12-2017

Seasonal Distribution of Sage-Grouse in Hamlin Valley, Utah and the Effect of Fences on Grouse and Avian Predators

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SEASONAL DISTRIBUTION OF SAGE-GROUSE IN HAMLIN VALLEY, UTAH AND THE EFFECT OF FENCES ON GROUSE AND AVIAN PREDATORS

by

Heather Hedden McPherron

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

of

MASTER OF SCIENCE

in

Wildlife Biology

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UTAH STATE UNIVERSITY
Logan, Utah

2017

ABSTRACT

Seasonal Distribution of Sage-Grouse in Hamlin Valley, Utah and the Effect of Fences on Sage-grouse and Avian Predators

by

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This research focused on general ecology of a small population of greater sage-grouse (*Centrocercus urophasianus;* hereafter sage-grouse) in the southern extent of their range (Hamlin Valley, Utah, USA) including the effect of fences on sage-grouse collision and the characteristics of fences that facilitate increased use by avian predators. I described the population size, seasonal distribution, and nesting success of sage-grouse from 2011-2012 using data collected from 16 radio-collared sage-grouse captured from four leks in Hamlin Valley, Utah. The average seasonal distribution sizes for breeding, summer, and winter habitats were 200.36 km^2, 364.58 km^2, and 219.68 km^2, respectively. The Hamlin Valley population was primarily one-stage migratory but non-migratory behaviors were also observed. Collared individuals moved an average of 9.24 km (95% CI = 6.79 – 11.69 km) from breeding to summer habitats and an average of 8.24 km (95% CI = 5.28 – 11.2 km) from summer to winter habitats. Birds from at least one of the leks used seasonal habitats in neighboring Nevada.

During 2011-2012, I surveyed over 450 km of fences for signs of collision and use by avian predators during all seasons (breeding, fall migration, and winter) in the Hamlin Valley and Bald Hills populations, both in southwestern Utah, USA. No sage-grouse collisions were observed, suggesting that management for sage-grouse in small populations may be better focused on improving habitat and reducing other causes of mortality which may be more prevalent and where money is limited, fence marking should be a lower priority as it may have less of an effect on mortality than the previously mentioned factors. Fence post width (i.e. the perching surface) was the best predictor of use as perch by avian predators. Additionally, posts that were perched upon were more frequently farther from other natural perching substrate, in areas of low density of surrounding vegetation, and along defined habitat edges. Results of this study suggest that fences with widths less than 0.3 m may reduce the likelihood of perching in sage-grouse habitat and that care should be taken to maintain contiguous vegetation on either side of the posts while maintaining low shrub density.

(119 Pages)

PUBLIC ABSTRACT

Seasonal Distribution of Sage-Grouse in Hamlin Valley, Utah and the Effect of Fences on Sage-grouse and Avian Predators

Heather Hedden McPherron

Greater sage-grouse (*Centrocercus urophasianus;* hereafter sage-grouse) numbers have declined throughout the western US and are considered a species of concern in most of the eleven states that are within their range. Sage-grouse habitats have been reduced by approximately 44% since European settlement of the Western United States began (Miller et al. 2011). Loss of habitat has contributed to an average decline of sage-grouse populations by 33% across the range (Connelly and Braun 1997). To expand our knowledge of this species, I monitored 16 radio-collared sage-grouse captured from four leks in Hamlin Valley, Utah, USA in 2011 and 2012 to determine habitat use. The Hamlin Valley population was primarily one-stage migratory but non-migratory behaviors were also observed. Birds from at least one of the leks used seasonal habitats in neighboring Nevada.

Sage-grouse evolved in habitats where infrastructure (e.g. vertical structures) was not common. Introduction of infrastructure, such as fences in their habitat, can cause direct mortality via collision but may also indirectly influence productivity by increasing artificial perches for avian predators (e.g. golden eagles (*Aquila chrysaetos)* , red-tailed hawks (*Buteo jamaicensis*), and common ravens (*Corvus corax*). This research focused on collision rates and increased potential for avian predation on two small populations on the southern portion of the range of current occupied sage-grouse habitat in southwestern

Utah. During 2011-2012, over 450 km of fences were surveyed for signs of collision and use by avian predators during all seasons (breeding, fall migration, and winter). No sage-grouse collisions were observed suggesting that management for sage-grouse in small populations may be better focused on improving habitat and reducing other causes of mortality which may be more prevalent. Fence post width (i.e. the perching surface) was the best predictor of use as perch by avian predators. Additionally, areas farther from other natural perches, with a low density of surrounding vegetation, and fences constructed along defined habitat edges were used by avian predators more frequently. Results of this study suggest that managers should construct fences with small widths to deter avian predators and care should be taken to maintain contiguous vegetation on either side of the posts while maintaining low shrub density.

ACKNOWLEDGMENTS

First and foremost I'd like to thank my advisor, Dr. Nicki Frey for giving me the opportunity to work with such an incredible species that launched in to a career in sage-grouse conservation and my committee members Dr. Frank Howe and Dr. Michael Conover for their time, patience, and guidance throughout this process. I would also like to thank Todd Black for his immense trapping expertise, Drs. Susan Durham and John Schmitz for their statistical prowess, to Jason Nichols of the Utah Division of Wildlife Resources for sacrificing many evenings to help catch sage-grouse, and to Doug and Carol Ann Schmutz who welcomed us in to their home as well as walked many fences collecting data. No project would be complete without financial support and for that I owe a tremendous amount of appreciation to Christine Pontarolo Fletcher in the Bureau of Land Management's Cedar City Field Office and to Sportsmen for Wildlife. Additional funds were provided by Utah State University's Center for Women and Gender.

Thanks to my dad, Henry Hedden, for all those forced vacations out west. Thanks to my high school teachers John Byrd and Kathy Strunk who showed me a love of birds, snakes, turtles, and all kinds of critters. I would also like to thank my friends and family who gave me the positive encouragement to keep pushing. And finally, I'd like to thank my husband Nate, who kept me company on those long days in the desert, gave me a hug when I needed it, and always found a way to make me laugh on even the most frustrating of days.

Heather H. McPherron

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

The greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) is the largest member of the pheasant family (Phasianidae) in North America (Schroeder et al. 1999). Adult greater sage-grouse have narrow, pointed tails; a mottled pattern of grayish brown, buff, and black on the upper parts of the body; and a spotty black abdominal pattern. Males have blackish brown throats, a dark V-shaped pattern on the neck, and white breast feathers. When strutting during spring mating displays, males inflate two gular sacs of olive green skin and filoplumes on the back of the neck. Females lack the V-shaped pattern, their throats are buff, and their lower throats and breasts are barred with blackish brown (Schroeder et al. 1999). Adult male greater sage-grouse are larger than adult females; Males range in size from 1.8 kg to 3.2 kg and measure 68 cm to 81.3 cm, while females weigh from 0.9 kg to 1.8 kg pounds and measure 50.8 cm to 63.5 cm.

Previously, it was assumed that the demographics of sage-grouse were similar to the demographics of other upland game species (Strickland et al. 1994). However, increases in technology over the past 30 years have revealed that sage-grouse have better annual survival, lower winter mortality than other grouse species, and some populations demonstrate migratory processes (Connelly et al. 1988, Schroeder et al. 1999, Connelly et al. 2000). The greater sage-grouse is a sagebrush-obligate species that depends on a variety of shrub-steppe habitats throughout the life cycle (Schroeder et al. 2004). Sage-grouse typically use several seasonal habitats that exhibit different qualities for different stages in the grouse life cycle. These seasonal habitats include lekking, nesting, brood-rearing, and wintering. Overall, large, interconnected expanses of sagebrush with healthy, native understories are an essential habitat component in all seasonal habitats (Connelly et al. 2004).

Historical distribution of the greater sage-grouse includes 13 U.S. states (Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Colorado, Utah, South Dakota, North Dakota, Nebraska, and Arizona) and three Canadian provinces (British Columbia Alberta, and Saskatchewan) (Schroeder et al. 1999, 2004, Young et al. 2000). Current distribution represents approximately 56% of historical range across 11 U.S. States (no longer occurring in Arizona and Nebraska) and two Canadian provinces (no longer occurring in British Columbia) (Schroeder et al. 2004). The decline of the species rangewide has led to several petitions to list the greater sage-grouse as threatened or endangered under the Federal Endangered Species Act (ESA). In 2010, the Service found that listing sage-grouse rangewide was warranted, but precluded by other higher priority listing actions (USFWS 2010) therefore designating sage-grouse a candidate species until a final listing decision could be made a priority. After lawsuits triggered a deadline to make a final decision by 2015, the Service determined that sage-grouse no longer warranted protection under the ESA. The Service changed their finding on sage-grouse in 2015 because they determined that the threats which caused the Service to initially designate sage-grouse as warranting ESA protection had been significantly reduced due to federal and state land use conservation planning efforts (USFWS 2015). Without a federal listing, sage-grouse management remains at the state level.

Within the state of Utah, sage-grouse are found in 26 counties, with the largest populations occurring in western Box Elder County, the Blue and Diamond Mountains in

Uintah County, Rich County, and Parker Mountain in south-central Utah (UDWR 2009). Estimates indicate that sage-grouse now occupy only 50% of their former range within Utah (UDWR 2009). Like elsewhere in their range, changes in distribution are the result of sagebrush alteration and degradation (Schroeder et al. 2004).

As part of an effort to improve sage-grouse management, the state of Utah created local working groups (LWG) to manage limitations to grouse populations within the state. The Southwest Desert Adaptive Resources Management (SWARM) Local Working Group (LWG) was formed in 2003. In 2006, the SWARM LWG developed a Sage-grouse Conservation plan with the objective of maintaining and improving current abundance and viability of sage-grouse populations and habitat within the Southwest Desert. The SWARM Resource Area is located in southwestern Utah in Beaver, Iron, and Washington Counties. The Resource Area contains three focus areas, the Hamlin-Pine Valley, Minersville-Bald Hills, and the Fremont area. The largest populations are in Hamlin Valley and the Bald Hills. Within the SWARM Resource Area, Hamlin Valley was identified as an area of concern because there was a lack of recent location and habitat use data on the sage-grouse inhabiting this area.

In 2005, SWARM identified obtaining information on habitat use and movements of greater sage-grouse within Hamlin Valley as a priority action (Frey et al. 2006). At that time, Hamlin Valley was considered the largest and most consistent breeding grounds for sage-grouse within the SWARM region. In addition, because Hamlin Valley spans the Utah-Nevada border it was thought that sage-grouse within the valley might be traveling between the two states, thus indicating a certain level of cooperation between the two would be needed for management of grouse in Hamlin Valley.

Causes of sage-grouse population declines are varied, but are generally related to habitat loss, modification, and fragmentation resulting from a wide array of anthropogenic actions. Development of sagebrush habitats for energy, agriculture, and urban expansion result in habitat loss as well as exacerbate threats from wildfire, predation, and disease (USFWS 2010).

Research on the impacts of elevated infrastructure on sage-grouse, especially fences, is limited. In the western United States, over 51,000 kilometers of fences were constructed on Bureau of Land Management (BLM) land from 1962 to 1997, with additional 1,000-kilometers added per year from 1996 to 2002 (Connelly et al. 2004). That has led to an estimated 2 km/km^2 of fences in many occupied sage-grouse habitats. Effects from fences include direct mortality through collision and indirect effects such as perch sites for raptors and ravens, creation of predator corridors, introduction of exotic vegetation species during the construction of the fence, and fragmentation of habitat (Call and Maser 1985, Braun 1998, Connelly et al. 2000, Beck et al. 2003, Connelly et al. 2004,).

The risk of avian collision with human infrastructure is primarily influenced by the mechanics of flight, including mode of landing, altitude gain, speed of flight, and whether birds travel alone or in flocks (Faanes 1987). Sage-grouse, like many grouse species, typically fly low and fast, are bulky birds with poor maneuverability (Call and Maser 1985), and are unable to gain vertical height quickly, making them likely candidates for collision in landscapes where fences are present. Much of the research available on fence collisions has taken place on European grouse species. In Scotland, Baines and Summers (1997) found that 93% of 281 collisions observed along 135 km of fences over one year were grouse species. And in a separate study conducted in Scotland on 80 km of fences over two years, 92% of 437 collisions were grouse species (Baines and Andrew 2003). Bevanger and Broseth (2000) looked at 179.9 km of fences over four springs in Norway and found 253 total collisions, 225 (89%) of which were grouse species - willow ptarmigan (*Lagopus lagopus*), rock ptarmigan (*L. mutus*), and the western capercaillie (*Tetrao urogallus*).

In North America, collisions have been documented for lesser prairie chicken (*Tympanuhus pallidicinctus*). In a New Mexico and Oklahoma study, fence collisions caused 33% mortality of 260 radio-marked lesser prairie chickens, second only to predation (Wolfe et al. 2007). In particular, this study also showed that females were more likely than males to collide and that collision was more common for older birds. Greater sage-grouse collision reports are mostly documented in unpublished reports (Danvir 2002); however recent work in southeastern Idaho has provided information on rates of sage-grouse collision and factors leading to collision (Stevens 2011). In his study, Stevens (2011) determined a sage-grouse fence collision rate of 0.75 strikes/km. Stevens also documented that collisions were more common on fences within 2 km of leks, constructed with steel t-posts, and on flatter terrain.

In addition to direct mortality, fences may indirectly increase mortality by increasing avian predator activity in the landscape. Research has suggested that the greatest single limiting factor of sage-grouse is nest predation by ravens (Batterson and Morse 1948) and that managing predators rather than habitat is more important in small, fragmented populations (Schroeder and Baydack 2001), such as Hamlin Valley. Fences indirectly create perching substrate for both raptors and corvids which may increase predation on grouse (Braun 1998, Oyler-McCance et al. 2001, Connelly et al. 2004) during every life-stage, including increased nest predation.

Raptors and corvids are avian predators of sage grouse adults, juveniles, and nests. In many prairie grouse species, the perceived presence of avian predators has also been shown to have non-lethal effects such as affecting the productivity, nest-site selection, and parental behavior (Schroeder and Baydack 2001, Manzer and Hannon 2005, Coates and Delehanty 2010). Avoiding avian predators results in behavioral changes that make high quality sage-grouse habitat become functionally unavailable (Dinkins et al. 2012, 2014) and could expose them to olfactory driven mammalian predators (Conover et al. 2010). At the landscape level, sage-grouse have been shown to choose areas with less avian predators (Dinkins et al. 2012). Increased landscape fragmentation by man-made structures has been documented to enhance raptor and corvid foraging and predation efficiency because of the increased availability of perch and roost sites, particularly in low canopy areas (Coates and Delehanty 2004, Bui et al. 2010). It is anticipated that the effect of fences on sage-grouse populations is similar to that of powerlines (Braun 1998, Connelly et al. 2004).

Several studies have reported raptors and corvids hunting sage-grouse from overhead transmission lines and other manmade elevated perches, such as fences (Wakeley 1978, Ellis 1984, Lammers and Collopy 2007). Elevated perches provide increased visibility of the surrounding area, especially in sage-grouse habitats which are relatively free of natural tree perches (Sonerud 1992, Wolff et al. 1999, Paton 2002, Leyhe and Ritchison 2004, APLIC 2006). Wolff et al. (1999) and Paton (2002) showed that hens will avoid nesting near perch sites that could easily be used by avian predators.

Manzer and Hannon (2005) showed that the best single scale model to predict nest success was the interaction between proximity of perch site and amount of vegetation concealment particularly for perch distances greater than 75m from nest sites.

Adult sage-grouse are most vulnerable to predation during spring and early summer, during the elaborate courtship display (Patterson 1952, Schroeder et al. 1999). However, the loss of hens in breeding condition, eggs, and young chicks to predation has the greatest influence because they contribute the most significantly to population productivity (Baxter et al. 2008, Connelly et al. 2011). Leu et al. (2008) and Bui et al. (2010) suggest that removal of anthropogenic features, such as fences, may be an important consideration on reducing the presence of predators in sage-grouse habitat.

RESEARCH PURPOSE

The focus of this research was to study the effects of one anthropogenic feature – fences - as it pertains to grouse collision and grouse predation by avian predators. Prior to this research, little was known about the ecology or impact of fences on grouse within Hamlin Valley. In 2005, the Southwest Desert Local Working Group (SWARM) completed an adaptive research management plan for sage-grouse and identified Hamlin Valley as a focus area highlighting the need for current data on grouse as a priority action item (Frey et al. 2006). Information from this study will be used to improve management of the species by identifying seasonal use patterns to aid in restoration and improvement of brood-rearing and wintering areas. Additionally, because Hamlin Valley lies primarily in Utah, but also partially in Nevada, understanding the habitat utilization and movements of grouse is crucial to developing cooperative management between the two states for conservation of the population.

The completion of this project contributes basic knowledge of the habitat use and distribution of sage-grouse in Hamlin Valley and of populations at the southern-most edge of their range. The collision study contributes knowledge to collision rates and collision factors in low-density populations. The avian predator study will provide insight into fence design that increases the likelihood of perching by avian predators of sage-grouse and provides information leading to management decisions that could reduce predator usage of fences in sage-grouse habitat. This research will provide SWARM, the BLM, the Utah Division of Wildlife Resources (UDWR), and United States Fish and Wildlife Service (USFWS) with information to guide management actions to improve habitat for the greater sage-grouse within Hamlin Valley.

The objectives of this study were:

1) Document the brood-rearing and summer habitat and movement of sage-grouse in Hamlin Valley;
2) Determine if sage-grouse are colliding with fences and if so, what factors increase collision risk;
3) Measure avian predator use of fences and model the fence design factors that may increase perching events.

STYLE

This thesis was written in multiple chapter format, following the style used in the *Wildlife Society Bulletin*.

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CHAPTER 2

SEASONAL AREAS AND MOVEMENT OF THE HAMLIN VALLEY, UTAH POPULATION OF GREATER SAGE-GROUSE

ABSTRACT. Little is known about the seasonal distribution, movements, and home range sizes of greater sage-grouse at the southern edge of their distribution. To expand our knowledge of this species, I monitored 16 radio-collared sage-grouse captured from four leks Hamlin Valley, Utah in 2011 and 2012. Of the four active leks, three are distributed in the lower part of the valley and are located an average of 6 km from each other. The fourth lek is located approximately 22 km north of the lower leks. The average seasonal distribution sizes for breeding, summer, and winter habitats were 200.36 km^2, 364.58 km^2, and 219.68 km^2, respectively. The Hamlin Valley population was primarily one-stage migratory but non-migratory behaviors were also observed. Collared individuals moved an average of 9.24 km (95% CI = 6.79 – 11.69 km) from breeding to summer habitats and an average of 8.24 km (95% CI = 5.28 – 11.2 km) from summer to winter habitats. Birds from at least one of the leks used seasonal habitats in neighboring Nevada. This study shows that interstate coordination between Utah and Nevada is paramount to sustaining distinct habitat features for the Hamlin Valley population and that habitat restoration should focus on increasing migratory corridors between the upper and lower valleys as well as complexes in the larger landscape.

INTRODUCTION

In the western United States, shrub-steppe ecosystems have been degraded by development, agriculture, overgrazing, exotic annual plant invasion, and changed fire regimes (Connelly et al. 2004). As a consequence, Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) and other sagebrush obligate species that depend on this ecosystem have declined. Sage-grouse habitats have been reduced by approximately 44% since European settlement of the Western United States began (Miller et al. 2011). Loss of habitat has contributed to an average decline of sage-grouse populations by 33% across the range (Connelly and Braun 1997).

