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# Vital Rates, Population Trends, and Habitat-Use Patterns of a Translocated Greater Sage-Grouse Population: Implications for Future Translocations

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VITAL RATES, POPULATION TRENDS, AND HABITAT-USE PATTERNS  
OF A TRANSLOCATED GREATER SAGE-GROUSE POPULATION:  
IMPLICATIONS FOR FUTURE TRANSLOCATIONS

by

Orrin V. Duvuvuei

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

of

MASTER OF SCIENCE

in

Wildlife Biology

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UTAH STATE UNIVERSITY  
Logan, Utah

2013

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**ABSTRACT**

Vital Rates, Population Trends, and Habitat-use Patterns of a Translocated  
Greater Sage-grouse Population: Implications for Future Translocations

by

Orrin V. Duvuvuei, Master of Science

Utah State University, 2013

Major Professor: Dr. Terry A. Messmer  
Department: Wildland resources

Translocations have been used as a management strategy to successfully augment declining native wildlife populations. Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) population declines on Anthro Mountain, Utah prompted managers to translocate sage-grouse and test protocols from a successful translocation project in Strawberry Valley, Utah. Sage-grouse from Parker Mountain, Utah were used as the source population for Anthro Mountain and Strawberry Valley translocations. Sixty hens were translocated to Anthro Mountain in 2009 and 2010; I monitored vital rates of the 60 translocated hens and 32 resident hens from 2009-2012. My objective was to determine the overall success of the translocation 4 years after the initial release and compare vital rates to the source population and Strawberry Valley.

In Chapter 2, I determined that survival varied by study area and hen age but was not affected by residency status. Annual survival of Anthro Mountain hens was lower

than Parker Mountain and Strawberry Valley hens. Adult hen survival in all three populations was higher than yearling survival.

In Chapter 3, I determined that the translocation contributed to population growth. Adult resident and previously translocated hens had the highest reproductive success, followed by resident yearlings, newly translocated adults, and newly translocated yearlings. Lek counts increased from 2009-2013 and a new lek was discovered in 2011. Survival was not affected by residency status or age, but varied greatly by year and season. Mean monthly survival was lowest in the fall; this differs from range-wide trends.

In Chapter 4, I determined that translocated hens adapted to the release area. They exhibited similar seasonal movements and used similar habitats as residents. The home range size of resident and translocated hens was comparable; however, previously translocated hens had smaller home ranges than newly released hens.

Despite landscape level differences between the source and release areas, translocated hens assimilated to the population and contributed to population growth. Although the translocation was successful, the low vital rate estimates are cause for concern. The low estimates suggest that factors such as predation, habitat quality and quantity, and anthropogenic influences may be problematic for this isolated population.

**PUBLIC ABSTRACT**

Vital Rates, Population Trends, and Habitat-use Patterns of a Translocated  
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Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) populations have declined range-wide with some local populations exhibiting dramatic decreases. In 2009–2010, radio-marked hens (30 hens in 2009 and 30 hens in 2010) were translocated from Parker Mountain in south-central Utah to augment a rapidly declining population on Anthro Mountain in northeastern Utah. Thirty-two resident female sage-grouse on Anthro Mountain were also radio-collared from 2009–2012.

I compared population vital rates (i.e., nest and brood success, and survival) of resident and translocated hens in Anthro Mountain's population to those of a translocated population in Strawberry Valley, Utah and the source population. Of these populations, Anthro Mountain sage-grouse exhibited the lowest average survival rates. Anthro Mountain survival rates were lower than range-wide estimates while hens in Strawberry

Valley and on Parker Mountain had survival rates comparable to the range-wide estimates.

I evaluated the effect of the translocations on the Anthro Mountain population 4 years after the initial release by comparing survival rates, reproductive success, home ranges, and breeding habitat use of translocated and resident hens. I also examined if the translocations had any effect on Anthro Mountain lek count trends. Vital rates were similar for resident and translocated hens regardless of age or year. However, resident and previously translocated adult hens had highest reproductive success and newly translocated yearling hens had the lowest. Home ranges and breeding habitat use were comparable for each cohort (yearling vs. adult and resident vs. translocated hens). Lek counts gradually increased from 2010 to 2013 and a new lek was discovered in 2011. Based on these data, the translocation efforts appeared to have augmented Anthro Mountain's declining population. The translocated sage-grouse successfully adapted to the release area and integrated into the resident population. Although lek counts indicated that the population increased, vital rates for both resident and translocated sage-grouse remained low compared to range-wide estimates. These observations suggest that other factors such as predation and habitat availability at the landscape scale may be inhibiting population growth. Managers should strive to mitigate limiting factors to stabilize this isolated population.

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## CHAPTER 1

### INTRODUCTION AND LITERATURE REVIEW

#### POPULATION STATUS

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse), the largest of all grouse species in North America, are dependent on sagebrush (*Artemisia* spp.) communities throughout their range for annual food and cover (Griner 1939). Sage-grouse were once found in 16 western states and 3 Canadian provinces, but populations declined range-wide over the past century (Schroeder et al. 2004). Currently, sage-grouse occur in 11 states and 2 Canadian provinces (Connelly and Braun 1997). In Utah, sage-grouse are estimated to occupy less than fifty percent of their historical range (Beck et al. 2003). Sage-grouse population trends based on male lek attendance rates continue to decline range-wide, with some local populations exhibiting dramatic decreases (Garton et al. 2011).

Concern about sage-grouse population declines resulted in petitions to the U.S. Fish and Wildlife Service (USFWS) to list the species under the Endangered Species Act of 1973. In December 2005, the USFWS announced that listing the sage-grouse was unwarranted. A lawsuit was subsequently filed to challenge the decision and process. The lawsuit resulted in a U.S. District Court ruling that the USFWS must reconsider its previous decision. In March 2010, after reviewing new information, USFWS concluded that listing the sage-grouse was warranted but precluded from listing by species of higher concern. The USFWS cited habitat loss and inadequate regulatory mechanisms for the declining population as a basis for their finding.

## **THREATS**

Because sage-grouse depend on sagebrush to complete their life cycles, they are only found within the distribution of the sagebrush ecosystem in western North America (Johnsgard 1983). Expansion of agriculture, invasive species, drought, change in fire regimes, and ranching activities have resulted in habitat loss and long-term impacts in sagebrush ecosystems (Swenson et al. 1987, Connelly and Braun 1997, Beck and Mitchell 2000, Connelly et al. 2004, Crawford et al. 2004). Habitat loss has been identified as the primary cause for range-wide sage-grouse population declines (Wallestad and Eng 1975, Connelly et al. 2004, Schroeder et al. 2004). Continuing development and urbanization in sagebrush ecosystems results in further fragmentation and loss of sage-grouse habitat (Aldridge and Boyce 2007, Walker et al. 2007, Doherty et al. 2008). In addition to direct habitat loss, infrastructure avoidance associated with development and urbanization may cause functional habitat loss and thus contribute to sage-grouse population declines (Lyon and Anderson 2003, Aldridge and Boyce 2007, Walker et al. 2007, Doherty et al. 2008).

## **VITAL RATES**

Compared to most other galliforms, sage-grouse are longer lived and have lower reproductive output resulting from smaller clutch sizes and lower reneating rates (Schroeder et al. 1999). Adult female survival, chick survival, and nest success are important to population growth and changes in any of these vital rates drive fluctuations within a population (Schroeder et al. 1999, Moynahan et al. 2006, Taylor et al. 2012). Vital rates are influenced by site-specific events such as disease, predation, and weather

and can vary by year, season, and geographic location (Johnson and Braun 1999, Naugle et al. 2004, Holloran et al. 2005, Moynahan et al. 2006, Taylor et al. 2012). Survival rates in some populations vary little, while survival in others may vary dramatically by season and year (Zablan et al. 2003, Beck et al. 2006, Moynahan et al. 2006). Range-wide annual survival rates of hens are documented to vary 37–78% depending on the study population, with winter survival rates being typically highest (Connelly et al. 2011a). Survival in long distance migratory populations has been reported to be lower than for more sedentary or non-migratory populations in Idaho (Beck et al. 2006). Nest success is also variable by year and location ranging from 15–86% (Connelly et al. 2004). Stable populations typically have higher nest success than declining populations (Dalke et al. 1963, Schroeder et al. 1999).

## **HABITAT**

Higher survival rates and nest success in some studies have been linked to habitat characteristics and vegetation cover. Shrub canopy cover and herbaceous understory are important vegetation parameters which may directly influence survival and nest success (Aldridge and Brigham 2002, Holloran et al. 2005, Aldridge and Boyce 2007, Robinson 2007, Kolada et al. 2009). Low survival and reproductive rates could be an indication of poor habitat conditions. Invasive species, change in fire regimes, drought, encroachment of unsuitable native vegetation, and overgrazing can all lead to unsuitable habitat conditions for sage-grouse (Connelly et al. 2000, 2004). Wildlife biologists recognize that protecting large expanses of viable sagebrush habitat is necessary to conserve sage-grouse populations (Braun et al. 1977). Wildlife managers strive to enhance population

growth by maintaining or improving key sagebrush habitat components that positively influence sage-grouse survival and reproductive success. Core areas are identified and habitat projects are implemented to achieve optimal sagebrush cover while increasing beneficial grass and forb cover (Pyke 2011, Connelly et al. 2011b).

The Utah Division of Wildlife Resources (UDWR) reported over 155,449 ha (384,125 ac) of habitat have been protected or enhanced in the state to benefit sage-grouse (UDWR, unpublished data). Herbicides and prescribed fires are used to treat invasive and unwanted plant species. Chaining, lop and scatter, and bullhogging of pinyon-pine (*Pinus edulis*) and juniper trees (*Juniperus* spp.) are used in areas where the trees are encroaching on sagebrush habitat. Seeding treatments are implemented to restore habitat to native shrubs, grasses, and forbs. Additionally, wildlife managers work with ranchers to implement livestock grazing regimes that are mutually beneficial to sage-grouse and livestock (UDWR 2009).

## **TRANSLOCATION**

Biologists have attempted sage-grouse translocations to augment declining populations in areas where habitat conditions within occupied or historic ranges approximates the recommended habitat guidelines (Reese and Connelly 1997, Connelly et al. 2000, Baxter et al. 2008). Translocations have been used successfully as a management tool to augment extirpated or declining wildlife populations for both game and nongame species including native upland game birds (McMahon and Johnson 1980, Woolf et al. 1984, Miller et al. 1985, Griffith et al. 1989).

Sage-grouse translocations have been attempted multiple times in 7 states and one Canadian province since the early 1930s, but despite these attempts, peer-reviewed published information regarding their success is sparse (Reese and Connelly 1997). Published and anecdotal sage-grouse translocation information indicates that despite being relocated to suitable habitat, translocated sage-grouse show little fidelity to their release site unless there are barriers to movement from the release site (Baxter et al. 2008).

In 1949–1950, 500 sage-grouse were trapped in Wyoming during August and September; the birds were banded and translocated to areas 32–64 km from the capture site that were open to hunting (Patterson 1952). Of these 500 sage-grouse, over half of the adult males and 80% of the adult females left the release site. Many returned to the exact capture area, while some were harvested in other areas, up to 48 km from the release site.

Colorado Parks and Wildlife (CPW) biologists released 20–30 sage-grouse to an area that was not previously occupied during a 1971–1972 translocation project (Reese and Connelly 1997). The release area was approximately 50 km from the nearest established population but was separated by a tall mountain range. Through personal communication with CPW, Reese and Connelly (1997) deemed the translocation successful because approximately 50 sage-grouse existed in the release area in 1996.

The first sage-grouse translocation that used radio-telemetry to monitor success occurred in the Sawtooth Valley, Idaho in 1986 and 1987 (Musil et al. 1993, Reese and Connelly 1997). During this time 196 sage-grouse were translocated approximately 144

km during the spring breeding season. Forty-four of 196 translocated sage-grouse were equipped with radio transmitters to monitor survival, reproduction and movements. Although some birds left temporarily, the translocated sage-grouse remained near the release site during the summer following release, and none were known to return to the capture site. Musil et al. (1993) hypothesized that high mountains surrounding the release site provided a barrier that deterred permanent dispersal from the valley.

Although previous sage-grouse translocations failed to provide criteria to evaluate success, Reese and Connelly (1997) estimated that 5% of sage-grouse translocations were successful compared to an 86% success rates for other native game species (Griffith et al. 1989). Persisting low population numbers following sage-grouse translocations were the reason for the low estimate. Translocated sage-grouse that are unfamiliar with the release habitat are likely to have reduced survival and reproductive rates and, therefore, contribute little to population growth (Taylor et al. 2012). However, Musil et al. (1993) found that sage-grouse translocated in Idaho reproduced successfully and that this management practice could be useful in restoring certain sage-grouse populations. Nevertheless, Reese and Connelly (1997) warned that translocations should be viewed as experimental and not as a viable option to restore extirpated populations.

### **Sage-grouse Translocations in Utah**

In Utah, two previous sage-grouse translocation efforts have been conducted. In the Wildcat Knolls, 18 males and 35 hens were released by UDWR biologists from 1987–1990 in sagebrush habitats. Lek counts increased following translocations and in 2008, 34 males were counted during the peak lek attendance (Perkins 2010). This

increase in male lek counts suggested that the translocation was successful (UDWR 2009).

The second translocation was conducted in Strawberry Valley, Utah over a period of 6 years (Baxter et al. 2008). Strawberry Valley is a montane valley surrounded by high mountain ridges and was historically occupied by as many as 3,000–4,000 sage-grouse (Griner 1939). Prior to sage-grouse translocation efforts, this population had declined to an estimated 150 breeding sage-grouse (Bunnell 2000). From 2003 through 2008, 336 hens from 4 different source populations were translocated to the area (Baxter et al. 2013).

The high mountain ridges surrounding Strawberry Valley provided a geomorphic barrier that may have discouraged translocated sage-grouse from leaving the area (Baxter et al. 2008). Additionally, Baxter et al. (2008) found that releasing hens in the spring time near active leks increased site fidelity. Survival and nest success rates of translocated hens in this study were comparable to range-wide estimates of hens in resident populations. At the conclusion of the translocation study, Strawberry Valley's population had increased to approximately 500 breeding birds (UDWR 2009). Baxter et al. (2008) concluded that adult hen and chick survival and nest success, metrics which may most influence population growth rates, were important to the success of this translocation effort (Dahlgren 2009, Guttery 2011, Taylor et al. 2012).

Based on the success of these translocation projects in Utah, the Utah Greater Sage-grouse Management Plan recognized translocations as a viable management tool for enhancing sage-grouse populations (UDWR 2009). The plan stated that “translocations

may be used to augment populations where  $\leq 165$  males ( $\leq 500$  adult sage-grouse) make up the breeding population, or an increase in genetic diversity is warranted.” The UDWR cautioned biologists to consider site differences between the source and release areas. The plan also stated that translocations in Utah should use the protocols described by Baxter et al. (2008).

Baxter et al. (2008) recommended that sage-grouse be released near an active lek during hours of breeding activity to increase site fidelity. Coupled with findings from previous sage-grouse translocation studies, Baxter et al. (2008) found it effective to release sage-grouse into sagebrush habitat distant from the source population and surrounded by a geomorphic barrier to dispersal (Reese and Connelly 1997). Additionally, translocations should be employed before the population dwindles to the point that a single stochastic event could extirpate a population (Baxter et al. 2008).

Baxter et al. (2008) reported that success should be determined based on translocated hen survival rates, courtship compatibility, reproductive success, fidelity to the release area, integration into the existing population, and overall contribution to the resident population. The metrics used to evaluate the translocation success in Strawberry Valley included 1) translocated female survival, 2) attendance at leks, 3) nest initiation, 4) nest success, 5) translocated hen's chick survival, 6) flocking and movements of the translocated females, and 7) changes or trends in resident male lek attendance.

### **Sage-grouse Management in Northeastern Utah**

In 2002, U.S. Forest Service (USFS) biologists on the Ashley National Forest began monitoring sage-grouse Anthro Mountain. The purpose of the research was to

gather baseline data and document population trends. From 2002 through 2006, sage-grouse were radio-collared to monitor vital rates, determine habitat use, and track movements. Survival rates of resident hens during this time were similar to those recorded by Connelly et al. (2011a) (B. Christensen 2007, USFS Ashley National Forest, unpublished report). The report concluded that Anthro Mountain provided nesting, brood rearing, and wintering habitats that were within the habitat guidelines recommended by Connelly et al. (2011a).

Anthro Mountain's sage-grouse population appeared to decline based on lek count indices which reported 44 males in 2006 to 13 males in 2008 (B. Maxfield, UDWR, unpublished data). Because of the concerns about population declines in an area where habitats were within published guidelines, the UDWR, USFS, and Utah State University initiated a sage-grouse translocation project in 2009. The sage-grouse population that inhabited Parker Mountain in south-central Utah was selected as the source population because it was deemed stable by the UDWR and was genetically compatible with the sage-grouse population on Anthro Mountain (Smith 2009). Translocation protocols, in compliance with Utah Greater Sage-grouse Management Plan (UDWR 2009), were based on the long-term translocation research conducted in Strawberry Valley. Strawberry Valley also used Parker Mountain as the source for the translocation efforts (Baxter et al. 2008).

The first phase of the Anthro Mountain project documented the effects of sage-grouse translocations on the population during the first two years after initial release (Gruber 2012). This study compared adult and chick survival of translocated and resident

hens as well as the nest success of each cohort. Gruber (2012) also investigated the integration of translocated sage-grouse into Anthro Mountain's population through flocking tendencies and by comparing translocated sage-grouse seasonal movements to resident birds.

## **RESEARCH PURPOSE**

The purpose of my research was to determine the impacts of the translocation to Anthro Mountain's population four years after initial release. In Chapter 2, I compared long-term annual and seasonal survival rates in two translocated populations to the source population to determine if survival differed between populations and among cohorts. This chapter answered the question: Were long-term seasonal and annual survival rates of resident and translocated hens on Anthro Mountain similar to those observed for Strawberry Valley and/or the Parker Mountain source population?

Chapter 3 focused on the ecology of sage-grouse in Anthro Mountain's translocated population and compared the vital rates of resident and translocated hens to determine their relative contribution to the population. This chapter answered two questions: 1) What were the vital rates and relative contributions of sage-grouse on Anthro Mountain and 2) Did the sage-grouse translocation augment the resident population on Anthro Mountain four years after initial release?

Chapter 4 compared seasonal movements, habitat use and home-ranges of resident and translocated sage-grouse on Anthro Mountain. This chapter answered the questions: 1) Did habitat use at reproductive sites differ for translocated and resident hens

on Anthro Mountain and 2) Did home-range differ for translocated and resident hens on Anthro Mountain?

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**CHAPTER 2**

**GREATER SAGE-GROUSE HEN SURVIVAL IN RESIDENT AND  
TRANSLOCATED POPULATIONS IN UTAH**

**ABSTRACT**

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) have experienced range-wide declines with some local populations exhibiting sudden short-term decreases. Adult hen survival has been identified as an important vital rate driving population growth. Translocations have been successfully used as a management strategy to augment declining native wildlife populations including upland game birds. However, sage-grouse translocations have had limited success because translocated birds released into unfamiliar habitats may exhibit survival rates lower than those of resident and source populations. I analyzed average annual and seasonal survival rates for resident and translocated hens in two translocated populations in Utah (Anthro Mountain and Strawberry Valley) to determine if they differed from the source population (Parker Mountain, Utah). Although each study area approximated the recommended habitat parameters, they differed in the amount of available contiguous habitat, site management, predator communities, and anthropogenic disturbances. The top survival model, which contained 14% of the AIC weight, indicated that survival was most influenced by the additive effect of study area and hen age, but was not affected by residency status. All hens on Parker Mountain and in Strawberry Valley had similar annual survival (0.56, 95% Confidence Interval (CI) = 0.51–0.60) which was higher than survival of all hens on Anthro Mountain (0.40, CI = 0.31–0.50). Adult hens on Parker Mountain and in

Strawberry Valley had the highest survival (0.59, CI = 0.53–0.64) followed by yearling hens in these 2 areas (0.52, CI = 0.46–0.59). Adult hens on Anthro Mountain had an annual survival of 0.43 (CI = 0.33–0.54); yearling hens had the lowest survival of all cohorts (0.36, CI = 0.26–0.48). Range-wide sage-grouse survival is typically lowest during the spring breeding season, but survival on Anthro Mountain was lowest from August through October (0.67, CI = 0.56–0.76) and highest in winter (0.97, CI = 0.91–1.0). Conversely, Parker Mountain and Strawberry Valley sage-grouse populations exhibited seasonal survival trends similar to other populations range-wide. Seasonal survival on Parker Mountain was lowest in the spring and summer (0.73, CI = 0.67–0.78) and highest from September through November (0.98, CI = 0.94–1.0). Seasonal survival in Strawberry Valley was lowest in the spring (0.78, CI = 0.73–0.83) and highest from August through October (0.87, CI = 0.82–0.92). Although the translocation and source populations were in relatively close proximity, sage-grouse seasonal and annual survival varied for the three populations. Site specific influences, such as land use patterns and predator management, may account for the observed differences in survival for these distinct populations. Because of the site specific influences on individual population vital rates, managers should not employ a comprehensive management regime based solely on recommended literature guidelines. They should manage each population according to unique landscape characteristics and habits of the population, and limiting factors should be mitigated. My research also demonstrated that managers should consider environmental factors for resident and source populations when planning sage-grouse translocations.

## INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) are dependent on sagebrush (*Artemisia* spp.) communities throughout their range for seasonal food and cover (Griner 1939). They were once found in 16 western states and 3 Canadian provinces, but now occur in 11 states and 2 Canadian provinces (Connelly and Braun 1997, Schroeder et al. 2004). Based on lek counts, populations have declined range-wide with some populations facing increased risk of extirpation (Garton et al. 2011). Sage-grouse populations in Utah have mirrored range-wide trends and currently occupy less than 50% of their historical distribution (Beck et al. 2003).

Stakeholders concerned about declining sage-grouse populations petitioned the U.S. Fish and Wildlife Service (USFWS) to list the species for protection under the Endangered Species Act of 1973. In 2010, USFWS concluded that listing the sage-grouse was warranted but precluded from listing by species of higher concern. The USFWS cited continued habitat loss and fragmentation as well as inadequate regulatory mechanisms as the greatest threats to the existence of the species.

Compared to other galliformes, sage-grouse are relatively long-lived with low fecundity rates (Schroeder et al. 1999). Therefore, adult hen survival constitutes an important component of population growth (Dahlgren 2009, Taylor et al. 2012). Annual survival rates of female sage-grouse range from 37–78% (Connelly et al. 2011a). Survival rates in some local populations may vary little while others exhibit drastic seasonal and annual swings (Zablan et al. 2003, Beck et al. 2006, Moynahan et al. 2006).

Additionally, populations that migrate long distances may exhibit lower annual survival than more sedentary or non-migratory populations (Beck et al. 2006).

Site-specific factors such as weather, predation, and disease affect survival and can vary by year, season, and geographic location (Johnson and Braun 1999, Naugle et al. 2004, Holloran 2005, Moynahan et al. 2006, Taylor et al. 2012). Late summer and winter are typically periods of high survival, while survival is lower during the spring breeding season (Connelly et al. 2000a, Naugle et al. 2004, Moynahan et al. 2006, Hagen 2011). Conversely, extreme winter weather and snows can reduce winter survival rates by impacting forage availability (Patterson 1952).

Predation constitutes the major source of sage-grouse mortality, but no predators specialize in sage-grouse. Thus, Hagen (2011) did not consider predation a limiting factor in most populations (Hagen 2011). Increased predation during the breeding season resulted in lower spring survival in Montana (Naugle et al. 2004, Moynahan et al. 2006). Survival rates are also affected by disease; for example, West Nile virus outbreaks in Montana and the Dakotas contributed to high mortality from July through October (Moynahan et al. 2006, Walker 2008, Swanson 2009).

Because sage-grouse are dependent on sagebrush communities, sufficient amounts of high quality habitat are important for stable populations (Connelly et al. 2000b, Schroeder and Baydack 2001). Therefore, protection and restoration of important habitats remains a high conservation priority range-wide. In areas where populations have declined while habitat conditions remained stable, managers have sought to augment populations through translocations.

A translocation is the intentional moving of animals from one portion of their range to another to establish or augment a declining population (Griffith et al. 1989, Dickens et al. 2009). Wildlife managers have successfully used translocations as a management tool to augment extirpated or declining wildlife populations for both game and nongame species including native upland game birds (Griffith et al. 1989, Snyder et al. 1999). Griffith et al. (1989) estimated an 86% translocation success rate for all native bird and mammal game species.

Translocated individuals that are unfamiliar with habitat in the release site may have lower survival than residents of the population (Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor et al. 2012). Translocated game birds may exhibit variability in seasonal and annual survival rates. Research conducted in Utah on established and self-sustaining non-native chukar (*Alectoris chukar*) populations found seasonal survival was lowest during peak fall raptor migration periods (Robinson et al. 2009). Female ring-necked pheasant (*Phasianus colchicus*) translocated in central Missouri were found to have lower survival in the spring than during other seasons (Wilson et al. 1992).

Biologists have attempted sage-grouse translocations to augment declining populations in areas where habitat conditions approximate the recommended guidelines for sustainable populations (Reese and Connelly 1997, Connelly et al. 2000b, Baxter et al. 2008). Sage-grouse translocations have been attempted multiple times in 7 states and one Canadian province since the early 1930s; most of these releases occurred in the fall (Reese and Connelly 1997). Despite these attempts, published information regarding

impacts to the populations is limited. Published and anecdotal information suggests that translocated sage-grouse show little fidelity to their release site unless there is a geomorphic barrier to movement, even when relocated to suitable habitat (Musil et al. 1993).

Although most previous sage-grouse translocations failed to provide criteria for evaluating success, Reese and Connelly (1997) estimated that 5% of sage-grouse translocations were successful compared to a 32% success rate for other grouse species in the United States (Snyder et al. 1999). This low success rate was based on the fact that population numbers remained low following sage-grouse translocations (Reese and Connelly 1997). Musil et al. (1993) found that translocated sage-grouse reproduced successfully and recommended that this management practice could be useful in restoring certain populations. However, because of low success rates, Reese and Connelly (1997) warned that sage-grouse translocations should be viewed as experimental. They further stressed that adequate monitoring is necessary to assess the fate of the translocations.

