adaptive Resource Management Working Group (PARM) was established. The community-based cooperative consortium was established to collaboratively address the low sage-grouse count concerns by initiated research to determine what might be limiting the population and come up with adaptive management strategies to increase the population. Therefore, in 1998 research began to investigate the reproductive ecology of sage-grouse. Based on the first 2 years of study, conducted by J. Flory, successful brood-rearing sites had higher herbaceous understory percent cover and lower percent shrub cover than unsuccessful brood-rearing sites.

Although there are a variety of sagebrush areas ranging from open to dense on 72 Parker Mountain, much of the high elevation sage-grouse habitat on the western half of Parker Mountain has big sagebrush stands with high canopy cover and little understory vegetation. Therefore, Flory hypothesized that such extensive areas of high shrub percent canopy cover and low percent herbaceous understory cover were potentially a factor limiting sage-grouse populations on Parker Mountain (J. Flory, Utah State University, personal communication).

With my research, I wanted to augment the database on the productivity and mortality of sage-grouse hens. In addition, I wanted to test the hypothesis that decreasing the density and cover of even-aged stands of mountain big sagebrush would diversify the age structure of the sagebrush stands and stimulate an herbaceous understory response. The objectives of my thesis research were to: 1) determine the nest initiation rates, nest success, nest characteristics, summer habitat use, summer movements, and mortality rates of female sage-grouse using telemetry and radio-marked hens, and 2) assess the effectiveness of using tebuthiuron to decrease mountain big sagebrush canopy cover and increase the herbaceous understory to benefit nesting and brood-rearing habitat for sage-grouse on Parker Mountain.

### **Habitat selection and reproductive success of sage-grouse hens**

I used radio-telemetry to determine nest initiation, nest site characteristics, clutch sizes, nest success rates, and adult hen mortality for collared hens from 2000-2002. The hens in this area had a slightly lower mean nest initiation rate (69%) compared to other states. Nest success rates (63%) were higher than Colorado, Idaho, Wyoming, Oregon

and Washington (Schroeder et al. 1999). Based on criteria outlined by Connelly et al. 73 (2000), nest site vegetation characteristics on Parker had very dense sagebrush canopy cover but had relatively sparse understory vegetation.

I tracked radio-collared hens to examine the relationship between specific vegetation characteristics, nest and brood-rearing locations, and habitat use patterns. Only in 2002 did brood-sites of broods surviving  $\geq 50$  days have a higher forb abundance and lower shrub density than those for broods surviving  $< 50$  days ( $p = 0.02$ ).

Movements of hens followed the phenological greening of the herbaceous understory with an elevational gradient. I was able to detect fidelity to nesting areas and subsequent movement patterns to summer foraging areas from hens nesting in consecutive years with operational collars. The movements and summer use areas demonstrate the extensive use of Parker Mountain from low elevations up to the high elevation sagebrush areas. Fidelity to nesting and brood-rearing areas indicates the need for a mosaic of varied percents of shrub canopy cover and herbaceous understory vegetation across Parker Mountain to successfully support the varied nesting sites and brood movements.

Collectively these results support implementation of projects that would improve sage-grouse brood-rearing habitat through the creation of areas with a varied sagebrush canopy cover and an interspersed abundant herbaceous understory.

#### **Tebuthiuron use for improving sage-grouse brood-rearing habitats**

I experimentally evaluated the effectiveness of a tebuthiuron herbicide treatment to improve sage-grouse brood-rearing habitat. The herbicide decreases sagebrush canopy

cover, thereby increasing microhabitat resources for grasses and forbs in the understory. Increased understory vegetation and associated insects are important for brood survival (Johnson and Boyce 1990). Pre-treatment vegetation data were collected summer of 2000, tebuthiuron was applied fall of 2000, and post-treatment vegetation data were collected in summer of 2002. This study evaluated the percent vegetation cover response of 4 variables; shrubs, grasses, forbs, and combined grasses and forbs. 74

Study results indicated that the herbicide successfully decreased percent canopy cover of big sagebrush; however, effects of the treatment on percent cover of grasses and forbs were confounded in 2002 by a severe drought. Percent grass cover decreased in all plots, treated and control, but it decreased less in the treated plots. Mean percent forb cover increased slightly in treated plots but decreased in control plots. Although, these differences in percent forb cover, in treated versus control plots, were not statistically significant. When grass and forb percent cover values were combined, they were statistically different in treated plots versus control plots. In treated plots, combined grass-forb percent cover data decreased less than in control plots.

Most of the herbaceous vegetation cover values decreased from 2000 to 2002 as a result of drought conditions. Despite the low precipitation conditions, forb percent cover values increased in treated plots and grasses decreased less in treated plots than in control plots. Results suggest that a more significant response would have been observed had there been normal precipitation. In the future, similar research should incorporate a larger sample size to detect responses from the treatment despite influence from other variables.