Sage-grouse are a wide-ranging species with potential for high mobility (Connelly et al. 2000). Connectivity and the ability for populations to exchange individuals is an important focus for conservation of the species, in order to avoid isolation (Oyler-McCance et al. 2005). Historically, sage-grouse distribution included 13 U.S. states (Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Colorado, Utah, South Dakota, North Dakota, Nebraska, and Arizona) and three Canadian provinces (British Columbia Alberta, and Saskatchewan) (Schroeder et al. 1999, 2004). Current distribution represents approximately 56 percent of historical range across 11 U.S. States (no longer occurring in Arizona and Nebraska) and two Canadian provinces (no longer occurring in British Columbia) (Schroeder et al. 2004). In Utah, estimates indicate that sage-grouse now occupy only 41% of their former range (Beck et al. 2003), a result of sagebrush alteration and degradation (Schroeder et al. 2004).

The decline in population size and distribution of sage-grouse is of special concern at the edges of sage-grouse distribution, where this study is focused (Fig. 2-1).

Increasing isolation due to habitat fragmentation at the edge of the overall range decreases dispersal opportunities from and to these areas (Oyler-McCance and Quinn 2011). However, lack of research on this population, has led to limited available information on habitat use, seasonal movements, and adjacent population connectivity.

Sage-grouse are generally considered to use three types of seasonal habitats which coincide with three life stages: 1) breeding habitat, which includes lekking, nesting, and early brood-rearing; 2) summer habitat which includes late brood-rearing habitats; and 3) winter habitat (Connelly et al. 2000).

Sage-grouse breeding occurs on areas known as leks. A lek is a traditional strutting ground where at least two male sage-grouse have attended in two of the last five years (Connelly et al. 2003). The most important feature of a lek is its proximity to nesting habitat (Schroeder et al. 1999). Males arrive on leks between late February and early June to perform ritualized courtship displays. Adult male sage-grouse exhibit fidelity to lek sites and have been shown to visit the same lek throughout the breeding season and year to year (Schroeder and Robb 2003). Mating is thought to occur on the lek and hens nest one to two weeks after the courtship display (UDWR 2009). Leks are usually located in open areas surrounded by sagebrush cover. Leks are typically found on gentle terrain, but have also been found in valley bottoms or draws (Rogers 1964). Rangewide lek habitat is not considered a limiting factor to grouse population growth (Schroeder et al. 1999).

Sage-grouse population declines are most often related to poor nest success (Baxter et al. 2008). Nest success ranges from 15% - 86%, depending on a variety of factors including the condition of the habitat and the age of the hen (Connelly et al.

2011). Average clutch size varies from 6.0 - 9.5 eggs throughout the species range (Schroeder 1997, Sveum et al. 1998). Nesting usually occurs under sagebrush within 5 km of the lek (Connelly et al. 2004, Knerr 2007), usually in habitats dominated by sagebrush with horizontal and vertical structural diversity (Connelly et al. 2004). Successful nests are most often found with understory composed of native grasses and forbs which serves to hide the nest, as well as to provide a food source for the hen and new chicks (Connelly et al. 2000). Nests are typically found under sagebrush (Schroeder et al. 1999) but have also been found under other shrubs or grass (Dahlgren et al. 2006).

Early brood-rearing usually occurs relatively close to nest sites (Connelly 1982, Gates 1983). Because sage-grouse chicks are dependent on insect prey after hatching (Johnson and Boyce 1990) for the protein content to grow quickly (Beckerton and Middleton 1982), preferred habitats are open stands of sagebrush with at least 15% canopy cover (Sveum et al. 1998, Connelly et al. 2000) of a diverse species richness of grasses and forbs, that typically support high densities of insects. As sagebrush habitats desiccate throughout the summer months, sage-grouse broods will typically move to more mesic sites, if such habitats are available. Diet shifts almost entirely to sagebrush as local vegetation desiccates, and insect populations decline, in the late summer (Schroeder et al. 1999).

Winter habitats appear to be somewhat similar across the range of sage-grouse because sage-grouse depend on sagebrush for their winter diet (Patterson 1952). Habitat selection is dependent on snow depths (Schroeder et al. 1999) because sage-grouse select areas where sagebrush remains relatively exposed (Beck 1977, Schoenberg 1982). Sage-grouse have been found to inhabit greater densities of sagebrush in winter than any other life-stage (Schroeder et al. 1999). Sage-grouse depend on sagebrush for more than just nutrition; they also use it for cover and temperature regulation during colder temperatures, sometimes burrowing beneath shrubs under the snow (Beck 1977). Topography may also play a part in habitat selection, where grouse typically move to lower elevations (Patterson 1952) than those used during the summer and select southward facing aspects (Crawford et al. 2004) to ensure that snow does not entirely cover the shrub canopy.

Previous research has suggested that seasonal movements can be highly variable within the same population (Connelly et al. 1988). Individual sage-grouse may have distinct areas used for breeding, summer, and winter or the habitats may be integrated (i.e. breeding and winter may overlap) (Connelly et al. 2000). Connelly et al. (2000) proposed a three-point definition of sage-grouse individual movement behavior as non-migratory (movements <10 km), one-stage migratory (movements ≥ 10 km between distinct seasonal ranges), and two-stage migratory (movements ≥ 10 km among three distinct seasonal ranges). During the breeding season, males arrive on leks between February through early May to perform ritualized courtship displays. Sage-grouse typically nest within 5 km the lek (Connelly et al. 2004, Knerr 2007). Following the cessation of breeding, as sagebrush habitats desiccate, sage-grouse move from areas centered around nesting habitat. In winter, sage-grouse sometimes migrate farther than is necessary to reach habitats that would be suitable, possibly demonstrating that the drive towards site fidelity is greater than meeting nutrition requirements (Connelly et al. 1988, Jensen 2006). Understanding when, where, and how far sage-grouse migrate is vital to the management of the population.

Hamlin Valley is thought to be a stronghold of Utah for sage-grouse populations due to the number of grouse currently there and the condition of grouse habitat in the valley (Frey et al. 2006). In addition, because Hamlin Valley spans the Utah-Nevada border it is thought that sage-grouse within the valley might be traveling between the two states, thus indicating a certain level of cooperation between the two would be needed to ensure the safety of grouse in Hamlin Valley. With relatively little known about the seasonal distribution, movements, and home ranges of sage-grouse within Hamlin Valley, Utah I examined these factors in relation to focal leks and seasonality of use. This study area provided a unique opportunity to document general ecology of a population of sage-grouse with relatively little previous research, individuals that occur at the extreme southern end of the species distribution range, and a population that is not threatened by habitat fragmentation or development of energy infrastructure.

Based on sage-grouse habitat models delineated by Utah Division of Wildlife Resources for Hamlin Valley, I expected sage-grouse to use habitat throughout the entire valley with seasonal differences between nesting, summer, and wintering habitat. I predicted habitats and seasonal movements would be similar to those of other sage-grouse populations. While this study is focused on a small, isolated population in Utah, the resulting conclusions may be projected to other similar areas throughout the region, particularly similar habitats in Nevada. Furthermore, the study results will be used to inform land managers of conservation measures and improvements necessary to maintain this population and restore connectivity with adjacent areas.

STUDY AREA

This study took place in Hamlin Valley, Utah (Beaver and Iron Counties) and Nevada (Lincoln County). Hamlin Valley occurs at the extreme southern edge of the sage-grouse range (Schroeder et al. 2004) in southwestern Utah (Fig. 2-1). Hamlin Valley is located approximately 17 km north of Modena, Utah. The study area was composed of 319.4 km^2 of sage-grouse habitat (as delineated by the Utah Division of Wildlife Resources [UDWR]) within a contiguous tract of land that lies between the Indian Peak and White Rock Mountain Ranges. Land ownership was composed of U.S. Bureau of Land Management (64.9%), Utah School and Institutional Trust Lands Administration (9.4%), and private lands (25.6%). Elevation ranged from 2000-2200m. Average highs for Hamlin Valley are 24.6°C, occurring in August. Average lows are -0.9°C, occurring in January with approximately 120 (range 74-153) frost free days per year. Hamlin Valley receives 22-40 cm of precipitation per year. Cattle grazing was the primary economic activity occurring in the study area with a single irrigated agricultural circle pivot operated sporadically in the southern end of the valley.

The dominant ecological system used by sage-grouse inhabiting the Utah portion of the study area was inter-mountain basins big sagebrush shrubland characterized by Wyoming sagebrush (*Artemisia tridentata wyomingensis*) and black sagebrush (*Artemisia nova*). Other common shrubs included rabbitbrush (*Chrysothamnus viscidiflorus, Ericameria nauseosa*), broom snakeweed (*Gutierrezia sarothrae*), and winterfat (*Krascheninnikovia lanata*). Common grasses included crested wheat grass (*Agropyron cristatum*). Indian ricegrass (*Achnatherum hymenoides*), blue grama (*Bouteloua gracilis*), needle-and-thread grass (*Heterostipa comata*). The annual invasive, cheatgrass

(*Bromus tectorum*), was also observed. Portions of the habitat were interspersed with great basin xeric mixed sagebrush shrubland, although these areas were not used by sage-grouse. In the Nevada portion of the study area, which was on the west side of the White Rock mountains, inter-mountain basins montane sagebrush steppe was the dominant ecological system characterized by the presence of mountain sagebrush (*A. tridentata vaseyyana*) and antelope bitterbrush (*Purshia tridentata*). In addition to the grasses, listed above, bluebunch wheat grass (*Pseudoroegneria spicata*) was present. Both the Utah and Nevada shrub-dominated portions were surrounded by great basin pinyon-juniper woodland.

The Hamlin Valley sage-grouse population consists of four occupied leks. Three are located in the lower valley approximately 6 km apart and the fourth is located 22 km north. The ten-year average number of male sage-grouse counted on all leks combined is 84, however looking at only the years the study was conducted 2011 - 2012, the two-year average decreases dramatically to 49 males total on all leks in Hamlin Valley. Using this two-year average, the total population was estimated to be around 185 individuals during the study period.

METHODS

Trapping and Radio-telemetry of Grouse

I captured sage-grouse in March and April 2011 and 2012 via common spotlighting techniques (Wakkinen 1990) and a 7.5 m × 7.5 m electromagnet drop net (Wildlife Capture Services, Flagstaff, AZ). I set up drop nets on leks in the evening in the general area where the most sage-grouse were observed strutting the day prior. On capture day, approximately two hours before sunrise, I arrived at the drop net and prepared the net for use and engaged the wireless drop system. I sat in the vehicle parked adjacent to the lek but in a position where the lek would be easily accessed. Once the sun provided enough light that sage-grouse were seen, I drove the vehicle slowly towards the sage-grouse until they moved away from the vehicle. I guided them until they were under the net and then dropped it, resulting in a successful capture. On one occasion multiple grouse were caught at the same time. Use of the drop net without herding resulted in no sage-grouse under the net, even if the net were placed on the same spot that males had been observed strutting multiple times on prior days.

Areas of capture were focused near the four known leks in the study area (Butcher Trough, Hamlin Wash, White Bridge, and Rain Gauge; Fig. 2-1). The goal was to capture 30 sage-grouse total. All captured birds were fitted with 24-g necklace VHF transmitters with an 8-hr mortality switch (Advanced Telemetry Systems, Isanti, MN). All capture and handling procedures were approved through the Protocol Application for Live Animal Use in Research, Teaching, or Training at Utah State University (IACUC # 1451). I assumed that the radio-collared birds were representative of the entire population and that attachment of the transmitter did not alter radio-collared bird behavior (Frye et al. 2014).

Collared individuals were located weekly by using handheld receivers, handheld 3-element Yagi antennas, and vehicle mounted omni antennas. Locations were ascertained by honing - following the direction of the antenna and signal strength until the individual was observed. Attempts were made to locate the individuals visually prior to flushing, but occasionally individuals flew before positive visual contact was made.

When this occurred, I marked the location where the birds flushed rather than pursue them. Once located, I recorded the Universal Transverse Mercator (North American Datum 1983) with <5 m error (using model eTrex Venture HC, Garmin International, Inc., Olathe, KS).

Defining Breeding, Summer, and Winter Seasons

The Hamlin Valley population is on the southern edge of the range of sage-grouse, therefore traditional seasonal definitions of various sage-grouse seasonal habitats were considered, but site-specific dates were necessary to determine distribution and movements between breeding, summer, and winter seasons. "Breeding distribution" included lek locations, pre-nesting and nest locations of females, and early summer locations of all birds. "Summer distribution" encompassed late summer habitats of both males and females. I started by looking at the traditional seasonal delineations for sage-grouse in Utah and fine-tuned the dates specific to Hamlin Valley by looking for timing of large movements (calculated as straight-line points between two consecutive locations) and the sustained usage of one area for each individual collared sage-grouse. Telemetry data were used to calculate deliberate switching from breeding (9 Mar through 21 May), summer (27 May through 2 Oct), and winter (24 Nov through 20 Feb). Dates were averaged across years to account for the small sample sizes.

Seasonal Distribution

I calculated seasonal distributions for year-round, breeding, summer, and winter using telemetry locations pooled together by the respective season. I calculated breeding, summer, and winter distribution using all telemetry locations within each season. For year-round distribution, I included all birds and locations from March 2011 through August 2012. I used ArcGIS Desktop (Environmental Systems Research Institute, Redlands, CA) Minimum Bounding Geometry to create a convex hull polygon for all locations for occupied use, and locations per season for seasonal distribution.

Movement

To assess the movement of the collared sage-grouse among seasons, I used the "genpointinpoly" tool with ArcGIS 10.1 to create a centroid within the seasonal home range distribution polygon I had previously established for each individual bird, to represent the average seasonal distribution location. I measured the distance between successive centroids. Using this estimated distance, I classified individuals as non-migratory (<10 km) or one-stage migratory (>10 km) following definitions in Connelly et al. (2000).

RESULTS

Capture

I captured 16 sage-grouse (n = 7 males, n=9 hens, 8.6% of the estimated population) from the Hamlin Valley Study Area. Three males were captured in Upper Hamlin Valley at the Rain Gauge Lek. The remaining thirteen were captured in Lower Hamlin Valley composed of the Butcher Trough lek (n = 1 male, n=3 hens) and White Bridge lek (n = 3 males, n=6 hens).

Seasonal Distribution

Data from all collared birds (n=16) and all telemetry locations (n=299) from

March 2011 through February 2013 were used to calculate the distribution of sage-grouse throughout Hamlin Valley. Occupied distribution for the entire study area, Upper Valley, and Lower Valley were 531.19 km^2, 95.70 km^2, and 118.13 km^2, respectively. For breeding, summer and winter distributions, I included all telemetry locations (n=114 n=150, and n=35, respectively) from all birds tracked over breeding (9 Mar - 21 May), summer (27 May - 2 Oct), and winter (24 Nov - 20 Feb). The breeding distributions for the entire study area and the Lower Valley were 200.36 km^2 and 115.56 km^2, respectively. A breeding distribution for the Upper Valley was not calculated because location data only represented locations of strutting males and would underrepresent breeding distribution when off-lek. The summer distributions for the entire study area, Upper Valley, and Lower Valley were 364.58 km^2, 48.80 km^2, and 44.54 km^2, respectively. The winter distributions for the entire study area and the Lower Valley were 219.68 km^2 and 94.19 km^2, respectively. A winter distribution for the Upper Valley was not calculated because all 3 individuals were only located twice and they were all within 0.1 km of each other and thus may underrepresent winter habitat.

Movement

Data from twelve (n= 6 hens; 6 males) individual collared sage-grouse from 2011-2012 were used to examine migratory behavior and seasonal movement patterns within Hamlin Valley. Migratory behavior and inter-seasonal movements for each individual sage-grouse were examined at the lek-complex level (i.e. Upper Hamlin Valley, Lower Hamlin Valley) because no connectivity was observed between sage-grouse captured in Upper and Lower Hamlin Valley during the breeding and summer seasons. However, during the winter of 2013, one collared female sage-grouse that had spent the previous summer in Lower Hamlin Valley was observed near the Rain Gauge lek and may be an indicator that there is connectivity that was otherwise not detected in the other collared sage-grouse. Unfortunately, there is only one data point for this female in Upper Hamlin Valley and it is unknown if it remained in the area for breeding.

Within the entire study area, 67% of the collared birds demonstrated one-stage migratory behavior. Eight sage-grouse (n= 4 hens, 4 males) moved an average of 11.20 km (95% CI = 7.62-14.77) between two distinct seasonal ranges, primarily between the breeding and summer habitats. The remaining four collared sage-grouse (n=2 hens, 2 males) were non-migratory, moving an average of 5.69 km (95% CI = 4.90-6.48) between seasonal habitats.

Upper Hamlin Valley. — All of the males (n=3) from the Rain Gauge lek moved from their breeding area in Utah, west to summer habitats in Nevada (Fig. 2-2). Two of these males moved more than 10 km from breeding to summer habitats, crossing over the White Rock Mountains to habitats in the Cobb Creek area. The remaining male stayed east of the White Rock Mountains near the Hermitage, a distance of less than 10 km, meeting the classical definition of non-migratory.

Lower Hamlin Valley. — Of the thirteen sage-grouse (n= 9 hens; 4 males) associated with lower Hamlin Valley, nine had multiple locations in more than one season. I was unable to calculate movement patterns of the remaining four due to dropped collars and mortality. The majority (n=6; 67%) of the collared sage-grouse within Lower Hamlin Valley demonstrated one-stage migratory behavior, moving distances greater than 10 km among breeding, summer, and winter habitats. However, I question whether this should be identified as migratory because at a landscape level these habitats were all fairly homogenous and remained in the vicinity of the three lek complex. Larger seasonal movements were reflective of individual preferences for small distributions within a larger landscape context. The remaining three (n= 2 hens, 1 male) demonstrated classical non-migratory behavior. One of the hens was the only hen to successfully fledge a brood. The hen and the brood had distinct early brood-rearing and late brood-rearing habitats, but were never greater than 10 km from one to the next.

Interseasonal Movement. — In 2011 all collared sage-grouse (n=3) moved from breeding habitats to summer habitats by June 29. In 2012 all but one sage-grouse moved to summer habitats by May 21. Typical movement pattern in Upper Hamlin Valley was west from the lekking area in Utah to summer habitats in Nevada. Lower Hamlin Valley sage-grouse moved southward. Six nesting attempts were observed during the 2011-2012 field season (Table 2-1). Average distance from lek to nest of the nests that were successful to hatching was 1.770 km while unsuccessful nests were 2.963 km. One hen moved more than 10 km from lek to nest and both the hen and nest were lost to coyote predation. Five of the six nests were initiated mid- to late-April, the latest nesting occurred was in early- May by the hen that moved over 10 km from the lek of capture. All sage-grouse were observed to move from summer to winter habitats by 24 November. Observations of the sage-grouse indicate that winter habitat is a much smaller subset of the overall available habitat (Fig. 2-3).

DISCUSSION

Seasonal Distribution

The results of this study suggest variation in the extent of movement distances, migration strategies, and seasonal habitats within birds of the same population and origin lek. Overall the population moved from breeding to summer (generally May-Jun) and summer to winter (generally Oct-Nov) habitats at about the same time, but individual migration dates varied.