In Utah, two sage-grouse translocation efforts have been conducted. On the Wildcat Knolls, 18 males and 35 hens were released by Utah Division of Wildlife Resources (UDWR) biologists from 1987–1990 in sagebrush habitat not previously inhabited by sage-grouse. The released sage-grouse were not radio-collared and the success of the translocation was evaluated by lek counts and establishment of new leks (Perkins 2010). In 2008, 27 males were counted on leks during the peak lek attendance (UDWR 2009, Perkins 2010). The persistence of the population 21 years after the initial translocation suggested that the translocation was successful (UDWR 2009). The release

site consisted of a small, isolated high elevation plateau surrounded by non-habitat areas. The plateau and characteristics of the surrounding area may have discouraged bird dispersal.

The second translocation was conducted in Strawberry Valley, Utah over a period of 6 years (Baxter et al. 2013). Strawberry Valley is a montane valley surrounded by high mountain ridges and was historically occupied by as many as 3,000–4,000 sage-grouse (Griner 1939). Immediately prior to sage-grouse translocation efforts, this population declined to an estimated 150 breeding sage-grouse (Bunnell 2000). Red fox (*Vulpes vulpes*) were indicated as a major factor limiting sage-grouse population growth in Strawberry Valley, and intensive predator management was practiced from 2000–2010 to reduce mammalian predator populations (Baxter et al. 2009). From 2003 through 2008, 336 hens from 4 different source populations were translocated to the area (Baxter et al. 2013). Movement and vital rates of radio-marked translocated sage-grouse, as well as population estimates from lek counts, were used to measure the success of the translocation (Baxter 2007).

The high mountain ridges surrounding Strawberry Valley provided a geomorphic barrier that discouraged translocated sage-grouse from leaving the area (Musil et al. 1993, Baxter 2007). Additionally, Baxter et al. (2008) reported that releasing hens near active leks in the spring increased site fidelity of translocated hens. Translocated hen survival rates were comparable to range-wide estimates of hens in resident populations (Baxter et al. 2013). Translocations were discontinued when Strawberry Valley's population increased to approximately 500 breeding birds and remained stable (UDWR 2009).

Baxter et al. (2008) concluded that adult hen survival, chick survival, and nest success, metrics which may most influence population growth rates, were important to the success of the sage-grouse translocation efforts in Strawberry Valley (Johnson and Braun 1999, Dahlgren 2009, Guttery 2011, Taylor et al. 2012).

Based on the success of these translocation projects in Utah, the Utah Greater Sage-grouse Management Plan considered translocations as a viable management tool for enhancing sage-grouse populations in the state (UDWR 2009). The plan stated that “translocations may be used to augment populations where  $\leq 165$  males ( $\leq 500$  adult sage-grouse) make up the breeding population, or an increase in genetic diversity is warranted.” The UDWR cautioned biologists to consider site differences when using this management tool and stated that translocations in Utah should employ Baxter et al. (2008) protocols.

From 2002 through 2006, U.S. Forest Service (USFS) biologists in the Ashley National Forest used radio-telemetry to monitor sage-grouse habitat use and vital rates on Anthro Mountain in northeastern Utah (Fig. 2-1). Resident hen survival over this period was similar to estimates reported range-wide (B. Christensen 2007, USFS Ashley National Forest, unpublished report). The report concluded that Anthro Mountain provided nesting, brood rearing, and wintering habitats that approximated recommended habitat guidelines (Connelly et al. 2000*b*).

Despite having adequate year-round habitat, Anthro Mountain’s sage-grouse population declined from 2006 to 2008 based on lek count indices (44 males in 2006 to 13 males in 2008; B. Maxfield, UDWR, unpublished data). Because of concerns about

population declines in areas where habitats were within published guidelines, the UDWR, USFS, and Utah State University (USU) initiated a sage-grouse translocation project in 2009.

The sage-grouse population that inhabited Parker Mountain in south-central Utah was selected as the source for translocations because it was considered stable and genetically compatible with Anthro Mountain's sage-grouse population (Smith 2009, UDWR 2009; Fig. 2-1). Vital rates and habitat use of sage-grouse on Parker Mountain were monitored from 1997 through 2009 (Chi 2004, Dahlgren 2006, 2009, Caudill 2011, Guttery 2011). Translocation protocols were based on the long-term translocation research conducted in Strawberry Valley which also used sage-grouse from Parker Mountain (Baxter et al. 2008, UDWR 2009).

During the first phase of Anthro Mountain's translocation project, Gruber (2012) reported that translocated sage-grouse had similar survival and reproductive success as residents, but that both rates were low compared to range-wide estimates. Additionally, translocated sage-grouse integrated into the population and displayed movement patterns similar to residents. Gruber (2012) concluded that the overall effect of the translocation was inconclusive and cited low survival and low reproductive success as the reasons for this finding.

The objectives of my study were to: 1) estimate average annual survival of hens in Anthro Mountain, Strawberry Valley, and Parker Mountain populations, and 2) determine if residency status in the population affected survival. I hypothesized that survival would vary by study area, age, and residency status.

## STUDY AREA

### Anthro Mountain, Utah

Anthro Mountain was located in Ashley National Forest in Duchesne County, Utah approximately 29 km southeast of the town of Duchesne (Fig. 2-1). This high elevation mountain big sagebrush (*A. tridentata ssp. vaseyana*) community contained approximately 2,500 ha of suitable sage-grouse habitat. Pockets of quaking aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii*) were intermixed throughout the sagebrush, and black sagebrush (*A. nova*) was found on ridge tops across the mountain. Dense, expansive stands of two-needle pinyon pine (*Pinus edulis*) and juniper (*Juniperus* spp.) (together, PJ) surrounded the mountain at the lower elevations and were encroaching on the sagebrush community. Other native vegetation included: gray horsebrush (*Tetradymia canescens*), serviceberry (*Amelanchier utahensis*), rabbitbrush (*Chrysothamnus viscidiflorus*), snowberry (*Symphoricarpos oreophilus*), lupine (*Lupinus argenteus*), June grass (*Koeleria macrantha*), basin wildrye (*Leymus cinereus*), salina wildrye (*L. salinus*), and bluebunch wheatgrass (*Elymus spicatus*). Smooth brome (*Bromus inermis*) was seeded in the 1950s in portions of the area.

Anthro Mountain received an average of 49 cm of precipitation annually. The majority of the precipitation occurred as heavy snows in winter and rain during the monsoon season in July and August. Anthro Mountain ranged from 2,400–2,800 m in elevation and was bordered by the Uintah Basin to the north and east, Gilsonite Canyon to the south, and Indian canyon to the west, all of which were lower in elevation than Anthro Mountain.

The current and historical land use was domestic livestock grazing (Thacker 2010). Sage-grouse hunting was not allowed on Anthro Mountain. In 2010, U.S. Department of Agriculture, Animal and Plant Health Inspection Services, Wildlife Services (WS) placed poison eggs on Anthro Mountain to remove corvids near active sage-grouse lekking and nesting sites. Although WS occasionally removed mammalian predators for livestock protection on Anthro Mountain, they did not intensively control predators for sage-grouse management as was practiced in the Strawberry Valley translocation.

Mammalian predators that inhabited Anthro Mountain included: coyote (*Canus latrans*), red fox, gray fox (*Urocyon cinereoargenteus*), mountain lion (*Puma concolor*), badger (*Taxidea taxus*), and long-tailed weasel (*Mustela frenata*). Raptors were observed using Anthro Mountain throughout the year. Avian predators detected on Anthro Mountain included: red-tailed hawk (*Buteo jamaicensis*), rough-legged hawk (*B. lagopus*), American kestrel (*Falco sparverius*), common raven (*Corvus corax*), golden eagle (*Aquila chrysaetos*), Cooper's hawk (*Accipiter cooperii*), northern harrier (*Circus cyaneus*), and sharp-shinned hawk (*A. striatus*). We also detected great-horned owls (*Bubo virginianus*) on several occasions while trapping in the spring of 2011 and 2012.

### **Parker Mountain, Utah**

Parker Mountain, the source of the translocated sage-grouse, was located in south-central Utah approximately 218 km southwest of Anthro Mountain (Fig. 2-1). Parker Mountain exhibited one of the largest contiguous sagebrush ecosystems in Utah (Chi 2004). This high elevation sagebrush ecosystem was characterized by rolling hills and

gently northeastern sloping plateaus (Chi 2004). The ridges and slopes were dominated by black sagebrush while mountain big sagebrush, bitterbrush (*Purshia tridentata*), and rabbitbrush were found in the drainages. Grasses commonly found on Parker Mountain included grama grass (*Bouteloua* spp.), wheatgrass, bluegrass (*Poa* spp.), squirreltail grass (*E. elymoides*), needlegrass (*Hesperostipa* spp.), and June grass.

Parker Mountain experienced hot, dry summers and received 25–51 cm of annual precipitation, most of which accumulated in the fall and winter (Chi 2004). Elevations on Parker Mountain ranged from 2,134–3,018 m. Parker Mountain was situated on 2 plateaus and was bounded by an escarpment to the west and Rabbit Valley to the east.

Coyotes were the predominant mammalian predator on Parker Mountain. Common avian predators detected on Parker Mountain were: red-tailed hawk, American kestrel, golden eagle, prairie falcon (*F. mexicanus*), and common raven (Dahlgren 2006, 2009). Previous research concluded that golden eagles were the main predators of adult sage-grouse on Parker Mountain (Chi 2004, Dahlgren 2006).

The predominant land use on Parker Mountain was season-long deferred-rotation livestock grazing from late May through October (Guttery 2011). Livestock entered lower elevation pastures in late May and moved to higher pastures as vegetation matured using a three pasture rotation. For livestock protection, mammalian predators, particularly coyotes, were seasonally removed on Parker Mountain (Chi 2004). Additionally, Wayne County, Utah, the county in which most of Parker Mountain was situated, had a bounty on coyotes which may have resulted in additional coyotes taken

from the study area (Chi 2004). The sage-grouse population on Parker Mountain was one of two hunted populations in Utah.

### **Strawberry Valley, Utah**

Strawberry Valley was located in north-central Utah approximately 68 km east of Anthro Mountain (Fig. 2-1). This montane sagebrush-steppe community had over 9,000 ha of sagebrush habitat (Baxter et al. 2008). Mountain big sagebrush was the predominant shrub with silver sagebrush (*A. cana*) found in wet meadows and riparian areas. Strawberry Valley experienced cool dry summers and cold wet winters and received about 58 cm of precipitation annually (Baxter 2007). Strawberry Valley ranged from 2,330–3,050 m in elevation and was surrounded by mountain ridges and high mountain meadows. The dominant feature in the valley was Strawberry Reservoir which covered approximately 6,950 ha.

Mammalian predators common to Strawberry Valley included coyotes, red fox, and raccoons. Avian predators, including many raptor species and corvids, were detected in Strawberry Valley (R. Baxter, USFS, personal communication). To aid in the translocation effort, WS conducted an active predator control program. Aggressive predator removal management was conducted from 2000–2010. During this time, WS targeted and removed invasive mammalian and avian predator species which included red foxes, raccoons (*Procyon lotor*), and corvids (Baxter et al. 2009).

## METHODS

*Field Techniques* – The UDWR and USU translocated 60 radio-marked female sage-grouse (30 yearlings and 30 adults) from Parker Mountain to Anthro Mountain in the spring of 2009 and 2010 (Gruber 2012). Thirty-two resident female sage-grouse (21 yearlings and 11 adults) were captured and radio-marked from 2009–2012 on Anthro Mountain.

Sage-grouse were captured by spotlighting roost sites at night; grouse were netted with long-handled hoop nets from the back of an all-terrain vehicle or on foot (Giesen et al. 1982, Wakkinen et al. 1992). Handling protocols were approved by Utah State University Institutional Animal Care and Use Committee (Permit # 1404). We determined the sex and age of each grouse using plumage characteristics outlined by Beck et al. (1975). Each captured sage-grouse was fitted with a necklace-mounted radio-transmitter equipped with an 8 hour mortality switch (Advanced Telemetry Systems, Insanti, MN and American Wildlife Enterprises, Monticello, FL). We bent the antenna to rest along the back of the sage-grouse to minimize interference with movement. After fitting the transmitter, the hens were weighed with a Pesola scale™ (Pesola, Zeg, Baar, Switzerland). For each grouse captured, we recorded the time and UTM coordinates (NAD 83) of the capture site and release time. We also recorded any injuries and comments about the bird's condition or behavior upon release.

Translocation followed protocols outlined by Baxter et al. (2008) and Reese and Connelly (1997). Each captured hen was placed in an individual cardboard box with holes for ventilation and transported overnight by vehicle to Anthro Mountain for release.

The hens were released during hours of breeding activity approximately 100 m from an established lek. Reese and Connelly (1997) recommended that translocated grouse be released in an area of sagebrush habitat that is surrounded by a barrier to movement. Although Anthro Mountain exhibited contiguous sagebrush habitat, there was no geomorphic barrier to dispersal from the release site (Baxter et al. 2008). The release was considered to be remote and isolated by areas of non-habitat. The non-habitats areas did not impede winter dispersal of resident birds (Gruber 2012, this study Chapter 4)

Survival of all collared sage-grouse in Anthro Mountain's population was monitored weekly from April through September. Radio-marked sage-grouse were located opportunistically from October through March due to logistic constraints caused by snow pack. All monitoring was conducted with on the ground telemetry and lasted from March 2009 through March 2013. Radio-collars that remained in one location for 8 consecutive hours broadcasted a faster pulse known as a mortality signal. If we detected a mortality signal, the date and time that it was first detected was recorded and used when analyzing survival.

Long-term sage-grouse research projects have been conducted on Parker Mountain and in Strawberry Valley. Researchers on Parker Mountain collected monthly hen survival data from 1998 through 2009 and compiled a robust dataset of monthly survival encounters using similar techniques as described above. Similarly, researchers began monitoring vital rates, movements, and habitat use of resident hens in Strawberry Valley in 1998. To bolster a declining population in Strawberry Valley, biologists translocated hens to the area from 2003 to 2008 from four different source populations

including Parker Mountain (Baxter et al. 2013). During this period, researchers monitored survival of translocated and resident hens monthly.

*Data Analysis.* – Survival data collected from tracking radio-marked hens was used to estimate survival. The ragged nature of the telemetry data was best suited for estimating monthly survival rates (MSR) of marked hens using the nest survival model in program MARK (White and Burnham 1999). The nest survival model allows for staggered entry, irregular monitoring of marked individuals, and right-censoring of missing individuals (Rotella et al. 2004). I used the R (R Development Core Team 2011) package RMark (Laake and Rexstad 2008) to construct nest survival models (White and Burnham 1999). Encounter histories for all populations were formatted into months beginning 1 April and ending 31 March.

Research conducted in the three populations did not occur in overlapping years; therefore, I could not directly compare inter-annual variation in survival for each population. Instead I examined the effects of hen age and residency status on average survival for each population. Hen survival was modeled as a function of study area (Anthro Mountain, Parker Mountain, or Strawberry Valley), residency status (newly translocated hens, translocated hens that survived at least one year in the release area, or resident hens), and hen age (yearling, adult). In addition to the null model, 18 *a priori* models were developed to test for variation in survival by study area, residency status, and age (Table 2-1).

Using the logit-link function, I obtained the maximum likelihood estimates of each model to test for variation in survival (Dinsmore et al. 2002, Rotella et al. 2004). I

used Akaike's Information Criterion adjusted for sample size to select the best estimating model for survival across all demographic parameters (AICc; Akaike 1973, Burnham and Anderson 2002). Estimates of variance and 95% confidence intervals were calculated using the delta method (Seber 1982).

Although I could not directly compare temporal variation in survival, I wanted to examine trends in seasonal survival for each population. In addition to the null model, I developed 10 *a priori* models to test for seasonal survival trends in each population (Table 2-2). I used Akaike's Information Criterion adjusted for sample size to select the model that best describes seasonal survival in each study area (AICc; Akaike 1973, Burnham and Anderson 2002). Estimates of variance and 95% confidence intervals were calculated using the delta method (Seber 1982). I then compared the overall seasonal survival trends for the three populations.

## **RESULTS**

Individual survival histories were recorded for 402 resident hens from 1998 through 2009 for Parker Mountain. In Strawberry Valley, survival histories for 284 resident and translocated hens were recorded from 1998–2008. Of these 284 hens, 60 were residents and 224 were translocated hens from Parker Mountain. From 2009–2012, individual survival encounters for 123 hens were recorded on Anthro Mountain and analyzed. Forty-four encounters were of resident hens and 79 were of translocated hens.

The top model testing for differences in survival indicated that average annual survival was most influenced by study area and hen age (Table 2-3). Parker Mountain and Strawberry Valley hens experienced similar survival and survival in both study areas

was higher than that on Anthro Mountain (Table 2-4). Additionally, adult hen survival was consistently higher than yearling hen survival in each of the study areas. Strawberry Valley and Parker Mountain adult hens had highest annual survival (0.59, 95% Confidence Interval (CI) = 0.53–0.64) followed by yearlings in the two study areas (0.52, CI = 0.46–0.59). Adult hens on Anthro Mountain had an annual survival of 0.43 (CI = 0.33–0.54) while yearling hens on Anthro Mountain experienced the lowest survival of all cohorts (0.36, CI = 0.26–0.48). Average annual survival of all hens in Strawberry Valley and on Parker Mountain was 0.56 (CI = 0.51–0.60) while all hens on Anthro Mountain had an average annual survival of 0.40 (CI = 0.31–0.50).

The model that best described temporal variation in survival on Anthro Mountain indicated that seasonal survival was consistently lowest from August through October (0.67; SE = 0.024) and was highest from November through March (0.97; SE = 0.0064). Conversely, seasonal survival rates on Strawberry Valley was lowest from April through July (0.78; SE = 0.0077) and highest from August through October (0.87; SE = 0.0095). On Parker Mountain, seasonal survival rates were lowest from April through August (0.73; SE = 0.0067) and highest from September through November (0.98; SE = 0.0067; Fig. 2-2).

## **DISCUSSION**

Adult hen survival is one of the most important vital rates driving population growth (Dahlgren 2009, Taylor et al. 2012). Translocated sage-grouse that are unfamiliar with habitat in the release site are likely to have reduced survival compared to residents in the population (Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor

et al. 2012). Although I hypothesized that translocated hens would have lower survival rates than residents on Anthro Mountain and in Strawberry Valley, there were no apparent effects of residency status on survival for any of the populations.

Hens on Anthro Mountain experienced lower annual survival, regardless of residency status or age, than hens in Strawberry Valley and on Parker Mountain, the source population. Both translocated and resident hens in Strawberry Valley had similar survival to resident hens in the source population, Parker Mountain. Adult hens had higher survival than yearlings regardless of study area or residency status.

I attempted to remove inter-annual variation in survival by ignoring the year effect and averaging annual survival across the research period for each study area. By averaging survival across the period of study, I attempted to remove the effects that an individual year might have on the survival rates. Because research in the 3 study areas was not conducted in the same years, my results may be slightly skewed.

Resident and translocated hens on Anthro Mountain had slightly higher average survival than the average survival of translocated sage-grouse in Idaho (0.36; SE  $\pm$ 0.07), but survival was at the low end of range-wide estimates for resident sage-grouse (37–78%; Connelly et al. 2011a). Average survival of resident and translocated hens in Strawberry Valley and resident hens on Parker Mountain was notably higher than survival of sage-grouse translocated in Idaho (0.36; SE  $\pm$ 0.07), but it was in the median of the reported range-wide survival rates (Musil et al. 1993, Connelly et al. 2011a).

Range-wide, late summer is typically a period of high survival while spring is a period of lower survival (Connelly et al. 2000a, Naugle et al. 2004, Moynahan et al.

2006, Hagen 2011). Seasonal survival on Parker Mountain and in Strawberry Valley mirrored the range-wide seasonal trends; monthly survival was consistently lower during the spring breeding season and higher in the fall and winter. Conversely, late summer and fall were periods of low survival on Anthro Mountain while spring survival was relatively higher.

Survival may have varied by population due to several factors including: amount of quality habitat, predator community dynamics and management regimes, migratory status, and anthropogenic disturbances. Sage-grouse require a mosaic of large, contiguous patches of sagebrush patches within their annual range and they are more likely to be affected by habitat fragmentation than generalist species because fragmentation can hinder movement between important seasonal areas (Leu et al. 2008, Sawyer et al. 2009).

Anthro Mountain, the study area with the lowest average survival, contained the least amount of suitable sage-grouse habitat (2,500 ha). In addition to having a smaller amount of suitable habitat, Anthro Mountain's sagebrush community was isolated by dense, expansive stands of PJ that surrounded the mountain. The dense PJ stands were also encroaching into the sagebrush habitat at lower elevations and diminishing the inhabitable area. The long sagebrush ridges that characterized Anthro Mountain were fragmented by intermixed pockets of quaking aspen and Douglas-fir and were separated by steep canyons. Anthro Mountain was further fragmented by two-tracks, low maintenance gravel roads and recent exploratory energy development. In Strawberry Valley, the development of Strawberry Reservoir resulted in direct habitat loss and

increased fragmentation. The remaining habitats in Strawberry Valley were intact stands of dense sagebrush that was treated to enhance sage-grouse breeding habitats. Parker Mountain was part of the largest contiguous sagebrush ecosystem in Utah (Chi 2004). Although Parker Mountain exhibited a well-defined network of two-tracks, fragmentation was limited (Dahlgren 2009, Caudill 2011). Neither Strawberry Valley nor Parker Mountain were impacted by energy development and PJ encroachment was minimal.

Predator management regimes might partially explain discrepancies in survival between the populations. Although no predators specialize in sage-grouse, predation has been identified as a factor that limits sage-grouse populations, particularly in fragmented landscapes (Braun 1998, Hagen 2011). Anthro Mountain and Strawberry Valley were fragmented landscapes with large amounts of edge predators including coyotes and red fox (Baxter et al. 2009). Despite this similarity, Strawberry Valley experienced higher overall survival than Anthro Mountain. Although WS occasionally removed coyotes from Anthro Mountain, intensive predator management was not practiced on Anthro Mountain as was practiced in Strawberry Valley. Intensive mammalian predator control was conducted from 2000–2010 in Strawberry Valley to improve sage-grouse survival and the practice appeared to be successful (Baxter et al. 2008, 2009). Intensive predator management was also practiced on and around the vast sagebrush ecosystem of Parker Mountain to reduce livestock depredations and for sport (Guttery 2011). Parker Mountain and Strawberry Valley had the highest survival of the three populations.

High quality habitat is important for reducing the effects of predation, and given an adequate amount of quality habitat, game birds can thrive in spite of predation by

native predators (Connelly et al. 2000b, Schroeder and Baydack 2001, Hagen 2011). Research on northern bobwhite (*Colinus virginianus*) suggested that predator removal is more effective at boosting survival in low-quality habitat than in high-quality habitat (Hagen 2011). However, when predator removal was practiced, fluctuations in survival were stabilized in both landscapes. Parker Mountain contained an expansive and intact sagebrush community that may have protected sage-grouse from exposure to predators. Although Strawberry Valley was more fragmented than Parker Mountain, the area contained vast amounts of high quality sage-grouse habitat. Anthro Mountain, on the other hand, had highly fragmented, low-quality habitat which may have resulted in increased exposure to predators. Therefore, the most effective long-term management on Anthro Mountain may be through increasing and improving overall habitat quality (Schroeder and Baydack 2001, Hagen 2011).

Differences in habitat scales and migration pathways in the study areas may have affected overall survival. Migration is an important component of an organism's life history because it connects multiple areas of discrete resources that are necessary for completing life cycles. Some sage-grouse populations migrate from breeding areas to wintering areas. Migrations typically occur along a broad network of routes and in a stepping-stone manner that allows the sage-grouse to rest and refuel (Sawyer et al. 2009, Smith 2013). During stopovers, sage-grouse select features similar to their summer and winter ranges while avoiding habitats that provide little cover or food (Smith 2013). Intact systems provide the necessary stepping stones while fractured landscapes can

hinder populations from moving between important seasonal habitats (Leu et al. 2008, Sawyer et al. 2009).

The sage-grouse on Anthro Mountain migrate to disconnected areas in multiple directions during the winter and migrations averaged 30–35 km (see Chapter 4). To reach these wintering areas, sage-grouse pass over unsuitable habitat and fractured landscapes. The fractured landscapes are dominated by pinyon and juniper and contain very little sagebrush cover for stopping over. When snow covers food sources, sage-grouse in Strawberry Valley are forced to migrate through a narrow corridor of suitable habitat as they move to their wintering areas (R. Baxter, USFS, personal communication). Sage-grouse rarely leave Parker Mountain, and migration occurs on an elevational scale. When snow pack covers food resources at the higher elevations, Parker Mountain sage-grouse will move through quality habitat to winter in suitable habitat at lower elevations (M. Guttery, USU, personal communication). The varying levels of stresses placed on migrating grouse in these 3 populations might decrease body conditions and lead to the varying survival rates.

Based on information provided by UDWR and USFS biologists in each area, the scale of human disturbance might also explain the differences in survival between the 3 populations. Studies have demonstrated that development negatively impacts sage-grouse because it prohibits dispersal and migratory movements (Walker et al. 2007, Doherty et al. 2008, Tack et al. 2011, Smith 2013). In addition to prohibiting movement and reducing habitat, anthropogenic disturbances elicit a response of avoidance, higher stress levels, and lower fitness (Smith 2013). Ultimately, these stresses reduce body

conditions and lower survival rates; the reduced body conditions make it more difficult to perform breeding rituals and raise broods while avoiding predators (Thiel et al. 2008).

