

POPULATION DYNAMICS AND MOVEMENTS OF TRANSLOCATED
AND RESIDENT GREATER SAGE-GROUSE ON ANTHRO
MOUNTAIN, UTAH

by

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ABSTRACT

Population Dynamics and Movements of Translocated and Resident Greater
Sage-Grouse on Anthro Mountain, Utah

by

Natasha W. Gruber, Master of Science

Utah State University, 2012

Major Professor: Terry A. Messmer
Department: Wildland Resources

Declining populations of greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) have increased stakeholder concerns regarding the management and stability of the species range-wide. Numerous conservation strategies have been identified to restoring sage-grouse population declines to include species translocations. Translocations have been used for many different wildlife species to help sustain genetic heterogeneity, reestablish, and augment declining populations. In a recent translocation study, researchers identified the protocols used to successfully translocate sage-grouse to restore declining populations in Strawberry Valley, Utah. This translocation occurred in a high elevation basin buffered by geomorphic barriers. I evaluated these protocols for use in translocating sage-grouse to augment a declining population that inhabited Anthro Mountain in northwest Utah. Anthro Mountain is a high elevation mountain dominated by sagebrush (*Artemisia* spp.) void of geomorphic barriers. I compared annual production, survival (i.e., vital rates), habitat use, and movements of translocated birds

and their progeny to the resident population. Lastly, I described the integration of translocated birds with resident birds and the overall efficacy of the translocation effort. I radio-collared and monitored 60 translocated female sage-grouse from Parker Mountain, Utah over a 2-year period (2009 and 2010) and compared their vital rates to 19 radio-marked resident sage-grouse. Adult survival was similar for resident and translocated birds, but higher for both groups in 2010 than in 2009. However, overall survival of both resident and translocated birds was lower than range-wide survival estimates. Nest success was slightly higher for resident birds than translocated birds but positively correlated to grass height for both groups. Chick survival was also slightly higher for resident birds than for translocated birds, and higher overall in 2010 than in 2009. Chick survival was positively correlated to grass cover for both groups. Translocated birds used similar habitats and exhibited migration behaviors similar to resident birds. From a methodology perspective, the translocations protocols were successful because the translocated birds quickly acclimated to the release area, and their survival and reproductive success were similar to the resident birds. The effect of the translocation on augmenting the local population was inconclusive.

(144 pages)

PUBLIC ABSTRACT

Population Dynamics and Movements of Translocated and Resident Greater
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Greater sage-grouse (*Centrocercus urophasianus*) populations have declined range-wide. Species translocations have been identified as a conservation strategy to augment declining populations in restored habitats. I evaluated protocols previously used to successfully translocate greater sage-grouse in Utah by comparing annual production, survival, habitat use, integration and seasonal movements of translocated birds and their chicks to the resident population. To conduct this study, I translocated 60 greater sage-grouse hens captured and radio-collared on Parker Mountain to Anthro Mountain in the spring of 2009 and 2010. I also captured and radio-collared 19 resident hens to serve as my control group. All radio-collared hens were re-located 2-3 times a week and habitat data was recorded at the location sites. From successful nests, 3 to 6 chicks were radio-marked with a 1-gm transmitter sutured to the chick's back. Vegetation measurements were recorded at brood and random sites until the broods fledged or failed. Survival and movement data were analyzed using Program MARK, R, and ArcGIS. Although this

research validated previously used translocation protocols, the effect of the translocation on augmenting the local population could not be confirmed.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

SPECIES DESCRIPTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) are the largest grouse species endemic to North America. Sage-grouse inhabit sagebrush (*Artemisia* spp.) ecosystems of western North America (Schroeder et al. 1999) and usually survive 2-5 years. Males are larger than females; weighing 1.7 to 2.9 kg and are approximately 65 to 75 cm long while females weigh 1.0 to 1.8 kg and are 50 to 60 cm long (Schroeder et al. 1999). Males have distinctive plumage patterns; their neck, breast, and upper belly are a whitish color while their upper body and undertail-coverts are of a fuscous coloration (Schroeder et al. 1999). During the breeding season males have pronounced filoplumes on the head, fleshy yellow combs above the eyes, and two yellow ocher patches that are exposed when the breast is distended for courtship displaying. Females are more cryptic in appearance, with a more fuscous overall appearance (Schroeder et al. 1999).

Biology

During the breeding season males congregate and display in an open area called a lek. Sage-grouse are polygamous, males breeding with several females and conversely for females (Patterson 1952). Adult and yearling females will come to the leks to breed, and then disperse to start a nest. Most females will disperse on average 3 to 5 km from the lek to nest the site (Holloran and Anderson 2005). Nest-to-lek distance is thought to be inversely correlated with the quality of habitat (Holloran and Anderson 2005). Sage-

grouse build ground nest bowls usually placed under sagebrush (*Artemisia spp.*), but have been known to nest under other shrubs such as rabbitbrush (*Chrysothamnus spp.*) (Patterson 1952). From nest initiation to the last egg laid, sage-grouse can take up to 11 days (Patterson 1952, Schroeder 1997). Clutch size can range from 4 to 11 eggs and incubation usually commences when the last egg is laid (Schroeder 1997, Aldridge and Brigham 2001). Incubation of the eggs can last from 25 to 28 days (Patterson 1952). Re-nesting may occur depending on date of nest initiation and age of nest at failure (Connelly et al. 1993). Re-nesting is more likely to occur if the nest is lost earlier in the breeding season (Connelly et al. 1993). Chicks are precocial upon hatching and leave the nest with the hen shortly after hatching (Schroeder et al. 1999). Chicks start flying at 10 days of age and are relatively strong fliers at 5.5 weeks of age (Girard 1937).

Brooding habitat is usually characterized by moist habitat with an abundance of insects and succulent forbs (Drut 1994, Gregg et al. 2008). Broods start breaking up at about 10 to 12 weeks of age when juveniles flock together and disperse to wintering grounds (Patterson 1952).

During fall and winter months sage-grouse diets consist mainly of sagebrush leaves (Patterson 1952). During spring and summer months their diets consist of insects, leaves, buds, flowers, and fruit (Bendire 1892). Arthropod abundance has been shown to be an important factor in chick survival, especially during the early-brood rearing period (Dahlgren et al. 2010, Drut et al. 1994).

Because of their unique dietary requirements and available habitat, sage-grouse may have distinct movements between seasonal ranges that can surpass 80 km (Connelly et al. 1988, Connelly et al. 2000). Populations may be migratory or non-migratory.

Connelly et al. (2000) describes three types of sage-grouse populations; non-migratory (no long distance movements), one-stage migratory (move between two distinct seasonal ranges), and two-stage migratory (move between three distinct seasonal ranges). Despite these large movements, sage-grouse display high fidelity to their seasonal ranges (Berry and Eng 1985, Connelly et al. 2000)

GREATER SAGE-GROUSE STATUS

Range-wide, the decline of greater sage-grouse populations has been of particular concern to wildlife managers and other stakeholders. Sage-grouse historically occurred in 16 western states and 3 Canadian provinces, now the species occurs in 11 states and 2 Canadian provinces (Schroeder et al. 1999). Schroeder et al. (2004) estimated that the potential presettlement habitat for sage-grouse encompassed 1,200,483 km² and the current range to be 668,412 km²; less than 60% of the historical range. Range-wide declines and extirpation of sage-grouse populations appear to be related to sagebrush habitat alterations including fragmentation, cultivation, development, encroachment by trees, changes in fire regime, resource extraction, invasive plant expansion, powerlines, and reduction of sagebrush (Braun et al. 1977, Connelly and Braun 1997, Schroeder et al. 2004, Lue and Hanser 2011, Wisdom et al. 2011).

Sage-grouse are sagebrush obligates, relying upon sagebrush for both shelter and sustenance, thus the loss of sagebrush habitat can directly impact the sage-grouse population. Although many avian species use sagebrush habitats seasonally, it is unique for birds to inhabit sagebrush year-round.

The sage-thrasher (*Oreospiza montanus*), brewer's sparrow (*Spizella breweri*), sage sparrow (*Amphispiza belli*), and Gunnison sage-grouse (*C. minimus*) are also

considered sagebrush obligates (Braun et al. 1976). All of these species are now believed to be declining. By restoring sagebrush habitat and implementing other management plans to benefit sage-grouse populations, sage-grouse may be viewed as an “umbrella” species, whereby their conservation could ensure the health of many other sagebrush-dependent species (Rich and Altman 2001, Braun 2005).

In response to range wide sage-grouse population declines, the U.S. Fish and Wildlife Service (USFWS) determined that sage-grouse warranted protection under the Endangered Species Act (ESA) and designated it a candidate species in 2010. Full protection however, was precluded because other species were facing more severe or imminent extinction threats. The candidate designation will be reviewed annually to determine whether a change in status is warranted (USFWS 2010).

Because sage-grouse were designated a candidate species, individual states will continue to retain management responsibilities for the species. The USFWS (2010) encouraged continued collaboration between states and private entities in identifying and implementing management actions that are necessary to ensure the future of the sage-grouse and thus avert a potential listing of the sage-grouse.

GREATER SAGE-GROUSE STATUS IN UTAH

Greater sage-grouse are considered a species of concern in Utah but now have been designated a high priority species because of the ESA designation. The Utah Division of Wildlife Resources (UDWR), relying on the historical distribution of sagebrush, reported that sage-grouse may have occupied all of Utah’s 29 counties. Currently, the species is found in 26 counties (UDWR 2009). Beck and Mitchell (1997) and Beck et al. (2003) estimated that sage-grouse are half as abundant in Utah as they

were prior to 1850 and only occupy 50% of their historical range in Utah. Braun (1998) summarized breeding population estimates range-wide and reported that approximately 11% of range-wide sage-grouse population occurred in Utah. The largest populations of sage-grouse in Utah can be found in Box Elder and Rich Counties in northern Utah, on Diamond and Blue Mountains in northeastern Utah, and on Parker Mountain in south central Utah (UDWR 2009). There are other smaller populations scattered throughout the state.

Population estimates, based on lek counts (estimations based on two assumptions: 75% of males are counted in the population and there are 2 females for every 1 male), for Utah in 2007 consisted of 22,780 birds, 2008 consisted of 18,700, 2009 consisted of 15,956, 2010 consisted of 15,612 and 2011 consisted of 11,688 (J. Robinson, UDWR, personal communication). Sage-grouse in Utah are hunted when the populations meet minimum population criteria of >500 breeding birds during the lek counts over a three-year running average (Connelly et al. 2000, UDWR 2009). The number of permits issued in Utah is conservative compared to some recommended guidelines (Connelly et al. 2000, UDWR 2009).

Because of the declines in the sage-grouse populations, local and range wide stakeholders have collaborated to create state and range-wide sage-grouse management plans. The UDWR (2009) identified five major threats to sage-grouse and their populations. These threats included predation, energy development, invasive species expansion, conifer encroachment, and habitat alterations. These threats are being addressed through the collective efforts of local sage-grouse working groups which have been organized specifically to identify and implement management actions and

conservation strategies to improve, restore, and maintain sage-grouse populations and their habitats (UDWR 2009).

THREATS AND MANAGMENT

Sage-grouse depend on sagebrush for both shelter and sustenance. The loss of sagebrush habitat has negatively impacted sage-grouse populations in Utah (UDWR 2009). Habitat loss, fragmentation, and alterations have largely been attributed to energy development, agriculture conversion, and land development and are implicated as the primary cause for their range-wide declines (Connelly et al. 2004).

Energy Development

Utah is ranked 9th in the nation for natural gas production and 13th in the country in crude oil production (Utah Department of Environmental Quality [UDEQ] 2010). In the Uintah Basin, Utah, oil and gas development has increased substantially, and is experiencing the greatest growth in oil and gas production in Utah (UDEQ 2010). Naugle et al. (2011) reported that energy development posed a major challenge to sage-grouse conservation. Energy development changed the composition and structure of vegetation, thus influencing habitat suitability in Montana (Walker et al. 2007). These effects resulted in indirect population impacts because of changes in distribution and abundance in predators, prey, and disease (Walker et al. 2007).

In the Powder River Basin of northeastern Wyoming and southeastern Montana, leks located in areas of extensive coal-bed natural gas (CBNG) development showed a more severe population declines, compared to leks with minimal or no CBNG development (Walker et al. 2007). In Alberta, Canada, 6 leks were disturbed and 4 leks

were abandoned, due to energy development (Aldridge 1998). Near Pinedale, Wyoming light traffic disturbance attributable to natural gas development, reduced sage-grouse nest initiation rates and increased distances moved from the lek during the nest-site selection (Lyon and Anderson 2003).

Although energy development can negatively impact sage-grouse populations, research also suggested that once energy development ceases and reclamation of the area has taken place, recovery of sage-grouse populations may occur, but may not achieve pre-disturbance levels (Braun 1986). Global energy demands are predicted to increase by 50 to 60% within the next twenty years (National Petroleum Council 2007). Because of the potential for oil and gas development in sagebrush steppe ecosystems, these demands may exacerbate sage-grouse habitat loss and degradation. Thus, energy development may pose as one of the greatest threats to the conservation of sage-grouse and their habitats (USFWS 2010).

Habitat conservation and restoration is important to sage-grouse management and conservation. Reclamation and restoration of energy development areas such as pipelines may help restore suitable grouse habitat, reconnect fragmented habitats, and create habitat corridors. Placement of new developments should be evaluated for potential impacts on seasonal sage-grouse habitat and predator deterrents and control may be important in decreasing sage-grouse mortality (Naugle et al. 2011). When restoration, development and other anthropogenic uses are proposed for sage-grouse habitat, guidelines for the management of sage-grouse (i.e., Braun et al. 1977, Connelly et al. 2000) should be used to help restore sagebrush ecosystems.

Agriculture Conversions

European settlement of the Intermountain West has resulted in the loss of large areas of suitable sage-grouse habitat through the removal of sagebrush for agricultural purposes (Wirth and Pyke 2003). Because most of the arable land in the western U.S. has been converted to agricultural land, the expansion of agriculture poses little threat to any remaining sage-grouse habitat (Connelly et al. 2004, USFWS 2010). However, permanent conversions of sagebrush habitats to cropland limit the ability of wildlife managers to restore sage-grouse habitat and connectivity of fragmented habitats (Connelly et al. 2004).

The primary land use of western sagebrush-steppe ecosystems is grazing by domestic livestock (Connelly et al. 2011). Over 50% of the currently occupied sage-grouse habitat is managed by the Bureau of Land Management (BLM). Privately-owned rangelands constitute an additional 31% (Connelly et al. 2011). There is little evidence that connects livestock grazing to changes in sage-grouse population levels (Braun 1987, Connelly and Braun 1997, Beck and Mitchell 2000, Connelly et al. 2000).

However, practices implemented on these rangeland habitats to increase forage production have altered sage-grouse habitats (BLM et al. 2000, Connelly et al. 2004). The use of herbicides was a common practice prior to the 1980's to reduce sagebrush canopy cover and increase forage production. This practice may have contributed to declines in breeding sage-grouse populations (BLM et al. 2000).

There is indirect evidence that indicates that reduced herbaceous understory, due to grazing, may impact sage-grouse during the breeding season (Braun 1987, Dobkin 1995, Connelly et al. 2000). Gregg et al. (1994) found in their Oregon study area, that

grass height and grass cover were important in nest success and nest site selection.

Depending on the grazing management practices, poor management can lead to the degradation of sage-grouse habitat (Vavra 2005, Guttery 2010), thus implementing good grazing management is important in maintaining ecological integrity of grazing lands.

Land Development

Land development including construction of roads, pipelines, fences, buildings, powerlines, wind turbines, and reservoirs can fragment and degrade sage-grouse habitat (Leu and Hanser 2011). Such developments may fragment habitat, creating barriers for migration and potentially creating traveling corridors for predators. A recent study on the potential hazards of fences to sage-grouse found that collision risks increased when fences were placed near large leks (Stevens 2011). Fence markers have reduced the number of sage-grouse fence collisions by 83% (Stevens 2011). Power transmission and distribution lines are used to transmit power to many of these man-made structures. Powerlines have been documented to increase availability of perch sites which may enhance raptor and corvid predation and foraging efficiency (Prather and Messmer 2010).

The USFWS (2003) recommend that wind turbines be placed at least 8 km from known grouse leks due to noise, disturbance, fragmentation, and increased predator access (Manville 2004). The development of water reservoirs can also impact sage-grouse habitats. For example, in Strawberry Valley, Utah, 4 of 5 active sage-grouse leks were inundated due to the expansion of the Strawberry Reservoir (Welch et al. 1990). When deciding on the placement of these structures and development, considerations should take into account impacts to the surrounding sagebrush habitat and proximity to sage-grouse breeding and wintering areas.

Predators

When prey populations decline, the interactions between predator control and habitat management and other management practices should be considered and evaluated for the specific dynamics of the area of concern (UDWR 2009). Coates and Delehanty (2010) and Bui et al. (2010) reported habitat alterations and anthropogenic subsidies contributed to increased densities of common ravens (*Corvus corax*) and corresponding declines in sage-grouse reproductive success. Baxter et al. (2007) concluded the major cause of the original sage-grouse population decline in Strawberry Valley, Utah, was due to habitat loss, but the limiting factor to the recovery of the population was predation by red fox (*Vulpes vulpes*).

Predator control is used to potentially decrease predation rates and ultimately increase the target species populations (Schroeder and Baydeck 2001). Predator control has been used to suppress coyote (*Canis latrans*), red fox, and common raven populations for upland gamebird management and in areas with heavy livestock grazing (Schroeder and Baydeck 2001, Kamler and Ballard 2002, Mezquida et al. 2006). For avian populations, predation of nests (i.e., eggs), chicks and incubating and brood-rearing hens are often thought to be major factors that impact recruitment rates and population dynamics (Messmer et al. 1999, Evans 2004, Baxter et al. 2007).

For sage-grouse, the most common nest predators include common raven, ground squirrel (*Spermophilus spp.*), red fox, and badger (*Taxidea Taxus*). Primary predators for adult and juvenile sage-grouse are golden eagle (*Aquila chrysaetos*), red-tailed hawk (*Buteo jamaicensis*), northern harrier (*Circus cyaneus*), Swainson's hawk (*B. swainsoni*), ferruginous hawk (*B. regalis*), common raven, coyote, weasel (*Mustela spp.*), and red

fox (Schroeder and Baydack 2001, Mezquida et al. 2006, Baxter et al. 2007). Currently, the data required to evaluate the actual long-term impacts of predator control and management on the survival of sage-grouse and other gamebird and waterfowl species is lacking (Schroeder and Baydack 2001, Hagen 2011).

In North America, predator control is seldom recommended as a long-term management option because of the high cost of predator management, protected status of certain predators, inadequate information, and the public concerns and attitude towards predator control (Messmer et al. 1999, Schroeder and Baydack 2001, Hagen 2011). Despite these issues predator control can be used as a component of a sage-grouse conservation strategy. Concomitantly, the removal of higher trophic level predators can increase the abundance of mesopredators (Mezquida et al. 2006). These mesopredators, in turn, are more efficient predators on nests, thus creating a more imperiled situation. Mezquida et al. (2006) found that with heavy coyote control, mesopredators populations such as red fox, badger, and ravens increased.

Increased predation rates of sage-grouse can be a consequence of habitat quality, predator composition, and prey populations and densities (Schroeder and Baydeck 2001, Evans 2004, Coates and Delehanty 2010). Habitat alterations (including anthropogenic structures) may cause a decline in upland gamebird populations because these mechanisms can create an environment where population dynamics are more sensitive to predation (Evans 2004, Coates and Delehanty 2010, Prather and Messmer 2010). For example, predation success may increase for predators that forage on habitat peripheries in areas where fragmentation has occurred because of the increased availability of habitat edges (Andrén and Angelstam 1988). Thus, habitat quality and quantity may be more

important and feasible method for predator control than lethal methods of control.

Because there are few studies that address the indirect effects of predator control on sagebrush communities, an evaluation of the habitat and other subsidies (i.e., garbage) that may help in proliferating predators should be evaluated before a predator control is implemented.

TRANSLOCATIONS AND REINTRODUCTIONS

Translocation and reintroductions are the deliberate release of a species into the wild in an attempt to augment, reestablish, or establish a species or population in a specified area (Griffith et al. 1989, Dickens et al. 2009). Translocations and reintroductions are conservation tools that have been used for many different avian and mammal species to help sustain genetic heterogeneity of small and declining populations, establish satellite populations to reduce risk of species loss, increase the range of a species, and augment populations that are at risk of extinction (Griffith et al. 1989). Griffith et al. (1989) reported that successful translocations of species included factors such as high habitat quality in the release area, release into core historical ranges, wild-caught animals were released (versus captive-reared animals), and a high quantity of released animals. Between 1971 and 1986 an estimated 700 translocations occurred per year in the United States, Canada, Australia, and New Zealand (Griffith et al. 1989). Forty-three percent of these translocations that occurred involved gallinaceous birds (Griffith et al 1989).

Multiple translocations have been attempted for prairie grouse throughout the United States. These species include the Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*), plains sharp-tailed grouse (*T. p. jamesi*), greater prairie

chicken (*T. cupido*), lesser prairie chicken (*T. pallidicinctus*), Attwater's prairie chicken (*T. c. attwateri*), and the greater sage-grouse (Snyder et al. 1999). Evaluations of prairie grouse translocations indicated that the success of the translocations increased when a project was conducted long-term (>3 years), released greater than 100 birds, birds were released in the spring, and a soft-release was utilized (Snyder et al. 1999).

The failure of released birds to disperse from the release site is thought to impact the success of translocations. Poor dispersal can result in increased mortality, decreasing the likelihood of establishment of the birds post-translocation (Dickens et al. 2009). Coates and Delehanty (2006) concluded, that if female Columbian sharp-tailed grouse were captured at later dates during the lek-visitation period, the hens were more likely to initiate a nest at the release site. Kurzejeski and Root (1988) in a study conducted in northern Missouri on reintroduced ruffed grouse (*Bonsa. umbellus*), reported that birds that exceeded the mean daily movement rate experienced higher mortality rates than more sedentary birds. Despite the increase in prairie grouse translocation attempts since the 1900s, the percentage of successful grouse translocations (36%) remained relatively low (Snyder et al. 1999).

Translocation is a tool that has been utilized to assist in managing sage-grouse in the West. Translocations efforts of sage-grouse have been attempted in seven states and one province (Reese and Connelly 1997): British Columbia, Colorado, Idaho, Montana, New Mexico, Oregon, Utah, and Wyoming. However, few of these translocations appeared successful largely because data and published information documenting the translocations and their outcomes were inadequate (Reese and Connelly 1997).

Conversely, translocations appeared to have been successful in Colorado, Idaho, and Utah (Musil et al. 1993, Coates et al. 2006 Reese and Connelly 1997, Baxter 2008). Utah has had two successful translocations. Sage-grouse were successful translocated to the Wildcat Mountains located in southcentral Utah and Strawberry Valley in central Utah (B. Maxfield, UDWR, personal communication, Baxter 2008, Perkins 2010).

Musil et al. (1993) conducted a successful translocation of sage-grouse in Idaho and concluded that translocation can be useful tool in restoring sage-grouse populations to suitable habitats. Baxter (2008) reported the successful sage-grouse translocation effort in Strawberry Valley, Utah, and also identified criteria that could be used to evaluate future translocations. The Strawberry Valley translocations occurred in a closed high elevation basin. This closed basin may have impacted the post-release movements of the released birds, thus enhanced the success of the translocation (R. Baxter, U.S. Forest Service, personal communications).