Although the majority of sage-grouse in Lower Hamlin Valley were one-stage migratory, the habitats were fairly homogenous throughout this part of the landscape. I observed that sage-grouse in Lower Hamlin Valley tended to be found in the general vicinity of actively managed cattle troughs. As the ranchers in Lower Hamlin Valley moved their cattle from pasture to pasture, thus emptying and filling different troughs, the sage-grouse moved too. On several occasions sage-grouse were observed near the troughs or overflow of troughs and sage-grouse scat was found to be composed of algae that appeared to come from the water troughs (personal observation).

Seasonal Movements

Based on the traditional definition of migration, which is described as movements >10 km between seasonal habitats (Connelly et al. 2000), 67% of the Hamlin Valley population exhibited one-stage migratory behavior and 33% exhibited non-migratory behaviors. Both migration strategies were exhibited by different individuals originating from the same lek, which suggests that movements are based on an individual’s availability to find resources necessary for each life history stage and are not influenced by the movement of other individuals. However, I would argue that habitat composition should be factored in to the definition of migration rather than distance, alone. Although 6 of the 9 tracked sage-grouse in Lower Hamlin Valley moved distances >10 km, the habitats appeared to remain similar. In Upper Hamlin Valley, one tracked sage-grouse, classified as non-migratory, shifted from Wyoming sagebrush dominated habitats with very little forb understory to a recently burned pinyon-juniper forest and riparian habitats.

There is approximately 22 km between the northern most extent of sage-grouse distribution in Lower Hamlin Valley and the southern extent of Upper Hamlin Valley. During the course of this study, no sage-grouse were observed using any habitat between the distribution of Upper and Lower Hamlin Valley use. It appears that all of the sage-grouse captured from the Rain Gauge lek move westward to Nevada whereas the sage-grouse in the Lower Valley moved slightly southward during the summer. The sage-grouse strutting at Rain Gauge lek are most likely part of a complex of leks that are managed by the Nevada Department of Wildlife.

Our study was limited by sample size, which was smaller than planned. Trapping the Hamlin Valley population was more difficult than expected; attempts were made in both spring and fall to capture birds. Traditional methods (i.e. spotlighting) to locate roosting areas failed and I found that roosting areas differed nightly. Spotlighting was successful on the lek immediately prior to sunrise, however this only resulted in captures of males, as they are the first to fly in to the area and hens typically arrive after strutting has begun. The most successful method to catch hens was the operation of a drop net on the lek with accompanied herding techniques.

MANAGEMENT IMPLICATIONS

During the 2011-2012, study seasons I did not observe any connectivity between the Upper and Lower portions of Hamlin Valley or movement between this population and sage-grouse in the Pine Valley. Movement from Hamlin Valley to Pine Valley would require crossing more than 22 km of pinyon-juniper and other unsuitable habitats. Restoration projects that focused on improving migration corridors by creating more suitable habitat within them should be implemented.

Sage-grouse captured at Rain Gauge lek were observed using summer habitats in Nevada. Distance from lek to summer habitats was approximately 13 km and crossed recently burned (2010) pinyon-juniper habitat. It is unknown if sage-grouse movement was impeded prior to the burn, however, similar habitat restoration by elimination of pinyon-juniper in the Lower Valley may be one recommendation to restore connectivity with Pine Valley. The Utah-Nevada connectivity demonstrates the need for interstate coordination to maintain successful populations of sage-grouse.

Brood-rearing and summer habitats are generally composed of riparian and wet meadow and can sustain forbs longer than drier habitats (Connelly et al. 2000). During the two years of the study, Hamlin Valley Wash was dry with limited mesic habitat in the study area. I observed sage-grouse migrating among the various pastures in Hamlin Valley, potentially associated with the proximity to water available in cattle troughs. A current lack of a mesic landscape may be contributing to low productivity and limiting population growth in Hamlin Valley which may be improved by better water management.

Future research for the Hamlin Valley population should focus on several actions. First, more detailed information should be collected to determine migration patterns using more frequent data points (such as by using GPS satellite transmitters) to determine if birds are attempting to disperse to the neighboring Pine Valley population (to the east) or Upper Hamlin Valley (to the north and west) but are abandoning migration due to habitat connectivity issues. Second, research should be conducted on vegetation composition and utilization of the large area of sagebrush habitat between Upper and Lower Hamlin Valley that were never observed as being used by sage-grouse during the course of this study, to find out if there are microsite differences that discourage use that could be remedied through habitat restoration projects. Third, because of the current lack of movement between populations, it may be beneficial to conduct an analysis of genetics to determine the level of isolation or connectivity occurring between the neighboring Nevada and Bald Hills populations. A study may determine if action should be taken (i.e. translocations) to improve genetic integrity or define this population as distinct. Finally, because of the low number of successful nests or observations of uncollared broods, a nest predation analysis should be conducted to determine what could be done to increase successful hatching, which could improve the stability of the entire population.

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TABLES AND FIGURES

Table 2-1. Comparison of greater sage-grouse nest fate to distance (km) from capture lek in Hamlin Valley, Utah, 2011-2012.

	Successful to hatching	Eggs lost to predator	Eggs and hens lost to predator
N	2	3	1
Average	1.770 km	2.963 km	10.666 km
Range	1.126 – 2.414 km	1.512 – 5.258 km	10.666 km

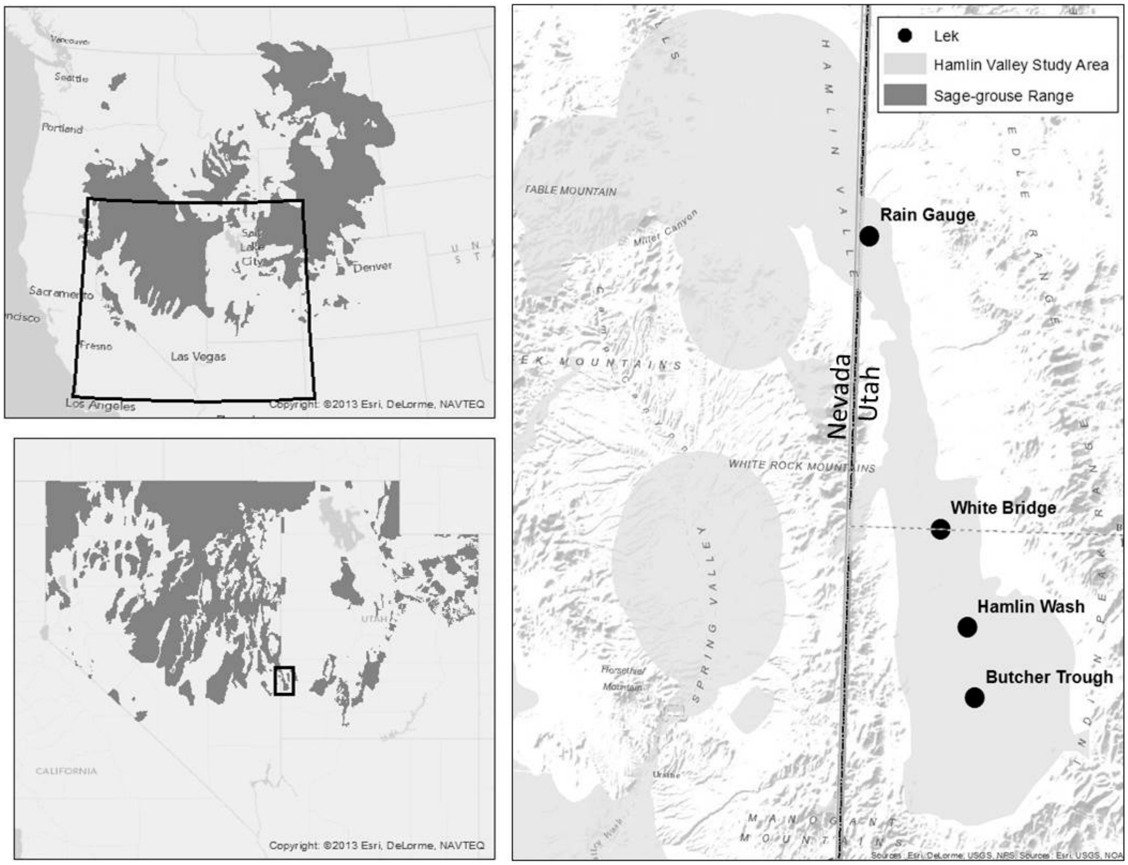

Figure 2-1. Hamlin Valley, Utah, USA study area in relation to the entire greater sage-grouse range.

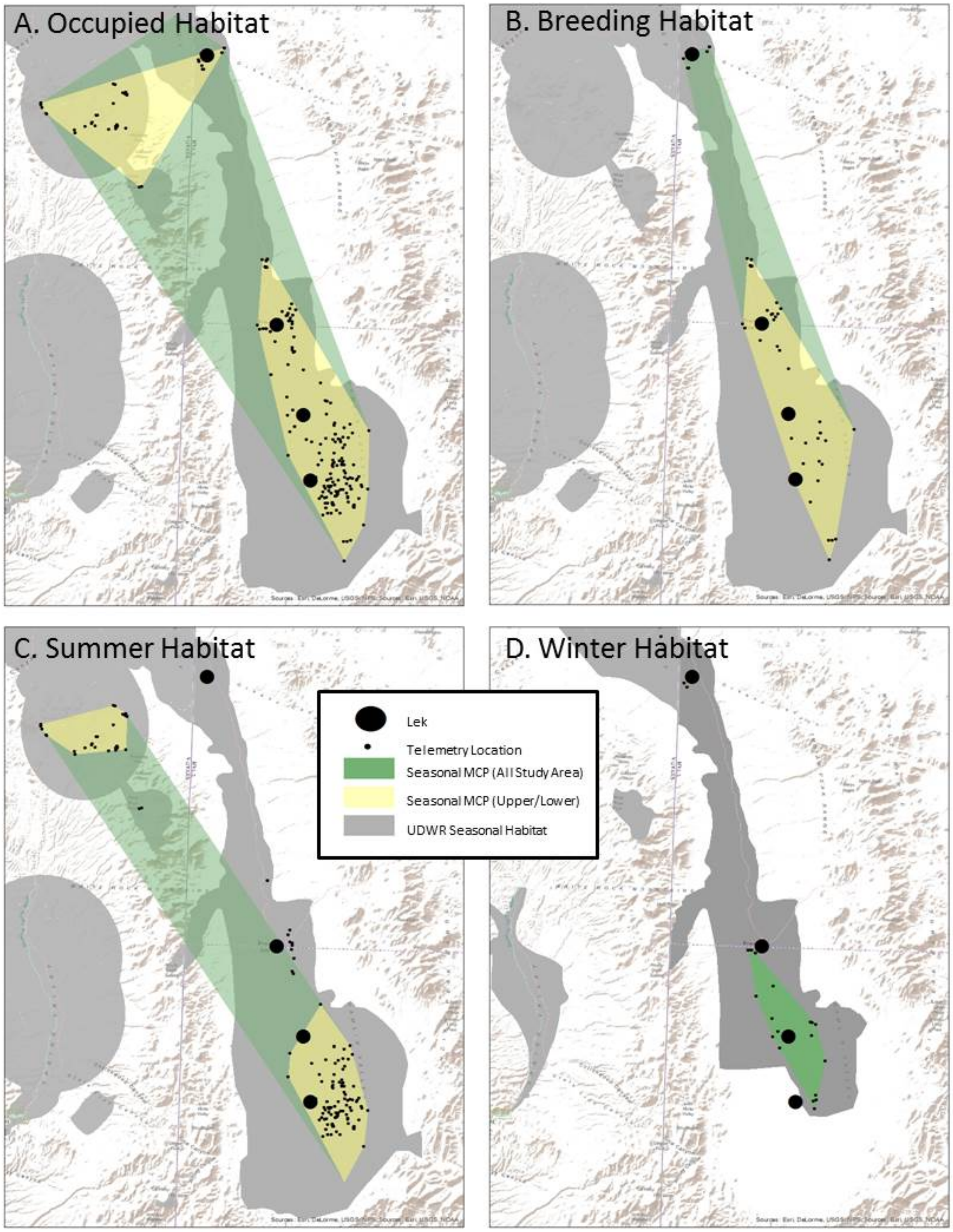

Figure 2-2. Seasonal distribution of greater sage-grouse within Hamlin Valley, Utah, USA, 2011-2012.

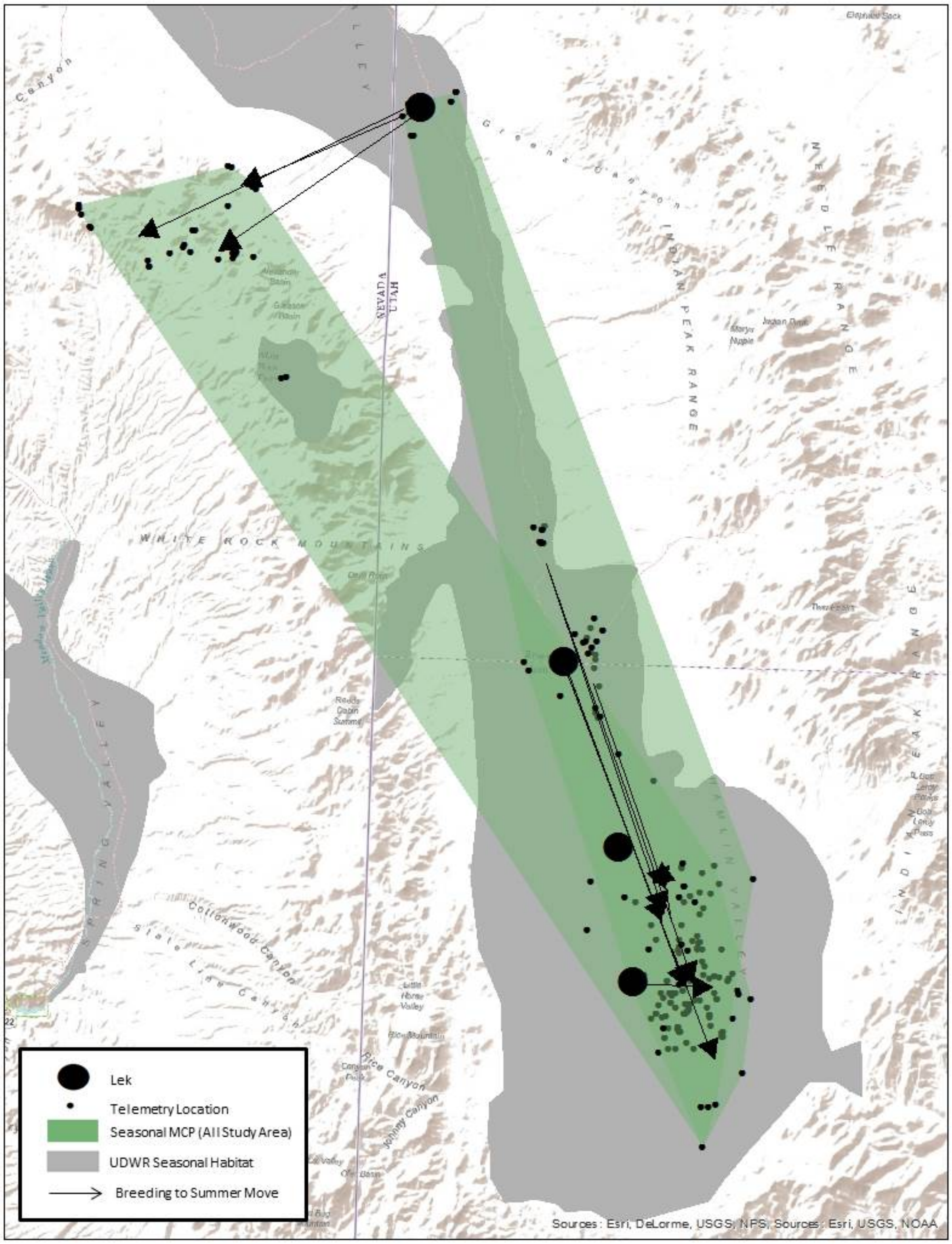

Figure 2-3. Seasonal movements of sage-grouse between breeding and summer habitats in Hamlin Valley, Utah, USA, 2011-2012.

CHAPTER 3

GREATER SAGE-GROUSE FENCE COLLISION OCCURRENCE WITHIN TWO SMALL POPULATIONS ON THE SOUTHERN EXTENT OF OCCUPIED HABITAT

ABSTRACT. Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) evolved in habitats where vertical structures, such as trees and fences, were not common. Previous research on similar grouse species has suggested that grouse are particularly susceptible to collision due to their mechanics of flight. Previous research on sage-grouse collision identified proximity to lek, terrain, and fence density as important factors influencing collision, however that study was limited to the breeding season and in large populations occurring within the midsection of their range. This research focused on two small populations on the fringe of the southern portion of the range of current occupied sage-grouse habitat during all major seasons for grouse. During 2011-2012, I surveyed 100 randomly distributed 1 km^2 plots during the brood-rearing, fall migration, and winter seasons. Also during the 2012 breeding season, I surveyed all fences within a 2.5-km radius of sage-grouse leks for signs of collision. In total, I surveyed over 450 km of fences and no sign of sage-grouse collision was observed. Thus, this data suggests that management for sage-grouse in small populations may be better focused on improving habitat and reducing other causes of mortality which may be more prevalent.

INTRODUCTION

Sage-grouse numbers have declined rangewide since Euroamerican settlement. From 1965 to 2015 sage-grouse populations declined approximately 66% (Nielson et al.

2015) which has led to numerous petitions to put sage-grouse on the endangered species list. In the 2010 warranted but precluded listing decision, the primary cause of decline was determined to be the present or threatened destruction, modification, or curtailment of habitat or range (USFWS 2010) including introduction of infrastructure in to sagebrush habitats. One common type of infrastructure found throughout sage-grouse habitat is fences.

Sage-grouse evolved in landscapes with relatively few vertical obstructions and therefore may be ill-equipped to coexist as these features invade their habitats; it is estimated that there are 2 km/km^2 of fences in many occupied sage-grouse habitats (Connelly et al. 2004). Effects from fences can include direct mortality, through collision risk, but also include indirect effects such as perch sites for raptors and ravens, creation of predator corridors, introduction of exotic vegetation species during the construction of the fence, and fragmentation of habitat (Call and Maser 1985, Braun 1998, Connelly et al. 2000, 2004, Beck et al. 2003, Knick et al. 2003). Avian collision risk is primarily influenced by the mechanics of bird flight, including mode of landing, altitude gain, speed of flight, and number of birds at take-off (Faanes 1987). Sage-grouse, like many grouse species, typically fly low and fast, are bulky birds with poor maneuverability (Call and Maser 1985), and are unable to gain vertical height quickly, thus making them likely candidates for fence collisions.

Much of the research available on avian collision has overwhelmingly shown that collisions are more frequent for grouse species, including western capercaillie (*Tetrao urogallus*), ptarmigan (*Lagopus* spp.), red grouse (*Lagopus lagopus scoticus*), black grouse (*Tetrao tetrix*), and lesser prairie-chicken (Baines and Summers 1997, Bevanger and Brøseth 2000, Baines and Andrew 2003, Wolfe et al. 2007). Greater sage-grouse collision reports are mostly documented in several unpublished reports (Danvir 2002, Christiansen 2009); however recent work in southeastern Idaho has provided information on rates of sage-grouse collision and factors leading to collision during the breeding season (Stevens 2011). Over two years examining 129.5 km of fences, Stevens (2011) found 86 sage-grouse collisions for a mean of 0.75 strikes/km. Stevens also documented that collisions were more common on fences constructed with steel t-posts, flatter terrain, and densities of fences greater than 1 km/km2 within 2 km of an active lek.