Anthro Mountain, the area with the lowest survival, was highly fragmented and experienced substantial anthropogenic influences. Two-track roads in the summer range received heavy recreational use by ATV riders and hunters. Four exploratory oil wells were located in Anthro Mountain's sage-grouse breeding range. Additionally, Anthro Mountain's wintering areas and non-habitat migration pathways were highly fragmented by energy development. Although there was a heavy human presence in Strawberry Valley, it consisted of recreational activity primarily focused around the reservoir and did not extend into the sagebrush habitat; energy development was non-existent in Strawberry Valley. Parker Mountain had a large network of unimproved roads that received low, dispersed recreational use. Thus, recreational uses on Parker Mountain, a much larger area, were more dispersed than on Anthro Mountain. Similar to Strawberry Valley, Parker Mountain was not impacted by energy development.

## **MANAGEMENT IMPLICATIONS**

Fluctuations in adult hen survival have a large effect on population growth, and adult survival is the most influential when populations are rapidly declining (Davis 2012). Simulation studies indicated that translocating all yearling hens resulted in an increase in both the overall population size and the mean extinction time in translocated populations (Davis 2012). No difference in survival was observed for resident and translocated hens; however, adult hens had a higher survival rate than yearlings regardless of the study area or residency status. Because yearling and adult survival play

different but vital roles in population growth, managers should consider moving both yearling and adult hens. Because adults had higher survival, though, managers should consider moving a higher proportion of adults when conducting translocations.

Although translocations generally improve population persistence, specific attributes within the release area might drive the overall success of sage-grouse translocations (Griffith et al. 1989, Rout et al. 2007, Davis 2012). My results indicated that, although characteristics at the release site differed from the source site, translocated sage-grouse experienced similar survival to residents in the release site. However, overall survival varied greatly between the 3 study areas. Because of this, managers should focus efforts on improving overall survival in each individual population, particularly those that warrant translocations.

Despite populations being in close proximity, there were stark differences in the factors influencing survival in each population. The difference in average annual and seasonal survival for each population is further evidence of the effects of site-specific characteristics. Managers should not employ a comprehensive management regime based solely on recommended literature guidelines. To enhance the success of sage-grouse translocations, unique characteristics in each population should be considered and limiting factors should be remedied prior to translocations.

Management actions that increase adult survival rates past their natural bounds should be considered for reversing populations in steep decline or improving the success of translocations (Davis 2012). Because quality habitat in sufficient amounts is important for reducing the effects of predation, managers should work to provide optimal habitat for

the sage-grouse population. If habitat restoration cannot be achieved in a timely manner in areas where predation rates result in low survival, managers should consider predator reduction programs (Hagen 2011). These programs might protect a sink population and reduce fluctuations in annual survival (Connelly et al. 2000*b*). In the case of Strawberry Valley, intense predator removal was necessary to increase survival and the success of the translocation efforts (Baxter et al. 2008, 2009). Predator reductions might also buffer translocated sage-grouse from predation as they adapt to the new area.

Lastly, understanding the movements and needs of migrating wildlife is crucial, even more so when considering translocations. To avoid severing migration corridors and compromising the population and the success of translocation efforts, managers should strive to determine migration corridors and seasonal destinations. By identifying these movements, managers will be able to make appropriate management decisions for each population. Examining seasonal movements will also assist with identifying areas where habitat can be improved to increase seasonal range connectivity. The increased connectivity will benefit translocated and resident sage-grouse by providing more opportunity to locate suitable habitat as they make their seasonal movements.

Additionally, managers should consider stopover points along the migration corridors of each population. Habitat improvements within the winter and summer ranges might not benefit translocated and resident sage-grouse if stopover habitats do not contain adequate food and cover for grouse to maintain body condition and avoid predators.

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Table 2 - 1. Models testing for variance in overall average survival of greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA from 2009–2013, in Strawberry Valley, Utah, USA from 1998–2008, and on Parker Mountain, Utah, USA from 1998–2009.

Model Name	Description
Null	No difference in survival
Group	Tests if there is a difference in survival between groups (Parker Mountain vs. Anthro Mountain vs. Strawberry Valley)
HenAge	Tests if a difference exists for age of hen (yearling and adult)
SVPM	Tests if Anthro Mountain differs from both Strawberry Valley and Parker Mountain.
AgeGroup	Tests the additive effect of age and group
AgeSVPM	Tests the additive effect of age and the SVPM model
TransGroup	Tests the additive effect of translocated status (resident and translocated) and group
TransSVPM	Tests the additive effect of translocated status (resident and translocated) and the SVPM model
TransAgeGroup	Tests the additive effect of translocated status, age, and group
TransAgeSVPM	Tests the additive effect of translocated status, age, and the SVPM model
OrdinalGroup	Tests the additive effect of ordinal and group. Ordinal tests if first year translocated hens differ from translocated hens that survived $\geq 1$ year
OrdinalSVPM	Tests the additive effect of ordinal and the SVPM model. Ordinal tests if first year translocated hens differ from translocated hens that survived $\geq 1$ year
OrdinalAgeGroup	Tests the additive effect of ordinal, age, and group
OrdinalAgeSVPM	Tests the additive effect of ordinal, age, and group
BinGroup	Tests the additive effect of binomial and group. Binomial tests if translocated hens that survived $\geq 1$ year become like residents
BinSVPM	Tests the additive effect of binomial and the SVPM model. Binomial tests if translocated hens that survived $\geq 1$ year become like residents
BinAgeGroup	Tests the additive effect of binomial, age, and group
BinAgeSVPM	Tests the additive effect of binomial, age, and the SVPM model

Table 2 - 2. Models testing for trends in seasonal survival of greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA from 2009–2013, in Strawberry Valley, Utah, USA from 1998–2008, and on Parker Mountain, Utah, USA from 1998–2009.

Model Name	Description
Null	No difference for season or month
4 season	Gives survival estimates for months April–June, July–September, October–December, and January–March
Nesting 1	Model to test if survival varies by nesting season (April–May), summer (June–August), or fall/winter (September–March)
Nesting 2	Model to test if survival is lower in nesting season (April–May) than other times of year (June–March)
3 Season	Model to test if survival varies from April–July, August–November, and December–March
Monthly	Model to see if survival varies by month
Fall 1	Model to test if survival varies from April–July, August–October, or November–March
Fall 2	Model to test if survival varies from April–August, September–November, or December–March
Fall 3	Model to test if survival varies from April–August, September–October, or November–March
Fall 4	Model to test if survival varies from April–August, September–October, or November–March
Spring	Model to test if survival is lower in the spring (April–June) than at other times of the year

Table 2 - 3. Models assessing variation in overall average survival of greater sage-grouse (*Centrocercus urophasianus*) by study area and cohort on Anthro Mountain, Utah, USA from 2009–2013, in Strawberry Valley, Utah, USA from 1998–2008, and on Parker Mountain, Utah, USA from 1998–2009.

Model	k <sup>a</sup>	AICc <sup>b</sup>	ΔAICc <sup>c</sup>	wt <sup>d</sup>	Deviance
AgeSVPM	3	1805.29	0.000	0.144	1799.28
SVPM	2	1805.71	0.425	0.117	1801.71
BinAgeSVPM	4	1805.97	0.677	0.103	1797.96
BinSVPM	3	1806.07	0.784	0.097	1800.07
TransAgeSVPM	4	1806.11	0.823	0.096	1798.1
AgeGroup	4	1806.81	1.516	0.068	1798.8
TransSVPM	3	1806.89	1.598	0.065	1800.88
Group	3	1807.49	2.200	0.048	1801.48
OrdinalSVPM	4	1807.75	2.464	0.042	1799.74
TransAgeGroup	5	1807.93	2.640	0.039	1797.92
OrdinalAgeSVPM	5	1807.94	2.653	0.038	1797.93
BinGroup	4	1807.95	2.657	0.038	1799.94
BinAgeGroup	5	1807.97	2.680	0.038	1797.96
TransGroup	4	1808.83	3.544	0.025	1800.82
OrdinalGroup	5	1809.75	4.465	0.015	1799.74
OrdinalAgeGroup	6	1809.94	4.654	0.014	1797.93
HenAge	2	1811.29	6.003	0.007	1807.29
Null	1	1811.47	6.176	0.007	1809.46

<sup>a</sup> K: number of parameters in each model

<sup>b</sup> AICc: Akaike's Information Criterion corrected for small sample size

<sup>c</sup> ΔAICc: Difference between a model and the top performing model

<sup>d</sup> wt: Model weight

Table 2 - 4. Average annual survival estimates of greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA from 2009–2013, in Strawberry Valley, Utah, USA from 1998–2008, and Parker Mountain, Utah, USA from 1998–2009.

Group	Survival Estimate	Standard Error	95% Confidence Interval	
			Lower CI	Upper CI
SVPM Yearling <sup>a</sup>	0.52	0.033	0.46	0.59
SVPM Adult <sup>b</sup>	0.59	0.029	0.53	0.64
AM Yearling <sup>c</sup>	0.36	0.056	0.26	0.48
AM Adult <sup>d</sup>	0.43	0.054	0.33	0.54

<sup>a</sup> SVPM Yearling: Yearling hens in Strawberry Valley and on Parker Mountain

<sup>b</sup> SVPM Adult: Adult hens in Strawberry Valley and on Parker Mountain

<sup>c</sup> AM Yearling: Yearling hens on Anthro Mountain

<sup>d</sup> AM Adult: Adult hens on Anthro Mountain

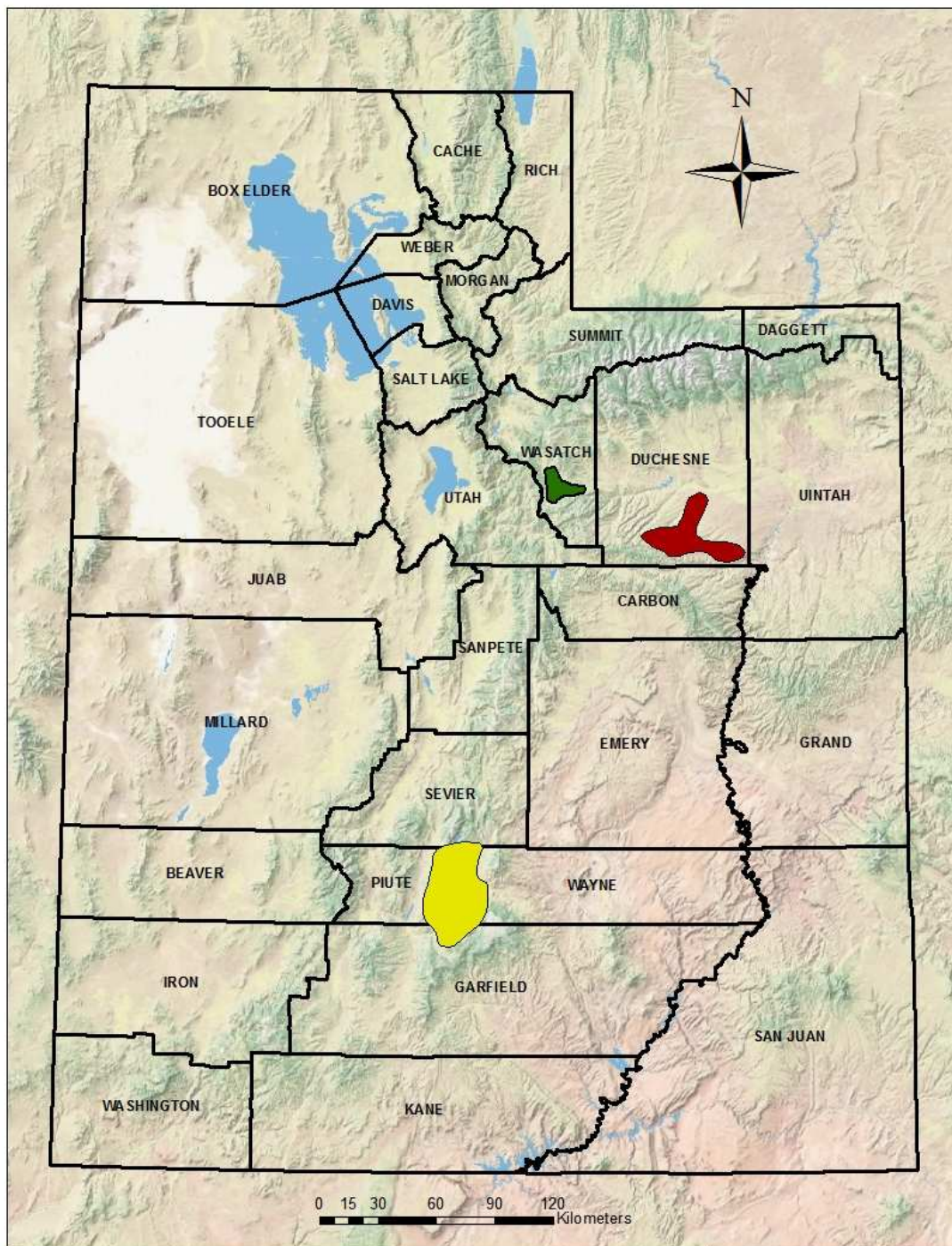


Figure 2 - 1. Map of Utah, USA that includes the three study areas (Anthro Mountain (red Polygon), Strawberry Valley (green polygon), and Parker Mountain (yellow polygon)).

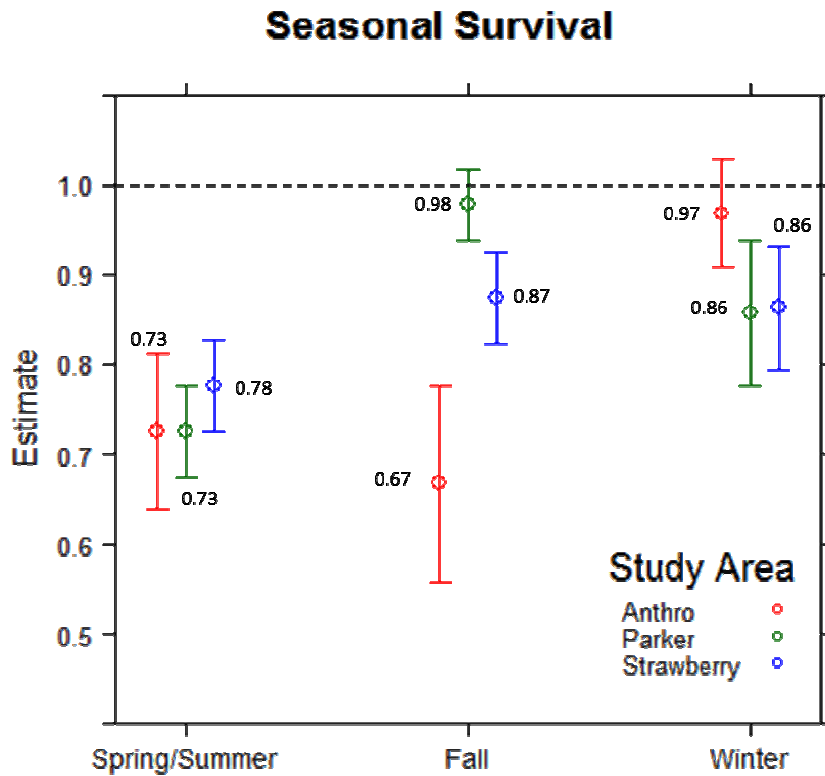


Figure 2 - 2. Average seasonal survival for greater sage-grouse (*Centrocercus urophasianus*) in each study area (Anthro Mountain, UT, USA, Strawberry Valley UT, USA, Parker Mountain, UT, USA). Anthro Mountain was researched from 2008–2012, Strawberry Valley was researched from 1998–2008, and Parker Mountain was researched from 1998–2009.

### CHAPTER 3

## VITAL RATES AND RELATIVE CONTRIBUTION OF TRANSLOCATED GREATER SAGE-GROUSE IN NORTHEASTERN UTAH

### ABSTRACT

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) have experienced range-wide declines with some populations exhibiting dramatic decreases. Managers have successfully used translocations to augment declining populations of native game animals including upland game birds. However, sage-grouse translocations have been used with limited success. Additional information is needed to determine factors that most limit the success of sage-grouse translocations. In 2009–2010, 60 radio-collared hens (30 each year) were translocated from Parker Mountain, in south-central Utah to Anthro Mountain, in northeastern Utah. I studied the vital rates of 60 translocated and 32 resident sage-grouse 4 years post-release to determine the relative contributions of each group on population productivity. Survival did not differ for resident (0.47, 95% CI = 0.31–0.63) and translocated (0.36, CI = 0.25–0.49) hens. The top model of survival, which accounted for 41% of the AICc weight, included year and season effects. Survival was consistently lowest from August through October and the probability of surviving this period was 0.66 (CI = 0.56–0.78) regardless of the year. Nest initiation, the probability that a hen will initiate a nest, was similar for previously translocated (translocated hens that survived  $\geq 1$  year) and adult resident hens (0.96, CI = 0.88–0.99; both groups). Yearling resident hens had the next highest nest initiation (0.87, CI = 0.67–0.95) followed by adult newly translocated hens (0.79, CI = 0.66–0.91) and yearling

newly translocated hens (0.50, CI = 0.30–0.69). There was no difference in nest success for resident and translocated or yearling and adult hens (0.53, CI = 0.41–0.65). Results testing for differences in brood success were equivocal. Overall brood success was 0.55 (CI = 0.41–0.69) for all grouse on Anthro Mountain. Some evidence suggests that adult hens had higher brood success than yearlings (Adult: 0.63, CI = 0.47–0.80, Yearling: 0.34 CI = 0.085–0.59) and that resident and previously translocated hens had higher brood success than newly translocated hens (Resident and Previously Translocated: 0.62, CI = 0.46–0.79, Newly Translocated: 0.38, CI = 0.12–0.63). More information is needed to determine the degree to which hen age and residency status impact brood success. Overall reproductive success, the probability that a hen will successfully raise a brood in a given year, was higher for adult resident and previously translocated hens (0.28, CI = 0.19–0.37) than resident yearlings (0.25, CI = 0.16–0.35), adult newly translocated hens (0.23, CI = 0.14–0.32), and yearling newly translocated hens (0.15, CI = 0.066–0.22). Adult hen survival has been previously identified as a major factor influencing population growth. Although adult and yearling translocated hens had similar survival, adults were more likely to raise a brood. Therefore, managers should consider translocating a higher ratio of adult hens to see a more immediate impact on population growth.

## **INTRODUCTION**

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) have declined range-wide over the past century (Schroeder et al. 2004). Once found in 16 western states and 3 Canadian provinces, sage-grouse currently occur in 11 states and 2 provinces (Connelly and Braun 1997, Schroeder et al. 2004). Male lek attendance rates suggest that

populations have declined range-wide with some local populations exhibiting dramatic decreases (Garton et al. 2011). Sage-grouse populations in Utah have mirrored the range-wide trends and currently occupy less than 50% of their historical distribution (Beck et al. 2003).

Compared to other galliformes, sage-grouse are longer lived and have lower reproductive output resulting from smaller clutch sizes and lower reneesting rates (Schroeder et al. 1999). Adult hen survival, chick survival, and nest success are important to population growth and changes in any of these vital rates drive fluctuations within a population (Moynahan et al. 2006, Aldridge and Boyce 2007, Dahlgren 2009, Guttery 2011, Taylor et al. 2012). Vital rates are influenced by events such as disease, predation, and weather (Johnson and Braun 1999, Naugle et al. 2004, Holloran 2005, Moynahan et al. 2006, Taylor et al. 2012).

Range-wide annual survival rate estimates for hens range from 37–78% and winter survival is usually higher than at other times of the year (Connelly et al. 2011a). Survival rates in long distance migratory populations are reportedly lower than more sedentary or non-migratory populations (Beck et al. 2006). Nest success is also variable by year and location ranging from 15–86% (Connelly et al. 2004). Stable populations typically have higher nest success than declining populations (Dalke et al. 1963, Schroeder et al. 1999). Predation of nests, chicks, and adults constitutes the major source of mortality in sage-grouse populations; however, predation is not considered a major limiting factor in most populations (Hagen 2011).

Because sage-grouse are sagebrush obligates, protection and restoration of important habitats remains a high conservation priority range-wide (Connelly et al. 2011*b*). In areas where year-round habitat conditions remained stable but populations have declined because of anthropogenic impacts, managers have sought to augment populations through translocations (Reese and Connelly 1997).

A translocation is intentionally moving animals from one portion of their range to another in order to establish or augment a population (Griffith et al. 1989, Dickens et al. 2009). Translocations have been successfully used as a management tool to augment extirpated or declining wildlife populations for both game and nongame species including native upland game birds (Griffith et al. 1989, Snyder et al. 1999). Griffith et al. (1989) estimated an 86% success rate for all native game species.

Biologists have attempted sage-grouse translocations in areas where habitat conditions in occupied or historic ranges approximate the recommended guidelines for sustainable populations (Reese and Connelly 1997, Connelly et al. 2000, Baxter et al. 2008). Sage-grouse translocations have been attempted multiple times in 7 states and one Canadian province since the early 1930s. Despite these attempts, published information on methods used and their impacts on populations is limited. Published and anecdotal sage-grouse translocation information suggests that, despite being relocated to suitable habitat, translocated sage-grouse show little fidelity to their release site unless there is a barrier to movement (Musil et al. 1993).

Although most previous sage-grouse translocations failed to provide criteria for evaluating success, Reese and Connelly (1997) estimated that 5% of sage-grouse

translocations were successful compared to 32% success rates for all grouse translocations in the United States (Snyder et al. 1999). Persisting low population numbers following sage-grouse translocations were cited as the reason for this low estimate of success (Reese and Connelly 1997). Translocated sage-grouse that are unfamiliar with new habitat are likely to have reduced survival and lower reproductive rates when compared to residents of the population (Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor et al. 2012). Therefore, translocated sage-grouse may contribute less to population growth.

Musil et al. (1993) found that sage-grouse translocated in Idaho reproduced successfully and that this management practice could be useful in restoring certain sage-grouse populations; however, Reese and Connelly (1997) warned that they should be viewed as experimental and not as a viable option to restore extirpated populations. They further stressed that adequately monitoring vital rates of translocated sage-grouse is necessary to assess the fate of these translocations.

In Utah, two sage-grouse translocation efforts have been successful. In the Wildcat Knolls and Horn Mountain area, 18 males and 35 hens were released by Utah Division of Wildlife Resources (UDWR) biologists from 1987–1990 in sagebrush (*Artemisia* spp.) habitats where sage-grouse were believed to be extirpated. The released sage-grouse were not radio-collared and the success of the translocation was evaluated by lek counts and establishment of new leks (Perkins 2010). In 2008, 27 males were counted on leks during the peak lek attendance (UDWR 2009, Perkins 2010). The

persistence of the population 21 years after the initial translocation suggested that the translocation was successful (UDWR 2009).

The second translocation was conducted in Strawberry Valley, Utah over a period of 6 years (Baxter et al. 2008). Strawberry Valley is a montane valley surrounded by high mountain ridges and was historically occupied by as many as 3,000–4,000 sage-grouse (Griner 1939). Prior to sage-grouse translocation efforts, this population had declined to an estimated 150 breeding sage-grouse (Bunnell 2000). From 2003 through 2008, 336 hens from 4 different source populations were radio-collared and translocated to the area (Baxter et al. 2013). Predator control was conducted from 1999 through 2005 and targeted mammalian predators and corvids (Bunnell 2000, Baxter et al. 2008). Vital rates and movement of radio-marked translocated sage-grouse, as well as population estimates from lek counts, were used to measure the success of the translocation (Baxter 2007).

The high mountain ridges surrounding Strawberry Valley provided a barrier that discouraged translocated sage-grouse from leaving the area (Baxter 2007). Baxter et al. (2008) also found that releasing hens in the spring near active leks increased site fidelity of the translocated grouse. Translocated hen survival and nest success rates were comparable to range-wide estimates of hens in resident populations. Translocations were discontinued when Strawberry Valley's population had increased to approximately 500 breeding birds (UDWR 2009). Baxter et al. (2008) concluded that adult hen survival, chick survival, nest success, and brood success, the metrics which influence population growth rates, were important to the success of the Strawberry Valley sage-grouse

translocation efforts (Johnson and Braun 1999, Dahlgren 2009, Guttery 2011, Taylor et al. 2012).

Based on the success of these translocation projects in Utah, the Utah Greater Sage-grouse Management Plan (UDWR 2009) identified translocations as a viable management tool for enhancing sage-grouse populations in the state. The plan stated that “translocations may be used to augment populations where  $\leq 165$  males ( $\leq 500$  adult sage-grouse) make up the breeding population, or an increase in genetic diversity is warranted.” The plan cautioned biologists considering translocations in Utah to use the protocols employed by Baxter et al. (2008).

Baxter et al. (2008) stated that translocation success should be based on hen survival, courtship compatibility, reproductive success, fidelity to the release area, integration into the existing population, and overall contribution to the resident population. Metrics used to evaluate the translocation’s success in Strawberry Valley included: 1) translocated female survival, 2) attendance at leks, 3) nest initiation, 4) nest success, 5) translocated hen’s chick survival, 6) flocking and movements of the translocated females, and 7) changes or trends in male lek attendance.

From 2002 through 2006, U.S. Forest Service (USFS) biologists in the Ashley National Forest used radio-telemetry to monitor sage-grouse movement, vital rates, and habitat-use on Anthro Mountain. The study found that sage-grouse migrate from Anthro Mountain in the winter and return in the spring with multiple trips in between. Two wintering areas were found, one approximately 32 km to the south and another approximately 26 km to the north of Anthro Mountain. Resident hen survival over this

period was similar to estimates reported range-wide (B. Christensen 2007, USFS Ashley National Forest, unpublished report). The report concluded that the study area provided nesting, brood rearing, and wintering habitats that were within the recommended habitat guidelines (Connelly et al. 2000).

Despite having adequate year-round habitat, Anthro Mountain's sage-grouse population declined from 2006 to 2008 based on lek count indices (44 males in 2006 to 13 males in 2008; B. Maxfield, UDWR, unpublished data). Because of the concerns about population declines in areas where habitats were within published guidelines, the UDWR, USFS, and Utah State University (USU) initiated a sage-grouse translocation project in 2009 to try to reverse the population declines.

The sage-grouse population that inhabited Parker Mountain in south-central Utah was selected as the source population for translocations because it was considered robust and was genetically compatible with the sage-grouse population on Anthro Mountain (Smith 2009). Translocation protocols followed procedures employed by Baxter et al. (2008).