In an evaluation of 56 attempts of sage-grouse translocations from 1933 to 1990, Reese and Connelly (1997) documented several features common to successful sage-grouse translocations. These included: 1) the grouse were transported quickly and were released the following morning after capture, 2) the release sites were confined sagebrush habitats with geomorphic barriers at least 100 km from the capture site, and 3) the grouse were captured during the breeding season (March and April) at night near leks. Reese and Connelly (1997) recommended releasing translocated sage-grouse in areas that contain ample year-round habitat and monitoring translocated populations to determine the success and feasibility of translocations as a management tool.

SIGNIFICANCE OF MY RESEARCH

My research was conducted on a small spatially-isolated population of sage-grouse that inhabited Anthro Mountain in northeastern Utah. The purpose of my research was to determine if the methodology used by Baxter (2008) in a closed basin would be applicable to high elevation areas where movements of the birds would not be restricted by closed basin topography (i.e., lack of geographic barriers). My translocation protocols included: 1) using source populations that were ≥ 100 km from the release site, 2) capturing the females at night near an active lek during the breeding season, 3) transporting the grouse overnight to the release area, 4) releasing the birds the morning following capture, and 5) releasing the birds < 250 m from an active lek. My research validated the translocation techniques used by Baxter (2008) for application in other areas of the west.

In Chapter 2, I compared survival of individually marked sage-grouse chicks, adult and juvenile hens, and nest success of resident and translocated sage-grouse. I modeled chick survival, adult and juvenile hen survival, and nest success for two consecutive years as a function of multiple covariates.

In Chapter 3, I evaluated the integration of translocated sage-grouse with resident sage-grouse and the fidelity of translocated grouse to the release area (Anthro Mountain). I also evaluated the success of the translocation using the criteria established by Baxter (2008).

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CHAPTER 2

FACTORS AFFECTING VITAL RATES OF RESIDENT AND TRANSLOCATED GREATER SAGE-GROUSE IN NORTHEASTERN UTAH

ABSTRACT

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations have declined range-wide. Species translocations have been identified as a conservation strategy to augment declining populations and/or reestablish new populations in restored habitats. However, before translocation can become a range-wide sage-grouse conservation strategy, better information will be needed regarding its applications under diverse environmental conditions. I evaluated the success of a 2-year sage-grouse translocation experiment conducted on Anthro Mountain in northeastern Utah. To conduct the experiment, I radio-collared and monitored 60 translocated female sage-grouse from Parker Mountain, Utah from 2009-2010 and compared their vital rates to 19 radio-marked resident sage-grouse. Survival of translocated and resident grouse was higher in 2010 than 2009 ($\beta=2.630$, 95% CL=2.122 to 3.138) but did not differ between translocated and resident birds. Survival, however, was low compared to range-wide estimates. Nest success was higher for resident (0.810, 95% CL = 0.593 to 1.027) than translocated birds (0.505, 95% CL = 0.209 to 0.801). Nest survival was positively related to grass height ($\beta = 0.170$, 95% CL = 0.009 to 0.330). I also evaluated factors influencing sage-grouse chick survival up to 50 days of age using a maximum likelihood estimator to model effects of year, hatch date, chick age, brood-female age, brood type (resident or translocated), and habitat variables on chick

survival. Twenty-four broods were marked across both years of the study resulting in 99 radio-marked chicks. The top demographic model indicated that chick survival was most influenced by the age of the chick, the year, and the brood type. In 2009 and 2010, chick survival to day 50 was higher for chicks for resident hens (0.078, 95% CL = 0.040 to 0.152; 0.150, 95% CL = 0.078 to 0.318) than chicks from translocated hens (0.002, 95% CL = 0.000 to 0.035; 0.078, 95% CL = 0.015 to 0.195). The probability of survival to 50 days was positively related to grass cover ($\beta = 0.058$, 95% CL = -0.063 to 0.183). The translocated birds quickly acclimated to the release area, and their survival and reproductive success were similar to the resident birds of Anthro Mountain. The translocation was conducted when the resident population had declined to its lowest recorded levels. This may have contributed to the observed high predation rates and reduced survival. The habitat models suggested that Anthro Mountain resident sage-grouse populations may benefit from management strategies that increase grass height and percent cover in nesting and brood rearing habitats. Although translocated bird survival and reproductive success was similar to resident birds, the high costs of translocation and monitoring (\$69,400) and low overall adult and chick survival dictate that translocations should not be implemented until the factors limiting the population growth in a population are mitigated.

INTRODUCTION

Translocation is the intentional release of a species into the wild in an attempt to reestablish, augment, or establish a species or population in a new area (Griffith et al. 1989, Dickens et al. 2009). Translocations and reintroductions have been successfully used for many different mammal and avian species to establish satellite populations to

reduce risk of species loss, help sustain genetic heterogeneity of small and declining populations, and augment populations that are at risk of extinction (Griffith et al. 1989).

Although multiple translocations have been attempted for grouse species throughout the United States, Snyder et al. (1999) reported less than 32% could be considered successful. Translocations have been conducted for Attwater's prairie chicken (*Tympanuchus cupido attwateri*), Columbian sharp-tailed grouse (*T. phasianellus columbianus*), greater prairie chicken (*T. cupido*), greater sage-grouse, Gunnison sage-grouse (*C. minimus*) lesser prairie chicken (*T. pallidicinctus*), plains sharp-tailed grouse (*T. p. jamesi*).

Translocations and reintroductions efforts to reestablish or augment small and declining populations of greater sage-grouse (hereafter sage-grouse) have been attempted in seven states and one Canadian province (Reese et al. 1997). Reese et al. (1997) evaluated 56 different sage-grouse translocation attempts. They concluded that few of these translocation attempts were successful. However, for many of these translocations, published data were also lacking regarding methods used and impacts on overall population trends.

The sage-grouse translocation attempts that were successful in Colorado, Idaho and Utah shared common features (Musil et al. 1993, Reese et al. 1997, Baxter et al. 2008). These features included: 1) birds that were transported quickly and released the following morning after their capture, 2) the release sites were at least 100 km from the capture site, 3) the release sites consisted of contiguous unfragmented sagebrush (*Artemisia* spp.) habitats exhibiting geomorphic barriers (i.e. closed basins, isolated plateaus), and 4) the grouse were captured near leks during the breeding season.

In Colorado, unmarked translocated birds were released in an area where no resident birds were present. The releases occurred in the spring of 1971 and 1972 and although no additional records exist, 50 breeding birds were observed in the release area in 1996 (Reese et al. 1997). The successful Idaho translocations were conducted over a two year period on lower elevation sites that exhibited suitable seasonal habitats to augment a declining population. Five new leks were established and the production of young by radio-marked translocated birds was observed (Musil et al. 1993).

One successful sage-grouse translocation in Utah was conducted over a four year period was conducted on Wildcat Knoll. Wildcat Knoll is a spatially-isolated high elevation plateau located in central Utah, that Utah Division of Wildlife Resource (UDWR) biologists believed was not inhabited by sage-grouse but afforded suitable habitat. Fifty-four sage-grouse were released over a four year period, starting in 1987. The released birds were not radio-collared and the success of the translocation was determined by the establishment and persistence of active leks (Perkins 2010).

The second successful Utah translocation occurred in Strawberry Valley in central Utah from 2003 to 2007 (Baxter et al. 2008). Strawberry Valley is a closed high-elevation basin. Success was measured by increased lek counts and survival using translocated birds that had been radio-marked. The success of this translocation may have been enhanced by multiple releases, predation management, and because the release site was a closed basin which possibly limited the post-release movements of the translocated birds (R. Baxter, U.S. Forest Service, personal communications).

Given long-term population declines in sage-grouse, managers have increased efforts to restore, protect, and enhance habitats (Stiver et al. 2006). Thus, there is

renewed manager interest in using translocation as a sage-grouse conservation strategy (Connelly et al. 2011). Because of inadequate data collection and published information documenting the sage-grouse translocation procedures and effects on populations, Reese et al. (1997) urged that research regarding the effect of translocations on population vital rates be part of the proposed translocation plans. This research would be essential before sage-grouse translocations should be considered a feasible conservation strategy (Reese et al. 1997). Adult and yearling survival, nest success, chick survival, and brood success (i.e. vital rates) are important indices of population productivity and persistence (Johnson and Braun 1999, Dahlgren et al. 2010, Guttery 2010). These metrics can only be obtained by radio-marking translocated birds and their progeny. Concomitantly, if resident hens and their chicks also can be radio-marked and monitoring simultaneously, a more in depth comparison between vital rates can be made to thoroughly evaluate the contribution of resident and translocated birds to overall population productivity.

The UDWR (2009) has identified species translocations as a conservation strategy to reestablish new populations and to augment declining populations in restored habitats in Utah. My research was conducted on a small, declining, spatially-isolated population of sage-grouse that inhabit higher elevation breeding areas located on Anthro Mountain in northeastern Utah. The purpose of my research was to determine if translocation methodologies used by Baxter et al. (2008) in a closed, high elevation basin would be applicable to an open high elevation area. To evaluate the success of this translocation, I modeled and compared survival of individually marked sage-grouse chicks, adult and yearling birds, and nest success of both translocated sage-grouse for two consecutive

years relative to multiple covariates. This is the first sage-grouse translocation study to simultaneously monitor vital rates of translocated and resident birds and their progeny.

STUDY AREA

Core Release Area

This study was conducted on Anthro Mountain in northeastern Utah located on the Ashley National Forest, 29 km southeast of Duchesne, Utah (Fig. 2-1). This area is managed by the U.S Forest Service (USFS). The topography of the study area consisted of high, narrow and flat ridges running north and south which are separated by deep, narrow canyons and draws. The vegetation community primarily consisted of mixed sagebrush, aspen (*Populus tremuloides*), juniper (*Juniperus osteosperma*) and pinyon pine (*Pinus edulis*). The dominant sagebrush species in this area was black sagebrush (*A. nova*) and mountain big sagebrush (*A. tridentate vaseyana*). Other native shrubs and grasses included: rabbitbrush (*Chrysothamnus viscidiflorus*), snowberry (*Symphoricarpos oreophilus*), lupine (*Lupinus argenteus*), June grass (*Koeleria macartha*), basin wildrye (*Leymus cinereus*), bluebunch wheatgrass (*Elymus spicatus*), and salina wildrye (*E. salinus*). Smooth brome grass (*Bromus inermis*) was seeded in the 1950's in portions of the area. The current and historical land was used for predominately domestic livestock grazing (Thacker 2010). Predator control has been sporadic in sage-grouse breeding areas on Anthro Mountain, but some coyote (*Canis latrans*) control has been implemented in surrounding areas for livestock protection. Oil and gas development are increasing in the area with up to 400 new oil wells being proposed for the area (R. Christensen, USFS, personal communication). The precipitation in the study area averaged 49 cm annually and the mean annual daily temperature ranged from 1.7°C to

13°C. The elevation ranged from 2,000 to 3,000 m. No sage-grouse hunting is permitted on Anthro Mountain.

Translocated Sage-grouse

The source sage-grouse population for the translocation was Parker Mountain in south-central Utah (Fig. 2-1). Parker Mountain was selected as the source population for the translocation of sage-grouse to Anthro Mountain because the population was robust and stable, ≥ 100 km from the release site, and was genetically compatible to Anthro Mountain sage-grouse (Reese and Connelly 1997, Oyler-McCance et al. 2005, Baxter et al. 2008, Smith 2009). The source area exhibited topography and elevations similar to Anthro Mountain and was characterized as a high elevation plateau that slopes to the north and east. The primary vegetation community was mountain big sagebrush, black sagebrush, bitterbrush, and rabbitbrush. Common grass species included grama grass (*Bouteloua* spp.), wheatgrass, bluegrass (*Poa* spp.), squirreltail grass (*E. elymoides*), needlegrass (*Hesperostipa* spp.), and June grass. The area was predominately used for sheep and cattle grazing (Guttery 2010). Mammalian predator control (i.e., coyote) was a common practice used on Parker Mountain to protect livestock. The average annual precipitation was between 40 and 51 cm. The elevation ranged from 2,150 m to 3,000 m. The sage-grouse population on Parker Mountain is hunted on a limited permit-only basis.

METHODS

Data Collection

Sixty sage-grouse hens (30 juvenile and 30 adult) were captured on Parker Mountain for translocation to Anthro Mountain in April of 2009 and 2010. The birds

were captured using all-terrain vehicles, spotlights and long handled nets at night near active leks (2100 hr to 0200 hr) (Giesen et al. 1982). The sage-grouse were then processed immediately at the capture site. Each bird was fitted with a 16-g necklace style radio transmitter (Advanced Telemetry Systems, Insanti, MN and American Wildlife Enterprises, Monticello, FL), weighed with a Pesola scaleTM (Pesola, Zug, Baar, Switzerland), and age (juvenile or adult) was determined using plumage characteristics. After processing, the sage-grouse were placed in individual cardboard boxes (30 cm x 23 cm x 30 cm) with ventilation and transported overnight in a pickup truck to Anthro Mountain (0200-0700 hr). The birds were released the morning following capture, within 200 m of one of the established leks on Anthro Mountain (Baxter et al. 2008). Transport boxes were lined up facing the lek and each grouse was released individually after the immediate area was scanned for predators.

On Anthro Mountain, 19 resident birds (6 juvenile and 13 adults) were captured in the spring and fall of 2009 and spring of 2010. Resident birds were captured at night using the techniques described above for translocated sage-grouse. Blood samples were taken from resident sage-grouse by clipping the toenail, collecting the blood on a Nobuto blood filter strip, and applying silver nitrate to the toenail to stop the bleeding (Smith 2009). Resident sage-grouse were immediately released at the capture location after the pertinent data was collected.

During the nesting season, all radio-marked hens were re-located 2 to 3 times a week to determine initiation of nesting and incubation of eggs. Nesting was confirmed by visually locating the hen, but the hen was not intentionally flushed off the nest. When the nest was confirmed, nests were monitored 2 to 3 times a week from a distance of

approximately 30 to 50 m to determine the fate of the nest. Once the eggs hatched (26-28 days of incubation) (Mawhinney et al. 2004), clutch size was estimated by counting eggshells after the female left the nest. If a nest failed, the cause was identified and the female was tracked 2 to 3 times a week to document re-nesting attempts.

When the chicks were 1 to 4 days old, 3 to 6 randomly selected chicks in every brood were radio-marked with a 1-g transmitter (Advanced Telemetry Systems, Insanti, MN and American Wildlife Enterprises, Monticello, FL). Each transmitter was sutured to the chick's back with a sterile 20-gauge hypodermic syringe just in front of and behind the transmitter (Connelly et al. 2003). The area of attachment was first sterilized with an alcohol swab. The suture thread was then placed through each needle, the syringes were removed, and the suture was threaded through and tied to the transmitter (Burkpile et al. 2002, Connelly et al. 2003). Cyanoacrylate glue was then used to secure the suture knot (Burkpile et al. 2002). Blood samples were also taken from each chick by either extracting a pin feather or by clipping the toenail. In between processing, the chicks were stored in a soft, heated cooler to prevent the chicks from losing body heat. Once all chicks in the brood were weighed, DNA taken, and transmitter attached (3 to 6 chicks from a brood), chicks were released together in a group at the location of capture. Broods were visually radio-tracked 3 times a week until the brood reached 50 days old. All broodless hens were radio-tracked 1 to 2 times a week.

For each nest and for one location a week for each brood (up to 50 days of age), habitat characteristics were measured. The line intercept method was used to determine shrub cover, shrub height, and shrub species (Connelly et al. 2003, D. Dahlgren, Utah State University, personal communication). Each transect consisted of four, 10 m

transects for brood sites and four, 15 m transects for nest sites. A random compass bearing was taken to determine the direction of the initial transect. Daubenmire frames, 20 x 50 cm every 3 m, were used along each transect to determine the percent cover of forbs and grasses at each site (Daubenmire 1959). A Robel pole was used at each vegetation plot to assess visual obstruction (Robel et al. 1970). The visual obstruction was assessed at 4 m along each transect and at 100 cm high, looking into and out from the Robel pole.

Hens were equipped with a radio transmitter containing a mortality signal (broadcasts a faster pulse), which broadcasted after the collar remained in one place for 8 to 12 consecutive hours. Once a mortality signal was detected, the site was located and the cause of death was determined. Chick mortality and disappearance were also recorded, although their radio transmitters did not contain a mortality signal. The chick's transmitter was located and the cause of death was determined when possible. If a chick transmitter was found without any remains or sign of predation the chick was presumed to be dead even though the transmitter could have been lost due to other reasons (Guttery 2010). The causes of death were classified as either avian or mammalian predator, unknown, or capture myopathy. Other features were recorded at the mortality site such as distance to perch sites, appearance of the bird and its remains, condition of the radio transmitter, and presence or absence of predator tracks, scat or whitewash. Incidental rodent observations were also routinely recorded throughout the summer months to monitor the availability of alternative prey for potential sage-grouse mammalian and avian predators.

During the fall and winter all marked sage-grouse were located monthly due to access and logistic limitations caused by snow. Periodic flights in a fixed-wing aircraft were used to locate sage-grouse that were undetectable from the ground throughout the year.

All bird locations were recorded using a Global Positioning System (GPS) in NAD 83. Additionally, the date, time, researcher, UTMS (Zone 12T), altitude, slope, aspect, group size, flocking with resident birds, nearest lek, habitat type, visible oil wells, nearest disturbances, and mortality were recorded at each location. All research activities and handling of sage-grouse were done in accordance with the Institutional Animal Care and Use Committee (IACUC) approved protocol at Utah State University under the permit # 1404.

Over the 2-year study period the translocations cost approximately \$29,400. This cost estimate included personnel to capture the birds (\$16,000), fuel, trucks, and ATV to transport the birds (\$2,600), and radio-collars (\$10,800). Additionally, costs for technicians to track the birds, graduate student tuition and stipend, and equipment and vehicles were estimated at \$40,000, totaling \$69,400 for the translocation project.

Data Analysis

Adult Survival

Data collected from year-round radio-tracking of the translocated and resident, juvenile and adult sage-grouse were used to conduct survival analysis. Hen survival was modeled as a function of bird age (juvenile or adult), year (2009 and 2010), and residency status (new translocated bird, previous year translocated bird, and resident bird) (Table 2-1). Nineteen *a priori* defined models were considered (Table 2-2). Birds that went

missing or were undetectable due to transmitter failure were right censored from the survival data. Birds that died due to capture myopathy were completely censored from the data.

Using nest survival models in Program MARK (version 5.0), the monthly survival rate of juvenile and adult sage-grouse were estimated using a logit-link function to attain the maximum likelihood estimates of all the parameters (Dinsmore et al. 2002, Rotella et al. 2004). Competing models were ranked using Akaike's Information Criterion corrected for small sample size (AIC_c) (Burnham and Anderson 2002). When multiple models were found to be supported by the data ($\Delta AIC_c \leq 2$), the most parsimonious models were retained for interpretation (Arnold 2010, Hamel et al. 2010). Models that did not converge were excluded from the analysis. To calculate the 95% confidence intervals and variance for juvenile and adult survival, the Delta Method was used (Seber 1982).

Nest Survival

A nest was considered to be successful if ≥ 1 egg hatched. Daily and overall survival rates of sage-grouse nests were estimated using nest survival models in Program MARK (Version 5.0) (Dinsmore et al. 2002, Rotella et al. 2004). A logit-link function was used to attain the maximum likelihood estimates of all parameters. Each model was ranked using AIC_c (Burnham and Anderson 2002). Competing models were evaluated using the principle of parsimony (Arnold 2010, Hamel et al. 2010). Models that did not converge because they were too complex for the small dataset were excluded from the analysis. The Delta Method was used to calculate 95% confidence intervals and variance

for nesting success (Seber 1982). Hens that were flushed off a nest by a researcher and did not return to the nest were censored from the nest survival data.

Seventeen *a priori* defined individual heterogeneity and temporal variation (Table 2-3) and 16 *a priori* defined habitat models (Table 2-4) were evaluated to determine which factors most strongly influenced nest success. For the demographic models I included combinations of the following covariates: day of the nesting season the nest was found (time trend), hen age (juvenile and adult), hen type (translocated or resident), year (2009 and 2010), and residency (i.e. new translocated bird, previous year translocated bird, and resident bird, Table 2-1). The date that the first nest was found was considered day number one of the nesting season, other nests were normalized to the first day of the nesting season (Baxter et al. 2008). Residency status was set up in 3 different ways as binary variables, as ordinal variables, and as dummy variables, to account for residency status and year (Table 2-1). The more simple top individual heterogeneity and temporal variation model was then used as a base model to build habitat models, due to convergence issues. For the habitat model I considered a combination of habitat characteristics that included: percent shrub, forb, and grass cover; average shrub, forb, and grass height; and Robel pole measurements (in and out). All habitat covariates were subjected to a correlation analysis ((PROC CORR, SAS System for Windows, v9.2) to test for multi-collinearity.

Chick Survival

I evaluated factors influencing sage-grouse chick survival from hatching to 50 days of age by modeling survival using the maximum likelihood estimator (Manly and Schmutz 2001), further developed by Fondell et al. (2008) and modified by Guttery

(2010). Program R 2.12.0 was used to model survival as a function of various covariates. I used 'OPTIM' and a logit-link function to attain maximum likelihood estimates of all parameters (Guttry 2010). Bootstrapping (1,000) was used to attain 95% confidence intervals for the parameters in the top models (Burnham and Anderson 2002). Chicks that went missing were right censored from the data after the last date of observation and capture mortalities were removed from the data set. The calculation for the estimate of the dependence in fates (denoted as D) among brood members takes into consideration, but does not distinguish, all unobserved forms of heterogeneity that influence chick survival' such as multiple chicks killed in one predation event (Dahlgren et al. 2010). As the estimate of D nears 1, each brood member's fate was considered to be more independent of one another. As estimates of D near the average brood size, the brood member's fate was considered to be more dependent on the fate of other brood members (M.R. Guttry, Utah State University, personal communication). The size of the brood is considered the number of chicks that were radio-marked in a brood (i.e. if there were 8 chicks in a brood but only 4 chicks were radio-marked, the brood size was considered to be 4).

I first modeled the effects of chick age, to determine variations in survival from day 0 to day 50. Multiple models were used to determine the best parameterization of chick survival relative to age. The best chick age model divided chick age into two categories; 0 to 20 and 21 to 50 days of age. Year effect (categorical) was then considered in conjunction with the chick age models. The best parameterization of chick age and year effect was used as a base model in considering combinations of other covariate effects on chick survival.

Twenty-one models were tested for individual heterogeneity and temporal variation explanation of chick survival and 19 models were tested for habitat influences on chick survival. Models that did not converge (due to a small effective sample size) were excluded. All models were compared using the quasi-likelihood version of the Akaike's Information Criterion ($QAIC_C$) that is adjusted for sample size (Akaike 1973, Burnham and Anderson 2002). The principle of parsimony was used to select a top model when multiple models were equally supported ($\Delta QAIC_C < 2$) by the data (Arnold 2010, Hamel et al. 2010). I first developed population dynamic models that contained a combination of different parameterizations of chick ages based on the biological development of the chicks (Dahlgren et al. 2010, Guttery 2010). I also used linear, quadratic, and cubic models of chick age treated as a continuous variable (Guttery 2010). I modeled effects of hatch date (Julian days), brood-female age (juvenile or adult), and brood type (translocated or resident) on chick survival (Table 2-5, Table 2-1).

To model the effect of habitat characteristics on chick survival, I used a subset of the data used for the demographic modeling, because not all locations included habitat data. I used the base model (chick age and year effect parameterization) used for the demographic models, as the base model for building the habitat models. As a result of a small sample size, I could not use the top demographic model to build the habitat models because the model was too complex for the dataset. I subsequently modeled the variation in chick survival, using chick age as a base model, as a function of habitat covariates (Guttery 2010). Habitat covariates included in the analysis were percent shrub cover, average shrub height, percent grass cover, average grass height, percent forb cover, average forb height, type of shrub, and whether a burn was absent or within 50 m of the

location area (Table 2-1). I also conducted a comparison of habitat use by resident and translocated birds using a one-factor ANOVA analysis (PROC GLM and PROC GLIMMIX, SAS System for Windows, v9.2) to identify any difference between habitat uses, due to model limitations because of complexity issues.