My research was a simple approach to investigating possible explanations for changes in sage-grouse populations on Parker Mountain. As with any system, there is a complicated interplay of variables determining the survival of a species on a spatial and temporal scale. To better understand the system in this area, I suggest further research on the spatial and temporal relationships of weather, soils, herbaceous vegetation, woody vegetation, invertebrate species and abundance, small mammal populations, specific lagomorph populations, wild ungulate populations, domestic ungulate populations, avian populations, predator populations, and anthropogenic influences.

It is important that the management of Parker Mountain be adaptive. This system, upon which so many human and wildlife existences are dependent, is an intricate web of participants, all of which have an influence on the entire ecosystem. Due to the stochastic nature of precipitation in this region and other dynamic variables, any effort to improve habitat for a single species should be carefully applied, with consideration of all possible outcomes. To maintain use from both humans and wildlife for a sustainable future, PARM has formed to better understand the natural systems on Parker Mountain and cooperatively establish an adaptive management plan to maintain and restore the integrity of the ecosystem.

As human populations inevitably grow, the need for careful conservation of remaining habitats is critical for all species. Efforts to manipulate or proactively manage habitats should be critically reviewed and tested in the specific areas before large-scale alterations are applied. Importance of monitoring before and after any applied habitat project cannot be overstated. The future of successful management decisions lies in the

information that is gained from past and present management and subsequent monitoring. Ecosystems are dynamic; therefore, let us recognize the need to manage dynamically. 76

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Table A1. Radio-collared hens (n = 13) that were monitored for more than 1 year on Parker Mountain, Utah, 2000-2002.

Bird #	Year	Site type	Clutch	Nest Fate	Habitat type	Aspect	Slope	Forb	Grass	Shrub	Litter	Distance travelled (m)
150.012	2000	* DID NOT NEST		/	/	/	/	/	/	/	/	/
	2001	Nest	6	success	arno/chvi	148	26	0.3	6.505	21.27	5.4175	/
	2001	Brood	/	/	arno	298	8	7.188	5	32.8	/	1113
	2001	Brood	/	/	arno	314	1	1.063	14.875	29.475	/	3259
	2001	Brood	/	/	arno/chvi	332	2	7.25	10	24.825	/	6345
	2001	Brood	/	/	arno	280	6	13.25	11.25	26.85	/	
	2001	Brood	/	/	aspen/artr	328	8	17.38	9.125	5	/	4839
	2001	Brood	/	/	arno	4	8	10.19	8.25	22.725	/	827
	2001	Brood	/	/	arno/chvi	30	1	9.875	7.5625	21.15	/	1260
	2001	Brood	/	/	arcal/chvi	334	2	26.31	12.438	27.975	/	1885
	2001	Brood	/	/	arcal/pine	324	3	18.19	4.625	1.4375	/	1024
	2001	Brood	/	/	aspen/arca	28	2	20.13	7.6875	4.75	/	549
	2001	Brood	/	/	arca	260	6	17.44	8.4375	15.125	/	263
	2001	Brood	/	/	arcal/chvi	321	3	18.63	7.125	11.125	/	
	2001	Brood	/	/	arno	280	4	12.94	10.875	21.175	/	369
	2001	Brood	/	/	arca	243	3	39.19	7.125	15.15	/	274
150.055	2000	* DID NOT NEST		/	/	/	/	/	/	/	/	/
	2001	nest	7	depredated	arno/chvi	355	2	3.138	6.435	36.65	5.8825	/
150.075	2000	*DID NOT NEST		/	/	/	/	/	/	/	/	/
	2001	*DID NOT NEST		/	/	/	/	/	/	/	/	/
	2002	**Nestled because later saw with young brood		/	/	/	/	/	/	/	/	/
150.095	2001	Nest	9	depredated	artr/chvi	132	2	0.93	6.085	33.418	4.0675	/
	2002	Nest	5	abandoned	artr/arno/chvi	242	10	1.148	5.2175	33.468	8.2175	/

Table A1. continued.

Bird #	Year	Site type	Clutch	Nest fate	Habitat type	Aspect	Slope	Forb	Grass	Shrub	Litter	Distance travelled (m)
150.115	2000	*DID NOT NEST		/	/	/	/	/	/	/	/	/
	2001	Nest	5	hatch	artr/cele	218	16	0.328	4.065	29.703	10.5	/
		Brood	/	/	artr	180	15	3	8.6875	28.975	/	103
		Brood	/	/	arno/artr	230	8	2.438	2.9375	31.325	/	534
		Brood	/	/	arno/artr	160	10	3.5	8.625	33.425	/	617
		Brood	/	/	artr	260	4	1.375	4.3125	51.875	/	187
		Brood	/	/	aspen/chvi	160	3	17.56	5.6875	14.1	/	2526
		Brood	/	/	chvi/artr/luca	220	6	9.875	5.3125	13.05	/	254
		Brood	/	/	artr/chvi	195	10	4.875	1.875	27.675	/	81
		Brood	/	/	aspen/chvi	160	3	16.25	8.25	20.125	/	298
		Brood	/	/	artr	300	13	10.94	6.5	40.6	/	92

Table A1. continued.