During the first phase of this translocation project, Gruber (2012) reported that sage-grouse translocated to Anthro Mountain had similar survival and reproductive rates as residents but that rates were low compared to range-wide estimates. Translocated sage-grouse integrated into the population and displayed summer movement patterns similar to residents (Gruber 2012). Gruber (2012) concluded that the overall effect of the translocation was inconclusive and cited low survival and reproductive success as the reasons for this finding.

The objectives of my study were to: 1) compare vital rates of translocated and resident hens, 2) determine and the relative contribution of translocated and resident sage-grouse on Anthro Mountain, and 3) assess the effects of the translocation on Anthro Mountain's population four years after the initial release.

## **STUDY AREA**

### **Anthro Mountain, Utah**

Anthro Mountain was located on Ashley National Forest in Duchesne County, Utah approximately 29 km southeast of the town of Duchesne (Fig. 3-1). This high elevation mountain contained approximately 2,500 ha of mountain big sagebrush (*A. tridentata ssp. vaseyana*) habitat and was intermixed with pockets of quaking aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii*). Black sagebrush (*A. nova*) was found on ridge tops across the mountain. Two-needle pinyon pine (*Pinus edulis*) and juniper (*Juniperus* spp.) were encroaching on the sagebrush community at the lower elevations. Other native vegetation included: gray horsebrush (*Tetradymia canescens*), serviceberry (*Amelanchier utahensis*), rabbitbrush (*Chrysothamnus viscidiflorus*), snowberry (*Symphoricarpos oreophilus*), lupine (*Lupinus argenteus*), June grass (*Koeleria macrantha*), basin wildrye (*Leymus cinereus*), salina wildrye (*L. salinus*), and bluebunch wheatgrass (*Elymus spicatus*). Smooth brome (*Bromus inermis*) was seeded in the 1950s in portions of the area.

Anthro Mountain received an average of 49 cm of precipitation annually with the majority of the precipitation in the form of heavy winter snow and heavy rains during the monsoon season in July and August. Anthro Mountain ranged from 2,400 m–2,800 m in

elevation and was bordered by the Uintah Basin to the north and east, Gilsonite Canyon to the south, and Indian canyon to the west, all of which were lower in elevation than Anthro Mountain.

The current and historical dominant land use was domestic cattle grazing (Thacker 2010). Sage-grouse hunting was not allowed on Anthro Mountain. In 2010, U.S. Department of Agriculture, Animal and Plant Health Inspection Services, Wildlife Services (WS) placed poison eggs on Anthro Mountain to target and remove corvids around active sage-grouse lekking and nesting sites. Although WS occasionally targeted and removed mammalian predators on Anthro Mountain, they did not intensively control predators as was practiced in the Strawberry Valley translocation (Baxter et al. 2008).

Many mammalian predators that inhabited Anthro Mountain included: coyote (*Canus latrans*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), mountain lion (*Puma concolor*), badger (*Taxidea taxus*), and long-tailed weasel (*Mustela frenata*).

Raptors were observed using Anthro Mountain throughout the year. Avian predators detected on Anthro Mountain included: red-tailed hawk (*Buteo jamaicensis*), rough-legged hawk (*B. lagopus*), American kestrel (*Falco sparverius*), common raven (*Corvus corax*), golden eagle (*Aquila chrysaetos*), cooper's hawk (*Accipiter cooperii*), northern harrier (*Circus cyaneus*), and sharp-shinned hawk (*A. striatus*). We also detected great-horned owls (*Bubo virginianus*) on several occasions while trapping in the spring of 2011 and 2012.

### **Parker Mountain, Utah**

Parker Mountain, the source population for the translocated sage-grouse, was located in south-central Utah approximately 218 km southeast of Anthro Mountain (Fig. 3-1) and exhibited the largest contiguous sagebrush ecosystem (> 200,000 ha) in Utah (Chi 2004). This high elevation sagebrush ecosystem was characterized by rolling hills and gently northeastern sloping plateaus. The ridges and slopes were dominated by black sagebrush while big sagebrush, bitterbrush (*Purshia tridentata*), and rabbitbrush were found in the drainages. Grasses commonly found on Parker Mountain included grama grass (*Bouteloua* spp.), wheatgrass, bluegrass (*Poa* spp.), squirreltail grass (*Elymoides*), needlegrass (*Hesperostipa* spp.), and June grass.

Parker Mountain received 25 cm–51 cm of annual precipitation with the majority of the precipitation accumulating in the fall and winter (Chi 2004). Elevations on Parker Mountain ranged from 2,134 m–3,018 m and the mountain was situated on 2 plateaus and was bounded by an escarpment to the west and Rabbit Valley to the east.

The predominant land use on Parker Mountain was livestock (sheep and cattle) grazing (Guttery 2011). To reduce livestock depredation, predators on Parker Mountain were removed throughout the year (Chi 2004). Additionally, Wayne County, Utah, the county in which most of Parker Mountain was situated, had a bounty on coyotes (*Canis latrans*) which may have resulted in additional coyotes taken from the study area (Chi 2004). The sage-grouse population on Parker Mountain was one of the few hunted populations in Utah (UDWR 2009).

Coyotes were the predominant mammalian predator on Parker Mountain.

Common avian predators detected on Parker Mountain were: red-tailed hawk, American kestrel, golden eagle, prairie falcon (*F. mexicanus*), and common raven (Dahlgren 2006, 2009). Previous research concluded that golden eagles were the main predator on adult sage-grouse on Parker Mountain (Chi 2004, Dahlgren 2006).

## **METHODS**

### **Data Collection**

Utah Division of Wildlife Resources and USU translocated 60 female sage-grouse (30 yearlings and 30 adults) from Parker Mountain to Anthro Mountain in the spring of 2009 and 2010. Thirty-two resident female sage-grouse (21 yearlings and 11 adults) were captured from 2009 through 2012 on Anthro Mountain (Table 3-1). Two resident hens from previous studies remained in the sample at the beginning of this study.

We captured sage-grouse by spotlighting roost sites near active leks, and grouse were netted with long-handled hoop nets from the back of an all-terrain vehicle or on foot (Giesen et al. 1982, Wakkinen et al. 1992). Handling protocols were approved by Utah State University Institutional Animal Care and Use Committee (Permit #: 1404). The sex and age of the grouse were determined using plumage characteristics outlined by Beck et al. (1975), and each captured sage-grouse was fitted with a necklace-mounted radio-transmitter equipped with an 8 hour mortality switch (Advanced Telemetry Systems, Insanti, MN and American Wildlife Enterprises, Monticello, FL). The antenna was bent to rest along the back of the sage-grouse to minimize interference with movement. After fitting the transmitter, the hens were weighed with a Pesola Scale™ (Pesola, Zeg, Baar,

Switzerland). For each grouse captured, I recorded the time and UTM coordinates (NAD 83) of the capture site and release time. I also recorded any injuries and comments about the bird's condition or behavior upon release.

Translocation followed protocols outlined by Baxter et al. (2008) and Reese and Connelly (1997). Hens on Parker Mountain were captured at night near active leks during the breeding season in April and May. Each hen was placed in an individual cardboard box with holes for ventilation and transported overnight in the back of a pickup truck to Anthro Mountain for release. The hens were released during hours of breeding activity approximately 100 m from an established lek (Gruber 2012).

Reese and Connelly (1997) and Baxter et al. (2008) recommended that translocated sage-grouse be released in suitable sagebrush habitat that is surrounded by a barrier to movement. Although Anthro Mountain had viable sagebrush habitat, there was no geographic barriers inhibiting sage-grouse from leaving the study area.

*Survival* – Survival of all collared sage-grouse in Anthro Mountain's population was monitored weekly from April through September. Radio-marked sage-grouse were located opportunistically from October through March due to logistic constraints caused by snow pack. Monitoring lasted from March 2009 through March 2013.

Radio-collars that remained in one location for 8 consecutive hours broadcasted a faster pulse known as a mortality signal. The date and time that a mortality signal was first detected was recorded and used for survival analysis.

*Nest Initiation and Nest Success* – During the spring lekking season, all radio-marked female sage-grouse were monitored every two to four days to determine the

nesting status. As hens localized in search of suitable nesting habitat and began laying eggs, precautions were taken to avoid flushing the hen so it did not abandon an initiated nest. During this phase, I circled the strongest signal and attempted to observe the hen through binoculars from a distance of approximately 10 m. I stood perpendicular to the strongest signal and spent a maximum of 10 minutes each day circling the hen. If the hen was located under a shrub, I drew a nest location diagram. If, after 10 minutes, I could not confirm a visual of the hen, I took an azimuth, estimated the distance to the strongest signal, and drew a diagram of the hen's approximate location. In each instance, I returned the following day to determine if the hen was in the same location. If the hen was in the exact same location for two consecutive days, I noted that the hen initiated incubation (Aldridge and Brigham 2001). If the hen was not on the nest on the second day, I checked the shrub for the presence of a nest. If a nest was absent, I continued with the relocation schedule until a nest was initiated.

Nesting hens were monitored three times a week to determine the fate of the nest and the date. I monitored nesting hens from approximately 50 m to avoid disturbing the hen. A 28 day incubation period was added to the date of incubation initiation to determine the approximate hatch date (Schroeder et al. 1999). As the approximate hatch date approached, I monitored the nest daily to determine exact hatch date. When a hen was located off the nest after initiating incubation, I inspected the nest to determine the status of the nest, clutch size, and number of eggs hatched. I considered a nest successful if it contained at least one egg with a detached membrane (Klebenow 1969). Nests were

classified as unsuccessful if they were depredated, abandoned, or if the hen died during incubation.

Broken eggs or empty nests indicated that the nest had been depredated; I inspected the nest, egg shells, and surrounding area for evidence (tracks, scat, hair, whitewash, and feathers) indicating the cause of the depredation. Coates et al. (2008) found mammalian nest depredation sign to be ambiguous; therefore I only distinguished between avian or mammalian predators. Eggs that were not crushed but had large holes in them indicated an avian depredation (Coates et al. 2008). Crushed egg shells likely indicated a mammalian predator such as a coyotes, American badgers, or ground squirrels (Coates et al. 2008). If the eggs or eggshells were not present and there were no clear indications of a predator, I recorded the cause of depredation as unknown. Hens with unsuccessful nests were monitored 2 to 3 times a week to document renesting attempts.

*Reproductive Success* – I monitored hens with successful nests three times a week until the brood was lost or the brood fledged at 50 days of age (Schroeder 1997). I noted anytime chicks were observed with a collared brood hen and if the hen gave a wing dragging or flutter-hopping display or aggressively approached the observer when flushed. In 2009 and 2010, transmitters were sutured to chicks to determine chick survival (Gruber 2012). In 2011 and 2012, I conducted brood counts at 35 and 50 days old. Brood counts consisted of either flushing or spotlighting the hen and counting the number of chicks with the hen.

If a brood hen made a large move, such as moving to a different ridge, I flushed the hen, observed her behavior, and searched for chicks. If the hen did not act broody

and no chicks were seen, I flushed the hen again during the next relocation to observe behavior and search for chicks. If chicks were not observed during the second flush, I recorded that the brood was unsuccessful. This information was used to acquire brood encounter histories and determine the status of the brood.

*Lek Counts and Searches* – I attempted to count all known established leks on Anthro Mountain a minimum of 3 times during the lekking season from 0.5 hours before sunrise to 1.5 hours after sunrise (UDWR 2009). Lek counts were conducted at approximately weekly intervals and the maximum number of males and females attending the lek were recorded at each visit. While conducting these counts, I documented any radio-collared sage-grouse that attended a lek to determine attendance of resident and translocated grouse. If no grouse were sighted on or near a lek, I searched the surrounding area for tracks or other evidence (i.e. tracks, feathers, pellets, and cecal droppings) that sage-grouse were using the lek.

In addition to counts at established leks, I annually searched for new leks on Anthro Mountain. Searches were conducted from 0.5 hours before sunrise to 1.5 hours after sunrise. These searches consisted of driving accessible roads and stopping every half mile to scan suitable sage-grouse habitat with binoculars while listening for displaying grouse (Connelly et al. 2003). If a ridge was inaccessible by vehicle due to snow pack, I accessed it on foot and scanned the area for signs of displaying grouse. In 2011, I also accompanied the UDWR and searched for new leks on Anthro Mountain from a helicopter.

## Data Analysis

*Survival* – Although 11 resident males were radio-collared, no males were translocated from Parker Mountain. Therefore, I did not use males in the survival analysis. Data collected from year-round tracking of radio-marked hens were used to estimate survival. Occasionally a hen would go undetected for an extended period. If a hen went undetected during the study, it was right-censored after the last known survival period. I wanted to test if capture and translocation impacted hen survival; therefore I also included hens that died within 2 weeks of capture.

The ragged telemetry data were best suited for estimating monthly survival rates (MSR) of marked hens using the nest survival model in program MARK (White and Burnham 1999). The nest survival model allowed for staggered entry, irregular monitoring of marked individuals, and right-censoring of missing individuals (Rotella et al. 2004). I used the R (R Development Core Team 2011) package RMark (Laake and Rexstad 2008) to construct nest survival models for program MARK (White and Burnham 1999). Encounter histories were formatted into months beginning 1 April 2009 and ending 31 March 2012.

I evaluated survival using a hierarchical process of model selection using Akaike's Information Criterion corrected for small sample size (AICc; Akaike 1973, Burnham and Anderson 2002, Miller and Conner 2005). I evaluated seasonal, annual, and demographic effects of sage-grouse survival rates by first selecting the best temporal model (season and year). Various seasonal models were evaluated to determine the interval that best described survival. I hypothesized that translocated hens would have

lower survival than resident hens. Therefore, my candidate models for stage 2 tested for differences in translocated status (translocated or resident), overall residency status (newly translocated, previously translocated, or resident), and hen age (adult or yearling; Table 3-2). In addition to seasonal and demographic differences, I considered the null model (no variation between cohorts, seasons, or years; Table 3-3). Using the logit-link function, I obtained the maximum likelihood estimates of each model to test for variation in MSR (Dinsmore et al. 2002, Rotella et al. 2004). Each model was ranked using AICc and I used the model selection procedures described by Burnham and Anderson (2002) to select the model that best described survival on Anthro Mountain (Akaike 1973). Using the top model, I estimated survival rates as derived parameters. Estimates of variance and 95% confidence intervals were calculated using the Delta Method (Seber 1982).

*Nest Initiation* – Nest initiation, the proportion of sexually mature females that were documented to initiate a nest, is based on a hen's attempt to nest and does not take nest fate into account. I coded hens that were known to attempt to nest as "10" and those that were not detected attempting to nest as "11." To avoid inflating estimates by double counting hens that renested, I only counted one nesting attempt per hen per year.

I estimated nest initiation using the R (R Development Core Team 2011) package RMark (Laake and Rexstad 2008) to construct the known fate models for program MARK (White and Burnham 1999). I developed 10 *a priori* models to capture potential variation in nest initiation for residency (translocated vs. resident), age (yearling vs. adult), and resident status (newly translocated, previously translocated, and resident; Table 3-4). Each model was ranked using Akaike's Information Criterion corrected for

small sample size and I based model selection on the minimization of AICc to select the model that best explained nest initiation for all hens on Anthro Mountain (Akaike 1973, Burnham and Anderson 2002). I then estimated the probability that a hen would nest and the 95% confidence intervals using the Delta Method (Seber 1982).

*Nest Success* – The date that the first nest was found was considered the first day of the nesting season and all subsequent nests were normalized to this date. I used the normalized date that each nest was found, regardless of incubation status, in the nest success analyses. Two hens incubated infertile eggs for longer than the average sage-grouse incubation period (>28 days) (Schroeder et al. 1999). Because these hens incubated a nest for longer than the natural incubation time, I counted the nests as successful. To avoid over-estimating the daily nest survival rate, I only counted a 28 day incubation period for these two hens. On two occasions, hens with failing collars went undetected for several weeks and were later relocated with broods. For the purpose of estimating nest survival, I censored hens if they went undetected during the nesting season (Baxter et al. 2008). If a hen was inadvertently flushed by research activities and abandoned the nest, the nest was excluded from the analyses. When a nest successfully hatched between consecutive checks, I used the midpoint of the checks as the hatch date. I did not use the midpoint of consecutive checks for unsuccessful nests because the MARK nest survival model automatically does this (White and Burnham 1999).

Daily survival rates (dsr) were estimated using the nest survival model in the R (R Development Core Team 2011) package RMark (White and Burnham 1999, Laake and Rexstad 2008). Ten *a priori* models were evaluated to determine which factors most

strongly influenced nest success (Table 3-5). I modeled combinations of several covariates including: hen age (yearling and adult), residency (resident or translocated), year (2009, 2010, 2011, and 2012), resident status (newly translocated, previously translocated, and resident), and no variation (null). I used the logit-link function to obtain the maximum likelihood estimates of all parameters (Dinsmore et al. 2002, Rotella et al. 2004). Each model was ranked using AICc and I used model selection procedures to select the model that best explained nest success (Akaike 1973, Burnham and Anderson 2002). I used a 28 day incubation period in conjunction with the dsr of the top model ( $\text{dsr}^{28}$ ) to extrapolate nest success for hens on Anthro Mountain. The Delta Method was used to calculate variance and 95% confidence intervals (Seber 1982).

*Reproductive Success* – I used the tracking and brood count schedule to estimate brood success using the R (R Development Core Team 2011) package RMark (Laake and Rexstad 2008) to construct nest survival models for program MARK (White and Burnham 1999). The date that the first successful nest hatched was considered the first day of the brood season and all subsequent broods were normalized to this date. I considered a brood successful if a hen successfully raised  $\geq 1$  chick to independence at 50 days of age (Schroeder 1997). I modeled 11 *a priori* models to determine which factors most strongly influence brood success (Table 3-6). Using the logit-link function, I obtained the maximum likelihood estimates of daily survival rates. Each model was ranked using AICc (Burnham and Anderson 2002). Models with  $\Delta\text{AICc} \leq 2$  of the top model were considered to be equally supported by the data. When this occurred, I reported the results of competing models and based my inferences on the most

parsimonious model (Arnold 2010). I extrapolated the overall brood success for hens on Anthro Mountain using a 50 day survival period in conjunction with the dsr of the model averaged estimates ( $\text{dsr}^{50}$ ). I calculated the 95% confidence intervals using the Delta Method (Seber 1982).

Sage-grouse exhibit a social brood rearing strategy in which brood mixing can occur (Dahlgren 2009). On multiple occasions, I observed broods with different sized chicks suggesting that younger or older chicks were adopted. This could bias brood success estimates low if chicks from one female were successfully raised by another or high if a radio-marked female adopted and raised chicks from a different brood. Therefore, I only compared the brood survival estimates to those from other studies with similar methodologies to avoid interpretation bias.

To determine the overall reproductive success of hens on Anthro Mountain, I multiplied the top ranked models for nest initiation, nest success, and brood success. Ninety-five percent confidence intervals for reproductive success were calculated using the Delta Method (Seber 1982).

## **RESULTS**

### **Survival**

Sixty translocated and 32 resident radio-collared hens were monitored (Table 3-1). No sage-grouse were injured during the capture, transport, or release, and all translocated hens were released approximately 100 m north of the most active lek on Anthro Mountain (Gruber 2012).

Thirteen yearling and 17 adult hens were translocated from Parker Mountain to Anthro Mountain in April 2009 (Gruber 2012). Fifteen resident hens were also radio-collared on Anthro Mountain in 2009 (6 yearlings and 9 adults, including 2 adult females that remained in the sample from a previous study). In April and May 2010, an additional 17 yearling and 13 adult hens were translocated from Parker Mountain to Anthro Mountain and 2 additional adult resident hens were captured on Anthro Mountain. In the spring and fall of 2011, 12 resident hens were captured and added to the sample size (11 yearlings and 1 adult). Five resident hens were captured in 2012 (4 yearlings and 1 adult).

Over the course of the study, one resident and 8 translocated hens were never re-located after release. Three collared hens were observed with new transmitters that were not transmitting a signal in 2010 (Gruber 2012). Of the 30 hens that were translocated in 2009, 7 were re-located in 2010 and 2 were re-located in 2011. Of the 30 hens translocated in 2010, 12 were re-located in 2011 and 3 were re-located in 2012 and were alive at their last location. No grouse that were translocated in 2009 were re-located in 2012.

The top survival model for hens on Anthro Mountain indicated that survival is most influenced by season and year and contained 41% of the weight (Table 3-3). The top 4 models included the same season and year effect and contained over 99% of the weight. There was no statistical support for general residency status (resident and translocated), specific residency status (resident, newly translocated, and previously

translocated), or age (yearling and adult) being influential to hen survival on Anthro Mountain.

Winter survival was highest while survival from August through October was consistently lower during each year of the study (Fig. 3-2). The probability of surviving August through October was 0.66 (95% Confidence Interval (CI) = 0.56–0.78) regardless of the year. The probability of surviving winter regardless of year was 0.97 (CI = 0.91–1.03). The lowest single seasonal survival period was from August through October of 2009 (0.53, CI = 0.36–0.69) and the highest single seasonal survival was from November 2012 through March 2013 (0.996, CI = 0.986–1.01).

Survival was higher in 2012 (0.887, CI = 0.496–0.984) than in all other years. The next highest annual survival was in 2010 (0.474, CI = 0.300–0.655) followed by 2011 (0.378, CI = 0.201–0.596). The lowest annual survival was in 2009 (0.242, CI = 0.132–0.399).

### **Nest Initiation**

Over the course of the study, 85 nests were initiated including 4 renests (Table 3-7). Resident hens initiated 34 nests and translocated hens initiated 51 nests. In 2009, 21 nests (including 1 reneest) were initiated by the 33 hens that were adequately monitored through the nesting season. Of the 33 hens, 5/7 resident and 16/26 translocated hens initiated nests. In 2010, 26 nests were initiated by 7 resident and 19 translocated hens (Gruber 2012). All radio-marked resident (7/7) and previously translocated (8/8) hens initiated a nest while 50% (11/22) of newly translocated hens initiated nests during 2010. In 2011, 23 nests were initiated (10 by resident hens and 13 by translocated hens)

including 2 renests (1 by a resident hen and 1 by a translocated hen). Twenty-one of 22 hens initiated a nest (9/10 resident and 12/12 previously translocated) including 2 hens with failing collars that were not located while nesting but reappeared with broods. In 2012, 15 nests were initiated including 1 reneest. Each of the 14 hens that were in the sample initiated a nest (3/3 translocated and 11/11 resident) and 1 resident hen reneested.

The top model for nest initiation indicated that the probability that a hen would nest was dependent on the additive effect of hen age and overall residency status (Table 3-4). Adult resident and previously translocated hens (hens that survived  $\geq 1$  year) had highest nest initiation (0.96, CI = 0.88–0.99) followed by yearling resident hens (0.87, CI = 0.67–0.95) and adult newly translocated hens (0.79, CI = 0.59–0.91). The lowest nest initiation was by yearling newly translocated hens (0.50, CI = 0.30–0.69; Table 3-8).

### **Nest Success**

The earliest initiated nest was found on 15 April 2009 by a translocated hen that was accidentally flushed off her nest by research activities (Gruber 2012). The latest initiated nest was a reneest found on 6 June 2011 by a translocated hen. Nest hatch dates ranged from 27 May–26 June in 2009, 29 May–20 June in 2010, 31 May–30 June in 2011, and 13 May–3 June in 2012.

During the 4 year study, 47/85 (55%) of nests that were initiated successfully hatched  $\geq 1$  egg (including nests that were abandoned by hens inadvertently flushed from the nest). Resident hens hatched 20/34 (59%) nests while translocated hens hatched 27/51 (53%) (Table 3-7).

In 2009, 3/5 (60%) resident hens and 8/16 (50%) translocated nests hatched  $\geq 1$  egg (Gruber 2012). The two unsuccessful resident nests were predated (1 mammalian and 1 unknown; Table 3-9). Of the 8 unsuccessful translocated hen nests, 4 were predated (1 avian and 3 unknown), 1 nest was abandoned for unknown reasons, and 3 hens were inadvertently flushed off their nests by researchers. One hen renested after being flushed off her first nest by a researcher and was successful on her second attempt.

In 2010, 7/7 (100%) resident and 8/19 (42%) translocated hens hatched  $\geq 1$  egg (Gruber 2012). Eleven nests were unsuccessful in 2010; 6 were depredated (1 mammalian, 2 avian, 5 unknown), 2 abandoned due to researcher error, and 1 nest was infertile.

In 2011, 5/10 (50%) resident and 9/13 (69%) translocated nests were successful. A resident hen that renested was unsuccessful while the translocated hen had a successful renest attempt. Three of the 5 unsuccessful resident nests were depredated by mammalian predators and 2 were caused by undetermined predators. Of the 4 unsuccessful translocated nests, 3 were due to predation (1 avian, 2 unknown) and 1 hen was killed off nest which caused the nest to fail (Table 3-9).

In 2012, 5/12 (41.7%) resident and 2/3 (66.7%) translocated nests hatched  $\geq 1$  egg. A resident hen that renested was successful on her second attempt. Six of the unsuccessful resident nests were depredated (3 mammalian, 2 avian, 1 unknown) and 1 nest had infertile eggs. The unsuccessful translocated nest was depredated by a mammalian predator (Table 3-9).

The average clutch size for all grouse in the study was 7.4 eggs per nest and average clutch sizes were slightly larger for all resident compared to all translocated hens on Anthro Mountain (Table 3-10). The average number of eggs hatched for all years was 4.3 with resident hens hatching an average of 4.5 eggs while translocated hens hatched an average of 4.2 eggs (Table 3-10).

For the analysis of nest success, I only included hens that were adequately monitored through the nesting season; I did not include nests where hens were abandoned due to researcher error. The nest survival analysis estimated that the null model was best supported by the data indicating that differences in nest success cannot be explained by hen age, residency status, or temporal variation (Table 3-5). Nest survival to 28 days was 0.53 (CI = 0.42-0.65; Table 3-11).