RESULTS

Adult Survival

Over the 2-year study period, 60 radio-collared translocated and 19 resident sage-grouse were monitored (Table 2-6). In April of 2009 (6 - 14 April), 13 juvenile and 17 adult hens were translocated from Parker Mountain to Anthro Mountain, in 2010 (19 April - 5 May), 17 juvenile and 13 adult hens were translocated. On Anthro Mountain, 12 resident birds were captured from April to May of 2009 (4 males and 8 females; 4 birds, 2 females and 2 males were previously collared from another study), 5 females were caught in October of 2009, and 2 females were caught in May of 2010. Six juvenile and 13 adult resident sage-grouse were captured on Anthro Mountain. The 2 males were used in the adult survival and movements analysis. No birds were injured during the capture, transport, or release events. All translocated birds were released approximately 100 m north of the most active lek on Anthro Mountain.

The best models of the adult survival analysis indicated a year effect on survival and also an interaction between year and hen age. Survival was higher in 2010 than in 2009 ($\beta = 2.630$, 95% CL = 2.122 to 3.138) (Table 2-7). There was no statistical support for generalized residency status (translocated or resident) or specific residency status (newly translocated bird, previously translocated bird, and resident bird) covariates

having an influence on adult survival. The probability of survival for adults in 2009 was 0.176 (95% CL = 0.060 to 0.291) and in 2010 it was 0.434 (95% CL = 0.276 to 0.591).

In 2009, adult birds had slightly higher survival (0.274, 95% CL = 0.088 to 0.460) than juvenile birds (0.063, 95% CL = -0.033 to 0.158). Inversely, in 2010 juvenile birds had a slightly higher survival (0.590, 95% CL = 0.290 to 0.897) than adults (0.352, 95% CL = 0.144 to 0.560).

During the study, 1 resident and 8 translocated birds were never re-located. This could have been caused by transmitter failure or in the case of translocated grouse large scale movements from the study site (Baxter et al. 2008). In 2010, three collared sage-grouse were observed with new transmitters that were not transmitting a radio signal.

A week after the translocation, 2 newly translocated birds died and their bodies were found whole with no signs of predation. Another newly translocated bird's death was attributed to the improper placement of a radio-collar in 2010. In both 2009 and 2010 most predation events could not be assigned to a specific predator (Table 2-8).

Nest Survival

Nest hatching dates ranged from 27 May to 26 June in 2009 and 29 May to 20 June in 2010 and incubation ranged from 27-28 days. Twenty-one nests were found in 2009 (Table 2-9). Nest initiation rates for resident and translocated hens in 2009, were 71% (5/7) and 62% (16/26), respectively. Of these nests, 3 (60%) resident hens and 8 (50%) translocated hens hatched ≥ 1 egg. One nest from a resident bird was found depredated by a mammalian predator and 1 nest was depredated by an unknown predator. Of the translocated bird's nests, 1 was determined to have been depredated by an avian

predator, 3 were depredated by an undetermined predator, 3 hens were inadvertently flushed off their nests, and 1 nest was abandoned for unknown reasons.

I documented 1 re-nesting attempt by a translocated hen after she was flushed off her first nest by a researcher at the initiation of incubation. Her first clutch had 9 eggs and her second clutch had 6 eggs. Two other translocated hens that were accidentally flushed off their nests during the early stages of nesting by researchers but did not return to their nests or re-nest. Their nests each contained 1 egg at the time of the flush. Another translocated hen abandoned her nest after a harsh winter storm. All 8 eggs contained near fully developed embryos. One resident hen was accidentally disturbed off her nest in the early stages of nesting by a researcher, but returned to the nest to successfully hatch out a brood; clutch size at initial flush was 1 egg and clutch size at hatching was 8 eggs (1 egg did not hatch). The average total clutch size for resident ($n = 3$) and translocated ($n = 12$) hens was 8.33 (SD = 0.58) and 7.13 (SD = 0.83) eggs, respectively.

In 2010, 26 radio-marked hens initiated nests (Table 2-9). Resident, previously translocated, and newly translocated hens initiated 100% (7/7), 100% (8/8), and 50% (11/22) nests, respectively. Mammals preyed on 1 nest, avian predators preyed on 2 nests, and undetermined predators destroyed 5 nests. Clutch size for successful nests averaged 7.57 (SD = 1.51) eggs for resident hens ($n = 6$), 8 (SD = 0) eggs for 2009 translocated hens ($n = 2$), and 6.33 (SD = 1.86) eggs for 2010 translocated hens ($n = 6$). One newly translocated hen was accidentally flushed off its nests by researchers during the late stages of egg laying and did not return to the nest nor re-nest; clutch size at flush was 6 eggs. Another newly translocated hen was flushed off her nest by a researcher but

returned to the nest to lay an additional egg and then abandoned the nest; final clutch size was 8 eggs. A previously translocated hen was flushed off her nest after 47 days of incubation and all of her 8 eggs were infertile.

In 2009, all resident birds that initiated nests ($n = 5$), nested under mountain big sagebrush. Ten translocated birds nested under mountain big sagebrush and 5 selected smaller pinyon-pines as their nest shrub type. All radio-marked birds in 2010 selected mountain big sagebrush for their primary nest shrub, with the exception of 2 previously translocated and 2 resident hens who selected pinyon-pine for a nest shrub. In addition, 2 newly translocated birds chose pinyon-pine areas which had been clear-cut (in 2009) with deadfall left in place for nest cover. There was no difference between resident status and nest type selected ($\chi_1^2 = 0.047, P = 0.829$).

For the nest success analysis using individual heterogeneity and temporal variation parameters, the selected model indicated that nest success was influenced by resident status (translocated or resident; $\beta = 4.850$, 95% CL = 3.459 to 6.241) (Table 2-10). Resident hens had a higher nest success rate (0.810, 95% CL = 0.593 to 1.027) than did translocated birds (0.505, 95% CL = 0.209 to 0.801). The top habitat model contained the effects of brood type and grass height (Table 2-4). There was also support for a model indicating an interaction between resident status and hen age. Resident adult birds had higher nest success (0.898, CL = 0.707 to 1.088) than resident juveniles (0.005, CL = -0.049 to 0.059), translocated adult (0.455, CL = 0.232 to 0.678) and juvenile birds (0.623, CL = 0.288 to 0.959). It is important to note that these numbers may be somewhat biased because there were fewer juvenile birds monitored, especially in the case of the resident birds.

The probability of a nest surviving to hatch date was positively correlated with grass height ($\beta = 0.170$, 95% CL = 0.009 to 0.330) (Table 2-11). Probability of a nest hatching in habitats with higher grass height (17.79 cm) for resident and translocated hens was 0.995 (95% CL = 0.683 to 1.049) and 0.647 (95% CL = 0.425 to 0.870), respectively. Nest survival in moderate grass height (15.23 cm) was 0.801 (95% CL = 0.555 to 1.048) and 0.512 (95% CL = 0.311 to 0.713) (Fig. 2-2, Fig. 2-3). The first and third quartile and median percent grass heights were used in determining high, moderate, and short grass height values for analysis. Grass height measurements at nest sites on Anthro Mountain ranged from 8.9 to 25.05 cm.

There was some support for a positive correlation between nest survival and grass cover ($\beta = 0.080$, 95% CL = -0.018 to 0.178). Nest success increased with increasing grass cover for both resident and translocated birds. However, there was no statistical evidence that showed a strong correlation between grass height and percent grass cover ($r(42) = 0.471$, $P = 0.002$). Grass cover measurements taken from nests on Anthro Mountain ranged from 8 to 42%.

Chick Survival

Ninety-nine chicks from 24 broods were marked during this study (Table 2-12). An average of 4 chicks were radio-marked per brood. Fifty chicks were radio-marked from resident hens and 49 from translocated hens. Brood amalgamation (i.e., brood-hopping) was observed for 2 different chicks in 2010 (Dahlgren 2009). One chick was observed approximately 700 m from its original brood with another brood, 2 days later this chick was located back with its original brood. In 2010, the radio transmitters used to track the chicks were problematic, in that, their design and battery life were

inadequate. Thus, survival estimations of some chicks may be suspect. In 2009 and 2010 more the chicks died during the months of June and July.

The top individual heterogeneity and temporal variation model indicated that chick survival was influenced by the age of the chick (0 to 20 days and 21 to 50 days of age), the year, and the brood type (resident or translocated, Table 2-13). Chick survival to 20 days of age for resident hens in 2009 (0.143, 95% CL = 0.079-0.295) and in 2010 (0.168, 95% CL=0.103-0.335) was slightly higher than for translocated chicks in those years (0.083, 95% CL = 0.037-0.153; 0.112, 95% CL = 0.050-0.278). In 2009 and 2010, chick survival to day 50 was slightly higher for chicks from resident hens (0.078, 95% CL = 0.040 to 0.152; 0.160, 95% CL = 0.078 to 0.318) than chicks from translocated hens (0.002, 95 % CL = 0.000 to 0.035; 0.078, 95% CL = 0.015 to 0.195, Table 2-14, Fig. 4, Fig. 5). Estimated heterogeneity in chick survival (D) in the top demographic model was 1.546 (95% CL = 1.288 to 2.110). This indicated that the level of dependency in chick survival among brood mates was low.

The top habitat model supported effects of grass cover and chick age but not brood type. The probability of survival to 20 and 50 days of age was positively correlated to grass cover ($\beta = 0.058$, 95% CL = -0.063 to 0.183, Table 2-15). Chick survival to 20 days old with median grass cover was 0.211 (95% CL = 0.027 to 0.307) and to 50 days old with median grass cover was 0.091 (95% CL = 0.014 to 0.417, Table 2-16, Fig. 5). Percent grass cover measured at brood sites ranged from 9% to 49%. Grass cover did not differ between translocated and resident brood sites ($P = 0.206$). The estimated variance in chick survival (D) in the top habitat model was 1.515 (95% CL =

1.158 to 2.386), suggesting that there was low dependence in fates among chicks in the same brood.

DISCUSSION

Adult Survival

My most parsimonious model was a year effect on juvenile and adult survival; there were no apparent survival differences between translocated and resident sage-grouse. In 2009, survival was estimated for both translocated and resident sage-grouse to be 18% and in 2010 at 43%. Translocated and resident adult survival estimates combined for 2010 (43%) are within parameters (37-78%) reported for sage-grouse in Utah (Bunnell 2000, Baxter et al. 2007, Dahlgren 2009). Average annual survival estimates for the translocated birds on Anthro Mountain (31%, both years combined) are lower than average annual survival estimates reported by Baxter et al. (2008) in his translocation efforts (60%). Survival for newly translocated birds was considerably lower in the first year (2009) of the translocation (18.1%) than survival for newly translocated grouse in the second year (2010) of the study (36%).

Annual juvenile and adult survival estimates for translocated and resident sage-grouse on Anthro Mountain were relatively low compared to the published literature (30 – 78%; Connelly et al. 2011). The overall survival for the translocated birds from Parker Mountain, Utah was lower in 2009 and 2010 (0.181 95 % CL= 0.045 to 0.317; 0.440 95% CL= 0.254 to 0.621) than survival estimates previously reported for resident sage-grouse on Parker Mountain (60%; Dahlgren 2006). In Idaho, Musil et al. (1993) reported an annual survival of 36% in the first 22 weeks post release for translocated birds.

Annual survival for resident sage-grouse on Anthro Mountain was lower (29%, both

years combined) than annual survival of resident birds in Wyoming (48% to 78%; June 1963), Idaho (48% to 75%; Connelly et al. 1994, Wik 2002), Colorado (61%; Hausleitner 2003), and Alberta, Canada (57%; Aldridge and Brigham 2001).

Because there was no difference in survival between resident and translocated birds, this observation suggested that translocated birds readily acclimated once they were released on Anthro Mountain. Baxter et al. (2008), was not able to compare resident versus translocated bird survival, but he did observe that survival was high and constant across months and years for sage-grouse translocated to Strawberry Valley. With no seasonal effects and moderate to high survival, birds translocated to Strawberry Valley, may have also acclimated quickly. However, the low survival rate of adult sage-grouse remains a concern and may be a limiting factor in population growth on Anthro Mountain (Taylor et al. 2012).

A number of factors may have contributed to the differing annual survival in resident and translocated grouse on Anthro Mountain. During 2009, temperatures were slightly lower and total precipitation was greater than in 2010 (Natural Resources Conservation Service 2012). Both resident and translocated sage-grouse were frequently observed flocking in wildfire burn patches (newer and older burns) during mid to late summer (July to October) of 2009. The wild fires increased grass and forb species at the expense of the sagebrush canopy (Wright 1985). Pyle and Crawford (1996) observed that burned areas were also readily used by sage-grouse post-burn, with use declining over time. Fire has also been shown in some areas to improve sage-grouse brood-rearing habitat because of the increase in forbs and grasses (Klebenow 1970, Gates 1983, Sime 1991).

However, fire and other methods of habitat alterations can also contribute to habitat loss and fragmentation further impacting sage-grouse survival (Connelly et al. 2000a). Taylor et al. (2012) analyzed range-wide sage-grouse vital rates and their effects on population growth. They concluded female and chick survival had the most influence on population growth. Taylor et al. (2012) recommended that management efforts first focus on increasing female survival by maintaining and restoring large, intact sagebrush landscapes and eliminating anthropogenic habitat features that subsidize predators that prey on sage-grouse.

Taylor et al. (2012) also cautioned that when manipulating sagebrush habitat to increase nesting and brood-rearing habitat, wildlife managers should not reduce the height or cover of sagebrush below what is required for adult sage-grouse in fall and winter seasons. Habitat fragmentation (e.g. fire) and the creation of edges have been shown to have a negative effect on habitat specific species by increasing susceptibility to predators (Faaborg et al. 1993, Burger et al. 1994). It is possible that the fires previously implemented on Anthro Mountain may have collectively reduced and fragmented sagebrush habitat that was historically used by the adult sage-grouse during the fall and winter seasons. This reduction in already limited fall and winter habitat could have ultimately affected the sage-grouse population production on Anthro Mountain.

On Anthro Mountain the primary predators of adult sage-grouse included the golden eagles, great-horned owl (*Bubo virginianus*), and coyotes. Annual raptor migrations were observed during the months of September and October and an influx of raptors on the mountain were also observed during the months of June and July during

both years of the study. Anthro Mountain had little to no mammalian or corvid predator control initiated during the study period.

In Strawberry Valley, Baxter et al. (2007) observed lower resident sage-grouse survival (44%) prior to red fox control being implemented. Sage-grouse survival rates increased to 68% post-control. A mammalian predator management program was initiated in 1999 in Strawberry Valley and continued throughout the translocation study (Baxter et al. 2008). In addition, DRC-1339 treated eggs were deployed to control common ravens in Strawberry Valley, from 2002 through 2005 (Baxter et al. 2008). In avian populations, predation of nests, chicks and incubating and brood-rearing hens are thought to be major factors that impact population dynamics and recruitment rates (Messmer et al. 1999, Evans 2004, Baxter et al. 2007). Although predator control is seldom recommended for management of sage-grouse, it proved a useful tool in the Strawberry Valley translocation success.

In 2009, I anecdotally observed, that there were fewer murids, ground squirrels, and lagomorph species available as prey for the main predators of sage-grouse on Anthro (Table 2-17). Such temporal variations and decrease (in 2009) in prey abundance may have incited prey switching behaviors in these predators (Randa et al. 2009, Hagen 2011, Fedy and Doherty 2011). The prey switching by predators on Anthro Mountain, may have contributed in the decreased survival of both juvenile and adult sage-grouse on Anthro in 2009.

Nest Survival

Nesting propensity (i.e., the likelihood a hen will initiate a nest) for translocated birds on Anthro in the first year of translocation (56%) was higher than for birds

translocated to Strawberry Valley, UT (39%), but and lower than birds (67%) translocated to Clear Lake National Wildlife Refuge, CA (Baxter et al. 2008, Bell 2011). Translocated birds that survived into the second year after their initial translocation ($n = 8$) exhibited a nesting propensity of 100% which was comparable to the nesting propensity of resident birds on Anthro Mountain and higher than in other translocation studies in Utah (71%) and California (86%) (Baxter et al. 2008, Bell 2011). Nesting propensity for translocated birds in their first year of translocation were lower than for resident birds in Idaho (69%), Oregon (78%), Wyoming (71%), Utah (76%), and Washington (99%) (Wallestad and Pyrah 1974, Gregg 1991, Connelly et al. 1993, Schroeder 1997, Dahlgren 2006). Nest initiation for resident Parker Mountain hens (1998 to 2009) for yearling and adult hens ranged between 63 and 79% (M. Guttery, Utah State University, personal communication). The nesting propensity of resident birds from Anthro Mountain (86%) was comparable to nesting propensities reported in other states.

In both 2009 and 2010, nesting propensity for newly translocated hens was lower than for resident birds on Anthro Mountain. There may be multiple factors that may have contributed to lower nesting propensities of newly translocated hens. These factors may include degree of assimilation to the release area, stress due to the translocation, weather conditions, hen age, spring body condition and breeding phenology at the time of capture (Barnett and Crawford 1994, Baxter et al. 2008, Devries et al. 2008).

Petersen (1980) observed that yearling and adult female sage-grouse averaged 9.5 and 7.6 days, respectively, between breeding and egg-laying (Petersen 1980). In 2009, I observed that as many as 4 translocated hens had initiated a nest and laid at least 1 egg in

less than 3 days after their release. These hens could have possibly been bred on Parker Mountain before the translocation or may have initiated a nest on Parker Mountain.

These factors could have contributed to a higher nesting propensity for translocated birds in 2009 than in 2010. Nesting attempts may be underestimated because some translocated birds moved off the mountain immediately after their release and returned to the mountain after the nesting period. Also, some nests may have failed before they were detected, which could also lead to an underestimation of nesting attempts.

The percent of nests that survived to hatching on Anthro were higher for resident birds (81%) than translocated birds (51%). Estimates for nest survival for translocated birds to Anthro Mountain were lower than translocated birds in Strawberry Valley, UT (68%) and higher than nest survival reported for translocated birds in Clear Lake National Wildlife Refuge, CA (45%). Crawford et al. (2004) summarized data from 14 different studies, and reported an average nest success across the sage-grouse range of 47.4%. Model selection results also indicated that nest survival for both resident and translocated hens were positively associated with grass height and grass cover, although grass height and grass cover were not highly correlated to one another. Grass height and/or grass cover have also been found to be important factors in sage-grouse nest survival in California, Oregon, South Dakota, Utah, and Wyoming (Gregg et al. 1994, Holloran and Anderson 2005, Baxter et al. 2008, Kaczor 2008, Bell 2011).

Shrub cover and height have been found in many studies across the sage-grouse range to also be important factors in nest survival, although in this study shrub cover and height was not as important as grass height and grass cover (Klebenow 1969, Wakkinen 1990, Gregg et al. 1994, Popham and Gutierrez 2003, Holloran et al. 2005, Kolada et al.

2009). In most avian studies the primary cause of nest failure remains nest predation. Maintaining sufficient vegetation structure may be an important factor in increasing nest success by affording sage-grouse hens and their nests with adequate concealment and in obscuring nest odors from predators (Gregg et al. 1994, DeLong et al. 1995, Schroeder and Baydack 2001, Manzer and Hannon 2005, Moynahan et al. 2007, Conover et al. 2010).

Chick Survival

Overall chick survival for both resident and translocated chicks was relatively low on Anthro Mountain. Resident chicks had a slightly higher survival than translocated chicks to both 20 and 50 days of age in both years of the study. Baxter et al. (2008), observed higher survival for translocated chicks to 50 days of age in the first 2 years of his study (47.2% and 58.1%). It is also important to note that Baxter et al. (2008) did not use radio-marked chicks, but used trained hunting dogs to determine chick survival. In 2006, Hennefer (2007) observed chick survival of 23.5%, with 1 year of data from radio-marked translocated chicks in Strawberry Valley, UT. Guttery (2010) reported that chick survival to 42 days of age for radio-marked chicks on Parker Mountain, UT, was influenced by cover conditions; it was 10.8% in poor and 51.6% in good years. In another study conducted from 2005 to 2006 on Parker Mountain, chick survival for radio-marked chicks was estimated to be 60% under good cover conditions (Dahlgren et al. 2010).

Predation was the main cause of chick mortality on Anthro Mountain. Predation has also been found to be the major source of chick mortality in other grouse studies (Larson et al. 2001, Schroeder and Baydack 2001, Aldridge 2005, Beck et al. 2006, Gregg et al. 2007, Dahlgren et al. 2010). Some of the chicks could have died due to

exposure to cold temperatures, especially in 2009, or starved to death, but these causes of mortality were difficult to determine, due to the scavenging of the carcasses by predators. During the study, two chick transmitters were found in coyote scat, two transmitters in a red-tailed hawk nest, and one transmitter in a weasel hole. Although no predator surveys were conducted, predators that were visually noted on Anthro Mountain were coyote, red fox, red-tailed hawk (*B. jamaicensis*), American Kestrel (*Falco sparverius*), raven, and golden eagles. During 2009, I observed fewer rodents than in 2010 (Table 2-17). This variation in alternative prey between years could have also influenced chick survival. Prey switching behaviors have been observed in coyotes and red foxes when there are shifts in the number and biomass of alternative prey that they consume (Randa et al. 2009).

Exposure to wet and cold weather can also influence chick survival especially when chicks are newly hatched and unable to thermo-regulate (Patterson 1952). In 2009, Anthro experienced a colder and wetter spring, with a few late spring snow storms. These colder weather events may have influenced chick survival. Because I did not record weather measurements, I could not include these factors into the survival analysis.

I also found evidence that survival was positively influenced by percent grass cover. Gregg and Crawford (2009) also found that by increasing the cover of short grasses (<18 cm), an individual chick's chance of mortality decreased by 8.6%. Guttery (2010) reported similar findings on Parker Mountain, UT. Hagen et al. (2007) conducted a meta-analysis of vegetation characteristics recorded at brooding sites throughout the sage-grouse range to determine overall effects of habitat selection. Through this analysis Hagen et al. (2007) found that vegetation at brood-rearing areas had less sagebrush cover,

taller grasses and greater forb and grass cover. These findings corroborate findings that grass cover had an important influence on chick survival on Anthro Mountain. Forbs did not come out as a top factor when modeling chick survival, because forbs would largely constitute a food resources rather than cover.

My top habitat model indicated that sage-grouse populations on Anthro may benefit from management strategies that increase grass cover (i.e., concealment) in brood rearing habitats, especially during the early brood rearing period. There are multiple habitat management tools that may be utilized to improve and increase grass cover in sage-grouse brood rearing areas.

Fire has been used on Anthro Mountain to create small openings in sagebrush to improve brood-rearing habitat (Thacker 2010). Thacker (2010) found that broods were selecting for areas treated by the prescribed burns that were less than 2 years old and that grass cover was higher at brood locations within the burns than at random sites. I also observed this behavior. Under certain conditions, creating small polygons in brood rearing areas where sagebrush canopy is dense and reseeding grasses and forbs where the understory is sparse, may improve and increase brood rearing areas. Caution should be used when using fire for habitat manipulation as it can easily escape, resulting in habitat destruction.

Poor quality brood rearing habitat can also affect chick survival. In the 1950's, approximately 80% of the tillable land was seeded to smooth brome on and around Anthro Mountain (Christensen 2006, Thacker 2010). Although native forbs have returned, areas that are still mostly dominated by smooth brome may be a limiting factor for brood rearing habitats, due to a decrease in biodiversity. Anthro Mountain is grazed

by cattle from mid-June through September, the grazing intensity is minimal. Managed grazing could be used to influence smooth brome and allow for an increase in variety of forbs and other grass species.