To date, much of the published literature on sage-grouse collision in North America has focused on large populations of grouse within the middle of the distribution and been conducted during the breeding season. Therefore, this research aimed to look at collision rates in a small population of grouse, on the fringe of the distribution, during all distinct grouse seasons – breeding, brood-rearing, fall migration, and winter.

STUDY AREA

The fence collision study took place in the Southwest Desert Resource Area of southwestern Utah, in two separate locations which were occupied by sage-grouse – Hamlin Valley and Bald Hills (Fig. 3-1). Both study areas were located in Beaver and Iron Counties, within the Bureau of Land Management's Cedar City Field Office (CCFO). Both study areas occurred at the southern edge of the range of sage-grouse (Schroeder et al. 2004). Neither population was hunted.

Bald Hills

The Bald Hills are located near Minersville, Utah. The study area consisted of approximately 1,613 km^2 of sage-grouse habitat in and around the Black Mountains. Land ownership was composed of the U.S. Bureau of Land Management (77.3%), Utah School and Institutional Trust Lands Administration (8.6%), private land (14.1%), and Department of Natural Resources managed lands (<1%). Elevation ranged from 1550 to 2400 meters. The average high temperature for the Bald Hills study area was 21.9° C, occurring in July. The average low was -1.8° C, occurring in January with approximately 83-180 (average of 128.3) frost free days per year. The Bald Hills area receives 31.8-33.7 cm of precipitation per year. Cattle and sheep grazing were common in spring and summer; and a portion of the study site consisted of crop agriculture, primarily alfalfa and corn. The Bald Hills were dominated by sagebrush steppe and pinyon-juniper forest habitats. The northeast portion of the study area had been re-seeded with native and non-native mixes of perennial shrubs, forbs, and grasses due to the Milford Flat wildfire that occurred in July 2007. There were 0.36-km/km^2 of fences in sage-grouse habitat; 576.624-km of fences.

Vegetation communities. — The vegetation communities were predominantly sagebrush dominated rangeland surrounded by encroaching pinyon-juniper, with smaller areas of aspen, mixed conifer, and mountain shrub. Common shrub species present included black sagebrush (*Artemesia nova*), Wyoming sagebrush (*A. tridentata wyomingensis*), Douglas rabbitbrush (*Chrysothamnus viscidiflorus*), and broom snakeweed (*Gutierrezia sarothrae*). Common forbs throughout the study area included rose heath (*Chaetopappa ericoides*), buckwheats (*Eriogonum spp.*), *Astragalus spp.*, globemallow (*Sphaeralcea spp.*), and phlox (*Phlox spp.*). Both native and non-native grasses were present throughout and included crested wheatgrass (*Agropyron cristatum*), needle-and-thread (*Hesperostipa comata*), bottlebrush squirreltail (*Elymus elymoides*), Indian ricegrass (*Achnatherum hymenoides*), blue grama (*Bouteloua gracilis*), and cheatgrass (*Bromus tectorum*) was identified, but rare in the study area.

Wildlife. — Common avian species included sage-grouse, horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), vesper sparrow (*Pooecetes gramineus*), mourning dove (*Zenaida macroura*), common raven (*Corvus corax*), pinyon jay (*Gymnorhinus cyanocephalus*), common nighthawk (*Chordeiles minor*), and American kestrel (*Falco sparverius*). Large raptors such as red-tailed hawk (*Buteo jamaicensis*), ferruginous hawk (*Buteo regalis*), northern harrier (*Circus cyaneus*), golden eagle (*Aquila chrysaetos*), short-eared owl (*Asio flammeus*), burrowing owl (*Athene cunicularia*), and turkey vulture (*Cathartes aura*) were also observed in the study area, but less frequently. Common mammalian species include pronghorn (*Antilocapra americana*), mule deer (*Odocoileus hemionus*), elk (*Cervus elaphus*), coyote (*Canis latrans*), several bat species, black-tailed jackrabbit (*Lepus californicus*) and the desert cottontail rabbit (*Sylvilagus audubonii*).

Sage-grouse Population Characteristics. — The Bald Hills population consisted of eight occupied leks and four potential leks. The ten-year average number counted on occupied leks within the Bald Hills area was 65 males, however with the inclusion of potential leks, the two-year average number increases dramatically to 131 males. Using the two-year average, the total population was estimated to be around 500 individuals during the course of this study.

Collision Model. — Using the model that Stevens et al. 2011 developed, 30% of the lands within five kilometers of the leks in the Bald Hills study site have terrain associated with a moderate to high risk of collision (Fig. 3-2). The risk is primarily driven by the leks at lower elevation, as they occur mostly on flat lowlands. The leks at higher elevation are typically surrounded by mountainous terrain and have low collision risk (average of 78% have low risk).

Hamlin Valley

The Hamlin Valley study area was located approximately 17-km north of Modena, Utah. It was composed of 319.4 km^2 of sage-grouse habitat within a contiguous tract of land that lies between the Indian Peak and White Rock Mountain Ranges. Land ownership was composed of the U.S. Bureau of Land Management (64.9%), Utah School and Institutional Trust Lands Administration (9.4%), and private owners (25.6%). Elevation ranged from 2000-2200-m. Average highs were 24.6° C, occurring in August. Average lows were -0.9° C, occurring in January with approximately 74-153 (average of 119.5) frost free days per year. Hamlin Valley typically receives 9-16 inches of precipitation per year. Cattle grazing was the primary activity occurring in the valley with a single agricultural circle crop of alfalfa operated in the extreme southern end of the valley. There were 0.662-km/km^2 of fences in sage-grouse habitat, 211.32 km total fences.

Vegetation communities.— The vegetation communities were predominantly sagebrush dominated rangeland surrounded by encroaching pinyon-juniper, with smaller areas of aspen, mixed conifer, and mountain shrub. Common shrub species present included black sagebrush, Wyoming sagebrush, Douglas rabbitbrush, and broom snakeweed. Common forbs throughout the study area included rose heath, buckwheats *Astragalus spp.*, globemallow, and phlox. Both native and non-native grasses were present throughout and included crested wheatgrass, needle-and-thread, bottlebrush squirreltail, Indian ricegrass, and blue grama. Cheatgrass was identified, but rare in the study area.

Wildlife. — Common avian species included sage-grouse, horned lark, western meadowlark, vesper sparrow, mourning dove, common raven, pinyon jay, common nighthawk, and American kestrel. Large raptors such as red-tailed hawk, ferruginous hawk, northern harrier, golden eagle, short-eared owl, burrowing owl, and turkey vulture were also observed in the study area, but less frequently. Common mammalian species include pronghorn, mule deer, elk, coyote, common bat species, black-tailed jackrabbit and desert cottontail rabbit.

Sage-grouse Population Characteristics.— The Hamlin Valley population consisted of four occupied leks. The ten-year average number counted on leks was 84, however looking at only the years the study was conducted 2011 - 2012, the two-year average decreased dramatically to 49 males. Using the two-year average, the total population was estimated to be around 185 individuals.

Collision Model. —Using the model that Stevens et al. 2012 developed, 28% of the lands within five kilometers of the leks in the Hamlin Valley study site have terrain associated with a moderate to high risk of collision. The amount of lands with moderate to high risk of collision is evenly distributed among all four leks.

METHODS

The CCFO provided a shapefile of all known fences within both the Hamlin Valley and Bald Hills study areas. To estimate sage-grouse collision rates, I surveyed fences adjacent to leks and in summer, fall, and winter seasons. Because sage-grouse movements and activities are centered around the lek during the breeding season, I surveyed all fences within 2 km of all leks (lek plots, Hamlin Valley = 4) following the cessation of that day's strutting activities. For the remaining seasons, I used ArcGIS to construct a select grid to sample fences for possible collisions. To begin, I imported a spatial data layer of current fences (provided by the Bureau of Land Management [BLM]), and clipped fences to spatial layers of seasonal sage-grouse habitats (UDWR 2009) limiting the study to areas where sage-grouse could potentially be found in each season. I randomly distributed 100 points along this constructed fence layer, precluding them from being closer than 2-kilometers from other points. Using the random point as the center, I overlaid a 1 km^2 spatial grid (sample plot) using ArcGIS (Fig. 3-3) to be surveyed for signs of sage-grouse collisions. The study was focused in Hamlin Valley, however, I combined it with Bald Hills to increase the sample size and diversity of fences (seasonal plots, Hamlin Valley = 60, Bald Hills = 40; Fig. 3-4).

I surveyed every lek plot twice during the lekking season. I surveyed each seasonal plot once during the summer (27 May through 2 Oct), fall migration (3 Oct – 24 Nov) and winter (24 Nov – 20 Feb).

Within each lek and seasonal plot, I searched all fences for evidence of avian collisions (i.e. carcasses, feathers, or any other sign of collision). Surveyors walked approximately 1-3 m from the fence, scanning out to 15 m away from the fence for sign.

Surveys were either conducted alone, with one surveyor looping around to cover both sides of the fence or by two surveyors walking on each side of the fence. When feather evidence was encountered, surveyors conducted more intense searches away from the fence in the prevailing wind direction to look for a carcass. All portions of the fence falling within the sample plot were surveyed. Number of plots surveyed and length of fence within plots by season are presented in Table 3-1.

RESULTS

Lek Collision Surveys

During the lek collision surveys, I surveyed 113.8 km of fences (Hamlin Valley n=63.86 km; Bald Hills n=49.94 km) during March and April 2012. This accounted for all fences present within 2 km of all occupied and potential leks known as of February 2012. There were no sage-grouse or other avian species collisions (Table 3-2).

Brood-rearing Collision Surveys

During the brood-rearing collision surveys, 137.2 km of fences were sampled in 100 1 km^2 sample plots [Hamlin Valley n=60 (81.8 km); Bald Hills n=40 (55.5 km)] during June and July 2011.

I observed five avian mortalities during sampling (Table 3-2). Four collisions were located in the randomly selected sample plots and one was located incidentally in the study area. The four species observed within the randomly selected sample plots included one pinyon jay, one horned lark, one golden eagle, and one short-eared owl.

Additionally, I incidentally observed one short-eared owl collision that was not located in one of the sample plots. There were no sage-grouse collisions observed.

The pinyon jay, short-eared owl, and golden eagle were identified as collisions by feather piles near wooden-post barbed-wire fences. The horned lark was positively identified as a collision by presence of the remaining carcass. The carcass of the incidental short-eared owl observation was still attached to the fence wooden-post barbed- wire fence. The estimated rate of collision with fences by flying species was 0.3 strikes/km. No fence collision rate could be calculated for sage-grouse.

Fall Migration Collision Surveys

During the fall migration collision surveys, 137.22 km of fences were sampled in 100 1 km^2 sample plots [Hamlin Valley n=60 (81.77 km); Bald Hills n=40 (55.45 km)] during September and October 2011 (Table 3-2). All 100 1 km^2 sample plots were in brood-rearing and winter habitats to account for migrating birds. A total of one aerial collision was observed, of an unknown bat species (*Myotis* spp.). There were no sage-grouse or other avian species collisions observed. Estimated rate of collision with fences by flying species was <0.01 strikes/km. No fence collision rate could be calculated for sage-grouse.

Winter Collision Surveys

During the winter collision surveys, 61.98 km of fences were sampled in 51 1 km^2 sample plots [Hamlin Valley n=35 (43.99 km); Bald Hills n=16 (18.0 km)] during December 2011 and January 2012. The 51 1 km^2 sample plots were located in Utah

Division of Wildlife Resources (UDWR) delineated winter habitats (UDWR 2009). There were no sage-grouse or other avian species collisions observed (Table 3-2).

DISCUSSION

I found that sage-grouse fence collisions in two small populations on the southern edge of the overall range of sage-grouse during any season (brood-rearing, fall migration, winter, and breeding) was uncommon. This is contrary to many previous studies (Baines and Summers 1997, Bevanger and Brøseth 2000, Stevens 2011) which indicated that collisions are highly likely for grouse species. Based on the proximity of fences to known lek locations and fences present throughout sage-grouse habitat on terrain associated with high collision risk, sage-grouse would be expected to have collided with fences within the study areas. Of the four annual seasons (breeding, summer, fall migration, and winter),I expected that sage-grouse would be most likely to collide during the breeding season. Even though numerous surveys were conducted on leks that were active within a few hours of surveys, no collision evidence was identified.

Future research on fence collision rates in small sage-grouse populations should be conducted for several years until enough collisions are observed to calculate fence and topographic characteristics that may be influencing fence strikes. It would also be interesting to look at sage-grouse flight dynamics to determine if smaller populations show mechanical and/or visual differences, possibly due to heightened vigilance or other factors. Motion cameras placed on and around fences surrounding leks could provide interesting small-scale differences of sage-grouse behavior rather than temporal and environmental characteristics.

MANAGEMENT IMPLICATIONS

Despite finding zero grouse collisions, other avian and bat species were found to have collided with fences including species protected by other regulatory mechanisms such as the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. Therefore, reducing fence collisions leading to avian mortality should be considered a priority for land managers.

Other studies have shown that marking fences with reflective markers decreases collision (Baines and Andrew 2003, Stevens 2011). I suggest that marking fences to increase visibility would be beneficial to many species for which collision has been observed (birds, bats, deer, etc.). However, management for sage-grouse in small populations may be better focused on improving habitat and reducing other causes of mortality which may be more prevalent. So, it is my suggestion that where money is limited, fence marking should be a secondary priority as it may have less of an effect on mortality than the previously mentioned factors. Another suggested management action is the removal of unnecessary fences within sage-grouse habitat, or future installations that consist of “lay down” fences that are only vertical during the necessary portions of the year to allow for grazing management. This would instantly decrease fence densities and would remove extraneous raptor and raven perches from the landscape.

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TABLES AND FIGURES

Table 3-1. Number of sample plots by season, total length (km) in parentheses.

Site	UDWR Delineated Habitat Type			
	Brood-rearing	Winter[1]	Brood-rearing and Winter	Total
Hamlin Valley	25 (37.78)	-	35 (43.99)	60 (81.77)
Bald Hills	24 (37.45)	-	16 (18.0)	40 (55.45)
TOTAL	49 (75.23)		51 (61.99)	100 (137.22)

[1] No habitats were delineated as winter habitats without also being brood-rearing habitats, therefore no plots were in winter habitat alone

Table 3-2. Summary of brood-rearing, fall, winter, and lek greater sage-grouse collision surveys in Hamlin Valley and Bald Hills, Utah, USA.

Season	Timing[1]	Total number of times each plot was surveyed	Total kilometers of fence surveyed[2]	Observed Collisions
Brood-rearing	June - July (2011)	1	137.22	Two passerines and two raptors
Fall	September – October (2011)	1	137.22	Unknown species of bat
Winter	December – January (2011/2012)	1	61.99	No collisions observed
Lek	March – April (2012)	2	56.89 km (surveyed twice = 113.8)	No collisions observed

1 Brood-rearing, fall, and winter collision survey were conducted only once. Since surveys were conducted throughout all suitable habitat, quantity and variety were selected over repetition.

2 **Brood-rearing surveys** were conducted in brood-rearing habitats;

Fall surveys were conducted in both brood-rearing and winter habitats to account for possible migration between the two habitats and because all winter habitats overlap brood-rearing habitats. The survey plots were the same as used in the brood-rearing season.

Winter surveys were conducted only in designated winter habitats.

Lek surveys were conducted along all fences within 2 km of a lek.

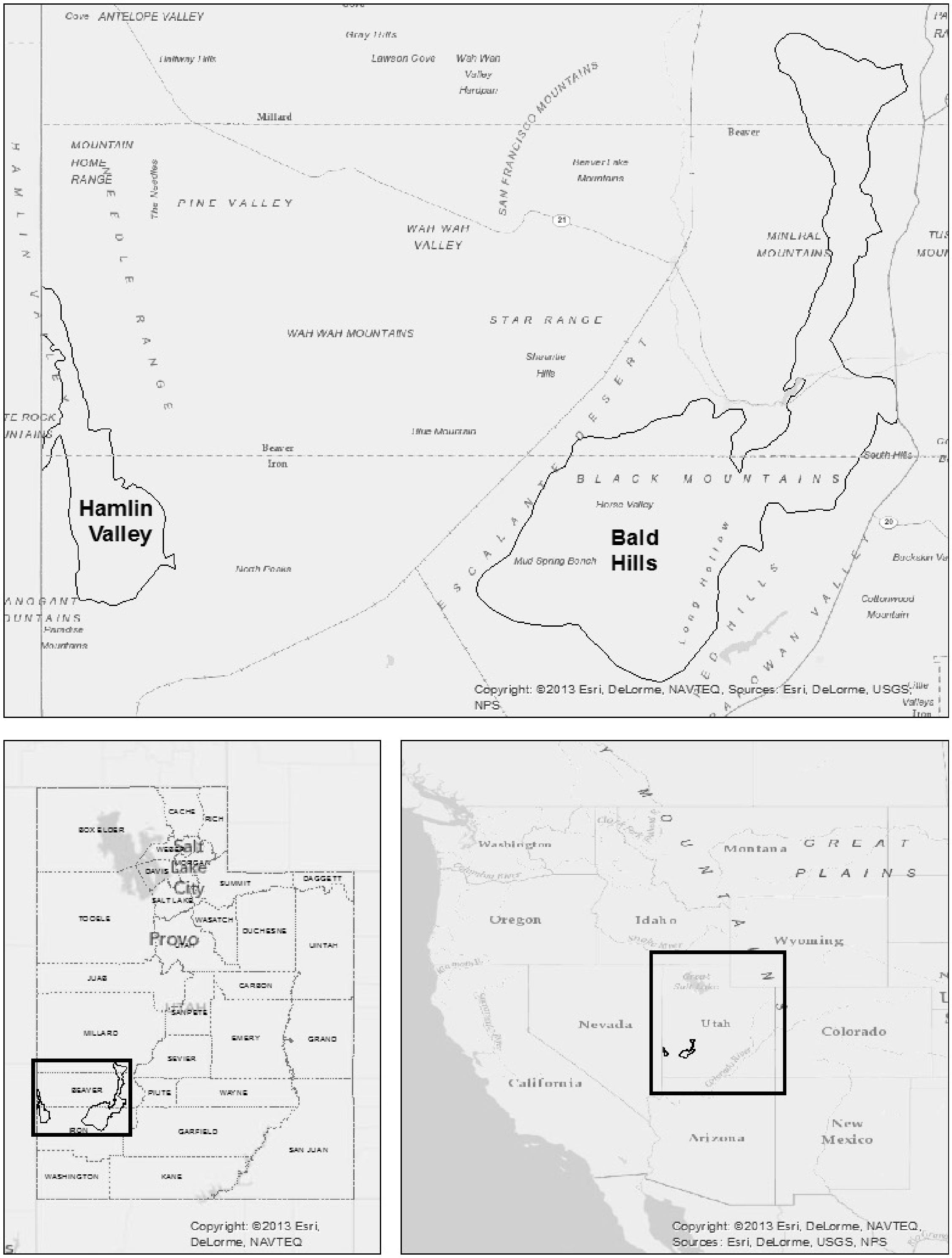
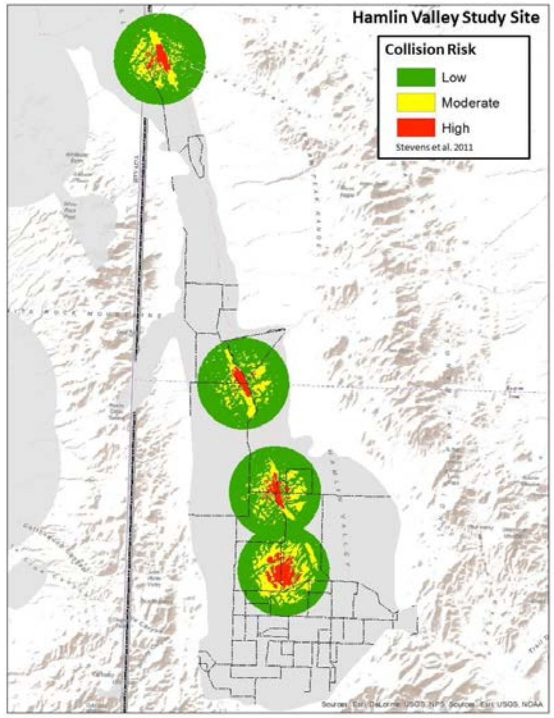


Figure 3-1. Greater sage-grouse fence collision survey study areas in Hamlin Valley and Bald Hills, Utah, USA



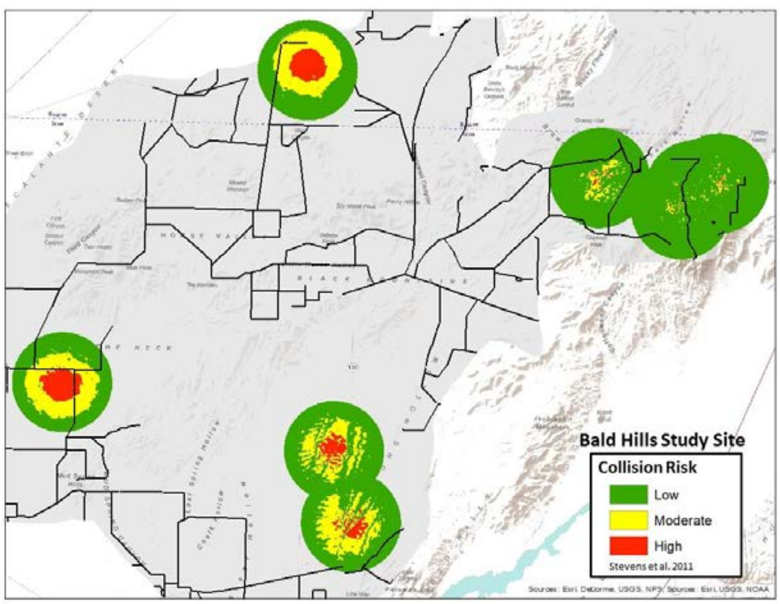


Figure 3-2. Greater sage-grouse fence collision models in Hamlin Valley and Bald Hills, Utah, USA.