### **Brood Success**

Over the course of the study, resident and translocated hens attempted to raise 47 broods (20 resident, 27 translocated). Of these 47, 27 broods (57.4%) had  $\geq 1$  chick reach independence at 50 days (12 by resident hens and 15 by translocated hens). In 2009, 45.5% (5/11) of broods were successful with 33% (1/3) of resident hens and 50% (4/8) of translocated hens raising broods to independence (Gruber 2012). In 2010, 53.3% (8/15) of brood hens successfully raised broods (5/7 resident brood hens and 3/8 translocated brood hens; Gruber 2012). In 2011, 64.3% (9/14) of all hens raised  $\geq 1$  chick to independence (3/5 by resident hens and 6/9 by translocated hens). In 2012, 71.4% (5/7) of all brood hens were successful (3/5 resident hens and 2/2 translocated hens; Table 3-12).

Using the principles of parsimony, the null model best explained variation in brood success for hens on Anthro Mountain (Table 3-6). When all effects were held at a constant, the probability that a hen would successfully raise  $\geq 1$  chick was 0.55 (CI = 0.41–0.69; Table 3-13). Although the null model was the most parsimonious model, hen age and residency status were competing models indicating there was some evidence that brood success was impacted by hen age and overall residency status (Table 3-6). The probability that an adult hen would successfully raise a brood to independence was 0.63 (CI = 0.47–0.80) while yearlings had a 0.34 (CI = 0.085–0.59) probability of being successful. Resident and previously translocated hens had higher brood success (0.62, CI = 0.46–0.79) than newly translocated hens (0.38, CI = 0.12–0.63; Table 3-13). More data is needed, however, to fully understand the role of hen age and residency status on predicting brood success.

### **Reproductive Success**

I analyzed the overall reproductive success of hens on Anthro Mountain by multiplying the top models for nest initiation, nest success, and brood success. Models with  $\Delta AICc \leq 2$  were considered to be equally supported by the data. When this occurred, I used the most parsimonious model to estimate overall reproductive success (Arnold 2010, Hamel et al. 2010). Adult resident and previously translocated hens had the highest reproductive success (0.28, CI = 0.19–0.37) followed by resident yearlings (0.25, CI = 0.16–0.35) and adult newly translocated hens (0.23, CI = 0.14–0.32; Table 3-14). Newly translocated yearling hens had the lowest reproductive success (0.15, CI = 0.066–0.22; Table 3-14).

## **Lekking**

Prior to 2011, the UDWR documented 4 leks on Anthro Mountain. In 2009 and 2010, 2 of the 4 leks were known to be active (Nutter's Ridge Lek and Alkali Ridge Lek). The maximum male count was 6 males in 2009 and 4 males in 2010 (Fig. 3-3). On 15 April 2011, a new lek (Jeep Trail Lek) was discovered on Anthro Mountain and was the only active lek in the study area. The maximum count in 2011 was 8 males and 9 females. In 2012, Jeep Trail and Alkali Ridge Leks were active. The total male count on these two leks was 18 (13 on Jeep Trail Lek and 5 on Alkali Ridge Lek; Fig. 3-3). The only lek to have documented female attendance was Jeep Trail Lek and the maximum female count was 7. In 2013, Jeep Trail Lek had a high male count of 24 and 2 traditional leks had an attendance of 6 total males (B. Maxfield, UDWR, personal communication).

In 2009, no translocated females were observed on leks, however translocated females were observed on leks in subsequent years. In 2010, 3 translocated females were observed on leks (Gruber 2012). In 2011, 1 translocated and 2 marked resident hens were observed on leks while 5 marked resident hens were observed attending leks in 2012.

## **DISCUSSION**

### **Survival**

Hen survival is one of the most important vital rates driving population growth (Guttry 2011, Taylor et al. 2012). Although I hypothesized that translocated hens would have lower survival rates than residents, there was no apparent effects of resident status

or age on survival. These findings were consistent with results from Strawberry Valley (Baxter et al. 2008). The top survival analysis model contained 41% of the AICc weight and indicated that survival in my study area was influenced by season and year.

Additionally, the top 4 models each contained the same seasonal and year effect and contained over 99% of the AICc weight. Similar to Anthro Mountain, hens in Strawberry Valley experienced a seasonal and year effect on survival (Baxter et al. 2013). Unlike Strawberry Valley which experienced high fall survival and low survival during the nesting season, survival on Anthro Mountain was lowest in the fall (August through October) and was higher in the winter and the nesting season (Fig. 3-2).

Average survival rates of all hens on Anthro Mountain (0.40, SE  $\pm$  0.05, all years) were slightly higher than average survival rates of male and female sage-grouse translocated in Idaho (0.36; SE  $\pm$ 0.07; Musil et al. 1993). Annual survival was lowest in 2009 (24%) followed by 2011 (38%) and 2010 (47%). Hens experienced highest survival in 2012 (89%) which was considerably higher than all other years. Survival in 2009 fell below the estimates reported for sage-grouse in Utah (30–78%); survival in 2010 and 2011 was within the estimates and survival in 2012 was above the estimates (Bunnell 2000, Baxter 2007, Dahlgren 2009). My reported estimates for 2009 and 2010 differed slightly from those reported by Gruber (2012). This discrepancy might be attributed to the fact that Gruber (2012) included males in survival estimates while I only used hens.

Resident hen survival (46% all years combined) was within survival rates reported throughout the sage-grouse range (37–78%; Connelly et al. 2011a) and survival rates of resident hens in Strawberry Valley (30%; Bunnell 2000). Translocated hens on

Anthro Mountain had lower survival estimates (36%, all years combined) than translocated hen survival in Strawberry Valley (60% average; Baxter et al. 2008).

Weather, predator abundance, and alternate prey availability could have contributed to the temporal differences in survival on Anthro Mountain. Moynahan et al. (2006) reported reduced survival following severe winter weather events. In 2009 and 2011, temperatures were slightly lower and total precipitation was greater than in 2010 and 2012. Anthro Mountain experienced above average snowfall in 2011 and snowpack persisted on Anthro Mountain through May. Hens in 2009 and 2011 had lower survival compared to 2010 and 2012. The winter encompassing 2011–2012 brought relatively little snowfall and the snowpack diminished in early April 2012. Survival following the 2011–2012 winter was notably higher than all other years. Although severe weather might not directly increase mortality rates, it may have a delayed effect and hinder the sage-grouse's ability to cope with the stresses of breeding, raising young, and avoiding predators.

Predation has been identified as a factor limiting sage-grouse populations (Braun 1998). Although sage-grouse face a suite of predators, none specialize in sage-grouse and predation is typically higher during the breeding season (Hagen 2011). My results, however, suggest that mortality was highest from August through October regardless of the year. Although ambiguous evidence at mortality sites and scavenging by rodents made it difficult to determine the exact cause of death in most cases (Larsen et al. 2008), predation appeared to be a major source of mortality. Predator densities are often highest in the fall and predation is likely to have more effect on population densities at this time

compared to the spring (Hewitt et al. 2001). Quality habitat in sufficient amounts is oftentimes adequate for reducing predation rates (Connelly et al. 2000, Schroeder and Baydack 2001, Hagen 2011). The increased mortality of sage-grouse in the fall may be in response to increased predator abundance coupled with fragmented that is not suitable to buffer the sage-grouse from predation.

Prey switching has been observed in predators in response to varying prey abundance (Randa et al. 2009, Fedy and Doherty 2010). Anecdotal evidence suggests that alternate prey (i.e. – rabbits, voles, and ground squirrels) increased from 2009 through 2012. During the 2012 season, I recorded an increase of incidental sightings of dusky grouse (*Dendragapus obscurus*) compared to prior field seasons. This perceived increase in alternate prey may have played a role in the higher survival rates in 2012.

Translocated sage-grouse that are unfamiliar with release habitats are likely to have reduced survival and lower reproductive rates when compared to residents of the population (Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor et al. 2012). Therefore, translocated sage-grouse would be expected to contribute less to population growth. Because models testing the maximum likelihood estimates did not support survival differences for resident and translocated hens, this suggested that the translocated hens adjusted to the release area and contributed to population growth.

### **Nest Initiation**

Differences in nest initiation were best described by the additive effect of hen age and the binomial covariate. The binomial covariate tested whether translocated hens that survived  $\geq 1$  year on Anthro Mountain (previously translocated) were similar to residents.

This model indicated that adult resident and previously translocated hens had the highest probability of nesting (96%) followed by yearling residents (87%). Adult newly translocated hens had a 79% probability of nesting while yearling newly translocated hens were the least likely to nest (50%). Nesting attempts may be underestimated because some nests may have failed before they were detected by researchers.

The likelihood that any hen newly translocated to Anthro Mountain would nest (65%) was higher than estimates from Strawberry Valley, UT (39%) and was similar to hens translocated to Clear Lake National Wildlife Refuge, CA (67%; Baxter et al. 2008, Bell 2011). Nest initiation for newly translocated hens on Anthro Mountain was lower than for resident hens in Idaho (69%), Montana (90%, 95%), and Washington (99%) (Connelly et al. 1993, Schroeder 1997, Tack 2009). Translocated hens that survived  $\geq 1$  year on Anthro ( $n=23$ ) had a nest initiation of 100% which was higher than all residents on Anthro Mountain (88%) and other translocation studies in Utah (71%) and California (86%) (Baxter et al. 2008, Bell 2011).

Newly translocated hens might have experienced lower nest initiation due to a combination of factors including: stress while being transported, differences in breeding schedules between capture and release area, and weather differences between capture and release area (Baxter et al. 2008). Hens that are stressed during transport might have to expend their remaining energy in survival rather than reproduction. Similarly, if a hen was translocated to Anthro Mountain after initiating a nest on Parker Mountain, the hen might not have resources to initiate a second nest and abandon nesting for the year altogether. Snow accumulation and weather can influence nest initiation by limiting food

or nest sites (Reed et al. 2004). If snowpack in the release area is different than that at the source area, translocated hens might not nest due to suboptimal conditions.

Additionally, early nesting is important because dates at which young hatch directly influences their growth rate and females might refrain from nesting if survival prospects of the young are too low (Reed et al. 2004).

First year breeding females may initiate fewer nests compared to adults (Connelly et al. 1993, Holloran 2005). Thus, the observed increase in nest initiation for previously translocated hens might be a result of the shift in age class of translocated hens from yearling to adult (Baxter et al. 2008). Assimilation and increased experience in the release area might also account for the high nest initiation of previously translocated hens.

### **Nesting Success**

Greater sage-grouse population declines have been related to poor nest success (Taylor et al. 2012). The top model was the null model indicating that nest success was not affected by hen age, residency status, or temporal variations. Nest success on Anthro Mountain was 53% for all years and cohorts which was lower than translocated hens in Strawberry Valley, UT (68%) but higher than reports for translocated hens in Clear Lake National Wildlife Refuge, CA (Baxter et al. 2008, Bell 2011). Crawford et al. (2004) reported that the average nest success over 14 sage-grouse studies was lower (47.4%) than the estimates found on Anthro Mountain.

In my study, nest success improved as the nesting season progressed. This is consistent with findings in California (Kolada et al. 2009). This might have been a result

of increased grass and forb structure which increased concealment from predators as the growing season advanced. This improvement might also be attributed to environmental factors or a change in the predator community from the beginning of the nesting season to the end. For example, the likelihood of a spring snowstorm causing a hen to leave her nest and allow the eggs to cool decreases as the season progresses. Lastly, the parental investment of hens in the later stages of incubation might decrease the likelihood that she will abandon the nest and increase the intensity of nest defense (Biermann and Robertson 1981).

The moderate support for resident hens having slightly higher nest success than translocated hens may indicate that resident hens are more capable of finding optimal nesting habitat. Translocated hens may be forced to nest in unsuitable habitat if they did not have adequate time to search for nest cover before initiating a nest, whereas resident hens would already have knowledge of the best nesting areas. Additionally, suitable nesting habitat at the source area might differ from suitable nesting habitat at the release area. Translocated hens might nest in habitat that was suitable on Parker Mountain but would expose nests to risks on Anthro Mountain.

### **Brood Success**

Brood success has been identified as a major factor influencing sage-grouse population trends (Guttry 2011, Taylor et al. 2012). Gruber (2012) documented low individual chick survival in 2009 and 2010 for resident and translocated hens with resident hens having slightly higher chick survival. Because I did not radio mark chicks

in 2011 and 2012, I could not compare individual chick survival for these years. Instead, I examined overall brood success for the study period.

In 2011 resident hens fledged an average of 2.7 chicks ( $n=3$ ) while translocated hens fledged 4.4 chicks per brood ( $n=5$ ). In 2012 resident hens fledged 3.7 ( $n=3$ ) chicks per brood and translocated hens fledged 2.5 ( $n=2$ ). Sage-grouse have a social brood-rearing strategy where chicks amalgamate with other broods. Guttery (2011) documented brood mixing to occur as early as 1 week post hatch and as late as 6 weeks with the majority of mixing occurring in weeks 2–4. On Anthro Mountain, a radio marked chick was documented with an unmarked hen in 2010. During a scheduled brood count in 2011, 1 hen that hatched 7 eggs was observed with 8 chicks. Additionally, at one brood check in 2012, a resident and previously translocated hen congregated with their broods under the same pinyon pine. Because of this behavior, my brood success estimates could be biased low if chicks from one hen were successfully raised by another or high if a radio-marked hen adopted and raised chicks from a different brood. These estimates could also be affected by the difficulty of finding chicks (Schroeder 1997).

Results for differences in brood success were equivocal. Therefore, additional research needs to be conducted to determine the factor that most affects brood survival on Anthro Mountain. All hens had a brood success rate of 55%. This estimate is slightly higher than those found in Washington (49.5%) but slightly lower than those found in Montana (60%) (Schroeder 1997, Tack 2009). There was equal support for 2 models that tested for hen age and overall residency status (resident, newly translocated, and previously translocated). The maximum likelihood estimate of an adult hen successfully

raising a brood was 63% compared to 34% for yearlings. Resident and previously translocated hens also had a higher brood success rate (62% for both groups) than newly translocated hens (38%). These results suggest that translocated hens surviving into their second year can adapt and be reproductively successful. Because adults with more experience are more likely to successfully fledge a brood, the increased success on Anthro Mountain could be a result of the age shift from yearling to adult. Although there was some support for these models, additional information is needed to fully understand their effect on brood survival.

### **Reproductive Success**

Nest initiation, nest success, and brood success are vital rates which most influence fluctuations within a population and are major drivers in population growth (Taylor et al. 2012). Reproductive success is the probability that a hen will initiate a nest, successfully hatch the nest, and successfully raise at least 1 chick to independence (Nest Initiation x Nest Success x Brood Success). In any given year, the maximum likelihood estimate of reproductive success was highest for adult resident and previously translocated (translocated hens surviving  $\geq 1$  year) hens (28%; both groups) than resident yearlings (25%), newly translocated adults (23%), and newly translocated yearlings (15%).

Musil et al. (1993) found that sage-grouse translocations can be useful in restoring certain populations if translocated sage-grouse reproduce successfully. The estimates of reproductive success suggested that resident hens, regardless of age, were more likely to be successful than newly translocated hens. Although residents had a higher likelihood

of reproductive success, newly translocated adults were only slightly less likely than resident yearlings. My results suggested that translocated adults contributed to population growth more readily than translocated yearlings. The results also suggested if a hen remained in the population for at least 1 year, the hen would become reproductively similar to resident adults in the population. Although translocated hens had lower reproductive success, they still contributed to population growth in their first year and had a contribution similar to residents in their second year after release. Therefore, translocated sage-grouse can contribute to population growth and translocation efforts could be useful with restoring populations.

### **Lekking**

Perkins (2010) used lek counts and the establishment of new leks as one parameter to evaluate their translocation efforts. Prior to the translocations on Anthro Mountain, male lek counts declined 70% from 44 males in 2006 to 13 males in 2008. In 2010, lek attendance on Anthro Mountain reached a low of 4 males. A new lek was found in 2011 (Jeep Trail Lek) and it was the only active lek in 2011 with a high count of 8 males. Statewide lek counts declined 25% from 2010 (3909 males) to 2011 (2925 males) (Bernales et al. 2013). In 2012, 18 males were counted on 2 leks on Anthro Mountain, a 125% increase from 2011. Statewide lek counts only increased 12% from 2011 to 2012 (2925 males to 3284 males). Thirty males were counted on 3 leks on Anthro Mountain during the 2013 lekking season (B. Maxfield, UDWR, personal communication). Since 2008, immediately prior to translocation efforts, lek counts have increased by 131%.

If the Jeep Trail Lek was established prior to 2011 and males were attending that lek rather than traditional known leks, total male counts would be low for 2010. Overall though, the increasing trend in male lek counts and the establishment of a new lek on Anthro Mountain suggested that the translocation effort assisted with augmenting this declining population.

### **MANAGEMENT IMPLICATIONS**

No difference was detected for resident and translocated hen survival. Compared to other studies, overall annual survival was low from 2009 through 2011, the years during and immediately following translocations, while hens exhibited high survival rates in 2012. These results suggest that translocations occurred during sub-optimal years and that survival might be the factor most limiting to population growth. High predation rates, less alternate prey, poor weather, and a reduced food supply might have hampered the immediate impacts of the translocations (Fedy and Doherty 2010).

The main difference in vital rates for resident and translocated grouse is nest initiation and the overall reproductive success of hens. Because all resident hens and second year translocated hens have higher reproductive success than newly translocated hens, this suggests that hens surviving into their second breeding season can contribute to population growth. Anthro Mountain is a fragmented sage-brush landscape that harbors many predator species. Therefore, predator control actions may be beneficial immediately prior to and during translocation years in order to buffer the translocated hens from predation and increase their chances of surviving into their second year (Baxter et al. 2008, Hagen 2011).

Additionally, because newly translocated adult hens exhibit higher reproductive success than newly translocated yearling hens, I conclude that adult hens more readily adjusted to the translocation and contributed to population growth. The increased experience of adult hens compared to yearlings increases the likelihood that they will be more successful nesters and brood hens in the release area (Connelly et al. 1993, Aldridge and Brigham 2001). Therefore, managers may see a more immediate impact to population growth if they translocate a higher proportion of adult hens.

Simulation studies have shown that translocations can prolong sage-grouse population persistence but that populations in need of translocations eventually become extirpated regardless of the methods used or the demographics of the translocated grouse (Davis 2012). Despite this result, managers should continue to monitor Anthro Mountain's sage-grouse population to determine the translocation's impact several years from now.

Lastly, research indicated that sage-grouse migrate from Anthro Mountain to various wintering areas. Because sage-grouse survival in migratory populations is typically lower than non-migratory populations (Beck et al. 2006), additional research needs to be conducted to determine if the stresses of migration might hinder survival of resident and translocated hens on Anthro Mountain. Specifically, managers must identify all the wintering areas and determine if migration occurs in stages or in a single flight.

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Table 3 - 1. Number of greater sage-grouse (*Centrocercus urophasianus*) captured on Anthro Mountain, Utah, USA and the number of greater sage-grouse translocated from Parker Mountain, Utah, USA to Anthro Mountain, 2009–2012.

Year	Resident		Translocated		Total	Capture Mortalities
	Adult	Yearling	Adult	Yearling		
2009	9	6	17	13	45	2
2010	2	0	13	17	32	2
2011	11	1	0	0	12	1
2012	4	1	0	0	5	0

Table 3 - 2. Demographic variables used in analyses of annual survival, nest initiation, nest success, and brood survival of greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA, 2009–2012.

Code	Factor	Factor Description
HenAge	Hen Age	Yearling (Start of 1st breeding season (~April 1) through end of second winter (~March 31)) Adult (Start of second breeding season (~April 1) onward)
Trans	Source Population	Translocated or resident hen
DV	Dummy Variables	Variables to determine if survival changes over time (DV1 & DV2) (Resident hens = 0,0, newly translocated hens = 2,1, and previously translocated hens = 1,0)
Bin	Binomial Variable	Variable to determine whether translocated hens that survived into their 2nd year become similar to resident hens. (Resident hens = 1, newly translocated = 0, previously translocated = 1)
Y	Year	Variable coded to model year specific vital rates (Intercept = 2009, Y1 = 2010, Y2 = 2011, Y3 = 2012)
Ordinal	Ordinal Variable	Arranged to determine if overall residency status has constant effect on survival (True resident = 0, previously translocated = 1, newly translocated = 2)
TimeTrend	Time Trend	Examines if a linear relationship of survival exists over time

Table 3 - 3. Models assessing the impact of age, residency status, and temporal variation in female greater sage-grouse (*Centrocercus urophasianus*) survival on Anthro Mountain, Utah, USA, 2009–2012.

Model	k <sup>a</sup>	AICc <sup>b</sup>	ΔAICc <sup>c</sup>	wt <sup>d</sup>	Deviance
Fall + (Y1 + Y2 + Y3)	6	326.07	0.00	0.41	313.95
Fall + (Y1 + Y2 + Y3) + HenAge	7	327.14	1.06	0.24	312.98
Fall + (Y1 + Y2 + Y3) + Bin	7	327.45	1.37	0.20	313.29
Fall + (Y1 + Y2 + Y3) + Trans	7	328.06	1.99	0.15	313.90
Y1 + Y2 + Y3	4	344.28	18.21	0.00	336.23
HenAge + Y1 + Y2 + Y3	5	345.64	19.57	0.00	335.56
Trans + Y1 + Y2 + Y3	5	346.31	20.24	0.00	336.23
Ordinal + (Y1 + Y2 + Y3)	6	347.29	21.22	0.00	335.17
Null	1	353.73	27.66	0.00	351.73
Trans	2	354.79	28.72	0.00	350.77
HenAge	2	355.00	28.93	0.00	350.98
Bin	2	355.43	29.36	0.00	351.42
Trans + HenAge	3	355.80	29.73	0.00	349.77
Bin + HenAge	3	356.82	30.75	0.00	350.78
DV1 + DV2	4	358.80	32.73	0.00	350.74
(DV1 + DV2) + HenAge	5	359.50	33.42	0.00	349.41

<sup>a</sup> K: number of parameters in each model

<sup>b</sup> AICc: Akaike's Information Criterion corrected for small sample size

<sup>c</sup> ΔAICc: Difference between a model and the top performing model

<sup>d</sup> wt: Model weight

Table 3 - 4. Models assessing the impact of age, residency status, and temporal variation in greater sage-grouse (*Centrocercus urophasianus*) nest initiation on Anthro Mountain, Utah, USA, 2009–2012.

Model	k <sup>a</sup>	AICc <sup>b</sup>	ΔAICc <sup>c</sup>	wt <sup>d</sup>	Deviance
HenAge + Binomial	3	81.80	0.00	0.46	17.39
HenAge + Y1 + Y2 + Y3	5	83.65	1.85	0.18	14.85
(DV1 + DV2) + HenAge	5	83.94	2.14	0.16	15.14
Binomial	2	85.17	3.37	0.09	22.89
DV1 + DV2	4	85.34	3.53	0.08	18.75
trans + HenAge	3	87.90	6.10	0.02	23.49
Y1 + Y2 + Y3	4	89.59	7.78	0.01	23.00
HenAge	2	90.18	8.37	0.01	27.89
Null	1	95.92	14.12	0.00	35.72
Trans	2	95.98	14.18	0.00	33.70

<sup>a</sup> K: number of parameters in each model

<sup>b</sup> AICc: Akaike's Information Criterion corrected for small sample size

<sup>c</sup> ΔAICc: Difference between a model and the top performing model

<sup>d</sup> wt: Model weight

Table 3 - 5. Models assessing the impact of age, residency status, and temporal variation in greater sage-grouse (*Centrocercus urophasianus*) nest success on Anthro Mountain, Utah, USA, 2009–2012.

Model	k <sup>a</sup>	AICc <sup>b</sup>	ΔAICc <sup>c</sup>	wt <sup>d</sup>	Deviance
Null	1	239.43	0.00	0.37	237.43
Trans	2	241.14	1.70	0.16	237.13
Bin	2	241.22	1.79	0.15	237.21
HenAge	2	241.44	2.00	0.13	237.43
Trans + HenAge	3	243.12	3.69	0.06	237.11
Bin + HenAge	3	243.21	3.78	0.06	237.20
DV1 + DV2	4	244.25	4.82	0.03	236.22
Y1 + Y2 + Y3	4	244.86	5.43	0.02	236.83
(DV1 + DV2) + HenAge	5	245.96	6.53	0.01	235.92
HenAge + Y1 + Y2 + Y3	5	246.87	7.44	0.01	236.83

<sup>a</sup> K: number of parameters in each model

<sup>b</sup> AICc: Akaike's Information Criterion corrected for small sample size

<sup>c</sup> ΔAICc: Difference between a model and the top performing model

<sup>d</sup> wt: Model weight

Table 3 - 6. Models assessing the impact of age, residency status, and temporal variation in greater sage-grouse (*Centrocercus urophasianus*) brood success on Anthro Mountain, Utah, USA, 2009–2012.

Model	k <sup>a</sup>	AICc <sup>b</sup>	ΔAICc <sup>c</sup>	wt <sup>d</sup>	Deviance
HenAge	2	173.06	0.00	0.22	169.06
Bin + HenAge	3	173.32	0.26	0.20	167.31
Bin	2	173.92	0.85	0.15	169.91
Null	1	174.26	1.20	0.12	172.26
Trans + HenAge	3	174.35	1.28	0.12	168.33
Trans + Bin	3	175.55	2.49	0.06	169.54
Trans	2	176.14	3.08	0.05	172.14
(DV1 + DV2) + HenAge	5	177.34	4.28	0.03	167.30
HenAge + Y1 + Y2 + Y3	5	177.55	4.48	0.02	167.51
DV1 + DV2	4	177.56	4.50	0.02	169.54
Y1 + Y2 + Y3	4	178.62	5.56	0.01	170.59

<sup>a</sup> K: number of parameters in each model

<sup>b</sup> AICc: Akaike's Information Criterion corrected for small sample size

<sup>c</sup> ΔAICc: Difference between a model and the top performing model

<sup>d</sup> wt: Model weight

Table 3 - 7. Greater sage-grouse (*Centrocercus urophasianus*) nest initiation by cohort on Anthro Mountain, Utah, USA, 2009–2012.