During the 2010 field season, the chick transmitters were problematic. The batteries in the chick radio transmitters were rated by the manufacturer as lasting 90 days. In reality, under field conditions at my study site few lasted beyond 40 days. Also the transmitter design did not allow for a stable attachment to the chick's dorsal side, thus some transmitters were able to detach from the chick's back while the chick was alive. When it was observed that the transmitter had fallen from the chicks back, the broods were caught again and re-sutured with new transmitters. The chicks that were re-sutured were counted as new chicks entering the study for analysis purposes.

MANAGEMENT IMPLICATIONS

Overall, survival and reproductive success of both translocated and resident birds was low compared to other sage-grouse studies. These results may suggest that the translocations were conducted in a high predation year, in the low portion of their population cycle, a low food year, or poor weather, thus contributing to a limited translocation success (Fedy and Doherty 2011). In part, the translocation could be deemed successful because the translocated birds quickly acclimated to the release area, and their survival and reproductive success were similar to the resident birds of Anthro Mountain. However, low adult and chick survival does not promote an increase in population growth. Wildlife managers should focus on increasing adult survival on Anthro Mountain to ensure future translocations to have the desired effect on population growth. Even though translocated bird survival and reproductive success were similar to

resident birds, the high translocation costs (\$69,400) and low overall survival indicate that translocations should not be done until the limiting factors in a population are determined. Because the resident and translocated population's survival and reproduction were low, additional research efforts may be needed to determine other possible underlying factors that are affecting the population on Anthro Mountain, like what are the limiting factors on adult survival, more intensive predator and alternative prey surveys, and fall and winter movements and habitat use.

Predator reductions may be beneficial in the first year of translocation to buffer the translocated birds (Connelly et al. 2000b, Hagen et al. 2004, Baxter et al. 2008, Hagen 2011). Since this translocation happened over a 2-year period and a small number of birds ($n=60$) were translocated, it may be beneficial to release a larger number of birds over a longer period of time (Griffith et al. 1989). The increase in translocation numbers may help to mitigate some of the effects of increased predation. Wildlife managers should be aware of the optimal holding capacity of the release site, so as not to over-populate the area, causing more detriment than good. Musil et al. (1993) released a total of 196 birds over a 2 year period and Baxter et al. (2008) released 137 birds over a 3-year period, both observed successful translocations.

It is important for wildlife managers to select source populations to translocate from using DNA factors. Smith (2009) observed differences in haplotype composition between the Anthro Mountain sage-grouse population and other northeastern Utah populations. Smith (2009) did recommend using Parker Mountain as a source population for translocation to Anthro Mountain because previous research has indicated that these populations have similar haplotype compositions (Oyler-McCance et al. 2005). If

wildlife managers used a source population that contained a difference in haplotypes, managers may risk negative impacts on adaptive differences in morphology and ecology in the resident sage-grouse population (Smith 2009). Demographic similarities between the source area and release area for translocation should also be taken into consideration when selecting a source population for translocation. The limiting factors on a sage-grouse population, such as adult survival, should be taken into account before extensive funds are used to implement a translocation.

Over the 2 year period of this study the high count for males on the leks were 6 males. In 2011, the high counts for males on the leks were 13 males (B. Maxfield, UDWR, personal communication). This increase in males strutting on the leks could be an indication that the effects of the translocation are perpetuating themselves 2 years after the initial translocation release. These observations and the results of our study may indicate that translocations can be an effective management tool to augment small and declining sage-grouse populations. The ultimate success of the translocation should be determined by the effects the translocation has on lambda. To determine the effect of translocation on lambda population vital rates should be monitored for several years following the initial translocation releases.

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Table 2-1. Factors used in nest, chick, juvenile, and adult greater sage-grouse survival models on Anthro Mountain, Utah, USA, 2009-2010.

Code	Factor	Factor Description
HA	Hen Age	Second year (SY) and After second year (ASY)
CA	Chick Age	0 to 20 days and 21 to 50 days of age
YR	Year	2009 or 2010
BT	Residency	Translocated hen or resident hen
HD	Hatch date	Calendar date adjusted to minimum value of 1
DV	Dummy Variable	Variables arranged to help determine survival changes over time (Resident bird = 0,0, newly translocated = 2,1, and previously translocated = 1,0)
ORDINAL	Ordinal Variable	Variables arranged to help determine whether residency status mattered overall (freshly translocated = 2, intermediate residency = 1, and longest residency = 0).
BINARY	Binary Variable	Variables arranged to help determine whether translocated birds that survived into their 2nd year became like or similar to resident birds (Resident birds = 0, newly translocated = 1, previously translocated = 0).
GHT	Grass Height	Mean grass height
GC	Grass Cover	Percent grass cover
FHT	Forb Height	Mean forb
FC	Forb Cover	Percent forb cover
SHT	Shrub Height	Mean shrub height
SC	Shrub Cover	Percent shrub cover
burn	Burn	Location of brood in a burn or not in a burn
ROBIN	Robel In	Mean visual obstruction due to vegetation towards brood-rearing site
ROBOUT	Robel Out	Mean visual obstruction due to vegetation out from brood-rearing site
(v)	Varied	Chick age (0-20 and 21-50 days of age) varied by year
(c)	Constant	Factor held constant across chick age

Table 2-2. Models assessing the impact of individual heterogeneity and temporal variation factors on translocated and resident greater sage-grouse adult and yearling survival, Anthro Mountain, Utah, USA, 2009-2010.

Model	K^a	AICc^b	Δ AICc^c	w^d
YR * HA	4	253.706	0.00	0.374
YR	2	254.958	1.25	0.200
HA + YR	3	256.469	2.76	0.094
BT + YR	3	256.963	3.26	0.073
BT * YR	4	258.315	4.61	0.037
NULL	1	258.552	4.85	0.033
ORDINAL * HA	4	258.791	5.09	0.029
BINARY * HA	4	259.321	5.62	0.023
BINARY	2	259.602	5.90	0.020
ORDINAL	2	259.855	6.15	0.017
DV1 + DV2 * HA	5	259.912	6.21	0.017
BT	2	260.259	6.55	0.014
HA	2	260.309	6.60	0.014
TIME TREND (mont	2	260.366	6.66	0.013
BINA + HA	3	260.483	6.78	0.013
ORD + HA	3	260.997	7.29	0.010
DV1 + DV2	3	261.442	7.74	0.008
BT + HA	3	261.761	8.06	0.007
DV1 + DV2 + HA	4	262.188	8.48	0.005

^a K: no. of parameters in each model.

^b AICc: Akaike's Information Criterion corrected for small sample size.

^c Δ AICc: difference between a model and the best performing model.

^d w: Akaike model weight

Table 2- 3. Models assessing the impact of individual heterogeneity and temporal variation factors on nest survival of translocated and resident greater sage-grouse, Anthro Mountain, Utah, USA, 2009-2010.

Model	K^a	AICc^b	Δ AICc^c	w^d
BT * HA	4	110.993	0	0.30534
BT	2	112.642	1.6487	0.1339
NULL	1	113.775	2.7816	0.07599
DV1 + DV2	3	114.341	3.3484	0.05724
ORD + HA	4	114.56	3.5665	0.05133
ORD * HA	4	114.56	3.5665	0.05133
BT + HA	3	114.611	3.6176	0.05003
BT + YR	3	114.65	3.6569	0.04906
ORD	2	114.812	3.8194	0.04523
HA	2	115.672	4.6791	0.02943
TIME TREND	2	115.732	4.7392	0.02855
BINA	2	115.748	4.755	0.02833
YR	2	115.763	4.7699	0.02812
DV1 + DV2 + HA	4	116.343	5.3502	0.02104
BINA * HA	4	116.685	5.6922	0.01773
ORD + HA	3	116.815	5.8216	0.01662
BINA + HA	3	117.687	6.6944	0.01074

^a K: no. of parameters in each model.

^b AICc: Akaike's Information Criterion corrected for small sample size.

^c Δ AICc: difference between a model and the best performing model.

^d w: Akaike model weight

Table 2- 4. Models assessing the impact of habitat factors on nest survival of translocated and resident greater sage-grouse, Anthro Mountain, Utah, USA, 2009-2010.

Model	K^a	AICc^b	Δ AICc^c	w^d
BT + GHT	3	110.052	0	0.26361
BT+ GHT + GC	4	111.058	1.0055	0.15945
BT +GC	3	111.327	1.2748	0.13936
BT	2	112.642	2.5895	0.07222
BT + ROBOUT	3	113.397	3.3449	0.0495
BT + FHT	3	113.749	3.6969	0.04151
BT + SHT	3	113.768	3.7155	0.04113
NULL	1	113.775	3.7224	0.04099
BT + ROBIN	3	113.85	3.7981	0.03947
BT + FC	3	114.03	3.9774	0.03608
BT + SC	3	114.611	4.5587	0.02698
BT*SC	4	114.937	4.8848	0.02292
BT*FHT	4	115.44	5.3879	0.01782
BT*FC	4	115.522	5.4698	0.01711
BT*SHT	4	115.601	5.5492	0.01644
TIME TREND (days	2	115.732	5.68	0.0154

^a K: no. of parameters in each model.

^b AICc: Akaike's Information Criterion corrected for small sample size.

^c Δ AICc: difference between a model and the best performing model.

Table 2- 5. Model selection results for models evaluating chick age and year effects on greater sage-grouse chick survival on Anthro Mountain, Utah, USA, 2009-2010.

Model	K^a	QAICc^b	Δ QAICc^c	w^d
CA + YR(v)	5	346.864	0.000	0.674
CA + YR(c)	4	349.303	2.439	0.199
CA	3	350.200	3.337	0.127

^a K: no. of parameters in each model.

^b QAICc: Quasi-likelihood version of Akaike's Information Criterion for small sample sizes.

^c Δ QAICc: difference between a model and the best performing model.

^d w: Akaike model weight

Table 2-6. The number of Greater sage-grouse translocated from Parker Mountain, Utah, to Anthro Mountain, Utah and the number of resident birds captured on Anthro Mountain, Utah, USA, 2009-2010. For ages and brood type, "RA" indicated resident (native to Anthro Mountain) adult hen and "TA" indicates translocated adult hen, "RJ" indicates resident juvenile hen, and "TJ" indicates translocated juvenile hen.

Year	Translocated	Resident	Ages	Capture Mortalities
2009	30	17	RA-11, RJ-6, TA-17, TJ-13	0
2010	30	2	RA-2, RJ-0, TA-13, TJ-17	2

Table 2-7. Parameter estimates and 95% confidence intervals for all factors used in the top individual heterogeneity and temporal variation models used to explain translocated and resident juvenile and adult greater sage-grouse survival on Anthro Mountain, Utah, USA, 2009-2010.

Parameters	Beta	SE	Lower CI	Upper CI
Model 1				
Intercept	3.114	0.510	2.111	4.115
Year	-1.764	0.600	-2.939	-0.589
Hen Age	-0.716	0.590	-1.879	0.447
Interaction	1.538	0.730	0.110	2.966
Model 2				
Intercept	2.630	0.259	2.122	3.138
Year	-0.772	0.332	-1.423	-0.122

Table 2-8. Predation of juvenile and adult greater sage-grouse on Anthro Mountain, Utah, USA 2009-2010.

Predator Typ	2009		2010			TOTALS
	Translocated <i>n</i> = 30	Resident <i>n</i> = 17	Newly Translocated <i>n</i> = 30	2nd Year Translocated <i>n</i> = 8	Resident <i>n</i> = 8	
Avian	1	1	1	0	0	3
Mammalian	4	0	0	0	1	5
Unknown	12	6	2	4	3	27

Table 2-9. Greater sage-grouse nest details for Anthro Mountain, Utah, USA 2009-2010. For hen ages and brood type, "RA" indicated resident (native to Anthro Mountain) adult hen and "TA" indicates translocated adult hen, "RJ" indicates resident juvenile hen, and "TJ" indicates translocated juvenile hen.

Year	# of Nests Initiated	# of Hatched Nests	Hen Age and Brood Type	% of Nests Hatched
2009	21(1 renest)	11	RA-4, RJ-1, TA-9, TJ-7	0.52
2010	26	15	RA-7, RJ-0, TA-16, TJ-3	0.58

Table 2-10. Parameter estimates and 95% confidence intervals for individual heterogeneity and temporal variation factors used to evaluate and explain greater sage-grouse nest survival (resident and translocated) survival on Anthro Mountain, Utah, USA, 2009-2010.

Parameters	Estimate	SE	Lower CI	Upper CI
Model 1				
Intercept	1.529	1.146	-0.717	3.775
idency Status	2.508	1.286	-0.012	5.027
Hen Age	3.994	1.522	1.011	6.978
Interaction	-4.512	1.661	-7.768	-1.256
Model 2				
Intercept	4.850	0.710	3.459	6.241
Residency	-1.185	0.763	-2.682	0.311

Table 2-11. Parameter estimates and 95% confidence intervals for all habitat terms used to evaluate and explain greater sage-grouse nest survival (resident and translocated) survival on Anthro Mountain, Utah, USA, 2009-2010.

Parameters	Estimate	SE	Lower CI	Upper CI
Model 1				
Intercept	3.533	1.078	1.420	5.647
Brood Type	-1.174	0.767	-2.677	0.330
Grass Cover	0.080	0.050	-0.018	0.178
Model 2				
Intercept	2.214	1.400	-0.531	4.958
Brood Type	-1.113	0.766	-2.614	0.388
Grass Height	0.170	0.082	0.009	0.330

Table 2-12. Greater sage-grouse chick capture details for Anthro Mountain, Utah, USA 2009-2010. For hen ages and brood type, "RA" indicated resident (native to Anthro Mountain) adult hen and "TA" indicates translocated adult hen, "RJ" indicates resident juvenile hen, and "TJ" indicates translocated juvenile hen.

Year	# of Broods Marked	# of Chicks Marked	Hen Age and Brood Type	Avg. Chicks Marked/Brood
2009	11	43	RA-3, RJ-0, TA-5, TJ-3	3.91
2010	13	56	RA-7, RJ-0, TA-4, TJ-2	4.31

Table 2-13. Parameter estimates and 95% confidence intervals for all individual heterogeneity and temporal variation factors used to evaluate and explain greater sage-grouse chick (resident and translocated) survival on Anthro Mountain, Utah, USA, 2009-2010.

Parameter	Beta	Lower CI	Upper CI
D	1.546	1.288	2.11
Age <20 Days	2.238	1.95	2.731
Age >20 Days	3.886	3.258	5.119
Year (2009)	0.082	-0.305	0.602
Year (2010)	2.468	0.1398	4.204
Broodtype (Resident)	-0.213	-0.651	0.227
Broodtype (Translocated)	-1.926	-4.3347	-0.377

Table 2-14. Individual heterogeneity and temporal variation variables in tandem with survival probabilities to 20 and 50 days of age for greater sage-grouse chicks on Anthro Mountain, Utah, USA, 2009-2010.

Additive Effect	Survival	95% CI
Chick Age + Year (1^a & 2^b) + Brood Type (1^c & 2^d)		
<20 days + Year (1) + Brood Type (1)	0.143	(0.079 - 0.295)
<20 days + Year (1) + Brood Type (2)	0.083	(0.037 - 0.153)
<20 days + Year (2) + Brood Type (1)	0.168	(0.103 - 0.335)
<20 days + Year (2) + Brood Type (2)	0.112	(0.050 - 0.278)
<20 days + Year (1 & 2) + Brood Type (1)	0.156	(0.106 - 0.290)
<20 days + Year (1 & 2) + Brood Type (2)	0.100	(0.054 - 0.196)
<20 days + Year (1) + Brood Type (1 & 2)	0.113	(0.070 - 0.205)
<20 days + Year (2) + Brood Type (1 & 2)	0.139	(0.084 - 0.279)
50 days + Year (1) + Brood Type (1)	0.078	(0.040 - 0.151)
50 days + Year (1) + Brood Type (2)	0.002	(0.000 - 0.035)
50 days + Year (2) + Brood Type (1)	0.159	(0.077 - 0.318)
50 days + Year (2) + Brood Type (2)	0.078	(0.015 - 0.195)
50 days + Year (1 & 2) + Brood Type (1)	0.130	(0.072 - 0.245)
50 days + Year (1 & 2) + Brood Type (2)	0.030	(0.002 - 0.078)
50 days + Year (1) + Brood Type (1 & 2)	0.023	(0.004 - 0.063)
50 days + Year (2) + Brood Type (1 & 2)	0.121	(0.048 - 0.251)

^a Year 1 = 2009

^b Year 2 = 2010

^c Brood Type 1 = Resident

^d Brood Type 2 = Translocated

Table 2-15. Parameter estimates and 95% confidence intervals for all individual heterogeneity and temporal variation factors used to evaluate and explain greater sage-grouse chick (resident and translocated) survival on Anthro Mountain, Utah, USA, 2009-2010.

Parameter	Beta	Lower CI	Upper CI
D	1.515	1.158	2.386
Age <20 Days	1.407	-0.689	3.783
Age >20 Days	2.485	-0.578	2.502
Grass Cover	0.058	-0.063	0.183

Table 2-16. Habitat variables in tandem with survival probabilities to ages 20, 28, 42, and 50 days of age for greater sage-grouse chicks of resident and translocated hens combined on Anthro Mountain, Utah, USA, 2009-2010. The first and third quantile and median average percent grass cover measured on Anthro Mountain were used in determining high, low, and median grass cover values for analysis.

Additive Effect	Survival	95% CI
Chick Age + Grass Cover		
<20 days + Grass Cover Low	0.146	(0.044 - 0.432)
<20 days + Grass Cover Median	0.211	(0.027 - 0.307)
<20 days + Grass Cover High	0.29	(0.037 - 0.444)
28 days + Grass Cover Low	0.111	(0.022 - 0.374)
28 days + Grass Cover Median	0.169	(0.065 - 0.359)
28 days + Grass Cover High	0.243	(0.066 - 0.530)
42 days + Grass Cover Low	0.068	(0.003 - 0.345)
42 days + Grass Cover Median	0.114	(0.027 - 0.307)
42 days + Grass Cover High	0.178	(0.037 - 0.444)
50 days + Grass Cover Low	0.051	(0.001 - 0.333)
50 days + Grass Cover Median	0.091	(0.014 - 0.282)
50 days + Grass Cover High	0.149	(0.026 - 0.417)

Table 2-17. Incidental rodent observations on Anthro Mountain, Utah, USA, 2009-2010. Large rodents include: ground squirrels, chipmunks, gophers, and rabbits. Small rodents include: mice, voles, and shrews.

Date	Large Rodents	Small Rodents	Total
June - August 2009	34	11	45
June - August 2010	91	10	101

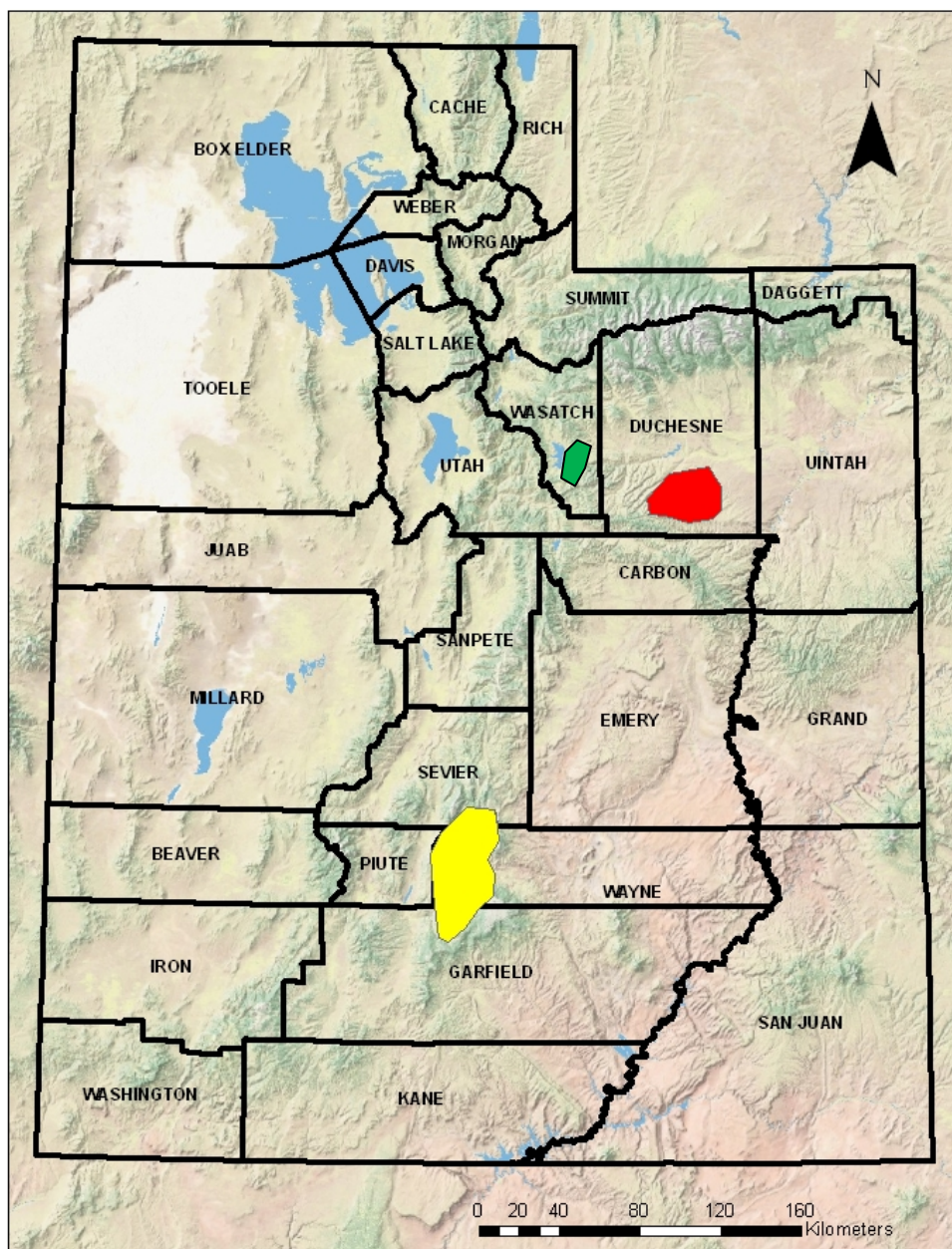


Figure 2-1. Map of Utah which includes Parker Mountain (yellow polygon), the source translocation population and Anthro Mountain (red Polygon), the release area for the greater sage-grouse translocation. The green polygon is Strawberry Valley, were Baxter et al. (2008) conducted a successful translocation.