Bird #	Year	Site type	Clutch	Nest fate	Habitat type	Aspect	Slope	Forb	Grass	Shrub	Litter	Distance travelled (m)
150.135	2000	Nest	8	hatch	arno	280	3	0.91	7.3175	32.82	0.1675	/
		Brood	/	/	artr	9	6	7.188	6.375	24.55	/	490
		Brood	/	/	artr/arno	360	6	10.13	10.313	38.725	/	49
		Brood	/	/	arno	227	7	5.438	10.625	20.325	/	437
		Brood	/	/	arno	135	6	1.375	10.188	27.95	/	1047
		Brood	/	/	arno/artr			3.875	14.063	20.825	/	895
		Brood	/	/	artr	90	4	1	11.25	24.275	/	465
		Brood	/	/	aspen/artr	64	8		12.938	39.125	/	
		Brood	/	/	arca	133	6	3.063	13.25	35.5	/	5221
		Brood	/	/	arca	46	19	12.38	14.063	35.75	/	186
		Brood	/	/	artr	42	7	5.125	17.375	43.225	/	1692
		Brood	/	/	artr/aspen	236	1	15.63	7.9375	12.8	/	3304
		Brood	/	/	artr/arca	30	16	20.06	13.125	32.925	/	419
		Brood	/	/	down aspen	300	1	5.188	12	3.75	/	
		Brood	/	/	aspen/luca	0	0	8.813	7.0625	0.725	/	282
	2001	Nest	8	hatch	arno/chvi	216	11	1.083	3.7175	40.838	3.6175	/
		Brood	/	/	artr/arno	96	14	5	6.0625	27.9	/	5880
		Brood	/	/	arno/chvi	94	20	7.188	6	39.725	/	2753
		Brood	/	/	arno	122	11	4.188	7	34.875	/	1839
		Brood	/	/	artr	260	8	17.06	8.0625	34.95	/	3683
		Brood	/	/	artr	54	4	18.31	8.3125	35.35	/	792
		Brood	/	/	artr	24	5	21.19	4.375	47.525	/	1124
		Brood	/	/	artr/arca	40	3	8.5	9.5	47.95	/	504
		Brood	/	/	artr	263	8	31.38	7	32.6	/	3204
		Brood	/	/	artr	92	8	16.38	11.563	40.45	/	796
		Brood	/	/	artr	50	5	28.88	10.875	38.15	/	1118
		Brood	/	/	arca	80	3	22.13	8.25	24.225	/	166
		Brood	/	/	artr	20	17	6.938	12.438	28.825	/	427

Table A1. continued.

Bird #	Year	Site type	Clutch	Nest fate	Habitat type	Aspect	Slope	Forb	Grass	Shrub	Litter	Distance travelled (m)
150.175	2000	Nest	8	hatch	arno/artr	0	0	1.985	4.339	38.515	0	/
		Brood	/	/	artr	0	0	8.938	8	31.4	/	592
		Brood	/	/	arno	270	12	9.375	14.875	14.55	/	2251
		Brood	/	/	chvi	90	5	7.688	9.6875	21.875	/	1828
		Brood	/	/	artr	180	7	13.19	12.125	19.425	/	86
		Brood	/	/	arno	120	3	21.56	12.938	19.675	/	309
		Brood	/	/	arno	74	6	4.25	9.625	24.05	/	147
		Brood	/	/	artr	38	6	13.69	9.8125	20.75	/	1200
		Brood	/	/	artr/arno	55	1	18.19	11.563	12.825	/	1629
		Brood	/	/	arno	246	2	10.38	7.8125	12.2	/	541
	2001	Nest	7	predator	arno/chvi	211	1	18.55	4.935	20.135	6.2	/
	2002	Nest	7	hatch	arno/chvi	96	3	2.548	7.1025	25.935	4.65	/
		Brood	/	/	aspen/artr	74	14	1.75	19.5	0.325	/	1517
		Brood	/	/	artr	302	3	19.88	17	26.45	/	1888
		Brood	/	/	arno	20	4	15	16.625	21.4	/	330
		Brood	/	/	artr	16	1	14.31	13.25	18.65	/	372
		Brood	/	/	artr/arno	0	0	14.69	16.313	17.85	/	130
		Brood	/	/	arca	243	4	17.31	12.938	9.65	/	7955
150.194	2001	Nest	4	abandon	arno/chvi	360	1	1.998	6.785	25.768	3.4025	/
	2002	Nest	6	abandon	arno/chvi	228	3	0.768	4.4175	26.188	7.1575	/
150.214	2001	**DID NOT NEST	/	/	/	/	/	/	/	/	/	/
	2002	Nest	unknown	predator	arno/chvi	132	10	1.28	4.55	21.718	6.6675	/



Table A1. continued.

Bird #	Year	Site type	Clutch	Nest fate	Habitat type	Aspect	Slope	Forb	Grass	Shrub	Litter	Distance travelled (m)
793	2001	Nest	unknown	predator	arno/chvi	142	2	1.118	2.5325	27.985	0.5	/
	2002	Nest	4	hatch	arno	131	7	0.4	2.115	26.963	11.018	/
		Brood	/	/	arno/chvi	29	2	3.125	8.75	26.6	/	/