Year	# of Nests Initiated	Resident Adults	Resident Yearlings	Translocated Adults	Translocated Yearlings	Hatched Nests	% of Nests Hatched
2009	21 (1 reneest)	4	1	9	7	11 <sup>a</sup>	0.52
2010	26	7	0	16	3	15 <sup>b</sup>	0.58
2011	23 (2 reneests)	3	7	13	0	14 <sup>c</sup>	0.61
2012	15(1 reneest)	7	5	3	0	7 <sup>d</sup>	0.47
All	85 (4 reneests)	21	13	41	10	47	0.55

<sup>a</sup> 3 nests abandoned due to observer error

<sup>b</sup> 3 nests abandoned due to observer error and 1 nest infertile

<sup>c</sup> 2 hens with failing collars not found on nest but appeared with broods

<sup>d</sup> 1 nest infertile

Table 3 - 8. Maximum likelihood estimates of nest initiation for all female greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA, 2009–2012.

Parameter	Estimate	SE	95% Confidence Interval	
			Lower CI	Upper CI
Yearling Trans	0.495	0.107	0.298	0.694
Adult Newly Trans	0.790	0.081	0.592	0.907
Yearling Res	0.866	0.067	0.674	0.953
Adult Res and Prev Trans	0.961	0.023	0.879	0.988

Table 3 - 9. Causes of failed greater sage-grouse (*Centrocercus urophasianus*) nests on Anthro Mountain, Utah, USA, 2009–2012.

	Avian		Mammalian		Unk		Abandoned		Infertile	
	Res	Trans	Res	Trans	Res	Trans	Res	Trans	Res	Trans
2009	0	1	1	0	1	3	0	4 <sup>a</sup>	0	0
2010	0	2	0	1	0	5	0	2 <sup>b</sup>	0	1
2011	0	1	3	0	2	2	0	1 <sup>c</sup>	0	0
2012	2	0	3	1	1	0	0	0	1	0
Total	2	4	7	2	4	10	0	7	1	1

<sup>a</sup> 3 nests abandoned due to researcher error; 1 abandoned nest for unknown reason following storm

<sup>b</sup> 2 nests abandoned due to researcher error

<sup>c</sup> Hen was killed off nest

Table 3 - 10. Average clutch size and number of eggs hatched per nest for resident and translocated greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, Utah, USA, 2009–2012.

	Clutch Size			Average Eggs Hatched		
	Resident	Translocated	All Hens	Resident	Translocated	All Hens
2009	8.33	7.25	7.47	N/A	N/A	N/A
2010	8.00	7.25	7.50	6.25	3.38	4.06
2011	7.80	7.10	7.33	6.40	4.50	5.13
2012	7.40	7.33	7.38	2.80	5.33	3.38
All Years	7.75	7.22	7.43	4.47	4.20	4.32

Table 3 - 11. Maximum likelihood estimates of nest success using a 28 day survival period for greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, Utah, USA, 2009–2012.

Parameter	Nest Success	SE	95% Confidence Interval	
			Lower CI	Upper CI
Null	0.533	0.004	0.415	0.651

Table 3 - 12. Number of broods attempted and successfully raised to independence by resident and translocated greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, Utah, USA, 2009–2012.

	Resident		Translocated		All Hens	
	Attempted	Success	Attempted	Success	Attempted	Success
2009	3	1	8	4	11	5
2010	7	5	8	3	15	8
2011	5	3	9	6	14	9
2012	5	3	2	2	7	5
All Years	20	12	27	15	47	27

Table 3 - 13. Maximum likelihood estimates of greater sage-grouse (*Centrocercus urophasianus*) brood success using a 50 day survival period for Anthro Mountain, Utah, USA, 2009–2012.

Parameter	Brood Success	SE	95% Confidence Interval	
			Lower CI	Upper CI
<b>Model 1 - Null</b>				
Null	0.550	0.003	0.406	0.694
<b>Model 2 - HenAge</b>				
Yearling	0.340	0.007	0.085	0.594
Adult	0.631	0.003	0.466	0.795
<b>Model 3 - Bin</b>				
Newly Trans	0.375	0.00679	0.121	0.630
Res and Prev Trans	0.622	0.00272	0.455	0.789

Table 3 - 14. Maximum likelihood estimates of overall reproductive success of greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, Utah, USA, 2009–2012.

Parameter	Reproductive Success	95% Confidence Interval	
		Lower CI	Upper CI
Newly Trans Yearling	0.145	0.0660	0.224
Newly Trans Adult	0.231	0.139	0.323
Res Yearling	0.254	0.158	0.349
Previously Trans and Res Adult	0.282	0.189	0.374

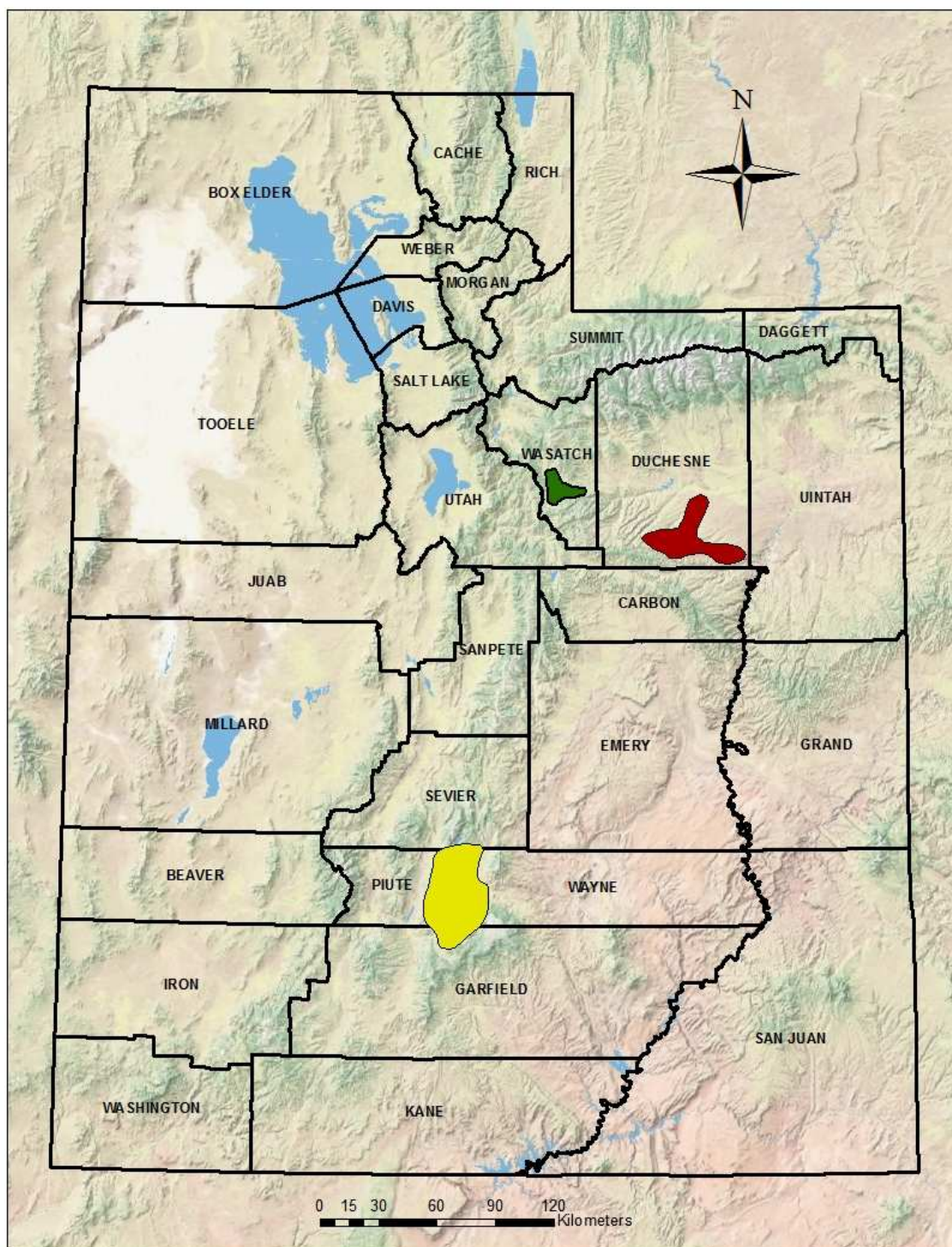


Figure 3 - 1. Map of Utah, USA which includes Anthro Mountain (red Polygon), Strawberry Valley (green polygon), and Parker Mountain (yellow polygon).

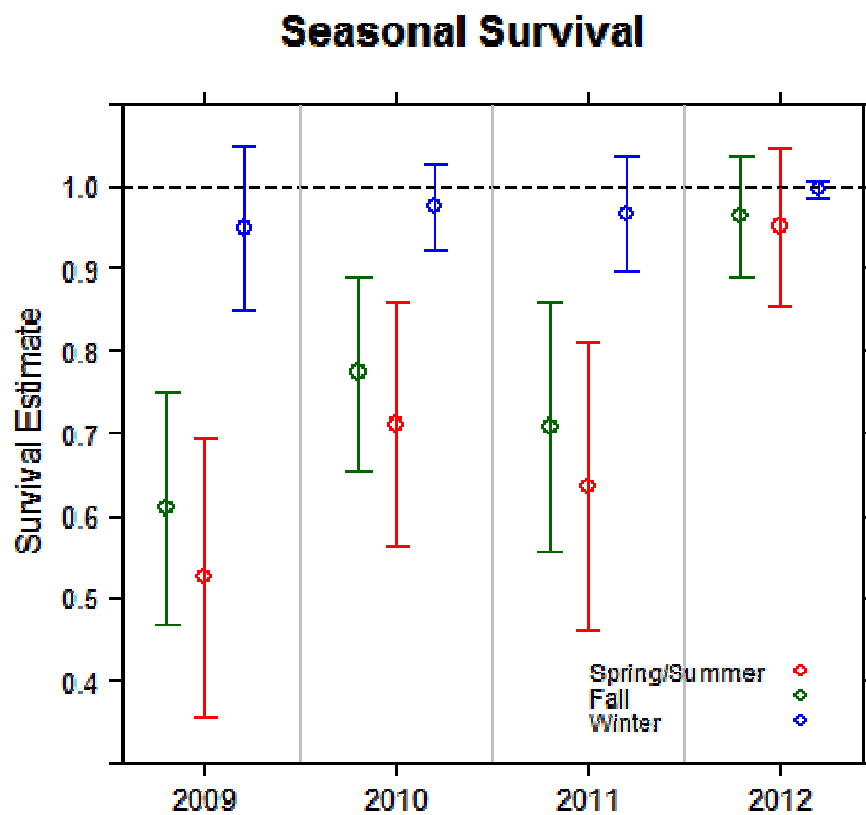


Figure 3 - 2. Trends in average seasonal survival for resident and translocated sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA from 2009–2012.

### Maximum Male Lek Counts on Anthro Mountain

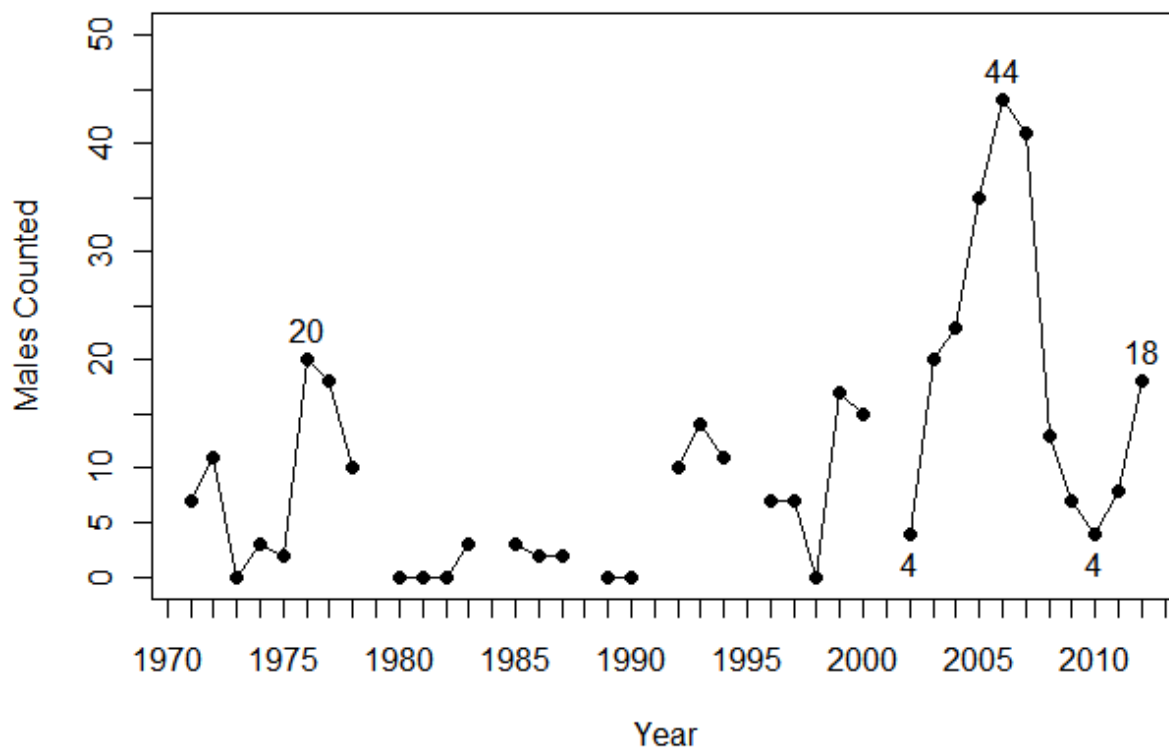


Figure 3 - 3. Lek count trends of male greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, Utah, USA, 1971–2012. Blank spaces indicated years in which lek counts were not conducted.

## CHAPTER 4

### LANDSCAPE EFFECTS ON TRANSLOCATED GREATER SAGE-GROUSE SEASONAL MOVEMENTS, HOME RANGES, AND HABITAT USE

#### ABSTRACT

Range-wide greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) declines have been attributed to the loss or fragmentation of sagebrush (*Artemisia* spp.) habitat. In areas where viable habitat has been protected or restored, wildlife managers may attempt translocations to augment declining populations. Translocations have been successfully used for native game animals including upland game birds. However, sage-grouse translocations have had limited success. Wildlife managers continue to express concerns regarding the ability of sage-grouse to adapt into the release habitats. In 2009 and 2010, 60 radio-collared hens (30 each year) were translocated from Parker Mountain, in south-central Utah to Anthro Mountain, in northeast Utah. Although the grouse were genetically compatible, release site topography, habitats, and seasonal migration patterns differed from the source area. I studied movements of the translocated sage-grouse and 32 resident sage-grouse from 2009–2012 to determine if home ranges and breeding habitat use differed for cohorts. I also compared the habitat-use patterns of the translocated birds to the source population to examine if the landscape at the release site affected home range and seasonal movements. Home range sizes did not differ for resident and translocated hens, but translocated hens that survived at least 1 year in the release area had smaller home ranges (225 ha, SE = 42.8, n = 22) than newly released hens (455 ha, SE = 68.8, n = 38;  $p = 0.037$ ). Additionally, the average home range and

seasonal movement patterns for translocated birds were smaller than the source population. Habitat use at nesting and brood rearing sites was similar for resident and translocated hens. The release site consisted of 2,500 ha of suitable but non-contiguous habitat compared to approximately 96,000 ha of contiguous suitable habitat at the source site. Sage-grouse in the source population migrated over contiguous habitat to their wintering areas at lower elevations. Conversely, sage-grouse on Anthro Mountain migrated over dense pinyon-juniper stands to reach the wintering areas 23–33 km from the summer range; the wintering areas were shared by both translocated and resident hens. These observations suggest that sage-grouse translocated into occupied sagebrush habitats isolated by expanses of non-habitat were capable of learning from residents and adapting to a new landscape. Ultimately, the success of future translocations may depend on individual population characteristics and land use management.

## **INTRODUCTION**

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) depend on sagebrush (*Artemisia* spp.) communities throughout their range for annual food and cover (Wallestad 1975, Schroeder et al. 2004). Sage-grouse populations have declined range-wide over the past century (Schroeder et al. 2004). Once found in 16 western states and 3 Canadian provinces, sage-grouse currently occur in 11 states and 2 provinces (Connelly and Braun 1997, Schroeder et al. 2004). Loss and alteration of suitable habitat is cited as the primary cause for observed declines (Connelly et al. 2004, Schroeder et al. 2004, Leu and Hanser 2011, Wisdom et al. 2011).

Compared to other galliforms, sage-grouse are longer lived and have lower reproductive output resulting from smaller clutch sizes and lower reneating rates (Schroeder et al. 1999). Nest success and adult hen and chick survival are important to population growth (Taylor et al. 2012). Changes in any of these vital rates drive population fluctuations (Moynahan et al. 2006, Aldridge and Boyce 2007, Dahlgren 2009, Guttery 2011, Taylor et al. 2012). These vital rates are closely linked to habitat characteristics such as shrub canopy cover and herbaceous understory (Gregg et al. 1994, Aldridge and Brigham 2001, 2002, Holloran 2005, Aldridge and Boyce 2007). Unsuitable habitat could result in decreased productivity and result in declining populations (Crawford and Lutz 1985, Sveum et al. 1998, Schroeder et al. 1999, Aldridge and Boyce 2007).

Because sage-grouse are dependent on sagebrush communities, protection and restoration of important habitats remains a high conservation priority range-wide (Connelly et al. 2011). Managers have implemented projects to improve nesting and brood rearing habitat. In areas where populations have declined while habitat conditions are within the recommended guidelines (Connelly et al. 2000), managers have sought to augment populations through translocations.

A translocation is the intentional release of animals into the wild to establish or augment a population (Griffith et al. 1989, Dickens et al. 2009). Translocations have been successfully used as a management tool to augment extirpated or declining wildlife populations for both game and nongame species including native upland game birds (Griffith et al. 1989, Snyder et al. 1999). Griffith et al. (1989) estimated an 86% success

rate for all native game species. Factors that impacted the success of translocations included habitat quality, habitat fragmentation, and dispersal of translocated sage-grouse from the release area (Kurzejeski and Root 1988, Griffith et al. 1989, Musil et al. 1993, Snyder et al. 1999, Baxter et al. 2008).

Biologists have attempted sage-grouse translocations to augment declining populations in areas where habitat conditions approximate the recommended guidelines for sustainable populations (Reese and Connelly 1997, Connelly et al. 2000, Baxter et al. 2008). Sage-grouse translocations have been used multiple times in 7 states and one Canadian province since the early 1930s (Reese and Connelly 1997). Reese and Connelly (1997) estimated that 5% of sage-grouse translocations were successful compared to a 32% success rate for other grouse translocations in the United States (Snyder et al. 1999). Managers cite the inability of translocated sage-grouse to integrate into release habitats as one of the factors most affecting the success of these efforts (Reese and Connelly 1997).

Home range size is often considered to be inversely related to habitat quality. Coates et al. (2006) found that availability of suitable habitat surrounding the release site was inversely related to the movements of translocated Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*). Because translocated animals are unfamiliar with new areas, they typically have larger home ranges and move longer distances than residents as they search for suitable habitat (Cope 1992, Beck et al. 2006, Dickens et al. 2009). The increased movement increases vulnerability to predators and could lead to lower survival and reproductive rates when compared to residents in the population

(Kurzejeski and Root 1988, Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor et al. 2012). For example, reintroduced ruffed grouse (*Bonasa umbellus*) in Missouri were reported to have higher mortality rates as their movement increased (Kurzejeski and Root 1988). Similarly, translocated sage-grouse may be less likely to contribute to population growth compared to residents (Taylor et al. 2012).

From 2002 through 2006, U.S. Forest Service (USFS) biologists on the Ashley National Forest began monitoring sage-grouse habitat use and vital rates on Anthro Mountain. Resident hen survival over this period was similar to estimates reported range-wide (B. Christensen 2007, USFS Ashley National Forest, unpublished report). The report concluded that Anthro Mountain provided appropriate nesting, brood rearing, and wintering habitats within the recommended habitat guidelines (Connelly et al. 2000).

Despite having adequate year-round habitat, Anthro Mountain's sage-grouse population declined from 2006 to 2008 based on lek count indices (44 males in 2006 to 13 males in 2008) (B. Maxfield, Utah Division of Wildlife Resources [UDWR], unpublished data). The concern about population declines in an area where habitat was within published guidelines, the UDWR, USFS, and Utah State University (USU) initiated a sage-grouse translocation project in 2009 to reverse the trend.

The sage-grouse population that inhabited Parker Mountain in south-central Utah was selected as the source population because it was deemed stable by the UDWR and was genetically compatible with the sage-grouse population on Anthro Mountain (Smith 2009). Translocation protocols were based on the long-term translocation research

conducted in Strawberry Valley which also included translocated sage-grouse from Parker Mountain (Baxter et al. 2008, UDWR 2009).

Gruber (2012) reported that sage-grouse translocated to Anthro Mountain had similar survival and reproductive success as residents, but both rates were low compared to range-wide estimates (Connelly et al. 2011). Translocated sage-grouse integrated into the population and displayed movement patterns similar to residents (Gruber 2012).

Gruber (2012) concluded that the overall effect of the translocation was inconclusive, however, and cited low survival and reproductive success as key limiting factors. The objectives of this study were to determine if habitat use and seasonal movement patterns for translocated and resident sage-grouse on Anthro Mountain differed. I subsequently compared the home range and seasonal movement of the translocated birds to those previously reported for the source population to determine how landscape size and characteristics may affect habitat-use patterns (Chi 2004, Dahlgren 2006, 2009, Caudill 2011, Guttery 2011)

## **STUDY AREA**

### **Anthro Mountain, Utah**

Anthro Mountain was located on Ashley National Forest in Duchesne County, Utah approximately 29 km southeast of the town of Duchesne (Fig. 4-1). Suitable sage-grouse habitat was limited to 2,500 ha. The area that immediately surrounded Anthro Mountain was characterized by two-needle pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*) (together, PJ). The PJ encroached on the sagebrush community at the lower elevations and created an isolated area of sagebrush habitat. This high

elevation sagebrush community consisted largely of a mountain big sagebrush (*A. tridentata ssp. vaseyana*) community intermixed with pockets of quaking aspen (*Populus tremuloides*) and Douglas-fir (*Pseudotsuga menziesii*). Pockets of black sagebrush (*A. nova*) was scattered on ridge tops across the mountain. Other native vegetation included: gray horsebrush (*Tetradymia canescens*), serviceberry (*Amelanchier utahensis*), rabbitbrush (*Chrysothamnus viscidiflorus*), snowberry (*Symphoricarpos oreophilus*), lupine (*Lupinus argenteus*), June grass (*Koeleria macrantha*), basin wildrye (*Leymus cinereus*), salina wildrye (*L. salinus*), and bluebunch wheatgrass (*Elymus spicatus*). Smooth brome (*Bromus inermis*) was seeded in the 1950s in portions of the area.

Anthro Mountain ranged from 2,400–2,800 m in elevation and was bordered by the Uintah Basin to the north and east, Gilsonite Canyon to the south, and Indian canyon to the west, all of which were lower in elevation than Anthro Mountain. Anthro Mountain received an average of 49 cm of precipitation annually with the majority of the precipitation as heavy winter snow and thunderstorms during the monsoon season in July and August.

The current and historical land use was domestic livestock grazing (Thacker 2010). Sage-grouse hunting was not allowed on Anthro Mountain. In 2010, U.S. Department of Agriculture, Animal and Plant Health Inspection Services, Wildlife Services (WS) placed poison eggs on Anthro Mountain to target and remove corvids around active sage-grouse lekking and nesting sites. Although WS occasionally targeted and removed mammalian predators on Anthro Mountain, intensive mammalian predator control was not used as was practiced during the Strawberry Valley translocation (Baxter

et al. 2008). Anthropogenic influences on Anthro Mountain included exploratory oil and gas development, unimproved roads along ridgelines, fence lines, and seasonal recreational traffic.

### **Parker Mountain, Utah**

Parker Mountain, the source of the translocated sage-grouse, was located in south-central Utah approximately 218 km southeast of Anthro Mountain (Fig. 4-1) and was part of the largest contiguous sagebrush ecosystems in Utah (Chi 2004). This high elevation sagebrush ecosystem contained approximately 96,000 ha of suitable sage-grouse habitat and was characterized by rolling hills and gently northeastern sloping plateaus (Chi 2004, Caudill 2011). The ridges and slopes were dominated by black sagebrush while big sagebrush, bitterbrush (*Purshia tridentata*), and rabbitbrush were found in the drainages. Grasses commonly found on Parker Mountain included grama grass (*Bouteloua* spp.), wheatgrass, bluegrass (*Poa* spp.), squirreltail grass (*E. elymoides*), needlegrass (*Hesperostipa* spp.), and June grass.

Elevations on Parker Mountain ranged from 2,134–3,018 m (Chi 2004). Parker Mountain was situated on 2 plateaus and was bounded by an escarpment to the west and Rabbit Valley to the east (Chi 2004). The predominant land use on Parker Mountain was livestock grazing (Guttery 2011). To reduce livestock depredation on Parker Mountain, WS removed mammalian predators throughout the year (Chi 2004). Additionally, Wayne County, Utah, the county in which most of Parker Mountain was situated, had a bounty on coyotes (*Canis latrans*) which may have resulted in additional coyotes taken from the study area (Chi 2004). The sage-grouse population on Parker Mountain was one

of the few hunted populations in Utah. Although Parker Mountain contained a vast area of contiguous sagebrush habitat, it was fragmented by gravel and unimproved roads, but traffic volumes were low (Caudill 2011). Energy development on Parker Mountain was non-existent.

## **METHODS**

### **Data Collection**

The UDWR and USU translocated a total of 60 female sage-grouse (30 yearlings and 30 adults) from Parker Mountain to Anthro Mountain in the spring of 2009 and 2010. Thirty-two resident female sage-grouse (21 yearlings and 11 adults) were captured from 2009 through 2012 on Anthro Mountain.