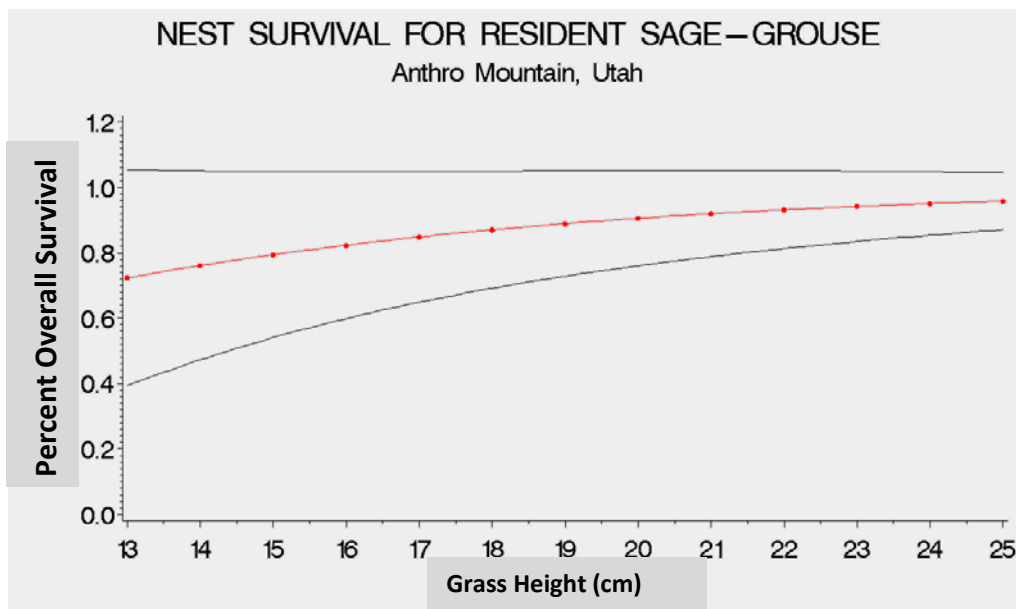


Figure 2-2. Overall survival probability for resident sage-grouse nests on Anthro Mountain, Utah, USA in correlation with grass height (cm), 2009-2010.

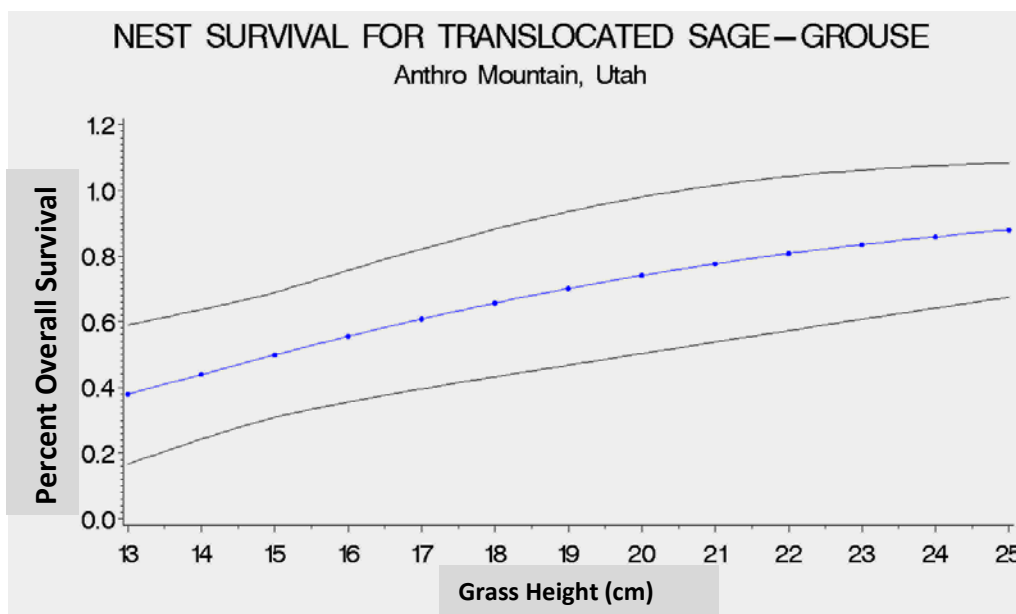


Figure 2-3. Overall survival probability for translocated sage-grouse nests on Anthro Mountain, Utah, USA in correlation with grass height (cm), 2009-2010.

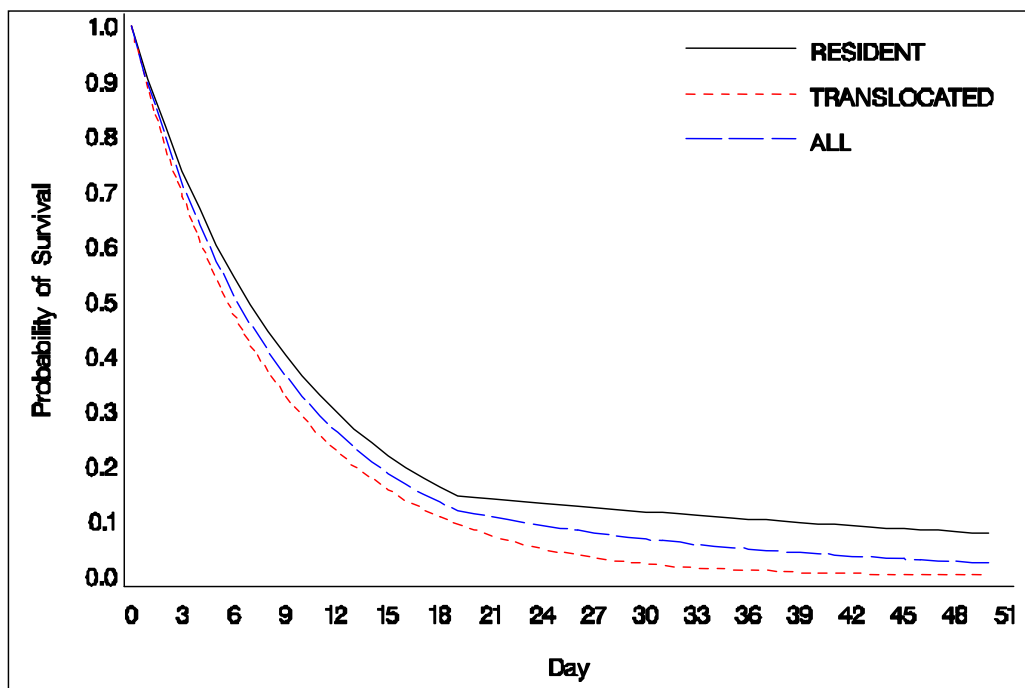


Figure 2-4. Survival probability for resident, translocated, and all sage-grouse chicks combined to 50 days of age on Anthro Mountain, Utah, USA, 2009.

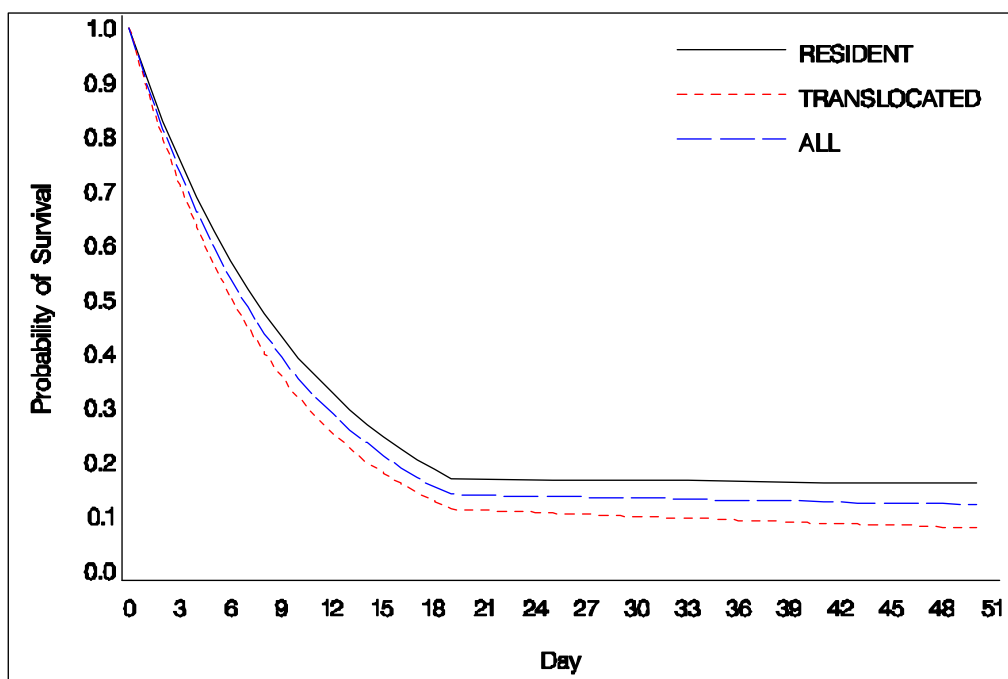


Figure 2-5. Survival probability for resident, translocated, and all sage-grouse chicks combined to 50 days of age on Anthro Mountain, Utah, USA, 2010.

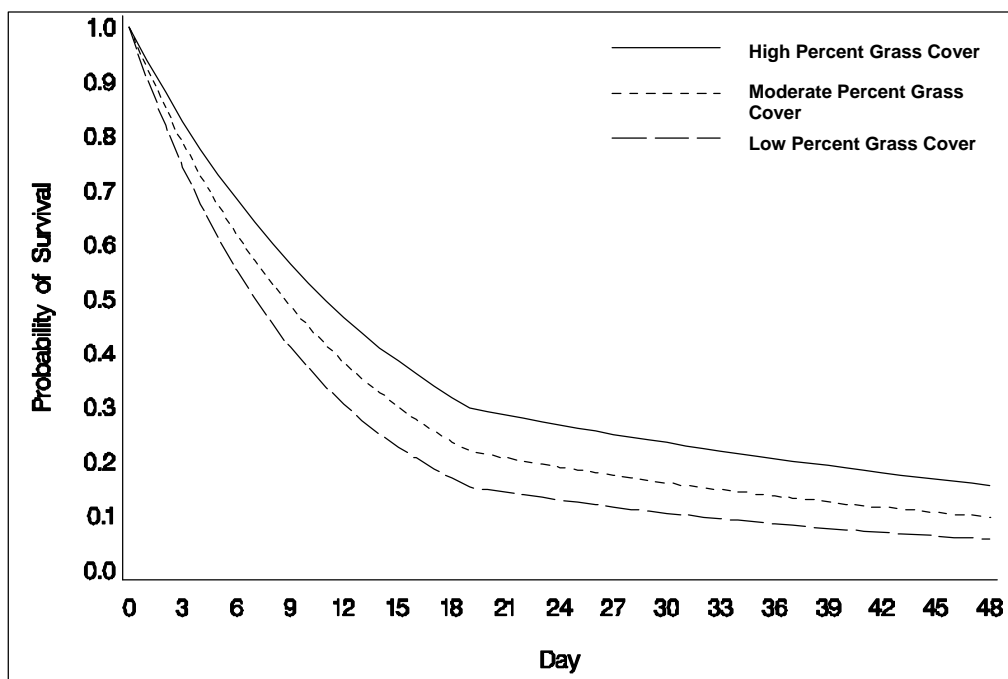


Figure 2-6. Survival probability for resident and translocated sage-grouse chicks combined to 50 days of age from 2009-2010 on Anthro Mountain , Utah, USA, in correlation with percent grass cover 2010.

CHAPTER 3

INTEGRATION OF TRANSLOCATED GREATER SAGE-GROUSE INTO A HIGH ELEVATION POPULATION IN NORTHEASTERN UTAH

ABSTRACT

Greater-sage grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) populations have declined range-wide over the last 50 years. These declines have been largely attributed to the loss and/or fragmentation of sagebrush (*Artemisia* spp.) habitats. Wildlife managers have implemented projects designed to restore degraded sagebrush habitats and subsequently used translocations to augment resident sage-grouse populations. The success of recent sage-grouse translocations have been attributed to the cumulative effects of geomorphic barriers (i.e., closed basins), improved habitats, and predation management which deterred dispersal of translocated sage-grouse. Although managers readily agree that improved habitat conditions and the presence of a resident population are essential translocation decision factors, the role of predation management and effect of geomorphic barriers on translocation success continues to be debated.

Between 2009-2010, I translocated 60 radio-collared sage-grouse hens captured on Parker Mountain located in southcentral Utah to Anthro Mountain northeast Utah to determine the effects of the absence of a geomorphic barrier and predation management on translocation success. Elevations at both sites range from 2000-3000 m. I compared seasonal behaviors and movements, spatial habitat-use patterns during the breeding season, and the home ranges of translocated birds to radio-collared resident birds to determine population integration.

Over the 2-year study period, translocated birds were both observed flocking and lekking with resident birds. Home ranges for translocated (59 km^2) and resident birds (52 km^2) exhibited 73.4% overlap. Across years translocated sage-grouse moved farther than did resident birds ($F_{1,53} = 9.22, P = 0.004$). Movement distances did not differ for resident and translocated birds in 2009 ($F_{1,32} = 1.52, P = 0.227$). However, in 2010, movements differed ($F_{3,31} = 7.51, P = 0.002$). The difference observed in annual movements in 2010 and across years may have been influenced by a smaller sample size in 2010. Movement distance from lek sites did not differ for resident and translocated birds by re-location periods (i.e., pre-nesting, early brood-rearing, broodless (i.e., lost their brood or never had a brood), and fall; $P=0.209$). Both resident and translocated birds moved more during the pre-nesting, fall, and broodless time periods compared to early brood-rearing periods ($F_{4,150} = 3.98, P = 0.004$). In 2009 and 2010, 93.8% and 94.7% of translocated birds, respectively nested within 3.2 km of the nearest lek. Although 23% of translocated birds moved distances ranging from 11-54 km away from the release site, similar movements were documented for the resident sage-grouse population. These large movements typically occurred from late fall to early spring. My results suggest that release protocols rather than geomorphic barriers had a greater influence on mitigating dispersal of translocated birds. Releasing the translocated birds near an active lek during the breeding season appears to have facilitated integration into the resident population.

INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) populations have declined range-wide and currently occupy less than 60% of their historical range (Schroeder et al. 2004). Sage-grouse historically occurred in 16 western

states and 3 Canadian provinces, now the species occurs in 11 states and 2 Canadian provinces (Schroeder et al. 1999). These range wide declines and extirpation of sage-grouse populations appear to be related to habitat alterations including fragmentation, cultivation, development, encroachment by trees, changes in fire regime, resource extraction, invasive plant expansion, and reduction of sagebrush (Braun et al. 1977, Connelly and Braun 1997, Schroeder et al. 2004, Leu and Hanser 2011, Wisdom et al. 2011).

Managers range-wide have implemented habitat projects to improve habitat for sage-grouse and address the resource threats associated with the decline of sage-grouse. These habitat improvements may lead to the use of species translocations to augment and increase sage-grouse populations in restored habitats. Translocations and reintroduction efforts of sage-grouse to reestablish and augment small and declining populations have been attempted in seven states and one province (Reese and Connelly 2007). Translocations of sage-grouse have had limited success; in an evaluation of 56 attempts of sage-grouse translocations since 1933 to 1990; only three attempts were considered successful (Musil et al 1993, Snyder et al. 1999, Reese and Connelly 2007). Factors impacting the translocation success include habitat quality, habitat fragmentation, predation, number of animals translocated, capture date, and failure of the translocated birds to integrate into the resident population due to an increase in dispersal from the release area (Kurzejeski and Root 1988, Griffith et al. 1989, Musil et al 1993, Snyder et al. 1999, Coates and Delehanty 2006, Reese and Connelly 2007, Baxter et al. 2008).

High dispersal rates on the part of translocated birds may result in increased mortality as translocated birds move longer distances over unfamiliar terrain in search of

suitable habitats or conspecifics (Cope 1992, Beck et al. 2006, Dickens et al. 2009). Increased dispersal from the release area could impede site fidelity, integration into the resident population, survival, and reproduction (Griffith et al. 1989, Wilson et al. 1992, Coates and Delehanty 2006, Coates et al. 2006, Baxter et al. 2008). Kurzejeski and Root (1988) reported that reintroduced ruffed grouse (*Bonasa umbellus*) in Missouri that moved more experienced higher mortality rates than sedentary birds. Coates et al. (2006) observed that the movements of translocated Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) were related to the availability of suitable nesting habitat relative to the release sites. Baxter et al. (2008) reported sage-grouse translocated to Strawberry Valley, Utah stayed close to the release site. Baxter et al. (2008) attributed the observed lack of dispersal to the presence of natural and artificial barriers (i.e., mountains, reservoir, and homes) that occur in and around the release area.

Increased dispersal may also interfere with the integration of translocated birds with the resident population. This interference with local integration could affect the ability of translocated sage-grouse to find a lek to breed and potentially learning areas that contain quality nesting, brood-rearing, and wintering habitats and seasonal migration corridors. To mitigate dispersal from the release area, Baxter et al. (2008) recommended releasing translocated birds during the breeding season and releasing the birds near an active lek. Coates and Delehanty (2006) observed that Columbian sharp-tailed grouse hens captured later during the lek-visitation period were more likely to initiate a nest at the release site. Because sage-grouse show high fidelity and attraction to lekking and nesting areas, the release of translocated birds during the breeding season and near an active lek could increase the likelihood of a successful translocation (Emmons and Braun

1984, Berry and Eng 1985, Dunn and Braun 1985, Reese and Connelly 1997, Baxter et al. 2008). Baxter et al. (2008) demonstrated that the release of translocated female sage-grouse near a lek (<250 m) during the breeding season, stimulated continued breeding behavior, increased the potential for interactions with the resident sage-grouse population, and possibly aided the attenuation in dispersal movements.

The purpose of my research was to determine if the translocation methodology used by Baxter et al. (2008) in a closed high elevation basin would be applicable to high elevation areas where movements of the birds would not be restricted by closed basin topography (i.e., geomorphic barriers). I evaluated if sage-grouse translocated into a high elevation open basin would successfully integrate with the resident population.

Integration metrics included lekking and flocking behaviors, nest and brood site spatial habitat selection from known leks, average movements, and home range size.

Specifically, I wanted to address whether translocated birds nested farther from leks than did resident birds, whether translocated birds movements differed from resident birds, and how far translocated and resident birds nested and also brood-reared from leks on Anthro Mountain. I hypothesized that if integration was successful these metrics would not differ for resident and translocated birds. My research validated translocation techniques used by Baxter et al. (2008) for application in other areas of the west.

STUDY AREA

Core Release Area

My study was conducted on Anthro Mountain in northeastern Utah. Anthro Mountain is located on the Ashley National Forest, 29 km southeast of Duchesne, Utah (UTM 0547839/4421185). The study area is a montane sagebrush- steppe, with black

sagebrush (*A. nova*) and mountain big sagebrush (*A. tridentate vaseyana*) the dominant shrubs. There are over 9,000 ha of available sagebrush on the mountain. There is a small population of sage-grouse established on the mountain. Anthro Mountain is characterized by high, narrow and flat ridges running north and south and is separated by deep, narrow canyons and draws. The vegetation community predominantly consists of mixed sagebrush, aspen (*Populus tremuloides*), juniper (*Juniperus osteosperma*) and pinyon pine (*Pinus edulis*). Other native shrubs include: rabbitbrush (*Chrysothamnus viscidiflorus*), snowberry (*Symphoricarpos oreophilus*), and lupine (*Lupinus argenteus*). Common grass species include: June grass (*Koeleria macarnta*), basin wildrye (*Leymus cinereus*), bluebunch wheatgrass (*Elymus spicatus*), salina wildrye (*Elymus salinus*) and smooth brome grass (*Bromus inermis*). The average annual precipitation in the study area was 49 cm and the mean annual daily temperature ranged from 1.7°C to 13°C. Elevations ranged from 2,000 to 3,000 m.

Source of Translocated Sage-Grouse

Parker Mountain, a high elevation plateau located in south-central Utah, provided the source for the translocated sage-grouse. Parker Mountain was chosen as the source population for the translocation of sage-grouse to Anthro Mountain because it was considered robust and stable, located ≥ 100 km from the release site, and is genetically compatible to sage-grouse already established in the release area (Reese and Connelly 1997, Oyler-McCance et al. 2005, Baxter et al. 2008, Smith 2009). The predominant vegetation community was mountain big sagebrush, black sagebrush, rabbitbrush and bitterbrush. Common grass species included bluegrass (*Poa* spp.), grama grass (*Bouteloua* spp.), June grass, needlegrass (*Hesperostipa* spp.), squirreltail grass (*E.*

Elymoides), and wheatgrass. The elevation and topography of Parker Mountain was also similar to Anthro Mountain. Average annual precipitation ranged between 40 to 51 cm. Elevation ranged from 2,150 to 3,000 m.

METHODS

Data Collection

In April and May of 2009 and 2010, I captured and radio-collared 60 greater sage-grouse hens (30 each year) from Parker Mountain, Utah on and around active leks using all-terrain vehicles, spotlights and long handled nets (Giesen et al. 1982). Each grouse was fitted with a 16-g necklace style radio transmitter (Advanced Telemetry Systems, Insanti, MN in 2009-2010 and American Wildlife Enterprises, Monticello, FL in 2010) at the site of capture. The sage-grouse were weighed using a Pesola scale™ (Pesola, Zug, Baar, Switzerland) and the age of the bird was determined. The sage-grouse were then placed in individual cardboard boxes (12"x 9"x 12") with ventilation and were transported overnight in a pickup truck to Anthro Mountain (0200 hr to 0700 hr). The birds were released the following morning <200 m north of most active lek (Alkali Lek) on Anthro Mountain. The transport boxes were lined up facing the lek, the immediate area was scanned for predators, and each grouse was then released individually.

I also captured and radio-collared 19 resident birds on Anthro Mountain in the spring and fall of 2009 and spring of 2010 using the techniques described above. Resident sage-grouse were released at the capture location. I monitored movements of radio-marked birds using a Communications Specialists™ (Communications Specialists, Orange, CA, USA) receiver, handheld 3-element Yagi antennas, and vehicle-mounted

Omni antennas to locate the birds 2 to 3 times a week. During the brood-rearing season, all broods were radio-tracked 3 times a week until the broods reached 50 days old.

Because of access limitations caused by snow and limited man-power, sage-grouse were located monthly during the late fall and winter. Three flights in a fixed-wing aircraft were used to locate grouse that had made large movements which were undetectable from the ground throughout the year.

Integration of the translocated birds with resident birds was monitored by visual observations and occasionally flushing of the flocks to determine the number of unmarked birds (i.e., unmarked resident birds) in the group. Lek attendance by translocated and resident birds was recorded using radio-telemetry and visual lek counts during the spring of 2009 and 2010. Additional data recorded at all the bird locations included: the date, time, researcher, UTMS (Zone 12T, NAD83), altitude, slope, aspect, group size, nearest lek, habitat type, visible oil wells, and nearest disturbances (i.e. fence, roads, 2-tracks, burned areas). All bird handling and research activities were done in accordance with the Institutional Animal Care and Use Committee (IACUC) approved protocol at Utah State University under the permit # 1404.

Data Analysis

All sage-grouse spatial location data were recorded using the geographic coordinate system Universal Transverse Mercator (UTMS) Zone 12 T. Location data were downloaded into the Geographic Information System (ArcView GIS 9.2) and were transformed into shapefiles. All shapefiles were then edited to determine whether there were any errors in the location data. Erroneous data other data that were censored from the shapefiles included; detection observations, observations with incomplete UTM data,

multiple nesting locations (same data), mortality locations, replicate locations in one day, locations of birds that were released and never relocated again. Data for missing birds and mortalities were right censored to the last location the bird was located alive.

Consecutive movement distances were calculated using a minimum, straight-line distance between 2 locations. All movement distances were calculated using a supplemental ArcView GIS 9.2 program; Hawth's Tools (Animal Movements Analysis).

Movement distance data were analysed using the SAS/STAT software (SAS Version 9.2). The GLM procedure was used for ANOVA, one-way analysis of variance to determine the differences between average movement distances of resident and translocated birds. Multiple covariates were used to compare these movements, these covariates included year, age of the birds, location type (pre-nesting, early brood-rearing, late brood-rearing, broodless, and fall/winter), and residency status (resident or translocated). Square root transformations of the distance data were used to meet the assumptions of normality. The PROC MEANS procedure was used to obtain descriptive statistics to summarize movement patterns. When the ANOVA test showed a p-value less than $\alpha = 0.05$, the Tukey's Studentized Range Test (HSD) was used to determine which means in the analysis differed and by how much the means differed. Birds that had ≤ 5 location points were eliminated from the data. Also, extreme location data and birds that were not located after the release were censored from the data set. Most location data encompassed the months of April through October of each year. There were however sporadic fall, winter and early spring locations collected. These sporadic locations were used only for the area of occupancy analysis.