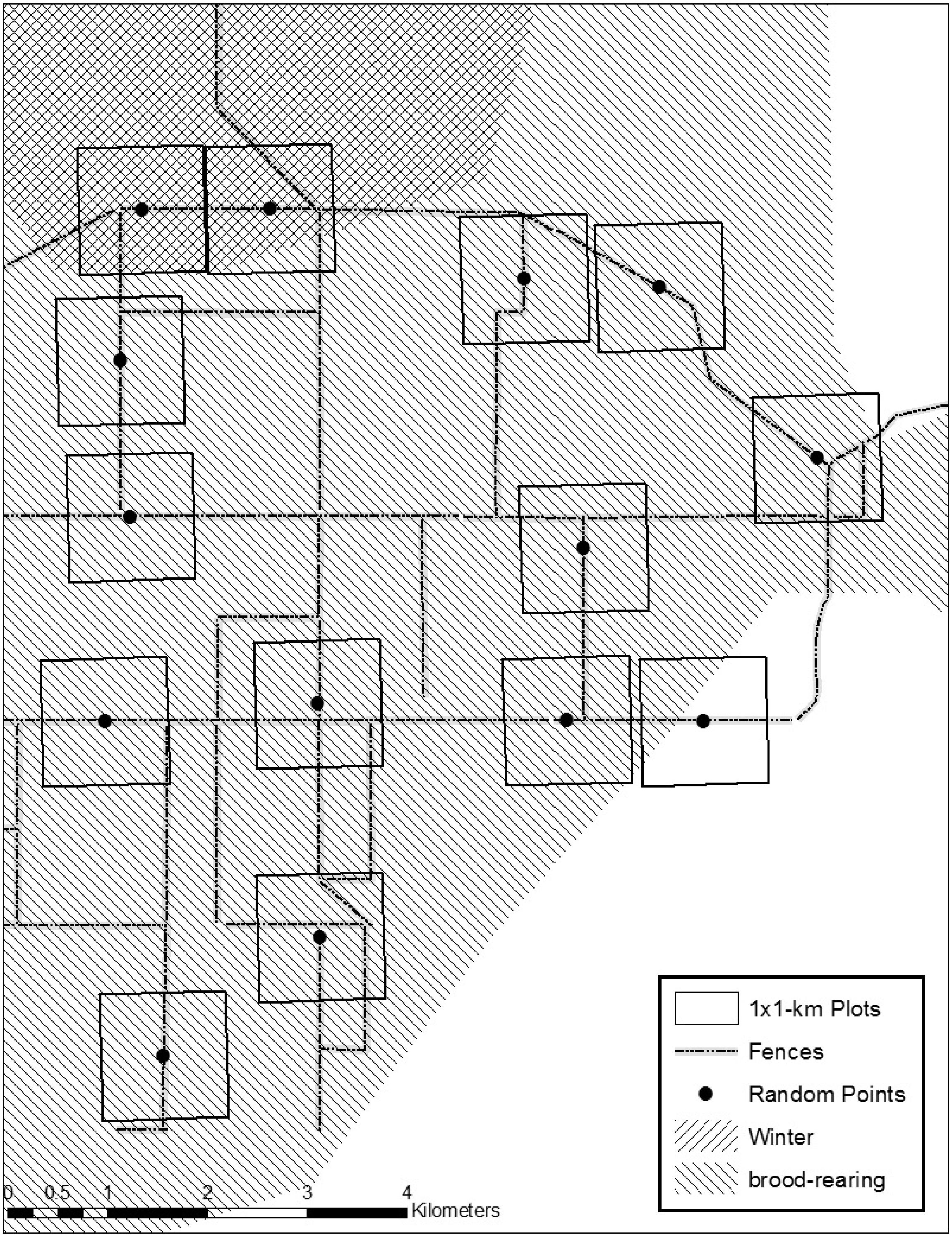


Figure 3-3. Greater sage-grouse winter and brood-rearing fence collision survey 1 km^2 sample plot design.

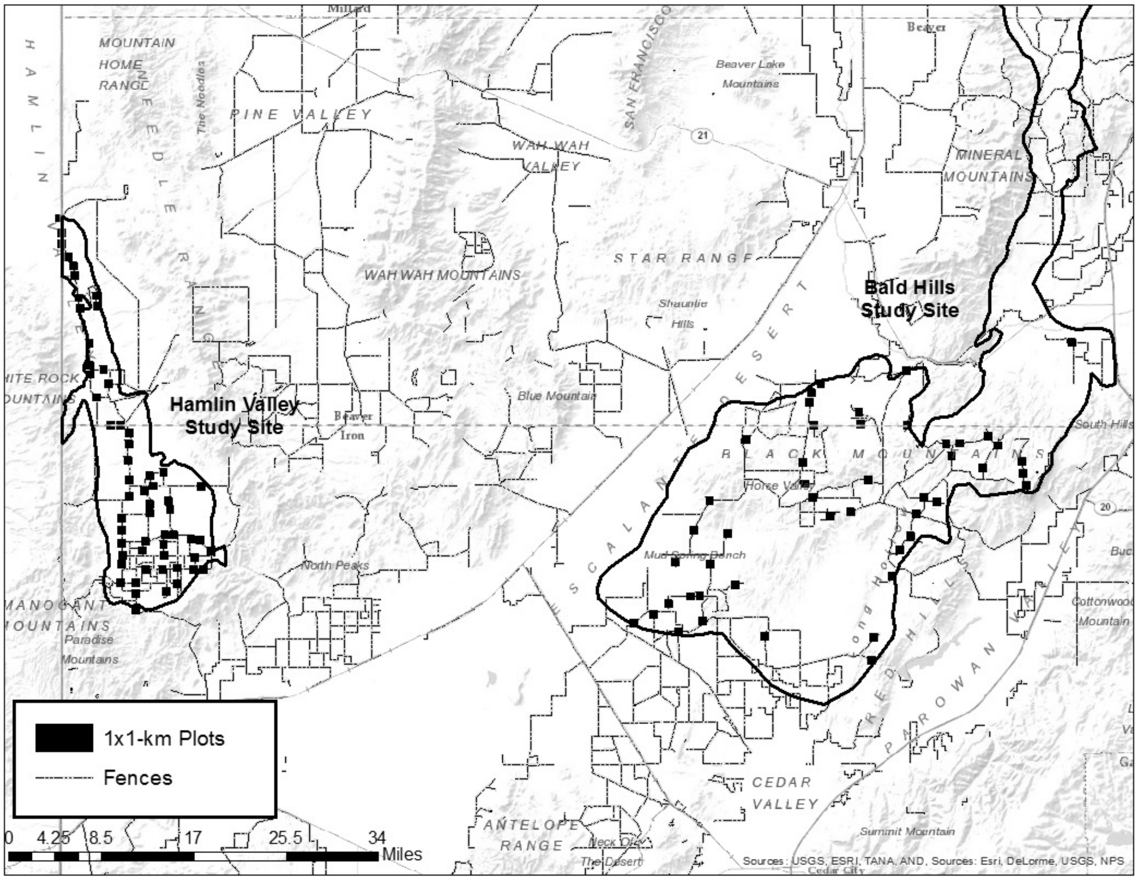


Figure 3-4. Greater sage-grouse fence collision survey sample plot locations in Hamlin Valley and Bald Hills, Utah, USA, 2011-2012.

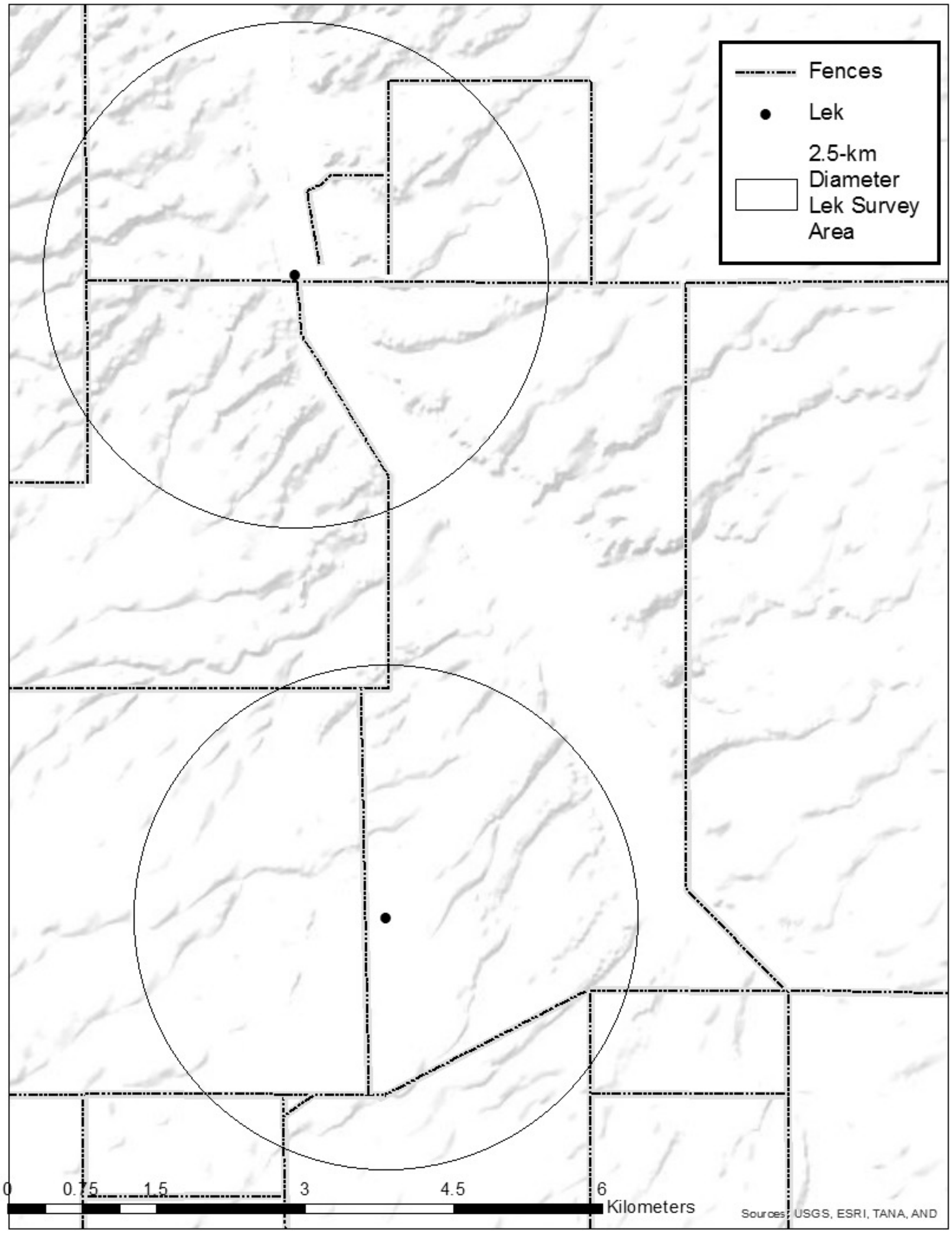


Figure 3-5. Greater sage-grouse lek collision survey sample plot design.

CHAPTER 4

CHARACTERISTICS OF FENCES IN SAGE-GROUSE HABITAT THAT FACILITATE INCREASED PERCHING BY AVIAN PREDATORS

ABSTRACT. Sage-grouse numbers have declined throughout the western US and are considered species of concern in most of the eleven states that are within their range. The primary cause of decline is associated with loss and fragmentation of their habitats. Introduction of infrastructure, such as fences in their habitat, can cause direct mortality via collision but may also indirectly influence productivity by increasing artificial perches for avian predators (e.g. golden eagles, red-tailed hawks, and common ravens). From March 2011 to September 2012, I collected and analyzed data on fence posts that were known to be used by avian predators. Regardless of fence type, post width (i.e. the perching surface) and height, terrain, density, and the placement of a fence within the edge of a habitat influenced the use of the fence by avian predators. Fences constructed with wood posts were more frequently used by avian predators when posts were wide, constructed in flatter terrain, and with increased density of surrounding vegetation. Perching on metal posts was increased along defined habitat edges or when other natural perches were limited. Results of this study suggest that managers should construct fences with widths equal to or less than 0.3 m to reduce opportunities for avian predator perching and care should be taken to maintain contiguous vegetation on either side of the posts while maintaining low shrub density.

INTRODUCTION

Sage-grouse numbers have declined rangewide since Euroamerican settlement and continue to decline approximately 6% each year (Connelly et al. 2004). The primary cause of decline was determined to be the present or threatened destruction, modification, or curtailment of habitat or range (USFWS 2010), including introduction of infrastructure into sagebrush habitats. One common type of infrastructure found throughout sage-grouse habitat is fences.

Currently, it is estimated that there are greater than 2 km/km^2 of fences in many occupied sage-grouse habitats (Connelly et al. 2004). Sage-grouse evolved with relatively few vertical obstructions within their landscapes and therefore may be ill-equipped to adapt as these features invade their habitats (Connelly et al. 2004). Effects from fences can include direct mortality, through collision risk, but also include indirect effects such as fragmentation of habitat and increasing perch sites for avian predators (Call and Maser 1985, Braun 1998, Connelly et al. 2000a, 2004, Beck et al. 2003, Knick et al. 2003).

Raptors and corvids are the primary avian predators of sage grouse adults, juveniles, and nests (Schroeder et al. 1999, Schroeder and Baydack 2001, Danvir 2002, Mezquida et al. 2006, Lockyer et al. 2013). In several grouse species, the perceived presence of avian predators has also been shown to have non-lethal effects such as affecting the productivity, nest-site selection, and parental behavior (Schroeder and Baydack 2001, Manzer and Hannon 2005, Coates and Delehanty 2010, Dinkins et al. 2012) which may be as great as or greater than the effects of direct predation (Creswell 2008). Avoiding avian predators may result in behavioral changes that make high quality sage-grouse habitat become functionally unavailable (Hartzler 1974, Ellis 1984, Knight et al. 1995, Connelly et al. 2000b, Manzer and Hannon 2005). The subsequent use of low-quality habitat could increase their exposure to olfactory driven mammalian predators (Schroeder and Baydack 2001, Conover et al. 2010). At the landscape level, sage-grouse have been shown to choose areas with less avian predators (Dinkins et al. 2012). The potential for raptors and corvids to limit other bird populations poses a need for wildlife managers to assess, and to every extent possible, limit factors which could increase avian predator accessibility to Greater sage-grouse.

Many species of diurnal raptors are known to prey on adult and juvenile sage-grouse, primarily the golden eagle (*Aquila chrysaetos*) (Schroeder et al. 1999, Schroeder and Baydack 2001, Danvir 2002, Mezquida et al. 2006), but to a lesser extent red-tailed hawk (*Buteo jamaicensis*), Swainson's hawk (*Buteo swainsoni*), ferruginous hawk (*Buteo regalis*), northern harrier (*Circus cyaneus*) (Hartzler 1974, Braun 1995, Schroeder et al. 1999, Schroeder and Baydack 2001, Rowland and Wisdom 2002). Adult male sage-grouse, in particular, are probably the most susceptible to predation while performing mating displays on the lek (Schroeder et al. 1999, Schroeder and Baydack 2001, Hagen 2011). In Utah, Danvir (2002) found 55% of all radio-marked sage-grouse in his study were killed by raptors.

The most common source of sage-grouse nest failure is predation, which accounts for 94% of nests lost (Moynahan et al. 2007) and can be a limiting factor in population growth (Nelson 1955, Wilcove 1985, Martin 1993a, b, Gregg et al. 1994, Schroeder and Baydack 2001). Corvids, especially the common raven (*Corvus corax*) (Coates et al. 2008), but also including the black-billed magpie (*Pica hudsonia*) (Holloran and Anderson 2003) are efficient nest predators of sage-grouse (Angelstam 1986, Marzluff and Balda 1992, Coates et al. 2008). Corvids were historically rare in sagebrush landscape, but have increased 300% in the western United States over the last 100 years mainly due to human developments (Boarman 1993, Luginbuhl et al. 2001, Sauer et al. 2011).

As a generalist predator that has adapted to human-altered habitats, corvids are of particular concern because they can dramatically reduce prey populations (Schneider 2001, Garrott 2003) and will continue to depredate bird nests even at low prey densities (Polis et al. 1997, Sinclair et al. 2008). Many studies have shown a positive correlation between corvid abundance in a given area and predation rates on open nesting birds (Angelstam 1986, Johnson et al. 1989, Andren 1992). The extent of this correlation poses a challenge for land managers to assess factors that could increase predation rates by this group of predators (Luginbuhl et al. 2001).