We captured sage-grouse by spotlighting roost sites near active leks; birds were netted with long-handled hoop nets from the back of an all-terrain vehicle or on foot (Giesen et al. 1982, Wakkinen et al. 1992). We determined the sex and age of each grouse using plumage characteristics outlined by Beck et al. (1975). Each captured sage-grouse was fitted with a necklace-mounted radio-transmitter equipped with an 8 hour mortality switch (Advanced Telemetry Systems, Insanti, MN, USA and American Wildlife Enterprises, Monticello, FL, USA). The antenna was bent to rest along the back of the sage-grouse to minimize interference with movement. After fitting the transmitter, the hen was weighed with a Pesola scale™ (Pesola, Zeg, Baar, Switzerland). For each grouse captured, we recorded the time and UTM's (NAD 83) of the capture site and release time. Any injuries or comments about the bird's condition upon release were also

recorded. Handling protocols were approved by Utah State University Institutional Animal Care and Use Committee (Permit # 1404).

Translocation followed protocols outlined by Baxter et al. (2008) and Reese and Connelly (1997). Each hen was placed in an individual cardboard box with holes for ventilation and transported by vehicle overnight to Anthro Mountain for release. The hens were released during hours of breeding activity approximately 100 m from an established lek (Gruber 2012). It was recommended that translocated sage-grouse be released in an area of sagebrush habitat surrounded by a barrier to movement from the release site (Reese and Connelly 1997, Baxter et al. 2008). Although Anthro Mountain had viable sagebrush habitat, there was no barrier inhibiting sage-grouse from leaving the study area.

*Homerange and Habitat-use.* – I monitored movements of radio-marked sage-grouse using a Communications Specialist™ telemetry receiver (Communications Specialist, Inc., Orange, CA, USA) and handheld 3-element yagi antennas. Each hen was located 2 to 3 times a week from April through August. All brood rearing hens were re-located 3 times a week until the brood reached 50 days of age. Each male was re-located at least once a week from April through August. Due to access limitations caused by snow pack, sage-grouse were monitored monthly during the late fall and winter.

Sage-grouse locations were evenly distributed across four time blocks (0600–1000, 1000–1400, 1400–1800, and 1800–2000) to avoid consistently locating the grouse at the same time and imparting a bias. If a sage-grouse was located after 2000 hours, I noted that it was a night location. To locate the sage-grouse, I followed the strongest

signal until I was within approximately 50 m and completed a circle around the strongest signal to pinpoint its location. If a grouse flushed, I noted the flock size and marked the exact location. If a grouse did not flush, I stood at a cardinal direction from the strongest signal, estimated the distance to the sage-grouse, and adjusted the UTM coordinates accordingly.

I conducted vegetation surveys to measure microsite habitat-use of breeding hens. Vegetation surveys were conducted at each nest site (four 15 m transects) and at one location a week for each brood (four 10 m transects) until the brood fledged at 50 days or was lost (Schroeder 1997). When gathering location information for brood vegetation plots, I visually located the hen and determined her exact location. Vegetation plots were centered on the nest or as close as possible to a brood's former location. We attempted to complete surveys within a week from the date of the nest fate or brood location so measurements approximated what was used by the hen.

Vegetation surveys included measurements of shrub canopy cover, herbaceous understory composition, and visual obstruction at each plot. I used the line intercept method along each transect to determine shrub canopy cover (Connelly et al. 2003). Herbaceous cover measurements were estimated using a 20 x 50 cm Daubenmire frame (Daubenmire 1959, Connelly et al. 2003). Daubenmire frame measurements were taken along each transect at 3 m intervals for the nest sites and 2.5 m intervals for the brood sites. I estimated the percentage and maximum height of grasses and forbs within the Daubenmire frame at each interval. I also estimated the percent of litter, rock, and bareground at each interval.

Hens on Parker Mountain were located monthly using the tracking techniques described above (Caudill 2011). These locations were used to determine movements and home ranges of hens on Parker Mountain. Vegetation characteristics at nest and brood sites on Parker Mountain were measured using the methods described above.

### **Data Analysis**

*Homerange and Habitat-use.* – All spatial location data were recorded using the projected geographic coordinate system Universal Transverse Mercator (UTM) Zone 12N. Location data were loaded into ArcMap 10.1 (Esri, Redlands, CA, USA) and edited to censor erroneous location data. I censored data with incomplete UTM coordinates, multiple locations in one day, and release locations. Nesting data for the same hen are not independent because they include identical UTM coordinates for each location; therefore I counted all nesting locations as a single relocation instance to assess home range (Springer 2003). I right censored missing grouse and mortalities at the last live location for the grouse. All hen and male grouse locations were used to determine area of occupancy for the Anthro Mountain sage-grouse population.

Descriptive statistics for home range and vegetation characteristics on Anthro Mountain were computed based on the raw data. These statistics were used to describe differences in home range and habitat-use for each cohort (resident, newly translocated, and previously translocated hens).

For the purpose of home range analysis, I only included hens with  $\geq 5$  locations (Springer 2003, Burnett 2013). Although there were sporadic winter locations, most location data were recorded from April through October of each year. Therefore, I

estimated seasonal home ranges using only the locations from April through October. The sporadic winter locations were only used for the area of occupancy. All home ranges and respective areas were calculated using a local convex hull (LoCoH) nonparametric kernel method which is a generalized minimum convex polygon home range estimator (Getz et al. 2007). I used LoCoH instead of the parametric kernel methods for constructing home ranges because LoCoH is superior in identifying inhospitable terrain and irregular structures (roads, ravines, ridges, and rocky outcrops), all of which were present on Anthro Mountain (Getz et al. 2007).

The home range data were not normally distributed. The Mann-Whitney-U test does not require data to be normally distributed (Rosner and Grove 1999). Therefore, I used the Mann-Whitney-U test to examine if home ranges differed for resident hens, newly translocated hens, or previously translocated hens. Results were considered significant if  $p \leq 0.05$ .

I tested for differences in vegetation characteristics at successful and unsuccessful nest locations. I also examined if a difference in habitat use existed between resident and translocated hens within years and for the entire study period. I used the Spearman rank correlation coefficient to test for inter-correlation among variables. The vegetation data were not normally distributed; therefore, I used the Mann-Whitney-U test to examine if differences in vegetation characteristics existed at nest sites (Rosner and Grove 1999). I considered results significant if  $p \leq 0.05$ .

Wintering home ranges of juvenile hens on Parker Mountain were calculated using the Home Range Extension in ArcView 9.2 to create 100% minimum convex

polygons. Descriptive statistics of home ranges and vegetation characteristics at nest and brood sites were calculated using the raw data for hens on Parker Mountain (Chi 2004, Caudill 2011). The descriptive statistics for home ranges and vegetation use on Anthro Mountain were then compared to those on Parker Mountain.

## RESULTS

Resident and translocated hens and resident males selected for the ridge habitats on Anthro Mountain from spring through fall (Fig. 4-1). Males were located on Cottonwood Ridge during the late summer and moved back to Anthro Mountain in the fall (Fig. 4-1). Hens were not located on Cottonwood Ridge. Although Cottonwood Ridge was considered part of the Anthro Mountain unit, this ridge was not connected to other ridges or geographic features of Anthro Mountain. Grouse were found on mortality in Whitmore Park and Fivemile Canyon while a few translocated grouse were located in Emma Park. During the winter, both resident and translocated sage-grouse were documented using several areas off Anthro Mountain while some stayed on the mountain (Fig. 4-2). One wintering area was approximately 23 km northeast of Anthro Mountain while another wintering area was approximately 33 km northeast of Anthro Mountain. Lastly, a wintering area was identified approximately 36 km east of Anthro Mountain. Despite wintering in close proximity to the Green River, no grouse were documented to cross the river. Additionally, some grouse were located approximately 10–30 km southeast of Anthro Mountain during the winter (Fig. 4-2). Due to the sporadic winter locations, we could not identify migration corridors or determine if the migrations

occurred as a single flight or in multiple stages. Not all radio-collared grouse were located in the winter.

Parker Mountain sage-grouse displayed an elevational migration pattern (Chi 2004, Caudill 2011). As winter snow pack accumulated, sage-grouse moved to lower elevations and were clustered together in high density areas. The grouse moved to higher elevations as summer progressed. Sage-grouse movement off of Parker Mountain was limited (M. Guttery, USU, personal communication).

No difference in home range existed between resident and newly translocated hens or resident and previously translocated hens on Anthro Mountain (Table 4-1). Previously translocated hens, however, had a smaller home range (225 ha, 95% Confidence Interval (CI) = 142–310 ha, n = 22) than newly translocated hens (455 ha, CI = 320–590 ha, n = 38; Fig. 4-3). Resident hens had an average seasonal home range of 389 ha (CI = 263–515 ha, n = 36). Males had an average home range size of 1069 ha (CI = 387–1651 ha, n = 11; Fig. 4-3). Caudill (2011) found that home ranges of juvenile hens on Parker Mountain from August–March averaged 4556.3 ha.

Both resident and translocated sage-grouse on Anthro Mountain were documented in habitats with a tree component. I obtained 92 locations of sage-grouse that were within 10 m of standing pinyon, juniper, and Douglas fir trees. These instances ranged from single or multiple birds under a single standing live conifer in the middle of a stand of sage to brood hens that were located in the middle of a thick pinyon-juniper forest. Both males and females were located within 10 m of the conifers and the locations

ranged temporally from 0805 hrs to 2240 hrs and from 2 January to 21 October. I also obtained 92 relocations of grouse that were directly in or within 10 m of aspen stands. Both resident and translocated hens used aspen stands; the majority of aspen use was by hens with broods. Locations in aspen stands ranged from 1 June to 18 October.

Thirty percent (25/82) of nest vegetation plots on Anthro Mountain contained tree canopy cover. Nests were located under mountain big sagebrush (n=60), pinyon pine (n=19), juniper (n=1), rabbitbrush (n=1), and a basin wildrye grass clump (n=1; Table 4-7). Eighty-four percent (16/19) of the nests that were located under pinyon pines were initiated by translocated hens (7 by newly translocated hens and 9 by previously translocated hens). A resident hen initiated the nest located under a juniper and another resident hen initiated the nest located under the basin wildrye clump.

Resident hens on Parker Mountain positioned all their nests under shrubs. Nesting substrate on Parker Mountain included: black sagebrush, big sagebrush, rabbitbrush, big sagebrush/bitterbrush combinations, and big sagebrush/snowberry combinations (Chi 2004). Hens did not place nests in areas with tree canopy cover (T. Messmer, USU, personal communication).

Forb height and grass height were the only vegetation characteristics to vary for successful and unsuccessful nests (Table 4-2). Successful nests had slightly taller forbs (9.84 cm, SE = 0.36) than unsuccessful nests (8.49 cm, SE = 0.54). Grass height was also taller at successful nests (17.73 cm, SE = 0.51) than unsuccessful nests (15.18 cm, SE = 0.59; Table 4-3).

Vegetation characteristics at resident and translocated hen nest sites on Anthro Mountain varied little within years. In 2009, the only nest site characteristic to differ for resident and translocated hens was nest shrub height ( $W = 69$ ,  $p = .004$ ; Table 4-4). Translocated hens nested under taller structures (82 cm,  $SE = 3.2$ ) than resident hens (51 cm,  $SE = 7.5$ ). In 2011, shrub cover at nest sites was the only characteristic to differ for resident and translocated hens ( $W = 86$ ,  $p = 0.029$ ; Table 4-4). Resident hens nested in areas with greater shrub canopy cover (24.13 cm,  $SE = 2.4$ ) than translocated hens (16.7 cm,  $SE = 2.9$ ). In 2010 and 2012, vegetation measurements at nest sites did not differ for resident and translocated hens.

Mean percent canopy cover at nest sites was the only variable that was significantly different for resident and translocated hens over the 4 year study ( $W = 1028$ ,  $p = 0.028$ ; Table 4-4). Translocated hens selected nest sites with less canopy cover (21.7%, 95% CI = 19.1–24.3) than resident hens (26.7%, 95% CI = 23.6–30.0). Over the entire study period, nest site vegetation averaged the following: 77 cm ( $SE = 3.6$ ) nest height, 128 cm ( $SE = 4.1$ ) nest diameter, 31cm ( $SE = 1.1$ ) shrub canopy height, 23.8% ( $SE = 1.1$ ) shrub canopy cover, 14.5% ( $SE = 0.73$ ) percent forb, and 17.57% ( $SE = 0.76$ ) percent grass (Table 4-5). Vegetation characteristics at resident nest sites averaged: 71 cm ( $SE = 5.0$ ) nest height, 135 cm ( $SE = 7.38$ ) nest diameter, 32 cm ( $SE = 1.48$ ) canopy height, 27% ( $SE = 1.48$ ) percent shrub cover, 15.3% ( $SE = 1.24$ ) percent forb, and 17.5% ( $SE = 1.07$ ) percent grass. Vegetation characteristics at translocated nest sites averaged: 81 cm ( $SE = 5.0$ ) nest height, 123 cm ( $SE = 4.59$ ) nest diameter, 31 cm ( $SE = 1.48$ ) shrub

canopy height, 21.68% (SE = 1.33) percent shrub cover, 13.9% (SE = 0.88) percent forb, and 17.6% (SE = 1.08) percent grass (Table 4-5).

Vegetation at nest sites on Parker Mountain averaged: 51 cm (SE = 2.2) shrub canopy height, 32.1% (SE = 1.0) shrub canopy cover, 2.26% (SE = 0.49) percent forb, and 6.09% (SE = 0.49) percent grass (Chi 2004; Table 4-6).

Within year vegetation measurements at brood sites did not vary for 2009, 2011, and 2012. In 2010, translocated brood hens used areas with a higher percent of grass (23.3%, SE = 2.20) than residents (18.0%, SE = 1.05;  $p = 0.027$ ). For all years combined, translocated brood hens used areas with taller shrubs (29 cm, SE = 1.03;  $p = 0.032$ ) and forbs (10.8 cm, SE = 0.34;  $p = 0.054$ ; Table 4-8) than resident brood hens (shrubs: 26 cm, SE = 0.094; forbs: 9.61 cm, SE = 0.27). Over the study period, vegetation at all brood sites on Anthro Mountain averaged: 27 cm (SE = 0.71) shrub canopy height; 21.2% (SE = 0.63) shrub canopy cover; 18.4% (SE = 0.55) forb cover, and 19.6% (SE = 0.55) grass cover.

Average vegetation characteristics at brood sites on Parker Mountain were not reported for all years combined (Chi 2004). Shrub canopy cover ranged from 19.5–28.9%, forb cover ranged from 3.0–12.4%, and grass cover ranged from 9.3–11.6%.

## **DISCUSSION**

Migration is an important component of many wildlife species' life histories because it connects multiple areas of discrete resources required for completing life cycles. Some sage-grouse populations are non-migratory while others migrate between wintering and breeding areas (Connelly et al. 2011). However, even within populations

considered migratory, individual birds may not migrate (Fedy and Doherty 2010). Some sage-grouse have been documented to travel up to 160 km between seasonal areas (Smith 2013). The sage-grouse on Anthro Mountain migrate to several disconnected areas in multiple directions during the winter, and these wintering areas were approximately 30–35 km from the summer range. Resident and translocated hens used similar wintering areas throughout the study. Sage-grouse on Parker Mountain sought wintering areas at lower elevations that were connected by sagebrush habitat when snowpack accumulated in the higher elevations (Chi 2004, Caudill 2011). Although the hens translocated to Anthro Mountain were not accustomed to migrating to disconnected areas, they successfully completed the migrations and shared wintering areas with resident hens in the population. The overlapping winter ranges indicated that the translocated hens learned the seasonal movement patterns from residents on Anthro Mountain and they adapted to their release area.

Sage-grouse migrations may occur in a single flight, in stages, or have more complicated seasonal movements (Connelly et al. 1988, Smith 2013). Although some wintering areas were identified, little is known about migration patterns of Anthro Mountain's sage-grouse population. Weak evidence indicated that migration might occur in stages and that grouse use stopover points to complete migrations. For example, 1 male was located in the Twin Knolls area (~ 32 km from Anthro Mountain) on 7 February 2013. On 11 March 2013, the same male was located in Big Wash approximately 10 km closer to Anthro Mountain and then located near an active lek on Anthro Mountain a week later on 19 March 2013 (Fig. 4-2). Migrations on Parker

Mountain occurred from September through November, and sage-grouse congregated in common wintering areas (Caudill 2011). Additionally, suitable habitat was contiguous between the summering and wintering ranges. Therefore, the issue of stopover areas and whether migrations occur in stages is less important than on Anthro Mountain.

Some sage-grouse, both resident and translocated, were not located on the known wintering grounds indicating that some wintering areas are undiscovered for this population. Lastly, because some sage-grouse stayed on Anthro Mountain throughout the winter, we can infer that the mountain contains some suitable wintering habitat and sage-grouse might prefer to stay on Anthro Mountain if food resources are not covered by winter snow.

Seasonal home range is an essential component of an animal's ecology because it has important implications for energetics, survival, and time budgets (Whitaker et al. 2007). Larger home ranges may be costly because they require individuals to expend more energy while increasing the potential for encounters with predators (Whitaker et al. 2007). Additionally, home ranges are inversely correlated to resource availability, habitat quality, and fitness; therefore, an animal is expected to use habitats that fulfill their resource needs within the smallest possible area (Badyaev et al. 1996, Whitaker et al. 2007). Animals more familiar with a given area can reduce movements while improving foraging efficiency, predator avoidance, and reproductive success (Badyaev et al. 1996). The smaller home range size of previously translocated hens compared to newly translocated hens indicates that previously translocated hens are more familiar with their release area and could more easily locate quality habitat. The larger home ranges of

newly translocated hens may also be an indication of exploratory movements in search of suitable habitat, whereas previously translocated hens already identified suitable habitat (Kemink and Kesler 2013).

The difference in home range may be partially explained by a shift in age class from yearlings to adults for previously translocated hens. Juvenile Appalachian ruffed grouse had a home range that was twice the size of adults (Whitaker et al. 2007). Because newly translocated sage-grouse included both yearlings and adults while previously translocated hens only included adults, the home range for newly translocated hens might be larger. This may also explain the smaller home range for previously translocated grouse compared to residents in the population. Residents included both yearling and adult grouse while previously translocated grouse were only adults; therefore, the home range might be slightly higher for all residents.

Resident hens on Parker Mountain had an average overall home range that was almost 8 times greater than the largest hen home range on Anthro Mountain. This might be attributable to the extensive contiguous habitat on Parker Mountain whereas suitable habitat on Anthro Mountain was limited and fragmented by roads and natural changes in vegetation. Anthro Mountain contained approximately 2,500 ha of suitable habitat compared to 96,000 ha on Parker Mountain. Because sage-grouse on Parker Mountain have a large area in which they can move, they are likely to have larger home ranges as they use different resources across the landscape. Conversely, Anthro Mountain sage-grouse have a finite area that can be utilized which may result in small home ranges.

Larger home ranges typically lead to higher predation rates, therefore higher mortality rates would be expected for newly translocated hens as they seek appropriate habitat types (Whitaker et al. 2007). Reintroduced ruffed grouse in Missouri were reported to have higher mortality rates as their movement increased (Kurzejeski and Root 1988). I reported that residency status did not affect survival of hens on Anthro Mountain (See Chapters 2 and 3). Because survival was similar for all cohorts but newly translocated hens had larger home ranges than previously translocated hens, we can conclude that the home range size does not significantly affect survival on Anthro Mountain.

An adequate amount of quality habitat can reduce predation rates by native predators (Connelly et al. 2000, Schroeder and Baydack 2001, Hagen 2011). Despite the fact that hens on Anthro Mountain had smaller home ranges than those on Parker Mountain, survival of Anthro Mountain hens was low compared to survival of resident hens on Parker Mountain (see Chapter 2). Suitable habitat is limited and highly fragmented on Anthro Mountain compared to Parker Mountain. Because the suitable habitat on Parker Mountain was so extensive, it may have buffered the hens from the pressures of predation and led to higher survival rates despite larger home ranges.

Sage-grouse require a variety of plant community types for breeding, nesting, and brood-rearing (Crawford et al. 2004). Nest sites are selected based on height and amount of shrub canopy cover and adequate vegetation structure provides a barrier to detection by predators (Klebenow 1969, Gregg 1991, Crawford et al. 2004). Nesting vegetation characteristics on Anthro Mountain were comparable to measurements found in other

studies and were within the recommended guidelines for stable populations (Connelly et al. 2000, Hagen et al. 2007). Mean shrub height and percent canopy cover at nest sites was lower for Anthro Mountain hens than Parker Mountain hens, but the percent of grass and forb cover was greater on Anthro Mountain than Parker Mountain (Chi 2004).

Sage-grouse typically position their nests under sagebrush, oftentimes mountain big sagebrush (Wallestad and Pyrah 1974, Gregg et al. 1994). Although mountain big sagebrush was the most frequently used shrub on Anthro Mountain, hens used a variety of other nesting substrates. Nests were commonly placed under pinyon pines and this anomaly appears to be unique to Anthro Mountain. Although others have reported grouse using areas with pinyon and juniper trees (Burnett 2013, H. McPherron, Utah State University, personal communication), there are limited reports of sage-grouse using these trees as nesting substrates. Both translocated and resident hens successfully nested under pinyon pines, but translocated hens nested under pinyon pines more frequently than residents. Although hens translocated from Parker Mountain to Anthro Mountain nested under pinyon pines, resident hens on Parker Mountain were not documented to nest under trees (Chi 2004, Dahlgren 2006). Parker Mountain contained a greater amount of sagebrush than Anthro Mountain and did not have extensive PJ encroachment. Additionally, the sagebrush on Anthro Mountain was not as dense as Parker Mountain (T. Messmer, USU, personal communication). Because high quality sagebrush habitat was in abundance on Parker Mountain, the availability of traditional nesting substrates was not limited. Conversely, the limited amount of sagebrush on Anthro Mountain, coupled with the encroaching PJ, may have forced the sage-grouse to adapt and use the available

habitat. Because sagebrush was less dense on Anthro Mountain, pinyons may have afforded increased concealment and protection for hens.

Hens on Parker Mountain nested in areas with greater percent canopy cover and taller shrubs than hens on Anthro Mountain. Additionally, the mountain sagebrush cover on Anthro Mountain was not as dense or tall as found on Parker Mountain (Chi 2004, T. Messmer, USU, personal communication). Hens translocated to Anthro Mountain may have been more inclined to nest under pinyons because the dense, tall trees may have provided the perceived concealment from predators that the hens were accustomed to on Parker Mountain.

Brood hens use specific habitats to meet the dietary needs of both herself and the brood (Klebenow 1969, Crawford et al. 2004). Forbs and insects comprise the majority of sage-grouse chick diets, and brood hens are typically found in areas of greatest forb abundance (Klebenow 1969). Vegetation characteristics at translocated and resident hen brood sites on Anthro Mountain were comparable those on Parker Mountain and within the recommended guidelines for stable populations (Connelly et al. 2000, Chi 2004, Hagen et al. 2007). Despite reproductive hens using similar habitat characteristics at both study sites, chick survival on Anthro Mountain was much lower than Parker Mountain. On Anthro Mountain, chick survival for resident hens ranged from 0.078–0.160, while chick survival for translocated hens ranged from 0.002–0.035 (Gruber 2012). Chick survival on Parker Mountain averaged 60% (Dahlgren et al. 2010). Intensive management efforts have focused on increasing brood rearing habitat on Parker Mountain (Chi 2004, Dahlgren 2006, Guttery 2011). The combination of increased brood rearing

habitat coupled with large contiguous stands of sagebrush may account for the large difference in productivity between Parker Mountain and Anthro Mountain.

## **MANAGEMENT IMPLICATIONS**

The use of pinyon pines as nesting substrates is evidence that, if the scale and availability of quality habitat dictates, sage-grouse can adapt and reproduce in marginal habitat. Although translocated hens adapted and reproduced in Anthro Mountain's marginal habitat and lek counts increased (see Chapter 3), the population is small and still at risk for extirpation. Disturbance and fragmentation along migration routes could deter sage-grouse from making important seasonal movements and result in a declining population.

Anthro Mountain sage-grouse use various wintering areas disconnected from the main summer area. Although we are aware of some of these wintering areas, others are still unidentified and the migratory habits of this population are unknown. I suggest that managers identify all wintering areas, migration corridors, and stopover areas for this population. With this information, managers will be better equipped to assess the highest priority areas and implement management actions to increase seasonal habitat connectivity. Ultimately, the increased connectivity will improve this population's health.

Resident hens on Parker Mountain displayed winter migration patterns that were elevational in nature. These seasonal migrations were to areas that were connected by contiguous habitat. Because sage-grouse translocated from Parker Mountain successfully migrated to Anthro Mountain's wintering areas which were separated from the summer

range by non-habitat, we can conclude that translocated sage-grouse adapted to the release area. Similar home ranges, habitat use, and overlapping wintering areas are further indication that translocated sage-grouse integrated into this migratory population. Because the resident population is migratory, it is likely that flocking with residents assisted with learning the migration patterns (Gruber 2012). My results indicate that when using translocation methods employed by Baxter et al. (2008), translocated sage-grouse can integrate into populations and adapt to landscapes that are starkly different than the source site. Due to their adaptability, translocating sage-grouse can assist with augmenting declining migratory populations.

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Table 4 - 1. Results of the Mann-Whitney-U test for differences in home ranges of resident and translocated greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, UT, USA 2009–2012.

	W	p-value
Resident vs. Newly Translocated	749	0.488
Resident vs. Previously Translocated	493	0.123
Newly Translocated vs. Previously Translocated	554	0.037

Table 4 - 2. Results of the Mann-Whitney-U test of differences at successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) nests on Anthro Mountain, UT, USA 2009–2012.

	W	p-value
NestHeight	651.5	0.5797
NestDiameter	839	0.1631
ShrubHt	807	0.428
% Shrub	702	0.7919
% Forb	614.5	0.2465
ForbHt	514	0.02888
% Grass	561	0.08816
GrassHt	446	0.00398

Table 4 - 3. Mean vegetation characteristics at successful and unsuccessful greater sage-grouse (*Centrocercus urophasianus*) nests on Anthro Mountain, UT, USA 2009–2012.