Area of occupancy of Anthro Mountain for translocated and resident birds was calculated using Hawth's Tools (Fixed Kernel Density Estimator) in ArcView GIS 9.2. The quartic approximation of a true Gaussian kernel function was used to calculate a fixed kernel density estimate using the Fixed Kernel Density Estimator (Beyer 2009). The 90% volume contour was used to delineate the area of area of occupancy for translocated birds combined and resident birds combined. The Intersect Analysis Tool was used to determine the area of occupancy that overlaps between resident and translocated birds. Analysis tool, Intersect, was used to determine area of occupancy overlap. All location data was used to calculate the area of occupancy, with the exception of extreme movement data and birds that were never located after the translocation (Fig. 3-1, Fig. 3-2). Area of occupancy is defined as the total area traversed by translocated and/or resident birds during normal activities such as foraging, mating, and caring for young.

RESULTS

Integration Behavior

Lekking

The Utah Division of Wildlife Resources (UDWR) documented 4 leks on Anthro Mountain. In 2009-2010, 2 of the 4 leks were known to be active during 2009 and 2010. The 60 radio-collared hens translocated were captured during the lekking period. The translocated hens were released at the same location, 100 m north of the most active lek on Anthro Mountain. During the very first translocation release (there were a total of 4 release events) in 2009, no resident males were observed strutting on the lek. However telemetry data confirmed there were at least 2 collared resident males and 1 collared

resident female ≤ 30 m from the lek when the releases were conducted. During subsequent translocation releases in 2009 and 2010 there were 1 to 6 males strutting on or near the lek. The peak male count for Anthro Mountain in 2009 was on 6 May 2012 and total of 6 males were counted. In 2010, peak male counts were on 7 May 2012 (4 males counted) (Table 3-1). In 2009 no translocated females were observed on the Anthro release lek, however in 2010 three translocated females were observed on the lek.

Flocking

In 2009, translocated hens began flocking with resident birds on April 16th within days after translocation (April 6th through April 14th). In 2010, flocking behavior was recorded on May 2nd, in the middle of the translocation period (April 19th through May 5th). By the end of June of 2009 and 2010, 100% of translocated birds that remained alive had been recorded, flocking with at least one resident bird. As each year progressed, translocated hens were increasingly observed flocking with resident birds.

Spatial Habitat Use Patterns Relative to Leks

Nest Sites

In 2009, of the birds that initiated nests, 93.8% of translocated hens and all resident hens nested within 3.2 km of the nearest lek (Fig. 3-3). Over half of the translocated (11/16, 68.8%) and resident (3/5, 60%) hens that nested, nested within 1.6 km of the nearest lek. In 2010, 87.5% (7/8) of previously translocated hens, 72.7% (8/11) of newly translocated hens, and 42.9% (3/7) of resident birds that were observed initiating nests, nested within 1.6 km of the nearest lek (Fig. 3-4). Over both years all of the radio-collared resident and translocated hens nested within 5.6 km of the nearest lek.

Nearly half of the translocated birds (7/16, 43.8%) that nested in 2009, nested within 3.2 km of the lek (Alkali Lek) that was closest to the release site. Similarly, 40% (2/5) of resident birds that nested, nested within 3.2 km of the nearest lek. Of the hens that nested in 2010, 81.8% (9/11) of newly translocated, 50% (4/8) of previously translocated, and 100% (7/7) of resident hens, nested within 3.2 km of the nearest lek to the translocation release site.

Brood Sites

In 2009, brood-rearing locations (Fig. 3-5, Fig. 3-6) for broods up to 50 days of age of translocated and resident hens were within 5.6 km of their nest site. Ninety-six percent of translocated brood-rearing locations and 100% of resident brood-rearing locations were within 3.2 km of their nest site in 2009. In 2010, all translocated and resident brood-rearing locations were within 3.2 km of their nest sites. All brood sites for translocated birds in 2009 were within 5.6 km² of a known lek, all resident brood sites were located within 3.2 km² of a known lek (Fig. 3-7). In 2010, 100% of resident, newly translocated, and previously translocated brood sites were within 3.2 km² of a known lek (Fig. 3-8).

Movements

In 2009, average distance travelled by translocated and resident bird did not differ ($F_{1,32} = 1.52, P = 0.227$). In 2010, the average distance moved by resident, newly translocated, and previously translocated birds differed by the three resident status groups ($F_{3,31} = 7.51, P = 0.002$). Average distances moved between locations by newly translocated birds were slightly higher (1.7 km, SE = 0.08 km) than average distances

moved by previously translocated (1.3 km, SE = 0.1 km) and resident birds (0.7 km, SE = 0.06 km). Over both years of the study, average distances moved between locations for translocated birds were slightly higher (1.5 km, SE = 0.05 km) than average distances moved by resident birds 0.9 km (SE = 0.06 km; $F_{1,53} = 9.22$, $P = 0.004$). Bird age ($F_{1,55} = 2.70$, $P = 0.106$) and the year ($F_{1,65} = 0$, $P = 0.988$) had no effect on movements of resident and translocated birds.

Distances moved by brood-rearing resident and translocated hens across years did not differ ($F_{1,21} = 4.29$, $P = 0.051$). However, movements differed for some location periods (pre-nesting, early brood-rearing and fall; $F_{4,150} = 3.98$, $P = 0.004$) across both years. Translocated and resident birds moved more during the pre-nesting and fall seasons relative to early brood-rearing movements. There was also a difference in average movements when comparing broodless bird movements to early brood-rearing movements (Table 3-2). Both broodless and pre-nesting birds moved on average more than did early and late brood-rearing females for both resident and translocated birds.

In 2009 and 2010, most translocated hen locations were within 8.3 km and 7.8 km of the release sites, respectively. However some birds engaged in large distance movements off the mountain. For example, one female that was translocated in 2009, was not relocated until one year after her release. She was subsequently recaptured on a lek near Fruitland Utah which is approximately 53.7 km northwest from the original release site. Other translocated birds also made large movements (from the release area) off the mountain (Fig. 3-9). The largest movement was 55 km southwest of Anthro Mountain to the sage-grouse population in the Emma Park area.

During the winter and early spring of both years several translocated and resident birds remained on Anthro Mountain near small exposed patches of mountain big sagebrush. Although some birds were located off the mountain during the winter months and others could not be relocated because of seasonal access limitations, most of the translocated and resident birds returned to Anthro Mountain in March and April for the breeding season.

Area of Occupancy

Area of occupancy for all translocated and resident birds combined in 2009 encompassed an area of 58 km² and 52 km², respectively (Fig. 3-10). The area of occupancy for resident and translocated birds overlapped 74.6% in 2009. In 2010, area of occupancy for newly translocated birds, previously translocated birds, and resident birds encompassed 57 km², 44 km², and 26 km², respectively (Fig. 3-11). Percent area of occupancy overlap for resident and newly translocated birds was 38.3%, for resident and previously translocated birds was 45.8%, and for previously translocated and newly translocated birds was 62.9%. It is important to note that there were fewer radio-marked resident and previously translocated birds than newly translocated birds in 2010. Combining locations taken from 2009 and 2010, area of occupancy for translocated (59 km²) and resident (52 km²) overlapped 73.4% (Fig. 3-12).

DISCUSSION

Integration

Based on the behavior and spatial habitat-use metrics I studied, the translocated birds fully integrated with the resident sage-grouse population on Anthro Mountain.

Translocated birds flocked with resident birds within a month of their release and were observed attending the active leks on Anthro Mountain. Nest sites and brood-rearing sites for translocated and resident birds were all within 5.6 km² of a known lek. Average distances moved by translocated birds was slightly higher than for resident birds, however, there was no difference in movements between resident and translocated birds by relocation period (i.e., pre-nesting, brood-rearing, and fall). My results suggest releasing the translocated hens near a lek during the breeding season may have helped to facilitate interactions between resident and translocated birds

Behavior

Reese and Connelly (1997) suggested and Baxter et al. (2008) observed that releasing translocated birds near an active lek could potentially increase interactions with resident birds increasing success of the translocation because of instinctive attraction of sage-grouse to leks and breeding habitat (Berry and Eng 1985). Although I observed few translocated females on the lek because of seasonal logistic constraints, the number of nesting hens encountered during the breeding season (16 nested in 2009 and 18 nested in 2010) suggested the hens visited the leks. At one translocation release event in 2010, a resident male was less than 10 m from the release site undetected. When one of the translocated females was released from the transfer box, the female flew to the lek and the male followed her.

The peak male counts for 2009 and 2010 were historically low on Anthro Mountain, however, there are anecdotal observations (many fecal droppings and feathers) of males lekking in other areas of the mountain that were not identified as established leks. Because of the low number of males that were seen on the leks, I speculate that

perhaps some breeding events may have taken place off the lek. One radio-collared male during the lekking season left the mountain and was detected approximately 48 kms southeast of Anthro Mountain. This male returned to Anthro Mountain a week later and began strutting on the lek. This behavior has previously been observed with resident birds (R. Christensen, USFS, personal communication). During a previous study on Anthro Mountain, a resident male was on a lek 48 kms southeast of the mountain in the same vicinity as the male I detected off Anthro Mountain during the breeding season (R. Christensen, USFS, personal communication).

Flocking

I observed translocated hens flocking with resident sage-grouse within days after their release. Intergroup flocking increased over time and may have been influenced by factors limitations in winter habitat availability (Baxter et al. 2008). These initial interactions between translocated and resident grouse may increase the success of the translocation and decrease permanent dispersal from the release area. Similar to my study, Baxter et al. (2008) observed that birds translocated to Strawberry Valley, Utah, were increasingly found in flocks with resident birds during the first year after their release.

I recorded multiple large distance movements (≥ 10 km) off Anthro Mountain. At some of these locations translocated birds were also observed in flocks with resident Anthro Mountain birds. Also many of these locations off the mountain were in areas where other populations of sage-grouse reside or have previously been documented. In previous research conducted on Anthro Mountain, radio-marked resident birds have been

located off the mountain in similar areas that the translocated grouse were located (R. Christensen, USFS, personal communication).

Although intensive winter and early spring locations were not obtained, anecdotally the Anthro Mountain population seems to fall in the 1-stage migratory category (movements between 2 seasonal ranges -winter/breeding and summer) as defined by Connelly et al. (2000), although, there seems to be multiple wintering areas used by Anthro Mountain grouse.

Movements

Although there were several large movements made off the mountain by translocated grouse, none of the birds were known to return to the capture site (Parker Mountain). This may be due to the fact that the capture site and release site were ≥ 100 km. Reese and Connelly (1997) also suggested that the release site be confined by geomorphic features such as mountains to prohibit the translocated birds from dispersing from the release area. Both Musil et al. (1993) and Baxter et al. (2008) had successful sage-grouse translocations and both attributed geomorphic barriers as aiding in the success of their translocations by deterring permanent dispersal from the release areas. Both successful translocations, observed the establishment of the translocated grouse near the release site.

My research site was located on a high elevation (2000 to 3000 m), open area, not constricted by geomorphic barriers. My data indicated that the translocated birds stayed within the historic and current range as the resident population on Anthro Mountain, even though there were no geomorphic barriers. These data may imply that translocations could be considered in areas that do not have geomorphic barriers.

During 2009, average distance moved and home ranges were similar between resident and translocated birds. These data may indicate that the translocated birds assimilated quickly to their new environment and that the release area contained adequate year-round habitat support translocated birds in the area (Reese and Connelly 1997). These results may also indicate that long-distance homing did not occur and that the translocated sage-grouse settled into the current and historic range of the resident population (Carrie et al. 1996). During 2010, however, average distances moved and home ranges did vary between groups (resident, newly translocated and previously translocated). It is possible that other extrinsic factors affected the movements of the grouse in 2010, such as moisture conditions, distribution of succulent vegetation, and perhaps the uneven sample sizes could have contributed to the variation in movements and distribution across the mountain (Berry and Eng 1985).

Movements of both resident and translocated birds were also influenced by breeding status and season. Broodless hens moved more than hens with early broods. Although brood movements may be in response to food availability, habitat quality, or risk of predation, but because sage-grouse are unable to regulate their body heat until about 2 weeks of age, movements of early broods may be limited (Wallestad 1975, Berry and Eng 1985). Spring or pre-nesting seasonal movements averaged higher than summer movements for early (0-20 days of age) and late (21-50 days of age) season broods. These differences seem logical because during the pre-nesting season, resident birds are moving back to their breeding grounds from their winter ranges, translocated birds may be acclimating to their new environment, and females will be searching for nest sites.

Spatial Habitat Selection of Nest and Brood Sites

Large movements from the release site may potentially increase vulnerability to predators and affect the overall success of the translocation (Kurzejeski and Root 1988, Cope 1992, Musil et al. 1993). My research demonstrated that the majority of translocated sage-grouse nested near the area of release, which has previously and currently been recorded as nesting habitat used by the resident population on Anthro Mountain. The majority of the translocated and resident grouse nested within 3.2 km of the lek closest to the release area and other known leks on the mountain. These findings are similar to research findings across the sage-grouse range for resident birds (Connelly et al. 2000, Manville 2004, Holloran and Anderson 2005, Robinson 2007). Similarly, a high proportion of translocated and resident grouse reared their broods within 3.2 km of their nest sites and known leks. In a study conducted on sharp-tailed grouse in Nevada, it was observed that translocated grouse released in an area that had been formerly selected for as nesting habitat by previously translocated grouse, moved less (Coates et al. 2006).

Area of Occupancy

Spatial patterns in the home range of sage-grouse may be influenced by available habitat, climate trends and anthropogenic influences (Aldridge et al. 2008). The spatial habitat use patterns of translocated and resident populations I studied overlapped by 73.4%. These spatial patterns mainly encompassed location from early spring until late fall and overlaid most of the available habitat on top of Anthro Mountain. These observations indicate that most of the translocated birds did reside in the current and historical range of the resident sage-grouse population. There were also several large movements by both translocated and resident sage-grouse outside the core (90%) area of

occupancy. These movements indicate potential connectivity between the Anthro Mountain sage-grouse populations and surrounding populations and demonstrate that Anthro Mountain is a migratory population.

MANAGEMENT IMPLICATIONS

Translocated sage-grouse acclimated rapidly to the Anthro Mountain area. Nesting, brood-rearing, summer, and fall locations and area of occupancy of translocated birds were similar to resident sage-grouse on Anthro Mountain. In both years of the study the translocated birds began flocking with resident birds soon after their initial release. Previously, successful translocations have released birds in areas with geomorphic barriers, which were attributed to deterring permanent dispersal from the release area. My study site was a high elevation, open area, with no geomorphic barriers to hinder dispersal from the release site. My data suggested that translocations could be considered in areas that do not contain geomorphic barriers and that releasing translocated birds near a lek during the breeding season can increase the interactions between resident and translocated birds, thus increasing the success of the translocation.

Both resident and translocated birds engaged in large seasonal movements off Anthro Mountain. This indicated that Anthro Mountain sage-grouse did interact with other sage-grouse populations in the area. These large movements may also reflect the population's adaptation to environments which exhibit a high degree of natural habitat fragmentation. Because the habitat is naturally fragmented and there is an increase in habitat fragmentation due to oil and gas development in the area, wildlife managers may want to consider protecting habitat corridors as bridges between the Anthro Mountain population and surrounding sage-grouse populations. Wildlife managers may also want

to consider the importance of the Anthro Mountain population, in relation to gene flow between surrounding sage-grouse populations. More information needed to be collected on the larger movements off Anthro Mountain to obtain more detailed information on corridor areas and connectivity. These observations and the results of our study may indicate that translocations can be an effective management tool to augment small and declining sage-grouse populations as long as factors limiting the resident population are addressed before the translocation.

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Table 3-1. Lek counts on Anthro Mountain, Utah, 2009-2010

Date	Time	Lek	# of Males	# of Females	Temp (° C)	Wind (mph)	% Cloud Cover
26-Mar-09	6:55	Nutters	1	0	-12	13-18	90
27-Mar-09	7:40	Alkali	1	0	-8	0-5	10
27-Mar-09	6:52	Nutters	0	0	-9	0-5	10
27-Mar-09	7:05	Cracker Grove	0	0	-9	0-5	10
27-Mar-09	7:40	Wire Fence	0	0	-9	1-3	10
2-Apr-09	8:17	Alkali	0	0	-7	8-12	50
2-Apr-09	6:50	Nutters	0	0	-11	8-12	40
2-Apr-09	7:09	Cracker Grove	0	0	-11	8-12	40
7-Apr-09	7:20	Alkali	1	0		1-3	20
7-Apr-09	6:30	Nutters	0	0		1-3	20
7-Apr-09	6:45	Cracker Grove	0	0		1-3	20
9-Apr-09	6:30	Alkali	2	0		1-3	40
13-Apr-09	6:05	Nutters	0	0	-1	4-7	10
13-Apr-09	6:11	Cracker Grove	0	0	-1	4-7	10
13-Apr-09	6:52	Wire Fence	0	0	-1	4-7	10
14-Apr-09	7:00	Alkali	3	0	3	4-7	90
17-Apr-09	6:00	Nutters	1	0	-4	1-3	100
17-Apr-09	6:15	Cracker Grove	0	0	-4	1-3	100
28-Apr-09	6:48	Alkali	5	0	3	1-3	10
30-Apr-09	6:00	Wire Fence	0	0	6	1-3	20
6-May-09	5:50	Alkali	6	2	7	1-3	30
6-May-09	7:20	Wire Fence	0	0	7	1-3	30
20-Apr-10	7:40	Alkali	3	0**			
21-Apr-10	6:00	Nutters	0***	0			
26-Apr-10	5:54	Nutters	0	0			
26-Apr-10	6:24	Cracker Grove	0	0			
28-Apr-10	8:00	Alkali	0****	0			
4-May-10	10:00	Alkali	2*	0			
11-May-10	6:10	Alkali	2	1	5	13-18	85
11-May-10	5:27	Nutters	0	0	5	4-7	98
11-May-10	5:54	Cracker Grove	0	0	5	4-7	90
11-May-10	6:25	Wire Fence	0	0	5	1-3	90

* 2 males were strutting on the left fork of Alkali about 100m north of the original lek

**Detected a radio-collared female on the lek, but did not visually see the hen

***Saw feathers and cecal droppings on lek

Table 3-2. Differences in average distances moved between location points for both resident and translocated birds combined across both years (2009-2010) between location types, on Anthro Mountain, Utah.

Location		Average Distance	
Type^a	<i>n</i>	(km)	SE
PN	56	1.70	0.10
EB	25	0.60	0.04
BL	48	1.60	0.06
EB	25	0.60	0.04
F	29	1.40	0.10
EB	25	0.60	0.04

a = BL= Broodless, EB= Early Brood (0-20 day of age), PN= Pre-nesting, F=Fall

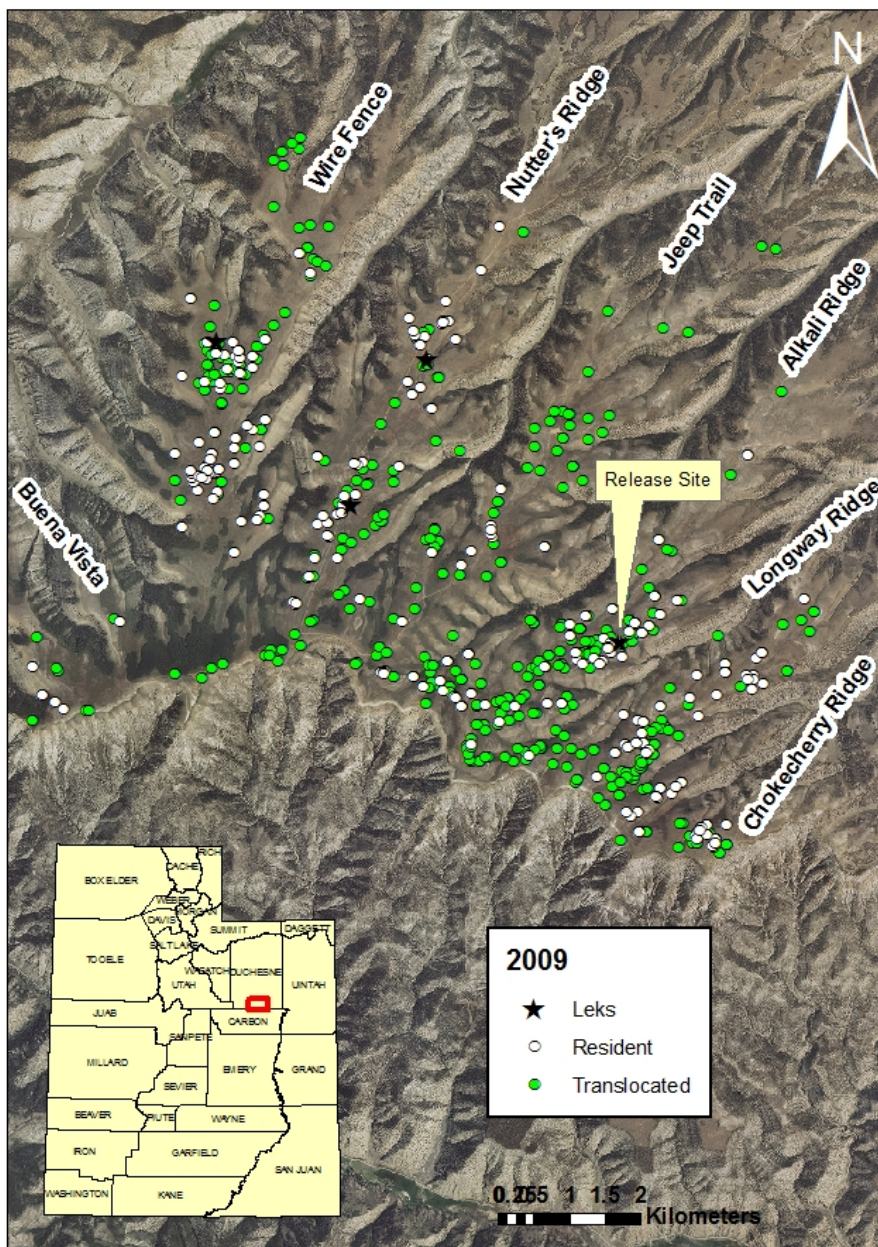


Figure 3-1. All radio-telemetry locations of resident ($n = 17$) and translocated ($n = 30$) greater sage-grouse on Anthro Mountain, Utah, USA, March through December 2009.