In a study by Manzer and Hannon (2005), successful nests were 8 times greater in landscapes with <3 corvids/km^2, and Coates and Delehanty (2010) found an increase in one raven per 10km was associated with a 26% increase in the odds of nest predation. High abundances of ravens may also reduce the amount of time spent off the nest by incubating female sage-grouse, compromising their ability to obtain sufficient nutrition (Coates 2007, Coates and Delehanty 2010). In a raven removal study Batterson and Morse (1948) removed ravens from one area and found a 32% increase in nest success rate versus the untreated area. Understanding the effects of raven abundance on sage-grouse nest predation in relation to habitat factors would aid management efforts designed to promote sage-grouse viability through habitat manipulation to reduce raven populations and the chance of ravens finding sage-grouse nests (Coates and Delehanty 2010).

Increased landscape fragmentation by man-made structures has been documented to enhance raptor and corvid foraging and predation efficiency because of the increased availability of perch and roost sites, particularly in low canopy areas (Braun 1998, Coates 2007, Bui et al. 2010). Ravens often roost in anthropogenic structures (e.g. fences) rather than trees or other natural substrate (Marzluff et al. 1996, Howe et al. 2014). Knight et al. (1995) found that ravens foraged near linear rights-of-ways (i.e. roads, powerlines, fences) and spent significant amounts of their time foraging directly on the linear-right-of-ways. It is anticipated that the effect of fences on sage-grouse populations is similar to that of powerlines (Braun 1998, Connelly et al. 2004).

Several studies have reported raptors and corvids hunting sage-grouse from overhead transmission lines and other manmade elevated perches, such as fences (Wakeley 1978, Ellis 1984, Lammers and Collopy 2007). Elevated perches provide increased visibility of the surrounding area, especially in sage-grouse habitats which are relatively free of natural tree perches (Sonerud 1992, Wolff et al. 1999, Paton 2002, Leyhe and Ritchison 2004, APLIC 2006). Paton (2002) and Wolff et al. (1999) showed that hens will avoid nesting near perch sites that could easily be used by avian predators. Manzer and Hannon (2005) showed that the best single scale model to predict nest success was the interaction between proximity of perch site and amount of vegetation concealment, particularly for perch distances greater than 75m from nest sites. Leu et al. (2008) and Bui et al. (2010) suggest that removal of anthropogenic features, such as fences, may be an important consideration on reducing the presence of predators in sage-grouse habitat.

Biological, topographical, and fence design factors can influence collision related probabilities for grouse on local scales (Stevens et al. 2012a, b). However, it is difficult to determine population level effects in Utah and across the range because there is a lack demographic data to determine whether populations can compensate for mortality via increased productivity, data on proportional mortality of male and female grouse, and data on fence location and density. Further information is needed to verify that sage-grouse avoid fences due to perceived predation risk and to evaluate the impacts on sage-grouse survival and reproduction.

The goal for this study was to relate avian predator use of posts to fence construction design. I had two objectives in this study: 1) to identify fence construction characteristics that are associated with avian predator use, and 2) to quantify the suite of fence characteristics and how typical combinations of those characteristics relate to avian predator use. I hypothesized that wooden fence posts were likely perched upon more than steel t-posts, because of the larger surface area. This information will be useful for managers seeking to reduce the effects of fences on sage-grouse by constructing fences that are less attractive to corvids, or modifying existing fences.

STUDY AREA

This study took place in southwestern Utah, in Hamlin Valley and Bald Hills, which included two separate populations of greater sage-grouse (Fig. 4-1; UDWR 2013). Both populations are located in Beaver and Iron Counties, within the Bureau of Land

Management's Cedar City Field Office. Both the Bald Hills and Hamlin Valley populations were located at the southern edge of the greater sage-grouse range (Schroeder et al. 2004). I used the Utah Division of Wildlife Resource's (UDWR) sage-grouse brood-rearing and winter habitat designation for the seasonal habitat designations (UDWR 2009).

The Bald Hills study area was located near Minersville, Utah. Elevation ranged from 1550 to 2400 meters. The average high was 21.9 ° C, occurring in July. The average low was -1.8° C occurring in January with approximately 83-180 (average of 128.3) frost free days per year. The Bald Hills area received 32 -34 cm of precipitation per year. Cattle and sheep grazing were common in the spring and summer; and a portion of the study site consisted of crop agriculture, primarily alfalfa and corn. There were 576.624 km (0.357 km/km^2) of fences in sage-grouse habitat (Fig. 4-2). Portions of the site had been re-seeded following a wildfire that occurred in July 2007. Due to fires, the northeast portion of the study area had been re-seeded with native and non-native mixes of perennial shrubs, forbs, and grasses. Sagebrush species present included black sagebrush (*Artemesia nova*) on ridges and Wyoming sagebrush (*A. tridentata wyomingensis*) in the bottoms.

The Hamlin Valley study area was a large contiguous tract of land (approximately 319 km^2 of sage-grouse habitat) located approximately 17 km north of Modena, Utah. Elevation ranged from 2000-2200 m. Average high occurred in August and was 24.6° C. Average lows were -0.9° C, occurring in January with approximately 74-153 (average of 119.5) frost free days per year. Hamlin Valley received 22-41 cm of precipitation per year. Cattle grazing was the primary activity occurring in the valley with occasional operation of a single agricultural circle crop of alfalfa that was operated in the extreme southern end of the valley. There were 211.32 km (0.662 km/km^2) of fences in sage-grouse habitat (Fig. 4-2). The vegetation communities were predominantly sagebrush dominated rangeland surrounded by encroaching pinyon-juniper, with smaller areas of aspen, mixed conifer, and mountain shrub.

Both study areas totaled approximately 1,932 km^2 of sage-grouse habitat. In total there were 787.9–km and 0.41–km/km^2 of fences across both study areas. Common avian predators present in both study areas included common raven, magpie, red-tailed hawk, ferruginous hawk, northern harrier, golden eagle, American kestrel (*Falco sparverius*), prairie falcon (*F. mexicanus*), great horned owl (*Bubo virginianis*), short-eared owl (*Asio flammeus*), and burrowing owl (*Athene cunicularia*).

METHODS

Avian Predator Use of Fence Posts

To determine the amount of avian predator usage of fences within Hamlin Valley and Bald Hills, I used the survey plots delineated for the collision survey (see Chapter 3). Using a shapefile of all known fences (provided by the Bureau of Land Management Cedar City Field Office) in the Bald Hills and Hamlin Valley study sites, I selected 100 random points along fences within sage-grouse habitats (Fig. 4-2). Using each selected random point as the centerpoint, I constructed 100 1 km^2 plots (i.e. sample plot) using ArcGIS (Fig. 4-3). Points were precluded from being closer than 2 km from another point so that plots did not overlap. The study was focused in Hamlin Valley; however, I combined it with Bald Hills to increase the sample size and diversity of fences. After the initial visit to all sites, I removed 4 plots (2 in each study area) because ground truthing revealed that wildfires in 2011 and 2012 had eliminated sage-grouse habitat and destroyed fences, thus removing the potential for detecting perching events. The final sample size was 96 (Hamlin Valley n = 58, Bald Hills =38).

All fences within the 96 1-km^2 plots were surveyed for sign of perching. A survey consisted of one surveyor walking the fence and searching for evidence of raptor/corvid perching at each fence post located within the plot and within 5 m either side of the fence. Evidence included whitewash on fence posts, feathers, observation of bird on post, raptor casts, and presence of bones at base of post. Because surveyors could not distinguish raptor/corvid whitewash from that of passerines, only fence posts where a combination of whitewash and bones, whitewash and raptor/corvid feathers, observation of raptor/corvid perching on post, or whitewash and raptor casts were found were quantified as a post used as an avian predator perch.

Perch Characteristics

To assess the factors influencing avian predators to perch on fence posts, I assessed third-order (e.g. local scale habitat conditions, fence post construction design) selection characteristics of avian predators. I focused on third-order selection characteristics assuming that avian predators had already selected the area because it was within their geographic (i.e. first-order) and home (i.e. second-order) ranges (Johnson 1980) and are now selecting specific areas for perching to hunt or scavenge. I used ArcGIS, to randomly select 325 of the known perching sites using the Create Random Points tool (Fig. 4-4 and Fig. 4-5). I selected the number of points in each study area based on the proportion of plots in each study area (60% Hamlin Valley, 40% Bald Hills). For each known perching site, I also sampled a random unused fence posts to assess the significance of the parameters measured at the use sites. I randomly generated one point for each of the 325 fence posts where avian predator use had occurred using ArcGIS. Random points were generated using the GIS fence shapefile layer, in the same plots that were surveyed for presence, and precluded from being closer than 5 m (representative of a typical span between two posts) from known used perches.

Surveyors returned to the randomly selected used and unused perches in August 2012 to measure all site level factors. I recorded general information about all selected fence posts including: date, site (Hamlin Valley or Bald Hills), habitat classification (shrub/scrub, grassland/herbaceous, evergreen forest, altered/disturbed), UTM coordinates, slope (GIS calculated), and elevation.

I selected the following possible fence and pole factors to measure: color of pole (wood, red, or green), pole material (wood or steel), whether the pole had a white cap (metal t-posts only), direction of fence (north-south, northwest-southeast, northeast-southwest), distance of the spans between fence posts (measured to the nearest m), width, height, and length of pole (measured to the nearest cm), and the degree that the pole was leaning. The height of the pole from the ground and length of the pole were measured to the nearest cm and were used to calculate the degree of lean using the following equation, where θ is the degree of lean:

$$\cos^{-1}\theta = \frac{\text{height of pole from ground}}{\text{total length of pole}}$$

I was also interested in determining the local vegetation and habitat characteristics that avian predators were using at a 10 m^2 size, representative of the typical span between poles. I measured distance to nearest tree (natural perching substrate), water source, and road using a rangefinder (Bushnell, Overland Park, KS) and calculated to the nearest meter. Two 5 m transects were extended within the plane of the fence (i.e. longitudinally) in opposite directions from the pole and two 5 m transects were extended in opposite directions perpendicular to the fence plane (i.e. laterally; Fig. 4-7). I measured distance (m) and height (cm) of nearest shrub in all 4 directions and counted all shrubs within the 10 m^2 plot to determine density. I assessed whether the fence created an edge effect or that the fence defined boundaries of two different habitats.

Data Analysis

I assessed the relationship between fence post structure and habitat characteristics and use of the post by an avian predator of sage-grouse. The response variable for all analyses was a binomial code based on whether a fence post was used by an avian predator, identified by signs of whitewash on fence posts, feathers, observation of bird on fence post, raptor casts, and/or presence of bones at base of fence post. I conducted all modeling within an information-theoretic model selection framework (Burnham and Anderson 2002) and performed all statistical tests using a generalized linear model framework in R (R Core Team 2016). I tested the null hypothesis that the structural attributes of fence construction and the habitat and vegetation characteristics surrounding the fences did not impact avian predator use. The structural, landscape, and topographic variables described above represented the predictor variables included in the analysis.

I used a multi-step analysis approach to relate fence post and habitat characteristics to perch use by avian predators. First, I screened all 21 individual post and habitat characteristics using single-variable logistic regression (Table 4-1). I screened the covariates for correlation, and eliminated covariates that were highly correlated or were ecologically redundant measures. Next, I constructed perch use models, carrying forward only 14 a priori hypothesized local-scale habitat and post characteristic variables that were significant at the $p \leq 0.15$ a baseline that indicated the variable is potentially influencing use from the single-variable modeling in the first step. I ranked the resulting models using Akaike's Information Criterion corrected for small sample sizes (AICc) to determine the best fitting and most parsimonious predictive model (Anderson 2008).

I used normalized Akaike model weights as a measure of strength of evidence for a given model and generated model averages to evaluate the relative importance of fence and habitat characteristics to account for uncertainty in the model selection procedures (Burnham and Anderson 2002). The model sets were large and multiple models had negligible differences in AICc scores, indicating that there might not be one single best model (Grueber et al. 2011). I used the suite of models that were within six units of the AICc score of the "top performing" model because the most parsimonious model may be missed otherwise (Richards 2008). I conducted the model averaging analyses using the model.avg function in the MuMIn package in R (Barton 2016) to account for uncertainty and obtain robust parameter estimates by calculating a weighted average of parameter estimates. Finally, I grouped the data by fence construction type to determine the interaction of these variables with either wood or metal fence posts and repeated the methods described above for each fence construction type individually.

RESULTS

From June 2011 – August 2011, I surveyed 124 km of fences and observed 1,179 posts used by avian predators out of approximately 17,000 posts that were surveyed (10 posts used per km; 6.9% total use). From June 2012- August 2012 I recorded parameters of use at 325 (27.6% of used posts) randomly selected used posts with 325 randomly paired posts that were not used.

The single-variable modeling (resulting from logistic regression) indicated that fence perching was positively influenced by pole material, distance to existing perches on the landscape (as indicated by nearest tree), height and width of fence post, shorter fence spans, average shrub density, flatter terrain, fences constructed along habitat edges, and shorter distances to roads and water sources (coefficient estimate $P < 0.05$, Table 4-2).

I combined thirteen variables identified as significant at the $p \leq 0.15$ level (Table 4-2) into 8,192 multiple variable models to determine which suite of factors best explained the likelihood of perching. The best multiple variable model included distance to nearest natural perch, pole height and width, whether the fence was classified as defining the edge of vegetation, flat terrain, and average shrub height and density. However, nine other models have AICc values within two units of the best model, and 216 models had AICc values within six units of the best model and can therefore be considered good explanations for the data (Table 4-3). As a result of model averaging pole width, distance to natural perches, shrub density, and fences on habitat edges were the covariates whose 95% confidence intervals did not include zero (Table 4-6). Pole width and shrub dnsity were included in all 217 models.

Metal Posts

For metal fence construction, the single-variable modeling indicated that perching on metal fence posts increased with greater distance to existing natural perches (i.e. trees), closer distances to water sources, and whether the fence was classified as defining and edge (coefficient estimate $p < 0.05$, Table 4-2).

I evaluated 32 multiple variable models of the attributes that were identified as potentially influencing use in the single-variable modeling, including all combinations of five fence post characteristics ($p \leq 0.15$, Table 4-2). The best multiple-variable model included pole width, fences that defined edge, and distance to nearest natural perch (Table 4-4). However, three other models have AICc values within two units of the best model, and 13 models had AICc values within six units of the best model and can therefore be considered good explanations for the data (Table 4-4). As a result of model averaging, distance to perch was included in all 14 of the top models and fences that defined edges were the only covariates whose 95% confidence intervals did not include zero (Table 4-7). Other covariates appeared in less than half of the top 13 models or had 95% confidence intervals on their estimates included zero (Table 4-7).

Wood Posts

Single-variable modeling indicated that perching on wooden fence posts increased with top width of post, flatter terrain, and average shrub density (coefficient estimate $p < 0.05$, Table 4-2).

I evaluated 512 multiple variable models of the attributes that were identified as potentially influencing use in the single-variable modeling, including all combinations of nine fence post characteristics, ($p \leq 0.15$, Table 4-2). The best multiple-variable model included pole width and poles that were not leaning, density of shrubs along fence, flatter terrain, and fences constructed along two track roads (Table 4-5). However, 13 other models have AICc values within two units of the best model, and 89 models had AICc values within six units of the best model and can therefore be considered good explanations for the data (Table 4-5). Pole width and shrub density were included in all 90 of the top models and were the only covariates whose 95% confidence intervals did not include zero (Table 4-8). Other covariates appeared in less than half of the top 90 models or had 95% confidence intervals on their estimates included zero (Table 4-8).

DISCUSSION

The different analysis approaches employed in this study provided different insights into the suite of fence characteristics influencing use of fence posts by avian predators of sage-grouse in southwestern Utah. The single- and multiple- variable modeling highlighted a few characteristics that were associated with more frequent avian predator use. The comparison of use across typical fence construction substrate (i.e. wood and metal posts) provided additional insight into the combinations of fence characteristics associated with differing levels of use.

Under the current land management uses applicable throughout sage-grouse habitat, fences are a necessary part of the landscape. Meeting the needs of constructing or maintaining fences must be met with an equal effort to reduce their negative effects on sage-grouse and other wildlife. A pattern emerged in this study about the variables that best predicted avian predator use of fence posts. Although increasing fence post widths, density of the surrounding shrubs, distance to nearest perches, and ultimately the type of fence (i.e. wood or metal t-posts) and flatter terrain were the most obvious features associated with increased use of fences by avian predators, the suite of characteristics derived in the multiple-variable modeling indicate that many factors may be ecologically important to an avian predator when selecting posts to perch.

Results of single-variable modeling suggest that overall, avian predators show preferential use of wooden posts ($p<0.001$), however, results of model averaging showed that the fence post material parameter was of low relative importance and had 95% confidence intervals that overlapped zero. Model averaging indicated that fence post width was a relatively strong predictor of use overall. Therefore, because greater average top of pole widths is associated with wood posts, it is likely that the width is the main driver.

Similarly to results from all poles, I found that on fences constructed with wood, perching was influenced by pole width, but also increased with denser shrubs within 2m of the fence. However, this may be more attributed to the age of the fence as fences that have been on the landscape longer will have had time to revegetate after construction (and thus will have denser surrounding habitat) and may show more avian predator use of the wood posts.

I found that when metal posts were used, habitat edges and distance to nearest natural perching substrate influenced perch use. Others (Coates et al. 2014, Howe et al. 2014) demonstrated that ravens preferentially constructed nests with reduced distance to edge which is likely related to my data that fence posts on edges received more use than posts that were not identified with edge. Increased edge can be associated with fragmented landscapes and in this study area, most likely indicate areas where pastures are receiving different amounts of cattle use. Both landscape fragmentation (Vander Haegan et al. 2002, Howe et al. 2014) and cattle (Coates et al. 2016) are known to increase raven occurrence. The increased fragmentation may indirectly influence raven use by providing less visual obstruction and an increase in prey detectability whereas cattle increase food subsidies. As ravens are the most frequent nest predator of sage-grouse (Lockyer et al. 2013), providing perches that may aid ravens in sage-grouse nest depredation is particularly concerning.

MANAGEMENT IMPLICATIONS

In conclusion, natural vertical structures are rare in sage-grouse habitats, therefore perching substrate for avian predators is limited. Construction of fences in these habitats can indirectly increase available perching structures for raptors and corvids (Braun 1998, Oyler-McCance et al. 2001, Connelly et al. 2004) which may increase predation rate on sage-grouse and depredation of nests. In small, fragmented populations, like Hamlin Valley and Bald Hills, managing predator behavior may be as important as habitat management (Schroeder and Baydack 2001).

These findings can inform interested parties of specific fence construction characteristics that are more or less prone to be used by avian predators in sage-grouse habitat. It may be possible to decrease use of fence posts with pre-construction design, such as choosing posts short posts with small widths. It may also be possible to decrease use of fence posts by controlling habitat by thinning sagebrush density and height in the immediate vicinity of the fence and homogenizing habitat on both sides of the fence, rather than allowing for an edge effect. Distance to nearest natural perch was also significant, but likely cannot be controlled for, however, by emphasizing individual fence posts with characteristics that are perched upon less when constructing in those environments, one could reduce overall perching events. When decreasing use of fences as avian predator perches is of interest, I suggest that managers use these findings to inform their decisions about construction materials and habitat manipulation. I recommend that new fences be constructed to minimize top width and at the minimum height necessary to meet the purpose of the fence. I also recommend that where possible, fences do not emphasize an abrupt change in habitat structure (i.e. edge effect) and that shrubs in the immediate vicinity of the fence be maintained at a lower density.