Success	n	<u>NestHt</u>		<u>NestDiam</u>		<u>Canopy Ht</u>		<u>% Canopy</u>		<u>% Forb</u>		<u>Forb Ht</u>		<u>% Grass</u>		<u>Grass Ht</u>	
		mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE	mean	SE
Yes	47	77.45	4.66	125.38	5.98	30.71	1.42	24.14	1.55	15.06	0.91	9.84	0.36	18.49	1.09	17.73	0.51
No	31	74.47	6.11	133.90	5.64	32.22	1.64	23.05	1.31	13.72	1.31	8.49	0.54	16.09	1.07	15.18	0.59

Table 4 - 4. Results of the Mann-Whitney-U test for differences in vegetation characteristics at nest sites for resident and translocated greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, UT, USA 2009–2012.

	<u>All Years</u>		<u>2009</u>		<u>2010</u>		<u>2011</u>		<u>2012</u>	
	n = 81		n = 21		n = 24		n = 21		n = 15	
	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value
Nest Shrub Height	647	0.190	69	<b>0.004</b>	69.5	0.545	35.5	0.181	11	0.348
Nest Shrub Diameter	915	0.197	29.5	0.512	60.5	0.975	78.5	0.105	15	0.717
Canopy Height	849	0.638	50	0.445	52	0.664	71	0.282	28	0.180
Percent Shrub	1028	<b>0.028</b>	43	0.842	68	0.619	86	<b>0.029</b>	27	0.233
Percent Forb	866.5	0.521	52	0.354	57.5	0.924	79	0.099	21	0.734
Forb Height	637	0.122	48	0.548	74	0.383	68	0.387	7	0.136
Percent Grass	805	0.958	32	0.548	67	0.657	46	0.557	15	0.734
Grass Height	931	0.736	56	0.208	79	0.227	66	0.468	14.5	0.665

Table 4 - 5. Average vegetation characteristics at greater sage-grouse (*Centrocercus urophasianus*) nest locations on Anthro Mountain, UT, USA 2009–2012.

	n	<u>Nest Shrub Height</u>		<u>Nest Shrub Diameter</u>		<u>Canopy Height</u>		<u>% Canopy</u>		<u>% Forb</u>		<u>% Grass</u>	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
Resident	34	71.38	5.01	135.26	7.38	31.77	1.48	26.77	1.64	15.28	1.24	17.54	1.07
Translocated	47	81.28	5.00	122.57	4.59	30.97	1.48	21.68	1.33	13.92	0.88	17.59	1.08
All	81	77.08	3.60	127.96	4.13	31.31	1.06	23.82	1.06	14.49	0.73	17.57	0.76

Table 4 - 6. Average vegetation characteristics at greater sage-grouse (*Centrocercus urophasianus*) nest sites on Parker Mountain, Utah, USA. From Chi 2004.

<u>Canopy Height</u>		<u>% Canopy</u>		<u>% Forb</u>		<u>% Grass</u>	
Mean	SE	Mean	SE	Mean	SE	Mean	SE
51 cm	2.2	32.1	1.0	2.26	0.49	6.09	0.49

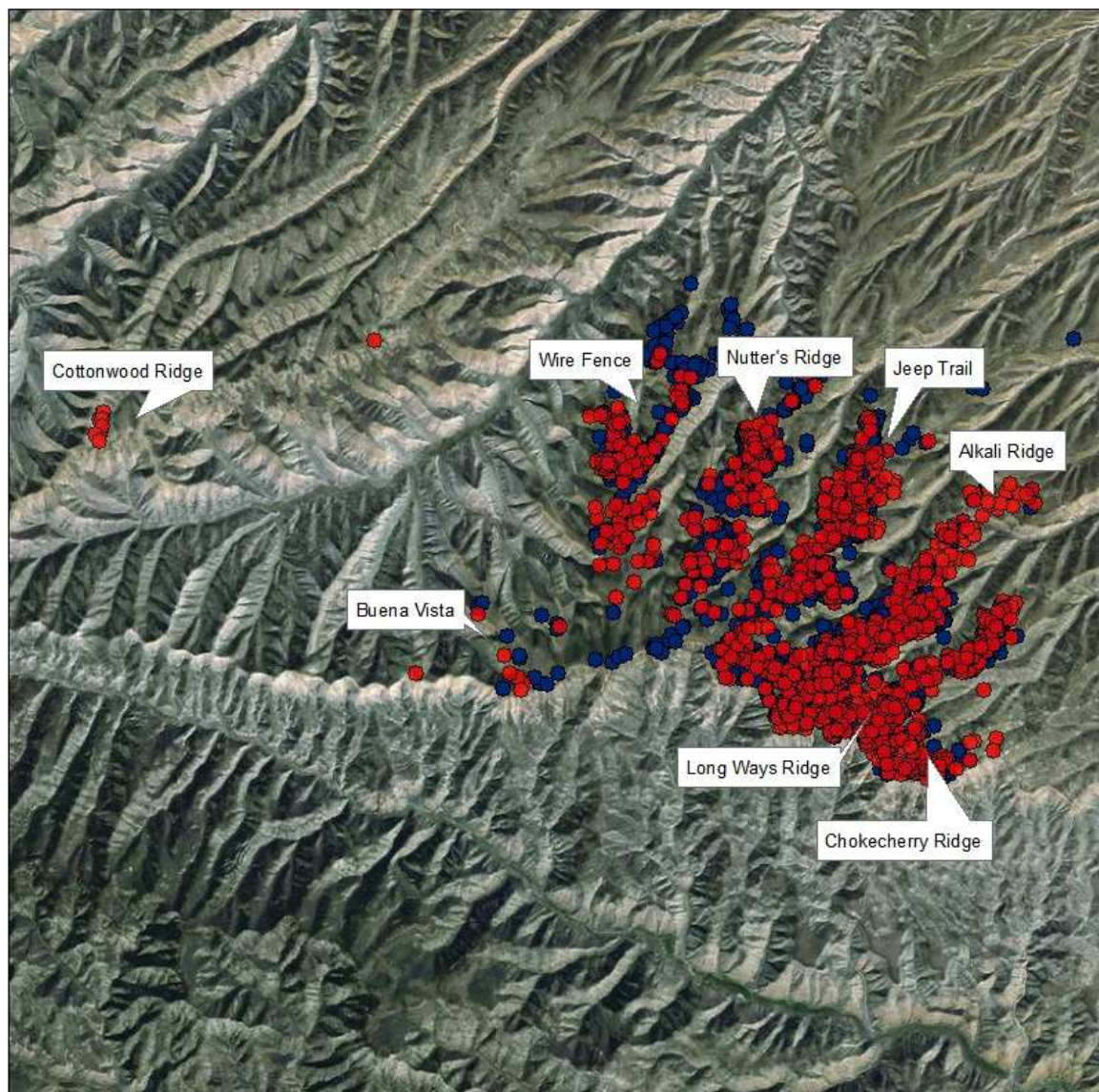
Table 4 - 7. Nesting substrates for resident and translocated greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, UT, USA 2009–2012.

Year	<u>Mountain big sage</u>		<u>Pinyon</u>		<u>Juniper</u>		<u>Rabbitbrush</u>		<u>Basin wildrye</u>	
	Res	Trans	Res	Trans	Res	Trans	Res	Trans	Res	Trans
2009	11	5	0	5	0	0	0	0	0	0
2010	4	15	2	4	0	0	0	0	0	0
2011	9	4	1	6	0	0	0	1	0	0
2012	10	2	0	1	1	0	0	0	1	0

Table 4 - 8. Results of the Mann-Whitney-U test for differences in vegetation characteristics at brood sites for resident and translocated greater sage-grouse (*Centrocercus urophasianus*) hens on Anthro Mountain, UT, USA 2009–2012.

	<u>All Years</u>		<u>2009</u>		<u>2010</u>		<u>2011</u>		<u>2012</u>	
	W	p-value	W	p-value	W	p-value	W	p-value	W	p-value
Canopy Height	5574.5	<b>0.032</b>	132	0.298	197	0.084	707	0.153	217	0.875
Percent Shrub	7016.5	0.493	131	0.286	249	0.483	879.5	0.937	248.5	0.558
Percent Forb	6362.5	0.550	141	0.433	346	0.232	711.5	0.164	249.5	0.542
Forb Height	5685.5	<b>0.054</b>	144	0.480	280	0.929	896	0.822	168	0.178
Percent Grass	6300	0.471	185	0.715	172.5	<b>0.027</b>	835.5	0.765	242	0.673
Grass Height	6251.5	0.414	199	0.457	193	0.071	1008	0.226	213	0.800

Anthro Mountain Greater Sage-grouse Locations  
Resident and Translocated Sage-grouse 2009 - 2012



0 1.25 2.5 5 7.5 10 Kilometers



**Grouse Locations**

- Residents
- Translocated

Coordinate System: NAD 1983 UTM Zone 12N  
Projection: Transverse Mercator  
Base map Provided by ESRI  
Created: 22 April, 2013 by Orrin Duvuvuei

Figure 4 - 1. Map of resident and translocated greater sage-grouse (*Centrocercus urophasianus*) locations on Anthro Mountain, UT, USA from 2009–2012.

## Seasonal Use Areas Anthro Mountain, Utah 2009-2012

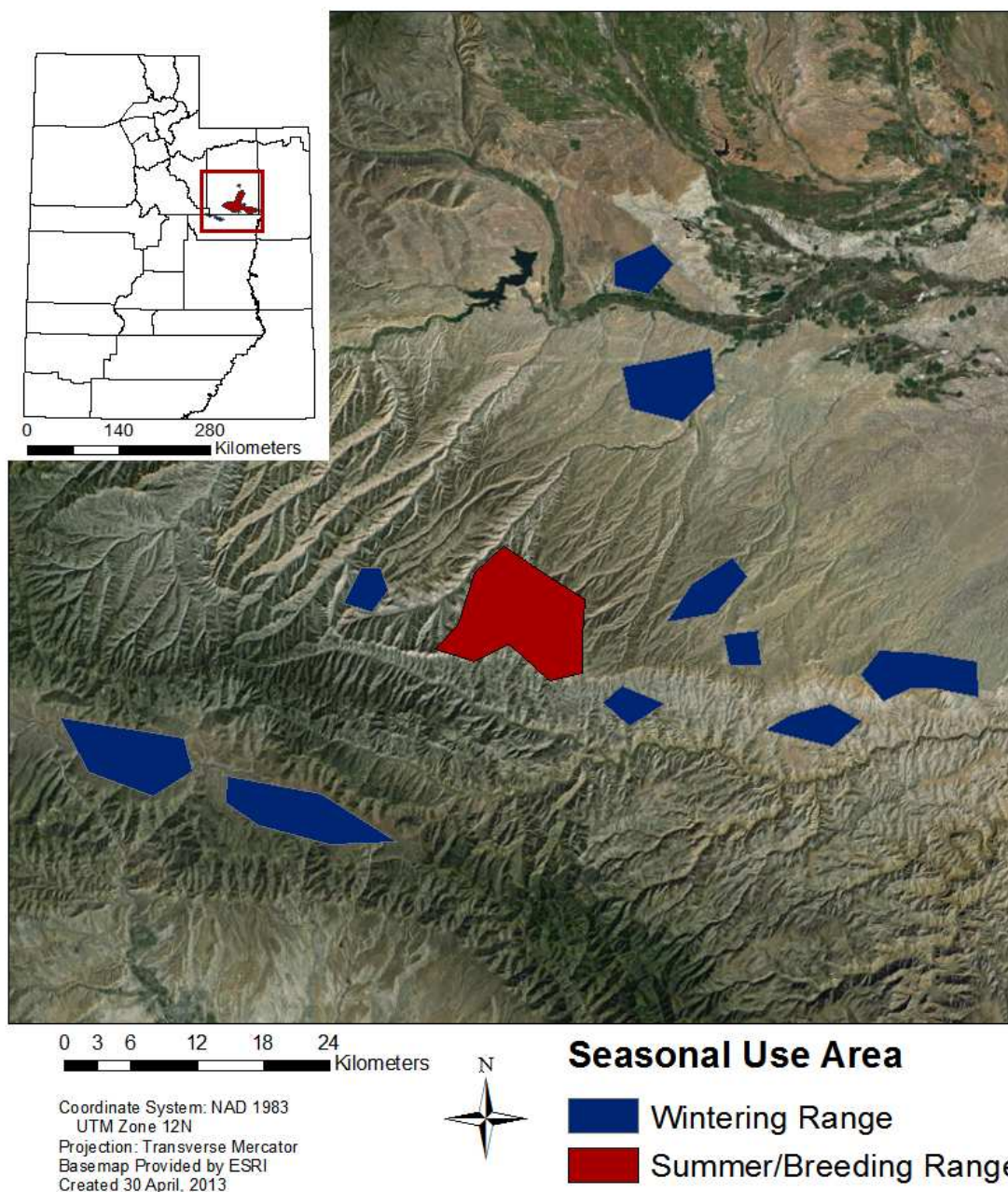


Figure 4 - 2. Map of seasonal use areas for resident and translocated greater sage-grouse (*Centrocercus urophasianus*) on Anthro Mountain, UT, USA from 2009–2012.

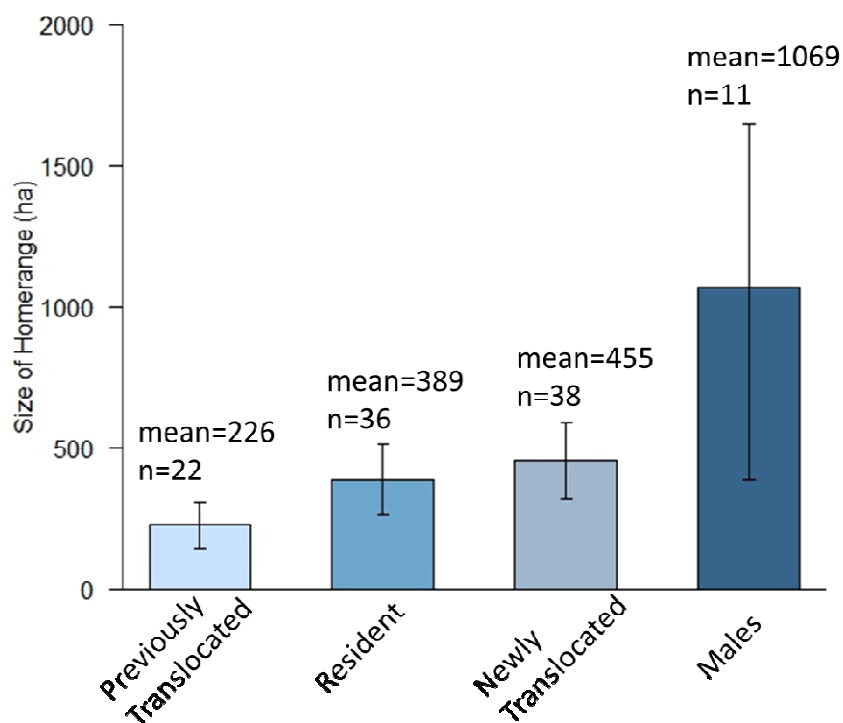


Figure 4 - 3. Average home range sizes for resident, newly translocated, and previously translocated greater sage-grouse (*Centrocercus urophasianus*) hens and resident males on Anthro Mountain, UT, USA 2009–2012.

## CHAPTER 5

### CONCLUSIONS

Greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) have declined substantially from their historic range and are a candidate for listing under the U.S. Endangered Species Act. Based on lek counts, some local sage-grouse populations exhibit dramatic decreases (Garton et al. 2011). Similar to range-wide trends, sage-grouse populations in Utah have declined and currently occupy less than 50% of their historical distribution (Beck et al. 2003). These declines highlight a need for management actions that will increase populations.

Declining populations warrant conservation and management actions to reverse the declines. Oftentimes, the best strategies to reverse the trends are directed at improving the most influential vital rates on population growth (Wisdom et al. 2000). When influential vital rates are improved or stabilized, managers may attempt translocations to augment declining wildlife populations (Fischer and Lindenmayer 2000, Davis 2012). In the case of sage-grouse translocations, long-term monitoring should be implemented to determine the overall effects to the population (Reese and Connelly 1997).

Sage-grouse were translocated to Anthro Mountain, Utah to reverse a declining population. Parker Mountain, Utah was chosen as the source population for the translocations because it was deemed stable and genetically compatible with Anthro Mountain's population (Smith 2009, Utah Division of Wildlife Resources (UDWR) 2009). During the first two years of this translocation project, translocated sage-grouse

exhibited similar survival and reproductive success as residents, but the rates were low compared to range-wide estimates (Gruber 2012). Additionally, translocated sage-grouse integrated into the population and displayed movement patterns similar to residents (Gruber 2012). Gruber (2012) determined that the overall success of the translocation was inconclusive, citing low survival and low reproductive success. I examined the effects of the translocation efforts on Anthro Mountain's sage-grouse population 4 years after initial release.

Translocated sage-grouse unfamiliar with a release area are likely to have lower survival compared to residents in the population (Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor et al. 2012). Therefore, translocated sage-grouse may contribute less to population growth. In Chapter 2, I compared average survival of resident and translocated hens in two translocated populations (Anthro Mountain and Strawberry Valley) to resident hen survival in the source population (Parker Mountain). By comparing these populations, I sought to determine if survival varied by residency status, age, and geographic location.

Although I hypothesized that translocated hens would have lower survival rates than residents on Anthro Mountain and in Strawberry Valley, residency status had no effect and average survival varied only by study area and hen age. Survival in Strawberry Valley and on Parker Mountain was similar and within the reported range-wide rates (Connelly et al. 2011). Anthro Mountain had the lowest survival of the three populations and estimates were low compared to range-wide survival rates (Connelly et al. 2011). Range-wide, survival is variable by season and typically characterized by

higher survival in late summer and fall and lower survival in the spring (Connelly et al. 2000a, Naugle et al. 2004, Moynahan et al. 2006, Hagen 2011). Parker Mountain and Strawberry Valley experienced lower survival in the spring which mirrored range-wide trends. Conversely, Anthro Mountain experienced lowest survival in late summer and fall.

To determine the overall effect of the translocation efforts on Anthro Mountain's population, I compared annual survival, seasonal survival, and reproductive success of translocated and resident sage-grouse on Anthro Mountain 4 years after the initial release (Chapter 3). In this chapter, I also examined Anthro Mountain's lek count trends. Survival on Anthro Mountain was most influenced by year and season and did not vary by residency status or hen age. Survival in 2009 was lowest of all years and survival was highest in 2012. Survival in 2012 was higher than range-wide estimates, but overall average survival for resident and translocated hens was low compared to range-wide survival averages (Connelly et al. 2011). Seasonal survival from 2009–2012 was consistently lowest in late summer and fall and was highest during spring and winter. Most sage-grouse populations range-wide experience high survival in the late summer and fall and lowest survival in the spring (Connelly et al. 2000a, Naugle et al. 2004, Moynahan et al. 2006, Hagen 2011).

Nest initiation was affected by hen age and overall residency status. Newly translocated yearlings were least likely to initiate a nest, while resident and previously translocated (translocated hens that survived  $\geq 1$  year on Anthro Mountain) adults were most likely to initiate a nest. Nest success and brood success did not vary by residency

status or age. The overall reproductive success (Nest Initiation x Nest Success x Brood Success) was highest for resident and previously translocated hens and was lowest for newly translocated yearling hens.

Sage-grouse populations are estimated based on lek counts. Prior to 2011, 4 leks were known on Anthro Mountain. In 2009 and 2010, 2 of the 4 leks were active. The maximum male count was 6 males in 2009 and 4 males in 2010. A new lek, Jeep Trail Lek, was discovered on Anthro Mountain in 2011 and was the only active lek in the study area. Jeep Trail Lek had a maximum count of 8 males in 2011. In 2012, 2 leks were active (including Jeep Trail Lek) and had a total male count of 18. During the 2013 lekking season, the Jeep Trail Lek had 24 males attending and 6 additional males were counted on 2 historic leks (B. Maxfield, Utah Division of Wildlife Resource, personal communication).

In Chapter 4, I examined differences in home ranges, movements, and habitat use for each cohort and compared them to residents on Parker Mountain. Anthro Mountain contained approximately 2,500 ha of suitable habitat while Parker Mountain had approximately 96,000 ha of suitable habitat. I sought to determine if translocated sage-grouse could adapt to release area landscapes that differ in size and habitat characteristics from the source area.

Because translocated grouse are unfamiliar with a new area, they typically have larger home ranges and move longer distances in search of suitable habitat (Cope 1992, Beck et al. 2006, Dickens et al. 2009). The increased movement of translocated grouse increases their vulnerability to predators and leads to lower survival and reproductive

rates than residents (Kurzejeski and Root 1988, Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008, Taylor et al. 2012). This could ultimately result in reduced contribution by translocated hens. Home ranges did not differ for resident and translocated hens. Hens that survived at least 1 year in the release area, however, used smaller home ranges than newly released hens. The average home range for juvenile hens on Parker Mountain was approximately 8 times greater than the largest female home range on Anthro Mountain.

Although we located several wintering areas for Anthro Mountain's sage-grouse population, they are not well defined and we were unable to locate all the hens during the winter. This information indicates that Anthro Mountain's sage-grouse may not consistently use a traditional wintering area. Additionally, there are no geographic barriers restricting the direction in which Anthro Mountain sage-grouse can migrate. The lack of geographic barriers coupled with poorly defined wintering areas may explain why not all sage-grouse were located during the winter. Because there are no well-defined wintering areas or movements, grouse may leave the mountain in different directions each winter and migrate until suitable wintering habitat is located. Weak evidence indicated that migration might occur in stages and that grouse use stopover points as they complete migrations. Parker Mountain sage-grouse display an elevational migration to connected areas when snow covers food resources at higher elevations (Chi 2004, Caudill 2011). Despite not being accustomed to migrating to disconnected areas, translocated hens found suitable wintering areas and returned to Anthro Mountain in the spring. Additionally, translocated hens shared wintering areas with resident hens indicating that

translocated hens adapted to the available habitat in the release area. The shared winter range also indicates that translocated hens learned seasonal movements from residents in the population.

Survival and nest success are directly related to habitat characteristics in the area (Aldridge and Brigham 2002, Holloran et al. 2005, Aldridge and Boyce 2007, Robinson 2007, Kolada et al. 2009). I examined habitat characteristics at brood and nest sites for resident and translocated hens on Anthro Mountain and compared habitat characteristics with hens on Parker Mountain. Habitat use for resident and translocated hens was similar throughout the study. Additionally, vegetation characteristics at breeding sites were within the recommended guidelines for stable populations (Connelly et al. 2000*b*). Shrub canopy cover and shrub height at nest sites was greater for reproductive hens on Parker Mountain compared to all reproductive hens on Anthro Mountain (Chi 2004).

Nesting cover for resident and translocated hens on Anthro Mountain included: mountain big sagebrush, two-needle pinyon pine (*Pinus edulis*), juniper (*Juniperus* spp), rabbitbrush (*Chrysothamnus viscidiflorus*), and basin wildrye grass (*Elymus cinereus*). Pinyon pines were commonly used for nesting cover on Anthro Mountain, and translocated hens used pinyon pines as nesting cover more frequently than residents. Resident hens were not documented to nest under pinyon pines or junipers on Parker Mountain. Resident hens on Parker Mountain nested in areas with greater percent canopy cover and taller shrubs than what is commonly available on Anthro Mountain (T. Messmer, Utah State University, personal communication). Because of this, hens

translocated to Anthro Mountain may have nested under trees because it approximated the height and canopy cover of nesting substrate on Parker Mountain.

My results from Chapter 2 support the theory that, despite being in close proximity, different ecological pressures influence survival in individual sage-grouse populations (Johnson et al. 2010). Managers should consider the unique characteristics of each population when developing management strategies. For example, managers should consider habitat quality within the population's annual range, effects of predation, and migratory status when conducting translocations.

In Chapter 3, I reported that newly translocated adults were more reproductively successful than newly translocated yearlings. Additionally, translocated sage-grouse that survive at least 1 year in the release population have a much higher likelihood of being reproductively successful. Because of this difference, managers should consider translocating a higher proportion of adult hens compared to yearlings to see a more immediate impact in the population.

In Chapter 4, I reported that translocated sage-grouse were highly adaptable to their release area. Although source and release site landscapes may differ, the translocated sage-grouse I studied demonstrated an ability to acclimate to the release area. Translocated sage-grouse learned the seasonal movements and migration patterns from residents in the release area and integrated into the population.

Wild pheasant translocation success was based on the translocated pheasant's fidelity to the release area, survival, and reproductive success (Wilson et al. 1992). Although landscapes, migration habits, and home ranges vastly differed for Anthro

Mountain and Parker Mountain populations, hens translocated to Anthro Mountain adapted to their new habitat. Results from Chapters 3 and 4 indicated that translocated sage-grouse displayed vital rates, habitat use, and home-ranges that were similar to residents of the population. Based on the translocated hens' adaptability and ability to survive, I concluded that this translocation project was successful. The increase in male lek attendance from 2009–2012, as well as the establishment of a new lek, is additional evidence that translocation efforts augmented this migratory population.

In conclusion, sage-grouse translocations can be an effective management tool to augment populations in landscapes that are significantly different than the source population. Adults typically have higher nest initiation than yearlings and their additional experience with raising a brood while avoiding predators might be beneficial when translocated to a new area, especially if the new area is highly fragmented. Although there was not a large difference, adult newly translocated hens had higher reproductive success compared to newly translocated yearlings. Therefore, managers may consider translocating a higher proportion of adults when augmenting sage-grouse populations. Because the suitable habitat on Anthro Mountain was surrounded by pinyon and juniper, it provided a habitat barrier to movement from the release site and forced the translocated hens to use the available habitat. After assimilating into the release population, translocated hens learned the necessary seasonal movements. This indicates a high level of adaptability of translocated hens. Not all sage-grouse were located during the winter suggesting that other wintering areas are undiscovered. Additionally, we do not know whether the migrations occur in one flight or multiple stages, nor do we know

the migration corridors. Managers should use GPS collars on grouse from this population to identify wintering areas and migration corridors that are crucial to the existence of this population. Lastly, managers should consider all the factors influencing the landscapes in the source and release population when conducting sage-grouse translocations.

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