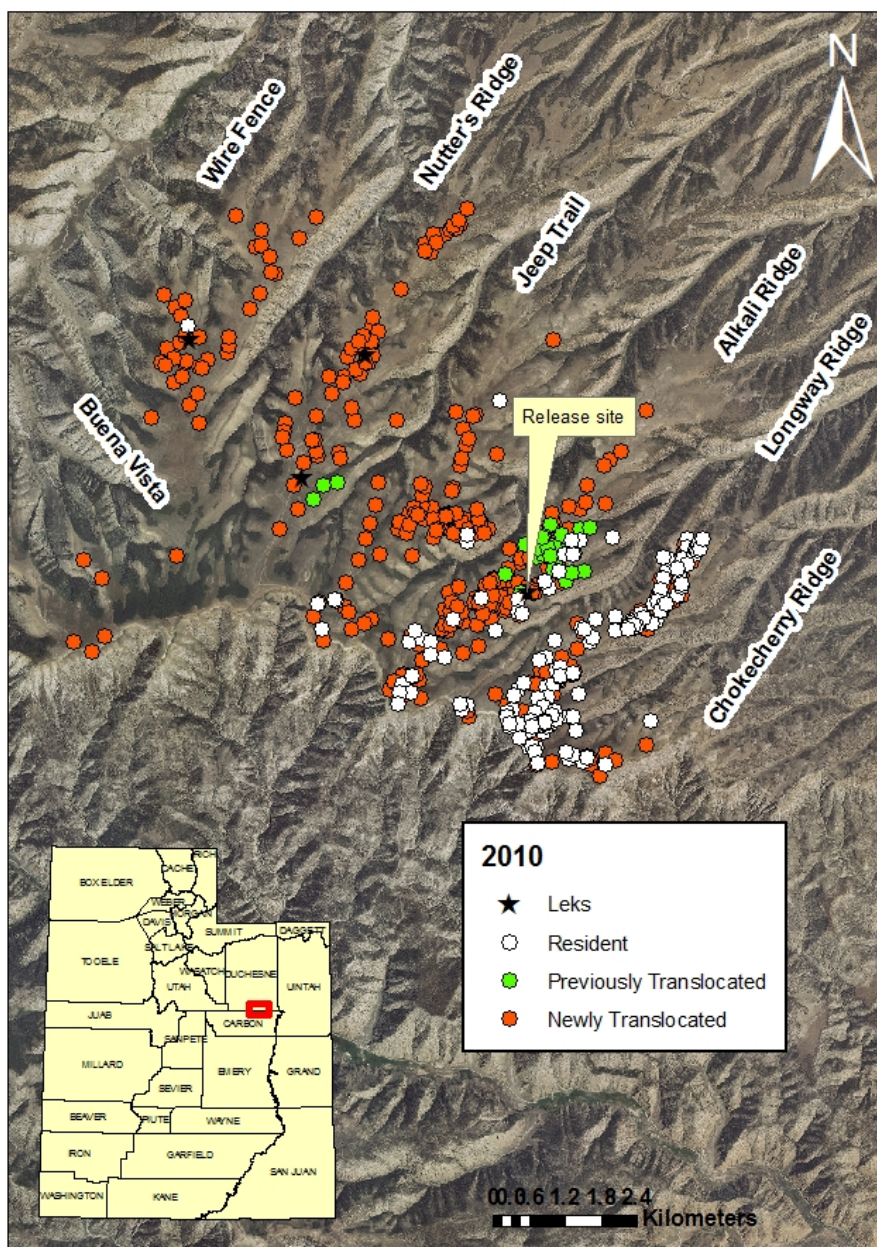


Figure 3-2. All radio-telemetry locations of resident ($n = 7$) and previously translocated ($n = 8$), and newly translocated ($n = 30$) greater sage-grouse on Anthro Mountain, Utah, USA, March through December 2010.

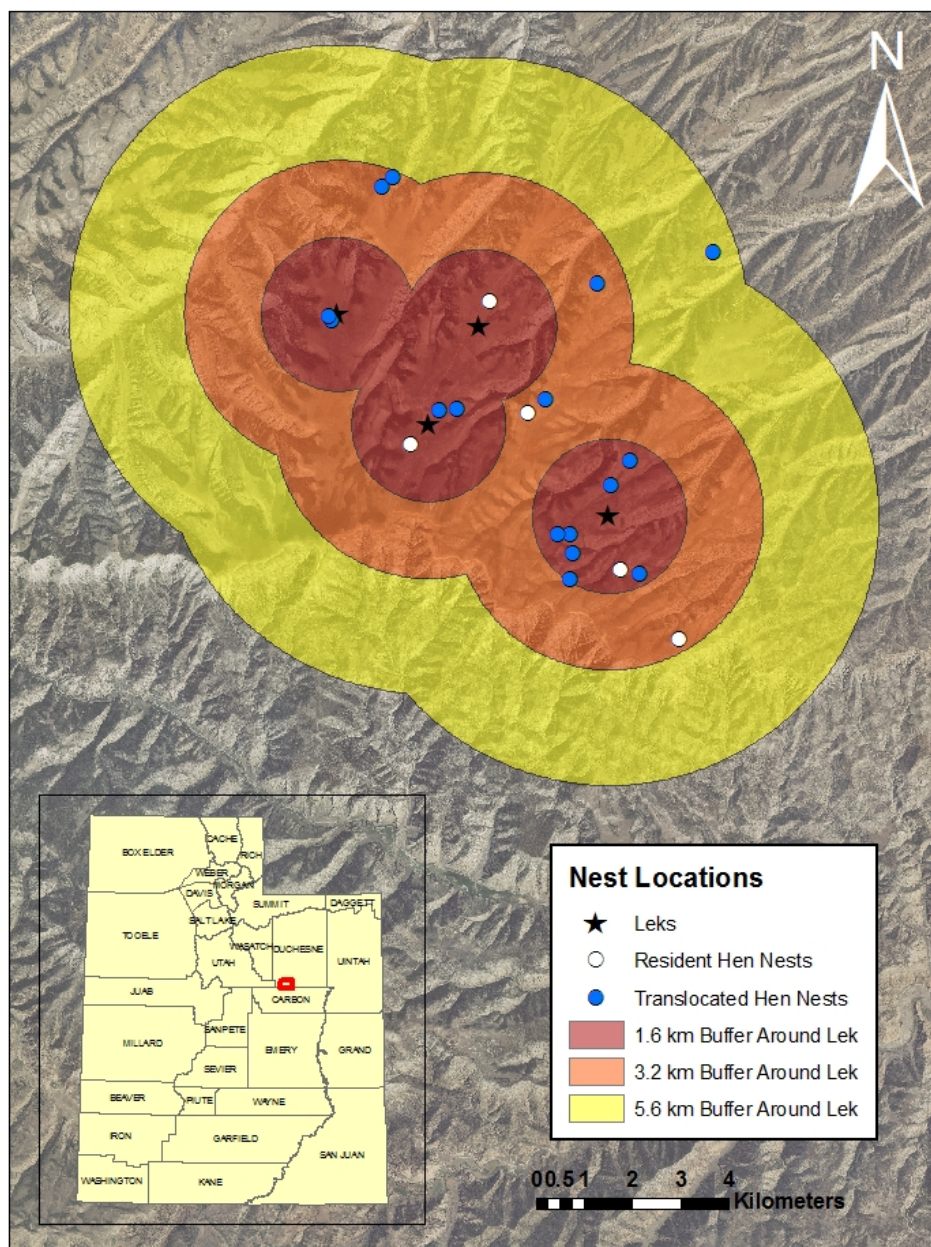


Figure 3-3. Resident ($n = 5$) and translocated ($n = 16$) greater sage-grouse nest locations in comparison to lek sites with a 1.6 km, 3.2 km, and 5.6 km buffer around each known lek on Anthro Mountain, Utah, USA, 2009.

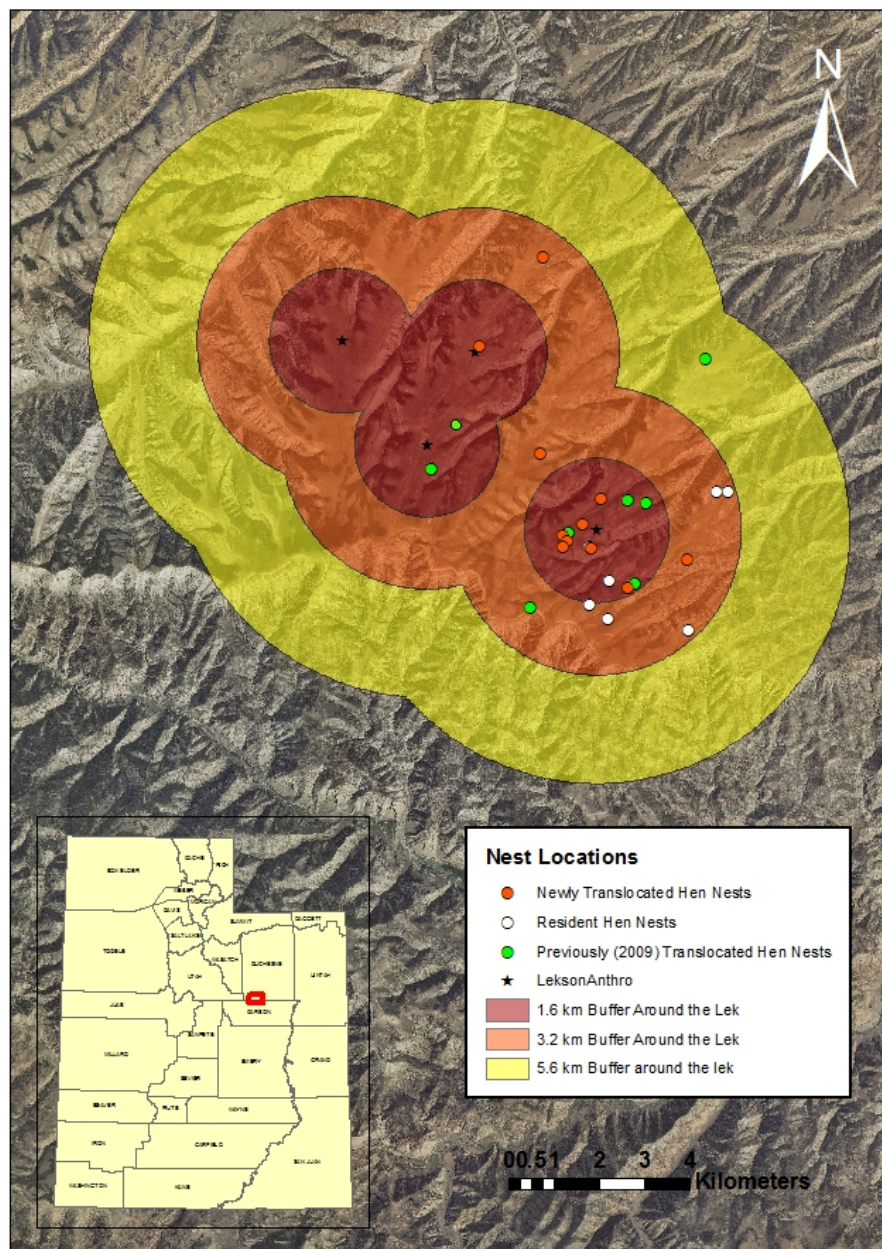


Figure 3-4. Resident ($n = 7$), previously translocated ($n = 8$), and newly translocated ($n = 11$) greater sage-grouse nest locations in comparison to lek sites with a 1.6 km, 3.2 km, and 5.6 km buffer around each known lek on Anthro Mountain, Utah, USA, 2010.

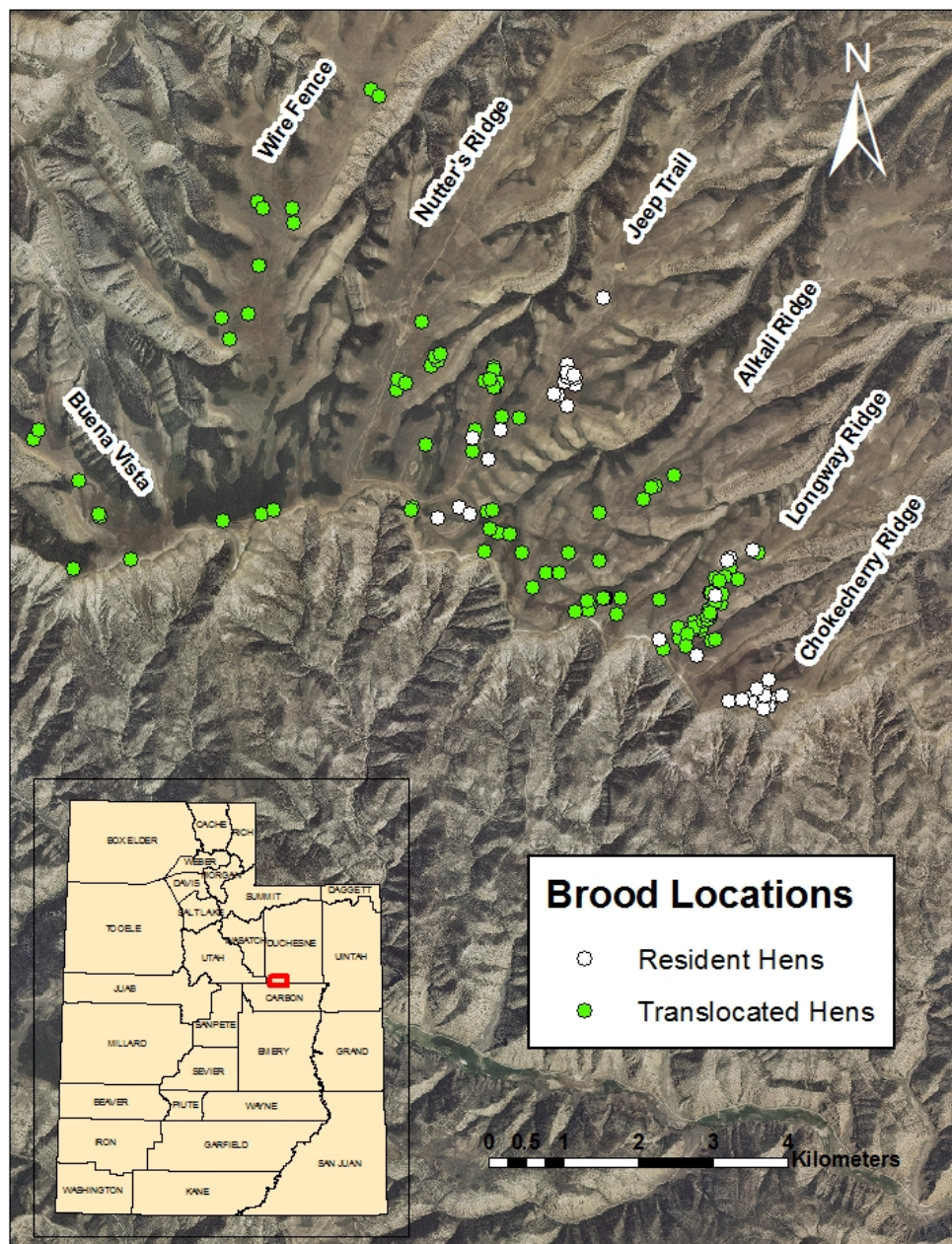


Figure 3-5. Brood site locations (up to 50 days of age) of resident ($n = 3$) and translocated ($n = 12$) greater sage-grouse on Anthro Mountain, Utah, USA, 2009.

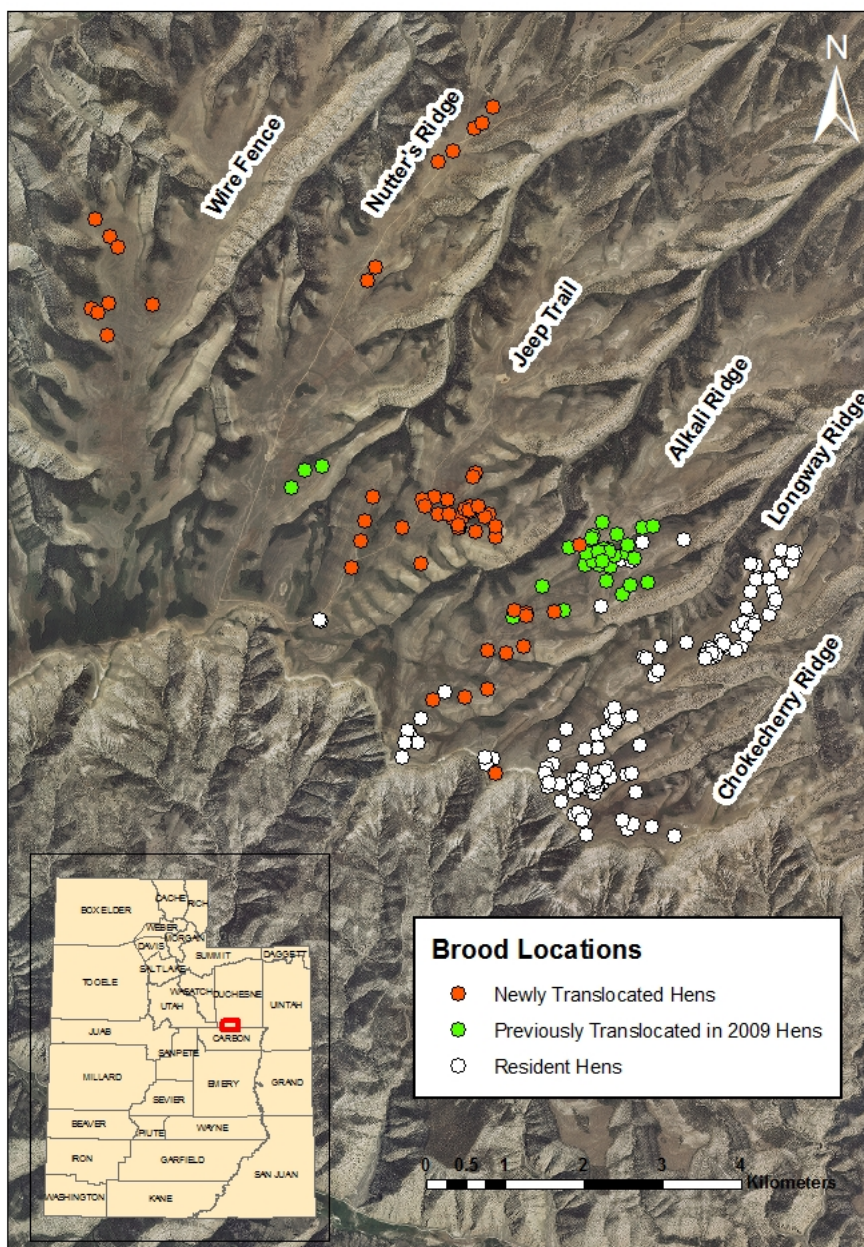


Figure 3-6. Brood site locations (up to 50 days of age) of resident ($n = 6$), newly translocated ($n = 6$) and previously translocated ($n = 2$) greater sage-grouse on Anthro Mountain, Utah, USA, 2010.

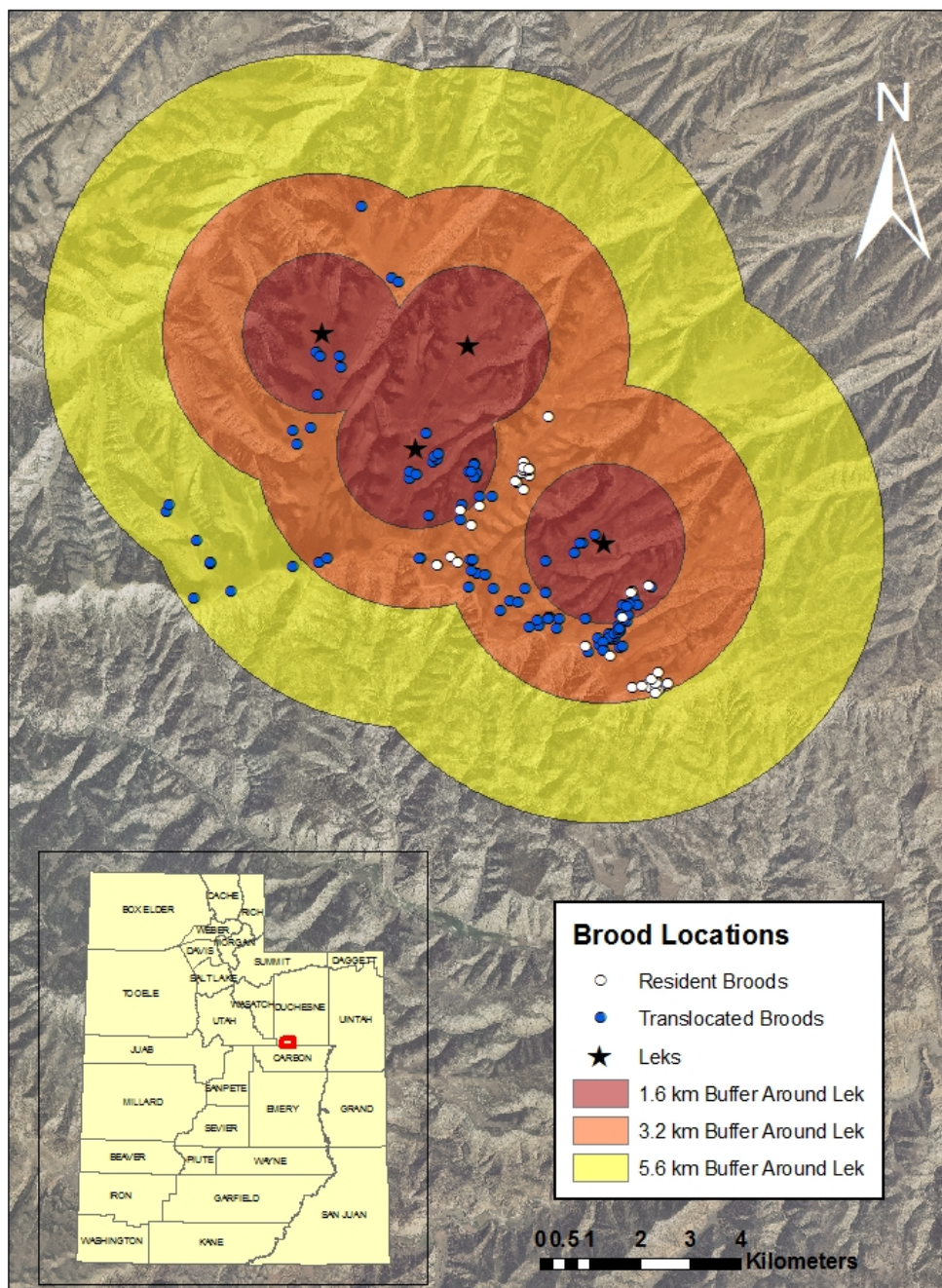


Figure 3-7. Resident ($n = 3$) and translocated ($n = 12$) greater sage-grouse brood locations in comparison to lek sites with a 1.6 km, 3.2 km, and 5.6 km buffer around each known lek on Anthro Mountain, Utah, USA, 2009.