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TABLES AND FIGURES

Table 4-1. Fence and habitat characteristics measured at fence posts used by avian predators with randomly paired unused posts within sage-grouse habitat in southwestern Utah, USA.

Code	Description	All Posts		Metal Posts		Wood Posts	
		Mean	SD	Mean	SD	Mean	SD
l.lnperchDIST	Log of Perch Distance	5.45	2.00	5.20	2.03	5.52	1.98
n.waterDIST	Distance to Water Source (in meters)	1427.12	1649.16	2149.99	2579.53	1193.55	1111.62
c.colorCODE	Pole Color Code (0=red, 1=green)	--	--	--	--	N/A	N/A
c.capCODE	White Cap Code (0=no, 1=yes)	--	--	--	--	N/A	N/A
c.materialCODE	Pole Material Code (0=steel, 1=wood)	--	--	N/A	N/A	N/A	N/A
n.poleHT	Pole Height (in meters)	1.64	0.35	1.30	0.12	1.75	0.33
n.poleWDTH	Pole Width (in meters)	0.06	0.03	0.03	0.01	0.07	0.03
n.angle	Pole angle (out from 90 degrees)	3.79	8.08	1.82	4.88	4.43	8.78
n.span	Average Span (in meters)	4.77	1.37	5.27	1.47	4.61	1.30
n.slope	Slope (GIS Calculated)	2.20	2.25	2.95	3.30	1.96	1.73
c.roadCODE	Road Code (0=two track and below, 1=major hwy/dirt)	--	--	--	--	--	--
n.roadDIST	Distance to Road (in meters)	270.15	672.64	384.83	1233.51	233.10	322.17
c.directionCODE	Fence Direction Code (0=E, 1=NorNW)	--	--	--	--	--	--
c.edgeCODE	Edge Code (0=no, 1=yes)	--	--	--	--	--	--
n.shrubDENS	Average Density of Shrubs (shrubs per sq meter)	0.69	0.42	0.54	0.43	0.74	0.41
n.shrubDIS	Average Distance to Shrubs (in meters)	0.78	0.74	1.01	0.86	0.71	0.68
n.shrubHT	Average Shrub Height (in meters)	0.60	0.39	0.54	0.38	0.62	0.40
n.shrubDISTLAT	Shrub Lateral Distance Average (in meters)	0.66	0.67	0.82	0.75	0.61	0.64
n.shrubHTLAT	Shrub Lateral Height Average (in meters)	0.58	0.40	0.51	0.36	0.60	0.41
n.shrubDISTLONG	Shrub Longitudinal Distance Average (in meters)	0.86	0.94	1.11	1.04	0.79	0.89
n.shrubHTLONG	Shrub Longitudinal Height Average (in meters)	0.62	0.39	0.58	0.57	0.63	0.33

Table 4-2. Single-variable model results relating post attributes to avian predator use of fence posts across all construction types (n= 650), wooden posts (n=490), and metal posts only (n=160) in Southwestern Utah. Estimates of effects shown are the coefficient (β), standard error of the coefficient (SE), and probability that the coefficient is equal to zero (P). The response variable is use (where 1= used, 0 = not used).

Variable	All Posts			Metal Posts			Wood Posts		
	β	S.E	P	β	S.E	P	β	S.E	P
y ~ 1 + l.lnperchDIST	0.14	0.04	<0.01	0.32	0.09	<0.001	0.09	0.05	0.06
y ~ 1 + n.waterDIST	<0.01	<0.01	0.02	<0.01	<0.01	0.04	<0.01	<0.01	>0.15
y ~ 1 + c.colorCODE[1]	0.40	0.39	>0.15	0.40	0.39	>0.15	N/A	N/A	N/A
y ~ 1 + c.materialCODE	0.86	0.19	<0.001	N/A	N/A	N/A	N/A	N/A	N/A
y ~ 1 + n.poleHT	0.59	0.23	0.01	-1.58	1.50	>0.15	0.08	0.28	>0.15
y ~ 1 + n.poleWDTH	14.92	2.83	<0.001	-59.24	32.43	0.07	12.21	3.31	<0.00
y ~ 1 + c.angleCODE	-0.34	0.19	0.07	0.11	0.48	0.82	-0.56	0.21	<0.01
y ~ 1 + n.span	-0.12	0.06	0.04	0.05	0.12	>0.15	-0.11	0.07	0.11
y ~ 1 + n.slope	-0.14	0.04	<0.001	-0.11	0.07	0.09	-0.11	0.05	0.04
y ~ 1 + c.roadCODE	0.16	0.16	>0.15	-0.14	0.35	>0.15	0.30	0.19	0.12
y ~ 1 + n.roadDIST	<0.01	<0.00	0.03	<0.01	<0.001	>0.15	<0.01	<0.01	0.13
y ~ 1 + c.edgeCODE	0.41	0.18	0.02	0.93	0.36	0.01	0.34	0.22	0.12
y ~ 1 + n.shrubDENS	0.64	0.19	<0.001	0.09	0.39	>0.15	0.65	0.23	<0.01
y ~ 1 + n.shrubDIS	-0.19	0.11	0.09	-0.09	0.21	>0.15	-0.12	0.14	>0.15
y ~ 1 + n.shrubHT	-0.32	0.22	0.14	-0.86	0.67	>0.15	-0.35	0.25	>0.15

[1] Post color variable applies only to metal t-post construction, therefore were not included when post types were mixed or for wooden posts only

Table 4-3. Model selection results for the top ten multiple-variable models relating fence construction characteristics for all post types to avian predator perching events in southwestern Utah, USA. All combinations of 13 construction and habitat characteristics identified as potentially related to perching events in the single-variable modeling were included in this model selection analysis (n = 8,192 models).

Rank	Formula	AICc	AICcWt	ΔAICc
1	y ~ 1 + n.poleHT + c.edgeCODE + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS	796.62	0.02	
2	y ~ 1 + n.poleHT + c.edgeCODE + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS + c.angleCODE	796.76	0.02	0.14
3	y ~ 1 + n.poleHT + c.edgeCODE + n.span + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS	798.21	0.01	1.59
4	y ~ 1 + n.poleHT + c.edgeCODE + n.span + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS + c.angleCODE	798.29	0.01	1.67
5	y ~ 1 + n.poleHT + c.edgeCODE + n.roadDIST + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS	798.31	0.01	1.69
6	y ~ 1 + n.poleHT + c.edgeCODE + n.roadDIST + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS + c.angleCODE	798.42	0.01	1.80
7	y ~ 1 + c.edgeCODE + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS	798.56	0.01	1.94
8	y ~ 1 + n.poleHT + n.waterDIST + c.edgeCODE + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS	798.58	0.01	1.96
9	y ~ 1 + n.poleHT + c.edgeCODE + n.shrubDIS + n.shrubHT + l.lnperchDIST + n.poleWDTH + n.slope + n.shrubDENS	798.60	0.01	1.98
10	y ~ 1 + n.poleHT + c.edgeCODE + n.shrubHT + l.lnperchDIST + c.materialCODE + n.poleWDTH + n.slope + n.shrubDENS	798.60	0.01	1.98

Table 4-4. Model selection results for the top ten multiple-variable models relating fence construction characteristics with metal posts to avian predator perching events in southwestern Utah, USA. All combinations of 5 construction and habitat characteristics identified as potentially related to perching events in the single-variable modeling were included in this model selection analysis (n = 32 models).

Rank	Formula	AICc	AICcWt	ΔAICc
1	y ~ 1 + c.edgeCODE + n.poleWDTH + l.lnperchDIST	189.96	0.23	
2	y ~ 1 + c.edgeCODE + l.lnperchDIST	190.21	0.20	0.26
3	y ~ 1 + c.edgeCODE + n.poleWDTH + n.slope + l.lnperchDIST	191.85	0.09	1.89
4	y ~ 1 + c.edgeCODE + n.waterDIST + n.poleWDTH + l.lnperchDIST	191.96	0.09	2.00
5	y ~ 1 + c.edgeCODE + n.waterDIST + l.lnperchDIST	192.07	0.08	2.12
6	y ~ 1 + c.edgeCODE + n.slope + l.lnperchDIST	192.11	0.08	2.16
7	y ~ 1 + c.edgeCODE + n.waterDIST + n.poleWDTH + n.slope + l.lnperchDIST	193.85	0.03	3.89
8	y ~ 1 + n.poleWDTH + l.lnperchDIST	193.85	0.03	3.90
9	y ~ 1 + c.edgeCODE + n.waterDIST + n.slope + l.lnperchDIST	193.97	0.03	4.02
10	y ~ 1 + l.lnperchDIST	194.05	0.03	4.09

Table 4-5. Model selection results for the top five multiple-variable models relating fence construction characteristics with wood posts to avian predator perching events in southwestern Utah, USA. All combinations of 9 construction and habitat characteristics identified as potentially related to perching events in the single-variable modeling were included in this model selection analysis (n = 512 models).

Rank	Formula	AICc	AICcWt	ΔAICc
1	y ~ 1 + n.slope + c.angleCODE + c.roadCODE + n.poleWDTH + n.shrubDENS	645.87	0.04	
2	y ~ 1 + n.slope + c.angleCODE + c.edgeCODE + n.poleWDTH + n.shrubDENS	646.26	0.04	0.39
3	y ~ 1 + n.slope + l.lnperchDIST + c.angleCODE + c.edgeCODE + n.poleWDTH + n.shrubDENS	646.30	0.04	0.44
4	y ~ 1 + n.slope + l.lnperchDIST + c.angleCODE + c.roadCODE + n.poleWDTH + n.shrubDENS	646.43	0.03	0.57
5	y ~ 1 + n.slope + c.angleCODE + n.poleWDTH + n.shrubDENS	646.52	0.03	0.66
6	y ~ 1 + n.slope + l.lnperchDIST + c.angleCODE + n.poleWDTH + n.shrubDENS	646.78	0.03	0.92
7	y ~ 1 + n.slope + c.angleCODE + c.roadCODE + n.roadDIST + n.poleWDTH + n.shrubDENS	646.90	0.03	1.04
8	y ~ 1 + n.slope + c.angleCODE + c.roadCODE + c.edgeCODE + n.poleWDTH + n.shrubDENS	646.91	0.03	1.05
9	y ~ 1 + n.slope + c.angleCODE + n.roadDIST + n.poleWDTH + n.shrubDENS	647.10	0.02	1.23
10	y ~ 1 + n.slope + c.angleCODE + n.span + c.roadCODE + n.poleWDTH + n.shrubDENS	647.21	0.02	1.34

Table 4-6. Model-average estimates of coefficients based on the best 217 models using all posts. No. models is the number of models (out of the top 217) including that parameter. Estimates of effects shown are the coefficient (β), unconditional standard error of the coefficient (SE), confidence interval, and relative importance.

Variable	β	Unconditional SE	Confidence interval	No. Models	Relative Importance
n.poleWDTH	3.42	0.71	(2.03, 4.81)	217	1.00
n.shrubDENS	0.16	0.05	(0.05, 0.26)	217	1.00
c.edgeCODE	0.11	0.05	(0.02, 0.21)	211	0.98
l.lnperchDIST	0.02	0.01	(0, 0.04)	168	0.86
n.shrubHT	-0.07	0.05	(-0.17, 0.03)	177	0.83
n.slope	-0.02	0.01	(-0.04, 0)	171	0.78
n.poleHT	0.11	0.06	(-0.01, 0.22)	139	0.7
c.angleCODE	0.06	0.05	(-0.15, 0.03)	105	0.47
n.shrubDIS	0.01	0.03	(-0.05, 0.07)	92	0.34
c.materialCODE	0.04	0.07	(-0.1, 0.19)	75	0.28
n.span	0.01	0.02	(-0.02, 0.04)	72	0.25
n.roadDIST	<0	<0.001	(<0, >0)	77	0.25
n.waterDIST	<0	<0.001	(<0, >0)	57	0.19

Table 4-7. Model-average estimates of coefficients based on the best 14 models using metal posts . No. models is the number of models (out of the top 14) including that parameter. Estimates of effects shown are the coefficient (β), unconditional standard error of the coefficient (SE), confidence interval, and relative importance.

Variable	β	Unconditional SE	Confidence interval	No. Models	Relative Importance
l.lnperchDIST	0.06	0.02	(0.02, 0.1)	14	1.00
c.edgeCODE	0.19	0.08	(0.04, 0.35)	8	0.88
n.poleWDTH	-9.57	6.54	(-22.39, 3.24)	7	0.51
n.waterDIST	<-0.01	8.95E-06	(<0, >0)	6	0.26
n.slope	<-0.01	6.26E-03	(-0.03, 0.02)	6	0.25

Table 4-8. Model-average estimates of coefficients based on the best 90 models using wood posts. No. models is the number of models (out of the top 90) including that parameter. Estimates of effects shown are the coefficient (β), unconditional standard error of the coefficient (SE), confidence interval, and relative importance.

Variable	β	Unconditional SE	Confidence interval	No. Models	Relative Importance
n.poleWDTH	3.17	0.77	(1.67, 4.67)	90	1
n.shrubDENS	0.16	0.06	(0.05, 0.27)	90	1
n.slope	-0.03	0.01	(-0.05, 0)	61	0.83
c.angleCODE	-0.11	0.05	(-0.2, -0.01)	54	0.78
c.roadCODE	0.07	0.05	(-0.03, 0.16)	45	0.49
l.lnperchDIST	0.02	0.01	(-0.01, 0.04)	50	0.48
c.edgeCODE	0.07	0.06	(-0.05, 0.18)	39	0.4
n.roadDIST	<0.01	<0.01	(<0, >0)	37	0.31
n.span	-0.01	0.02	(-0.05, 0.02)	39	0.3

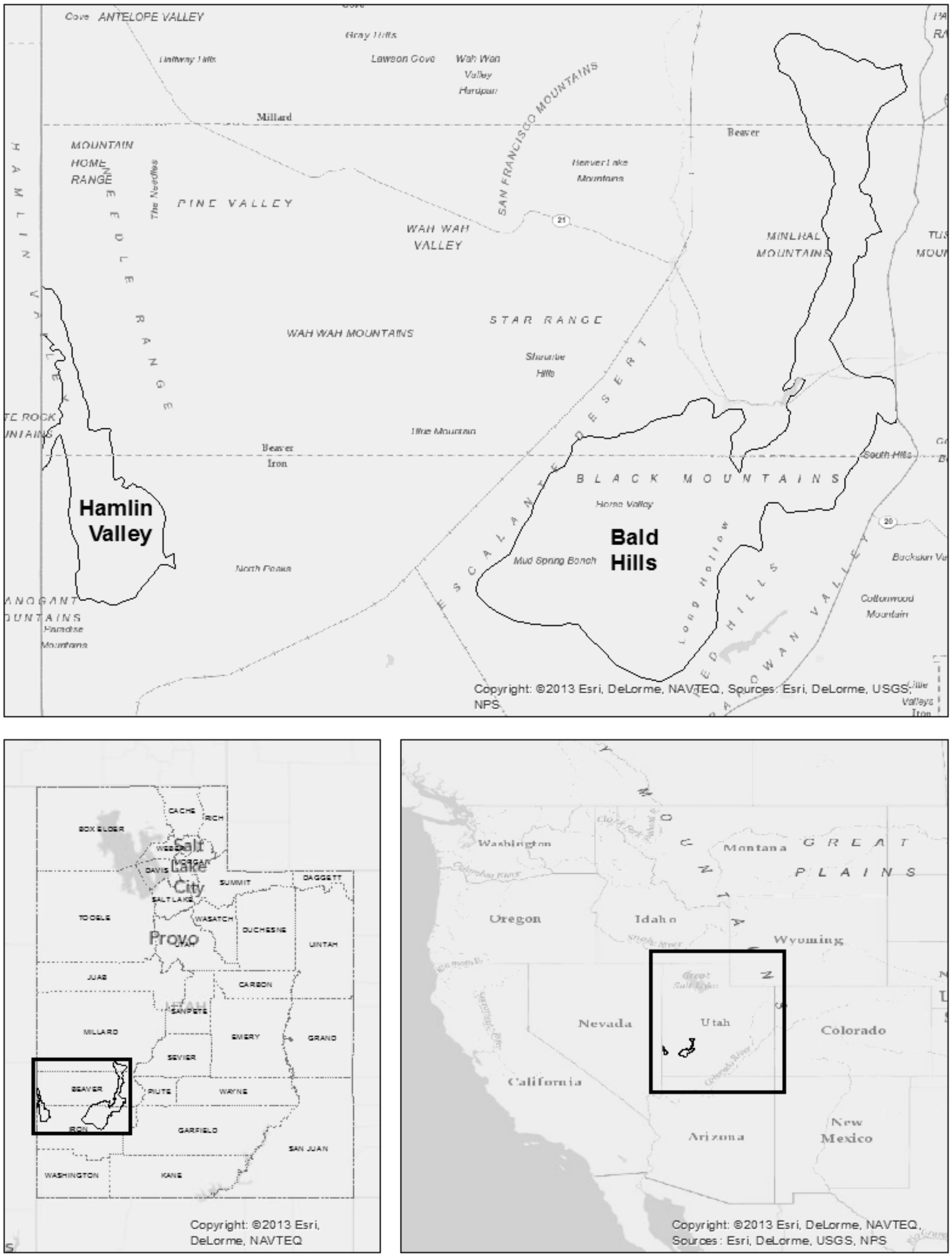

Figure 4-1. Hamlin Valley and Bald Hills study area, Utah, USA.

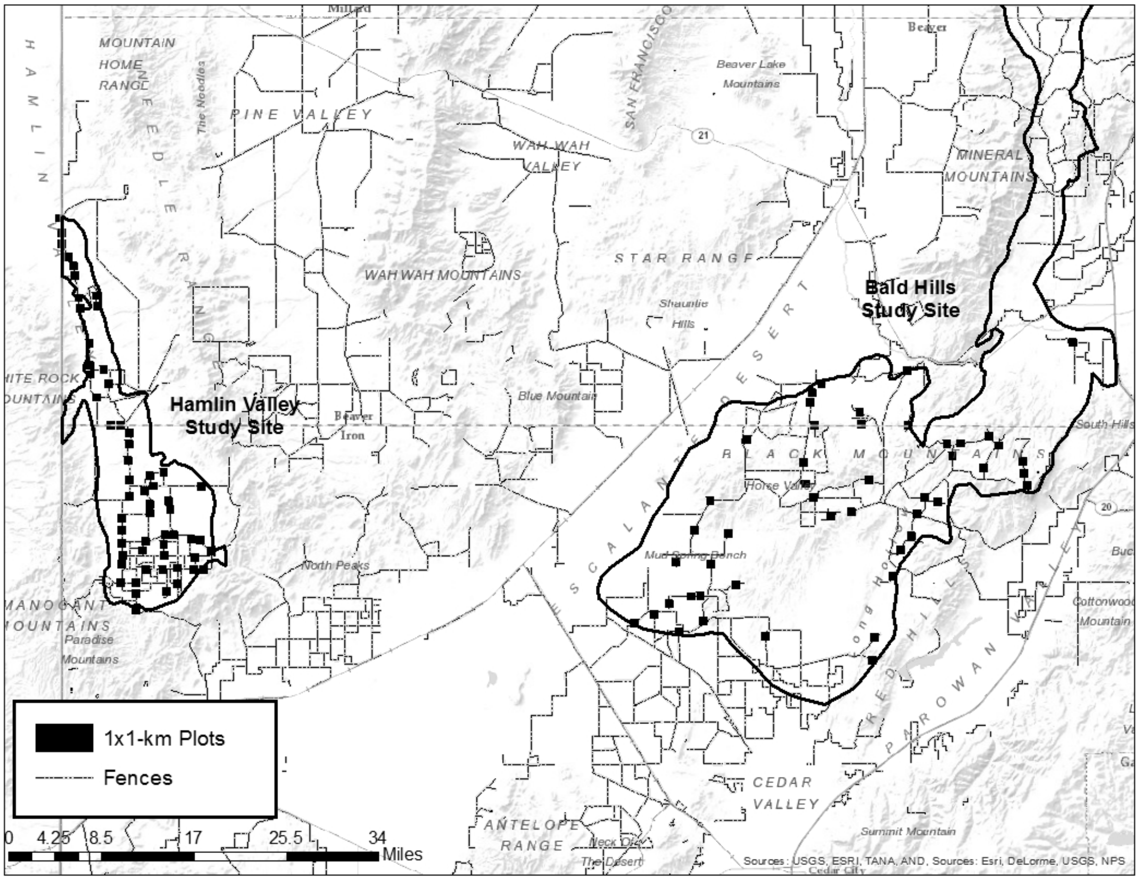

Figure 4-2. Fences within the Cedar City BLM Field Office (Utah, USA) and study area. Includes the randomly generated fence sample plots.