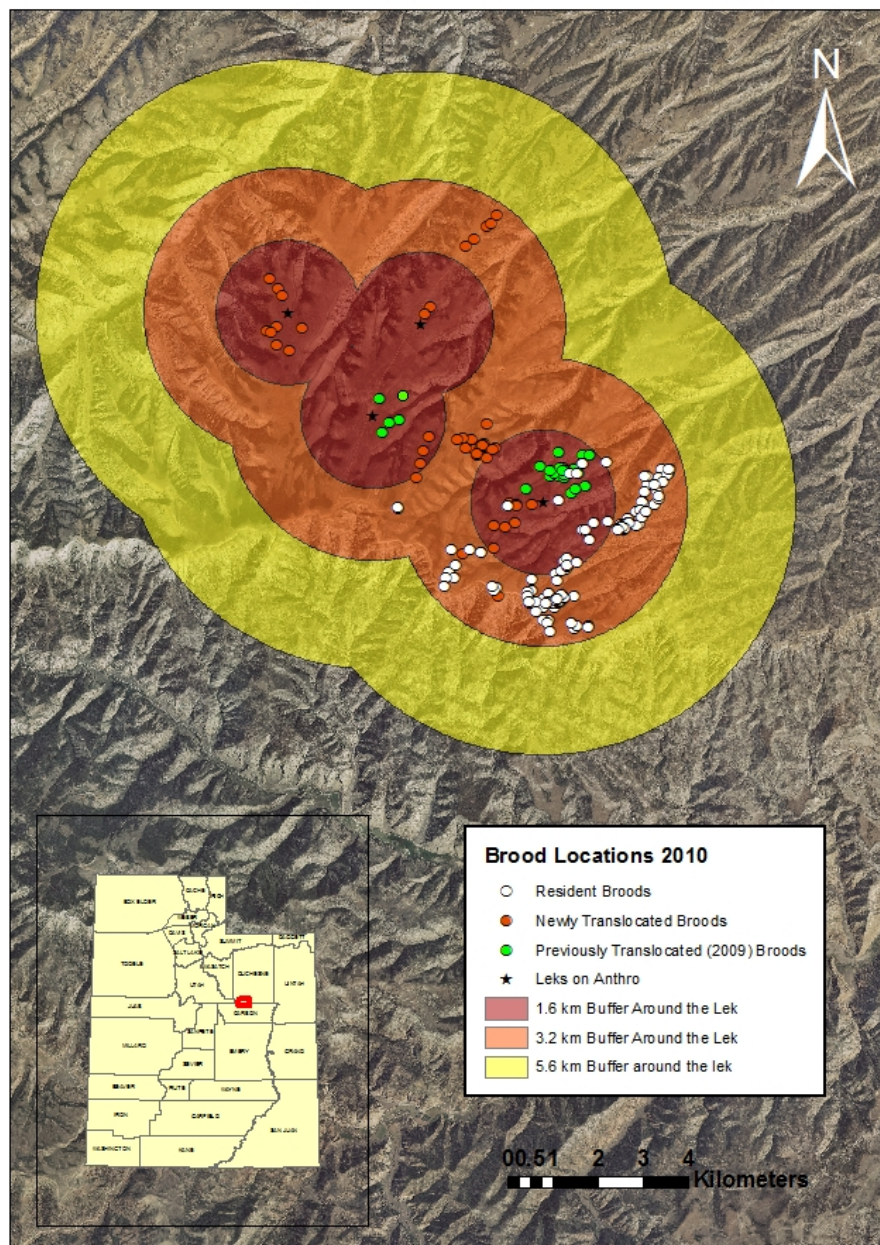


Figure 3-8. Resident ($n = 6$), newly translocated ($n = 6$) and previously translocated ($n = 2$) greater sage-grouse brood locations in comparison to lek sites with a 1.6 km, 3.2 km, and 5.6 km buffer around each known lek on Anthro Mountain, Utah, USA, 2010.

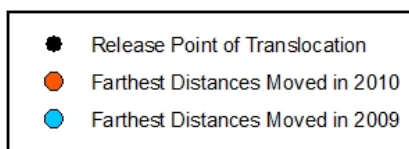
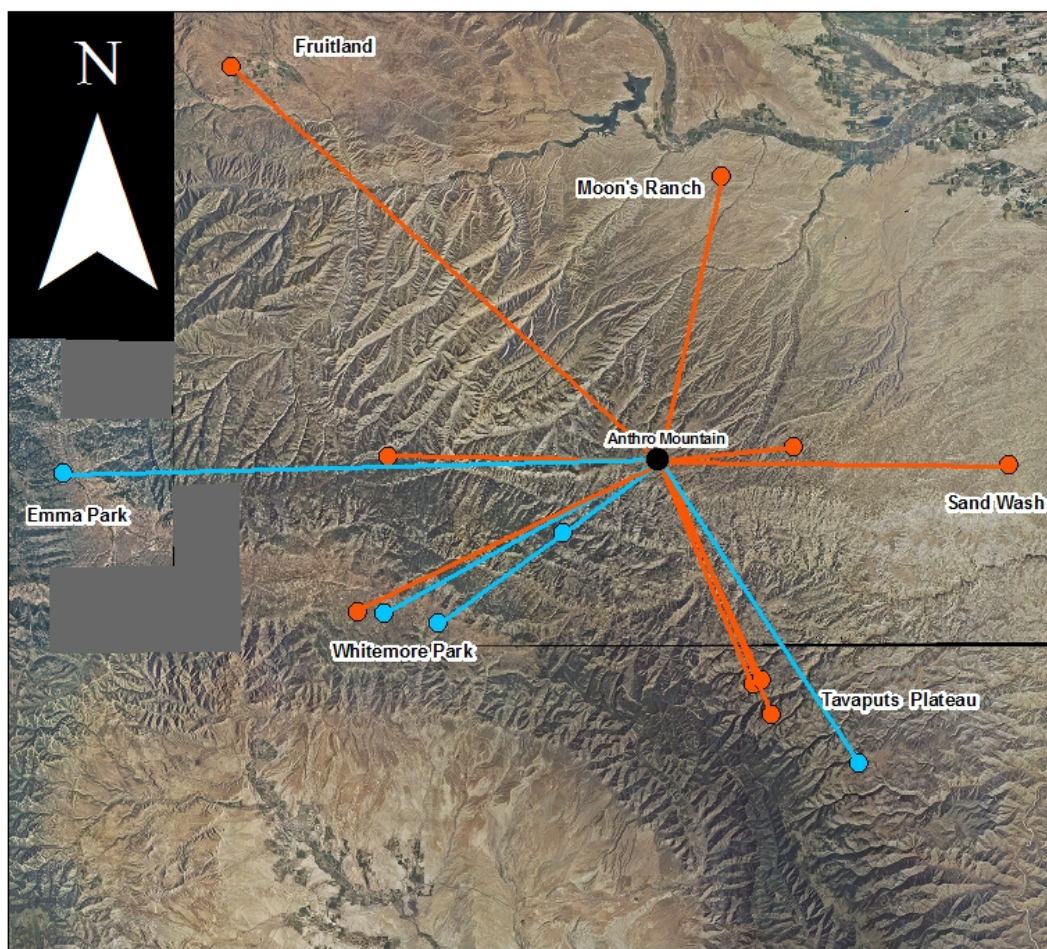


Figure 3-9. Largest distances (≥ 10 km) moved by translocated greater sage-grouse from original release site on Anthro Mountain, Utah, USA, 2009-2010.

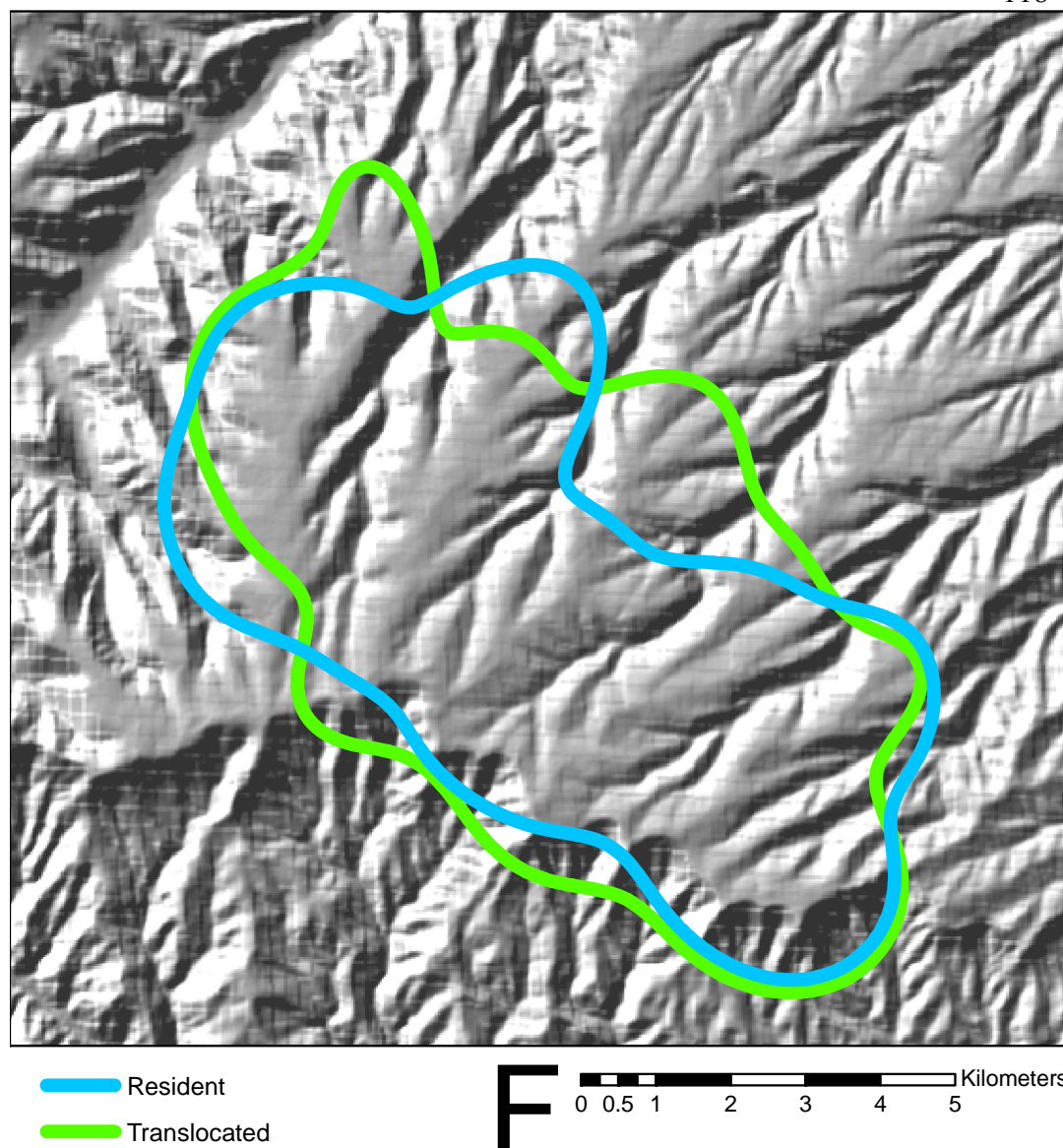


Figure 3-10. Area of occupancy for resident ($n = 17$) and translocated ($n = 30$) greater sage-grouse on Anthro Mountain, Utah, USA. 2009. Area of occupancy for resident and translocated birds was 52 and 58 km², respectively.

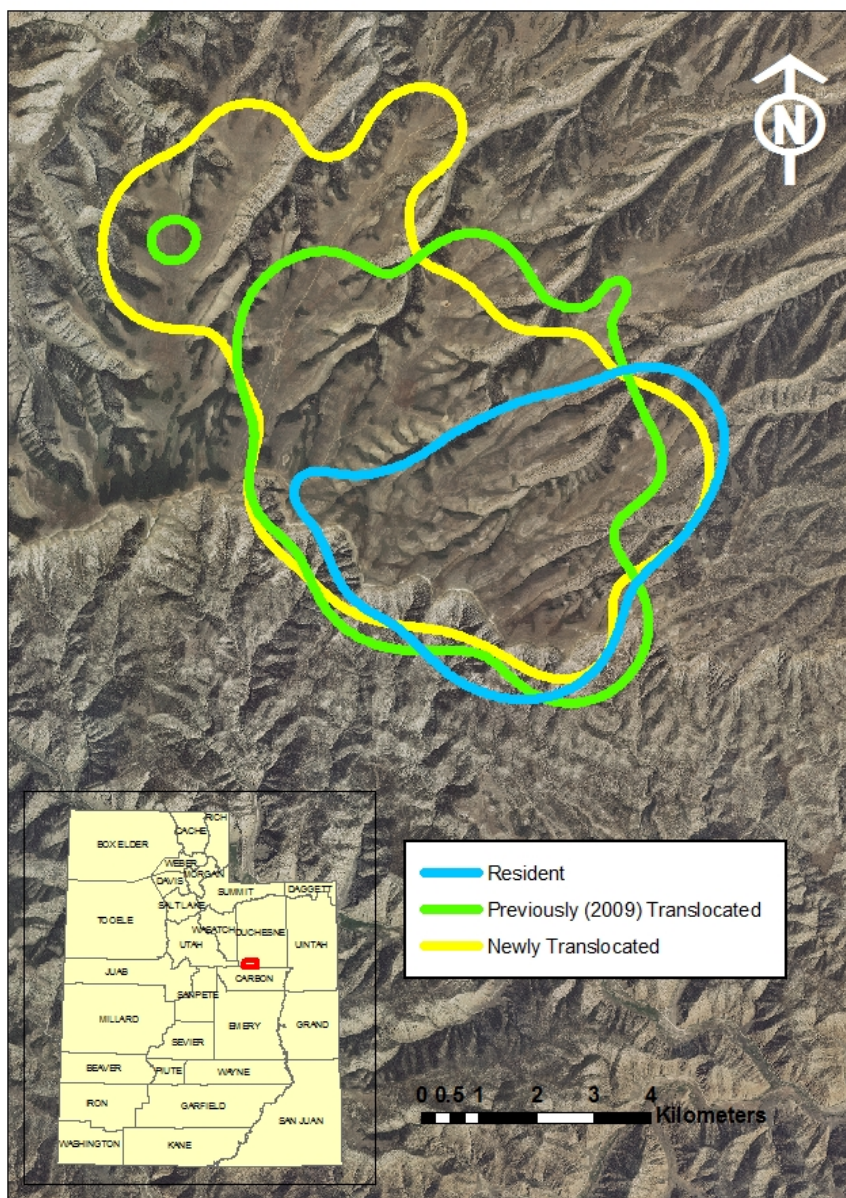


Figure 3-11. Area of occupancy for resident ($n = 7$), newly translocated birds ($n = 20$), and previously translocated ($n = 8$) greater sage-grouse on Anthro Mountain, Utah, 2010. Area of occupancy for resident birds, previously translocated, and for newly translocated birds was 26, 44, and 57 km², respectively.

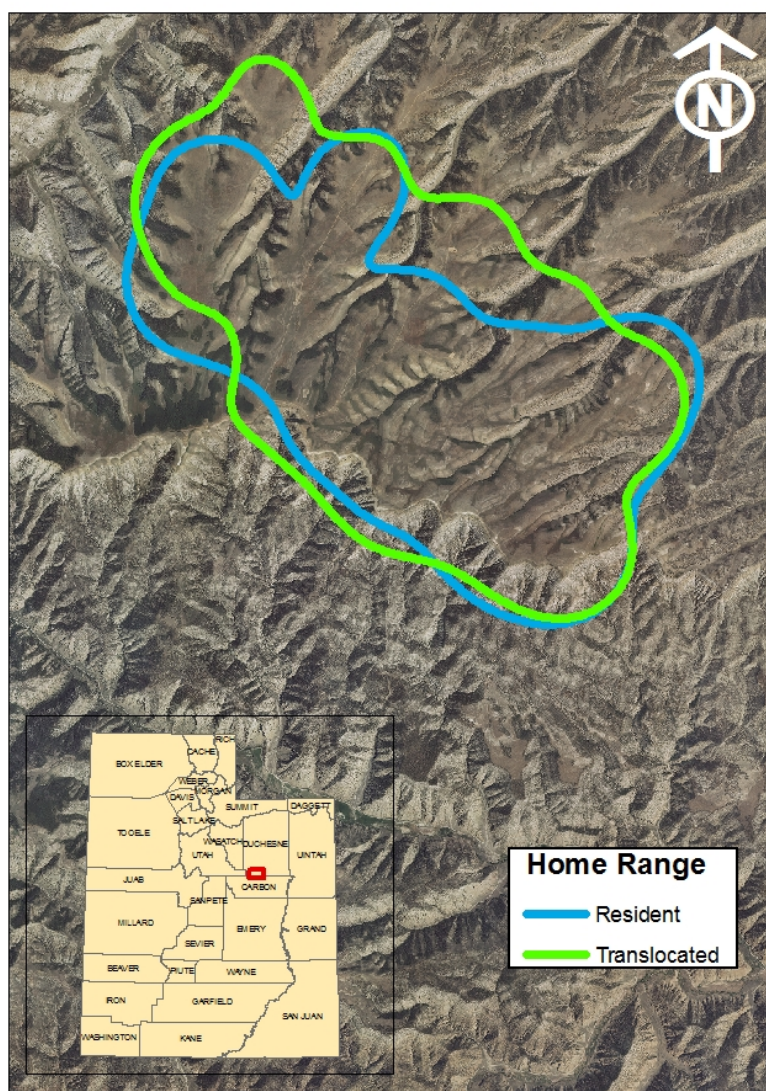


Figure 3-12. Area of occupancy for resident ($n = 19$) and translocated ($n = 60$) greater sage-grouse on Anthro Mountain, Utah, USA (2009-2010). Area of occupancy for resident and translocated birds was 52 and 59 km², respectively.

CHAPTER 4

CONCLUSIONS

In response to range-wide greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) population declines, the U.S. Fish and Wildlife Service (USFWS) determined in 2010 that the sage-grouse warranted protection under the Endangered Species Act (ESA) and designated it as a candidate species. In 2015, the USFW will review the status of the sage-grouse to determine whether listing the species fully under the ESA is warranted (USFWS 2010). In response to this decision many states within the sage-grouse range are preparing comprehensive sage-grouse action plans to mitigate the species threats identified by the USFWS. Federal, state, and private entities are collaborating to identify and implement management actions that are necessary to ensure the future of the sage-grouse and avert a potential listing of the sage-grouse.

To help mitigate long-term sage-grouse population declines, wildlife managers have been implementing project to protect and enhance sage-grouse habitat. As these habitats are restored, managers and other stakeholders have expressed increased interest in augmenting local populations through translocations. Translocations are conservation tools that have been used for many different wildlife species to help sustain genetic heterogeneity of small and declining populations, reestablish populations, increase the range of a species, and augment declining populations (Griffith et al. 1989).

Reese and Connelly (1997) evaluated 56 sage-grouse translocation attempts and ascertained that few of these translocations were successful and the use of these tools has not been properly tested with sage-grouse, due to inadequate data and published information documenting the translocations and their outcomes. However, translocations

appeared to have been successful in Colorado, Idaho, and Utah (Musil et al. 1993, Reese and Connelly 1997, Baxter et al. 2008).

Baxter et al. (2008) reported a successful translocation effort in Strawberry Valley, Utah. This translocation followed Reese and Connelly (1997) recommendations and identified new criteria to implement and evaluate a successful translocation. Reese and Connelly (1997) identified several features that were common to the successful sage-grouse translocations. These included: 1) the grouse were transported quickly and released the following morning after capture, 2) the release sites were confined sagebrush habitats with geomorphic barriers ≥ 100 km from the capture site, and 3) the grouse were captured during the breeding season (March and April) at night near leks (Reese and Connelly 1997). Baxter et al. (2008) released the birds ≤ 250 m from an active lek to increase the exposure of translocated birds to the resident breeding bird population.

The Strawberry Valley translocations were implemented in closed high elevation basin, surrounded by geomorphic barriers (i.e., mountains, reservoir, and housing development). These geomorphic barriers may have impacted the post-release movements of the released birds, thus enhancing the success of the translocation (R. Baxter, U.S. forest Service, personal communications). My research was conducted on a small, declining spatially-separated population of sage-grouse that inhabited Anthro Mountain in northeastern Utah. Anthro Mountain is a high elevation, open area with no geomorphic barriers to deter large scale movements from the release area by the translocated birds. The overall objectives of my research were to determine if the methodology used by Baxter et al. (2008) in a closed basin would be applicable to high elevation areas where movements of the birds would not be restricted by closed basin

topography, compare resident and translocated birds to determine the efficacy of the translocation and to help refine translocation techniques used by Baxter et al. (2008) for application in other areas of the west.

From 2009-2010, I radio-marked and monitored 60 translocated sage-grouse, 19 resident sage-grouse and 99 of their radio-marked progeny. Annual survival of the translocated and resident adult sage-grouse was influenced by year. In 2009 survival rates were lower than 2010. Overall, survival for translocated and resident hens were relatively low compared to averages reported range wide (Connelly et al. 2011). Chick survival was also low for both resident and translocated birds. Chick survival for resident birds was higher than for translocated birds. Predation was the predominate cause of chick mortality on Anthro Mountain. I also found evidence that chick survival was positively influenced by percent grass cover. Chick survival increased as grass cover increased.

Nest survival rates were higher for resident birds than translocated birds. Estimates for nest survival for translocated birds to Anthro Mountain were lower than translocated birds in Strawberry Valley, UT and higher than nest survival reported for translocated birds in Clear Lake National Wildlife Refuge, CA. Nest survival for both resident and translocated hens were positively associated with grass height and grass cover, although grass height and grass cover were not highly correlated to one another.

Extrinsic factors such as climate and alternate prey availability may have influenced overall survival on Anthro Mountain. In 2009, temperatures were cooler and more rain events occurred than in 2010. Exposure to wet and cold weather can also influence chick survival especially when chicks are newly hatched and unable to thermo-

regulate their body heat (Patterson 1952). Incidental rodent observations indicated that in 2009, there were fewer murids, ground squirrels (*Spermophilus* spp.), and lagomorphs available as prey for the main predators of sage-grouse on Anthro Mountain. Prey switching behaviors have been observed in red fox (*Vulpes vulpes*) and coyotes (*Canus latrans*) when there are shifts in the number and biomass of alternative prey that they consume (Randa et al. 2009). Fedy and Doherty (2011) observed highly correlated population cycles between cottontail rabbits (*Sylvilagus floridanus*) and sage-grouse.

Integration of translocated birds with resident birds may positively affect the outcome of a translocation effort. Because of strong attraction of sage-grouse to leks and breeding habitat, Reese and Connelly (1997) and Baxter et al. (2008) suggested that releasing translocated birds near an active lek could potentially increase interactions with resident birds and make the success of the translocation more likely (Berry and Eng 1985). In both years of the study the translocated birds began flocking with resident birds soon after their initial release near an active lek. Translocated and resident bird area of occupancy overlapped and spatial nesting and brood-rearing habitat selection were similar between resident and translocated birds. Some large movements (≥ 10 km) away from the release site were observed for translocated birds, but current and historical data indicate that resident birds make similar large movements. Our data suggests that the translocated birds did acclimate rapidly to the release area. Nesting, brood-rearing, summer, and fall locations and home ranges of translocated birds were within the current and historic range of resident sage-grouse on Anthro Mountain.

In summary my research demonstrated that survival and reproductive success was similar between resident and translocated birds, but was low overall compared to other

sage-grouse studies. These results may reflect that the translocation coincided with high predation year, poor weather year, low food year, or low portion of their population cycle, thus contributing to a limited translocation success.

Secondly, sage-grouse populations on Anthro may benefit more from management strategies that attempt to increase grass height in nesting habitat and grass cover in brood-rearing habitats, especially during the early brood rearing period. Thirdly, translocated birds quickly integrated with the resident population and exhibited spatial habitat use patterns similar to resident birds. In summary, the translocation was successful in that, the translocated birds quickly acclimated to the release area, and exhibited occupancy, movements, survival and reproductive success similar to the resident birds. However, adult and chick survival for both resident and translocated sage-grouse was low on Anthro Mountain. The Anthro Mountain population may benefit from increasing, enhancing and restoring adult and chick sage-grouse habitats.

The ultimate success of the translocation should be determined by the effect the translocation has on λ . To determine the effect of translocation on λ population vital rates should be monitored for several years following the initial translocation releases. Population monitoring should include, tracking the translocated birds using radio-telemetry, or at a minimum, lek counts should be conducted every spring to determine the population trends of the sage-grouse population where the translocation occurred. In light of the results from my research, I would recommend to wildlife managers for future translocation attempts to select source populations to translocate using DNA factors (Oyler-McCance et al. 2005, Smith 2009), that translocations should be considered in areas that do not contain geomorphic barriers, to

release translocated birds near an active lek during the breeding season to increase interactions with the resident population, and to consider the importance of the Anthro Mountain population, in relation to gene flow and habitat corridors used between surrounding sage-grouse populations. Also, my research indicated that there is low adult and chick survival for both resident and translocated birds on Anthro Mountain, I would recommend additional research to determine the factors limiting survival for adults and chicks on Anthro Mountain and in any other area where translocations might be considered, to optimize on the effort and money used to implement a translocation. Information is also needed on the large movements that sage-grouse make off of Anthro Mountain (i.e., GPS radio-collars) to obtain more detailed information on corridor areas used and connectivity of Anthro Mountain sage-grouse and surrounding sage-grouse populations.

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