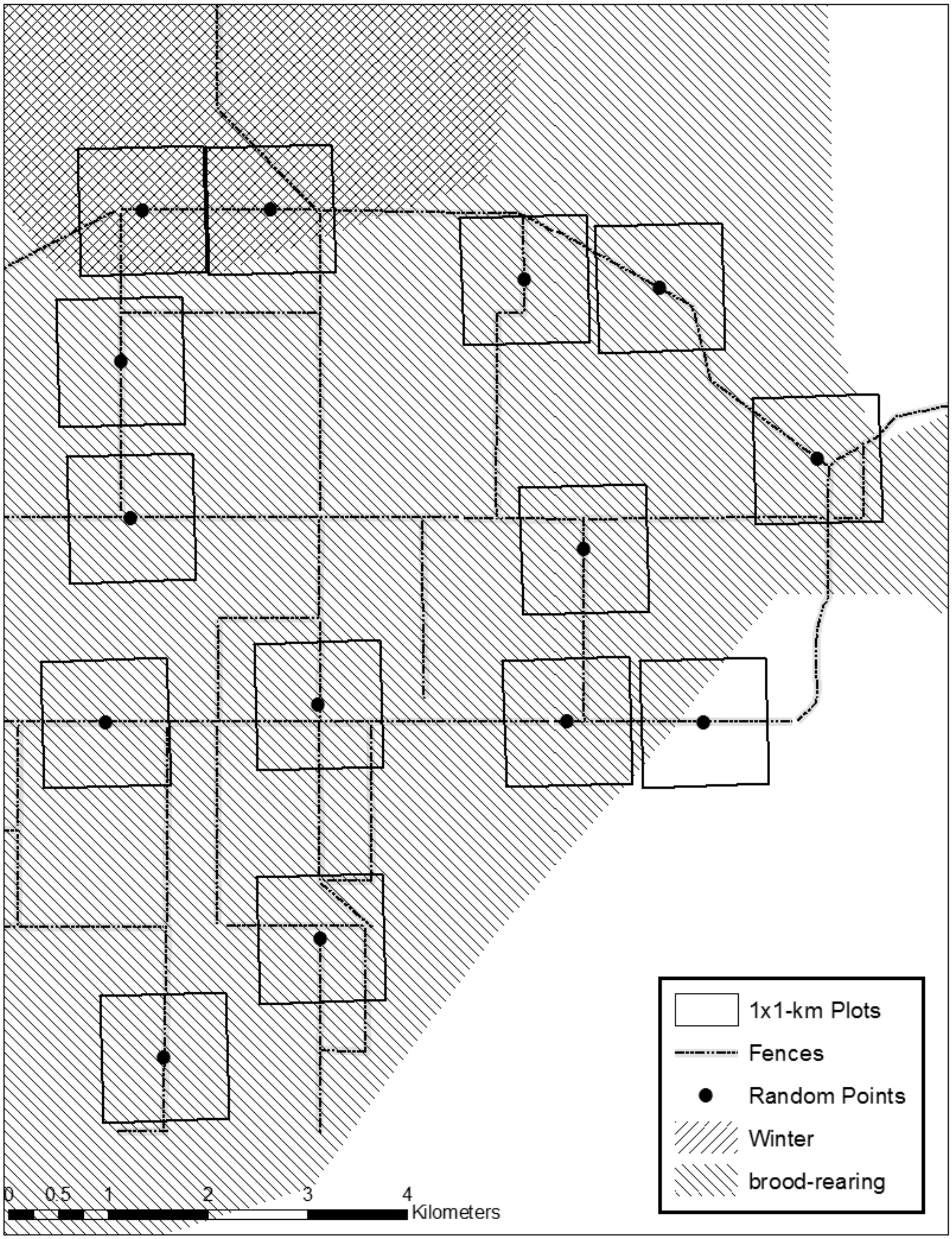

Figure 4-3. Avian predators fence use survey 1 km^2 sample plot design.

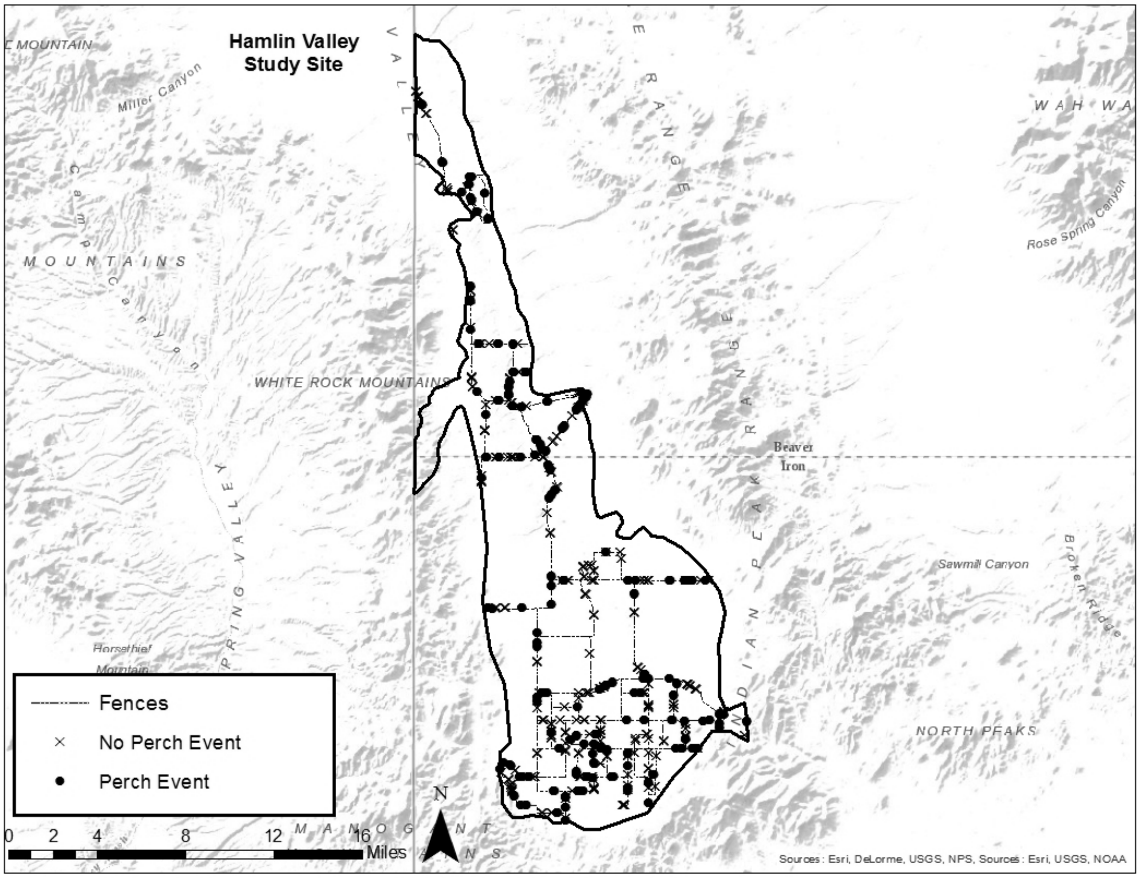

Figure 4-4. Location of used posts and randomly paired unused posts in Hamlin Valley, Utah, USA.

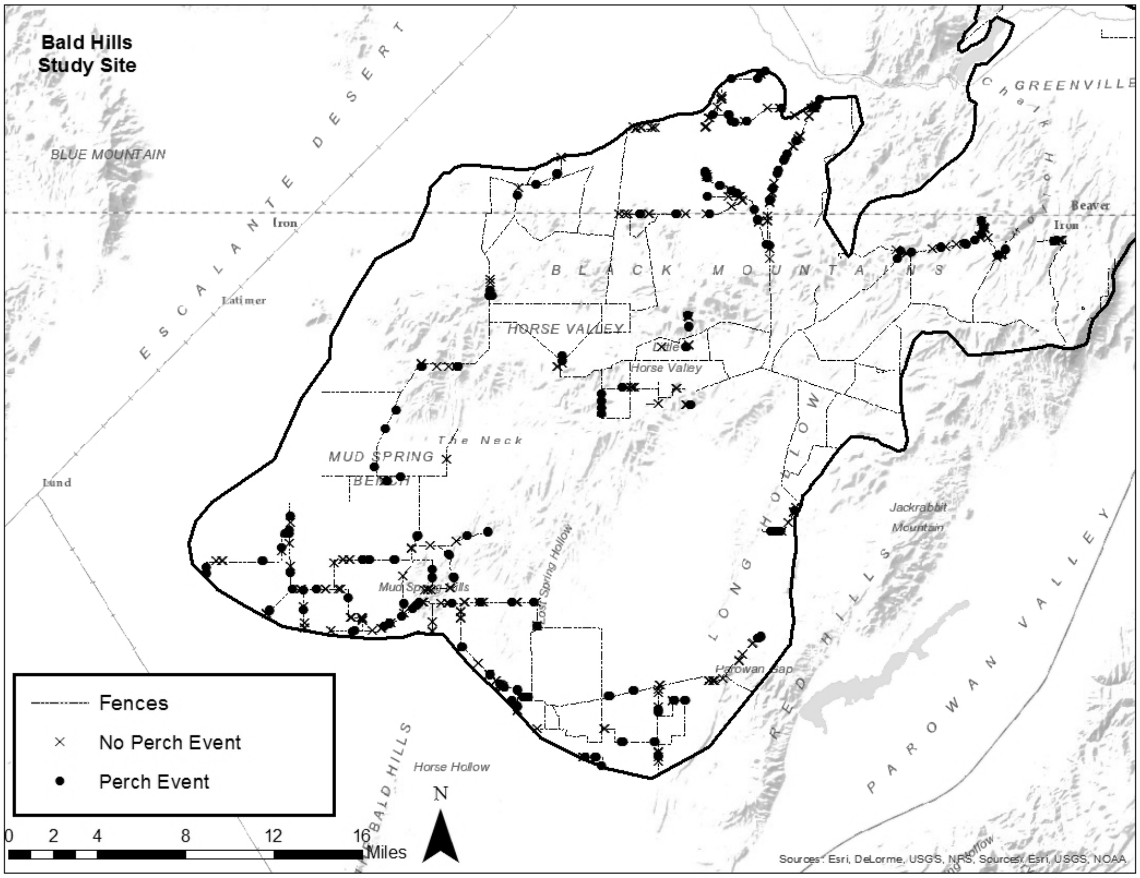

Figure 4-5. Location of used posts and randomly paired unused posts in Bald Hills, Utah, USA.

Figure 4-6. Wooden post (Upper) and metal post (Lower) fence construction types typical within the study areas.

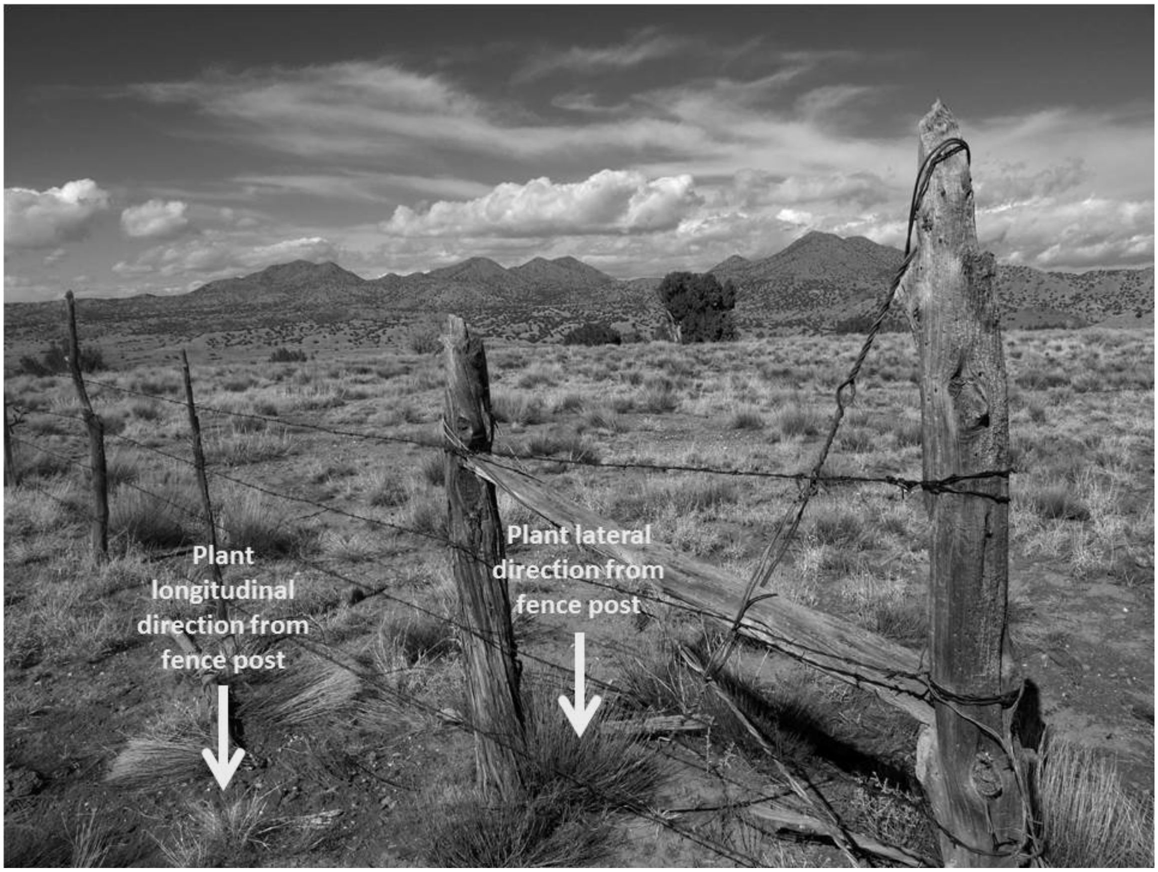

Figure 4-7. Distribution of plants in lateral and longitudinal directions from the sampled post.

CHAPTER 5

SUMMARY

In their 2010 decision, the United States Fish and Wildlife Service concluded that habitat loss and fragmentation, including introduction of infrastructure such as fences, was a significant threat to Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) such that the species may warrant protection under the Endangered Species Act. Therefore understanding how populations of sage-grouse within Utah use habitat seasonally, and how infrastructure affects sage-grouse is important for effectively conserving sage-grouse and managing shrub-steppe communities. This research focused on documenting the seasonal movements of sage-grouse within Hamlin Valley and how fences affect sage-grouse in the Southwest Desert Region (i.e. Bald Hills and Hamlin Valley populations).

In Chapter 2, I document general ecology of sage-grouse within Hamlin Valley, a population that occurs at the extreme southern end of the species distribution range and a population that is not threatened by habitat fragmentation or development of energy infrastructure. The Hamlin Valley sage-grouse population consists of four occupied leks with a ten-year average population estimate of 224 individuals (average of 84 total males counted on the 4 leks). In 2011 and 2012, I monitored 16 radio-collared sage-grouse captured from four leks Hamlin Valley. During the study period, the total population was estimated to be approximately 185 individuals (average of 49 total males counted on the 4 leks). Of the four active leks, three are distributed in the lower part of the valley and are located an average of 6 km from each other. The fourth lek is located approximately 22 km north of the lower leks. No connectivity was documented between the upper and lower parts of the valley. When considered separately, the average seasonal distribution sizes for breeding, summer, and winter habitats were 200.36 km^2, 364.58 km^2, and 219.68 km^2, respectively. The Hamlin Valley population was primarily one-stage migratory (moving between breeding and wintering habitats), but non-migratory behaviors (breeding and wintering occurred in the same habitats) were also observed. Collared individuals moved an average of 9.24 km (95% CI = 6.79 – 11.69 km) from breeding to summer habitats and an average of 8.24 km (95% CI = 5.28 – 11.2 km) from summer to winter habitats. Birds from at least one of the leks used seasonal habitats in neighboring Nevada for nesting and brood-rearing. This research suggests that there may be an overall lack of typical brood-rearing and summer habitats within the Utah side of Hamlin Valley which emphasizes that interstate coordination between Utah and Nevada is important to sustaining distinct habitat features for the Hamlin Valley population and that habitat restoration should focus on increasing migratory corridors between the upper and lower valleys as well as complexes in the larger landscape.

In Chapters 3 and 4, I focused on potential effects from construction of fences in sage-grouse habitat. I found that sage-grouse collision with fences in two small populations on the fringe of the overall range of sage-grouse as uncommon. Based on proximity of fence to known lek locations and fence presence throughout sage-grouse habitat on terrain associated with high collision risk, sage-grouse would be expected to have collided with fences, however, despite numerous surveys no collision evidence was identified. Despite finding zero grouse collisions, other avian and bat species were found to have collided with fences including species protected by other regulatory mechanisms such as the Migratory Bird Treaty Act and the Bald and Golden Eagle Protection Act. Therefore, reducing fence collisions leading to avian mortality should be considered a priority for land managers. I suggest that marking fences to increase visibility would be beneficial to many species for which collision has been observed (birds, bats, deer, etc.). However, management for sage-grouse in small populations may be better focused on improving habitat and reducing other causes of mortality which may be more prevalent. Future research on fence collision rates in small sage-grouse populations should be conducted for several years until enough collisions are observed to calculate fence and topographic characteristics that may be influencing fence strikes.

This research is the first study to address the characteristics of fences that may lead to increased perching by avian predators of sage-grouse. My data suggest that avian predators do show preferential use of wooden posts, however, because the fence post material parameter was not included in any of the top models for overall use and that fence post width was the strongest predictor of use overall, the width of posts is likely the driver and not the material itself. I recommend that new fences be constructed to minimize top width and at the minimum height necessary to meet the purpose of the fence. I also recommend that where possible, fences do not emphasize an abrupt change in habitat structure (i.e. edge effect) and that shrubs in the immediate vicinity of the fence be maintained at a lower density. In conclusion, natural vertical structures are rare in sage-grouse habitats, therefore creating enhanced opportunities for sage-grouse mortality by increasing collision risk and increasing perching substrate for avian predators.