5-2012

Avian Response to Post Wildland Fire Reseeding Treatments in Great Basin Shrubsteppe

Adam B. Brewerton
Utah State University

AVIAN RESPONSE TO POST WILDLAND FIRE RESEEDING TREATMENTS IN

GREAT BASIN SHRUBSTEPPE

by

Adam B. Brewerton

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

of

MASTER OF SCIENCE

in

Ecology

Approved:

Thomas C. Edwards Jr. Major Professor	Ron J. Ryel Committee Member
Kimberly A. Sullivan Committee Member	Mark R. McLellan Vice President for Research and Dean of the School of Graduate Studies

UTAH STATE UNIVERSITY
Logan, Utah

2012

ABSTRACT

Avian Response to Post Wildland Fire Reseeding

Treatments in Great Basin Shrubsteppe

by

Adam B. Brewerton, Master of Science

Utah State University, 2012

Major Professor: Dr. Thomas C. Edwards, Jr.
Department: Wildland Resources

We investigated the effects of different fire restoration treatments on five shrubsteppe bird species in the Great Basin of central Utah. Sagebrush communities and the associated avifauna are under particular threat due to changing fire regimes. Although fires are locally destructive, it is hypothesized that they improve habitat by increasing landscape-level heterogeneity. As long as fire follows a historic fire regime, the plant and animal communities can usually recover. However, fires can and often do burn outside of the normal regime. The Milford Flat Fire, which occurred in west-central Utah, was the largest wildfire recorded in the Great Basin. Considered catastrophic, concern existed that natural recovery of sagebrush and its avifauna would be unlikely. To prevent this, vegetation reseeding treatments were applied immediately post-fire. These treatments included two seed mix types, with or without a shrub component, and three mechanical applications, drill seeding, aerial seeding followed by chaining, and aerial seeding only. We surveyed the avian community in the different treatment types and in untreated areas within the fire using line transect distance sampling methods. Using a space for time substitution, we sampled nearby unburned areas as reference to represent pre-fire conditions. We hypothesized that the treatment areas would be more similar to the reference than the untreated areas, and that the treatments would all have similar effects. We found some effect on the presence and extirpation of the birds at the guild and overall bird level. We found no significant effect from the treatments on the five study species at the species level, and no effects on bird densities. The effects of the restoration treatments were overshadowed by the effect of the fire on changing the habitat, namely, the density of sagebrush. We saw a pattern of birds responding to the removal or survival of sagebrush and the treatments were insufficient in affecting a short term response.

(51 pages)

PUBLIC ABSTRACT

Avian Response to Post Wildland Fire Reseeding

Treatments in Great Basin Shrubsteppe

by

Adam B. Brewerton

Wildfire is often considered a destructive force. However, we have learned that fire is a natural part of many ecosystems and can even be productive by recycling nutrients, and allowing for regrowth. A natural pattern of fire frequency allows for native plants and animals to recover from its destructiveness and capitalize on its benefits. Environmental changes, such as exotic invasive species, like cheatgrass, and livestock grazing, can make recovery less likely. Cheatgrass also promotes fire. As cheatgrass establishes, fires become more frequent and larger, making it hard or impossible for native plants to recover. Land managers often reseed to restore fire areas to prevent the further spread of cheatgrass, breaking the cycle of more frequent, larger fires. We looked at how fire restoration affects sagebrush songbirds that depend on sagebrush shrubs for nesting. Sagebrush songbirds are declining as sagebrush habitat is lost by changing fire cycles and other human impacts.

The Milford Flat Fire, which occurred in west-central Utah, was the largest wildfire to burn in the Great Basin. It represents an unnaturally large, catastrophic fire. Reseedings were applied to combat invasive weeds and prevent soil erosion. It is assumed that this will lead to the recovery of native plants and animals. We compared the response of birds in these treatment areas with bird response in areas that were not

reseeded and nearby areas where the fire did not burn. These unburned areas approximated what might have been in the absence of the fire. In unseeded areas, birds were occurring at the same or better rate than unburned areas. In areas where the fire burned more severely and removed the sagebrush more completely, the sagebrush birds were replaced by grassland birds. The reseedings did not have any immediate negative impacts; and can be considered relatively successful. However, in the areas of most severe fire they were insufficient at restoring the native habitat. Recovery following a catastrophic fire like this is slow, especially in dry sagebrush habitats. Long-term effects of the fire and the subsequent restoration treatments will only be seen with continued monitoring and study on the Milford Flat.

ACKNOWLEDGMENTS

First of all I would like to thank and dedicate this thesis to my loving wife, Chelsea. She shares my passion for the natural world and has been and continues to be a great support in the pursuit of this passion. I also would like to dedicate this thesis to my adorable daughter Aspen. She is an unimaginable joy. They both remind me every day of what is most important. I would also like to thank my parents and family for their love, support, and influence.

I am indebted to my advisor, Thomas C. Edwards, Jr., and for the lessons he has taught me as a teacher and as a mentor. I also need to thank Russell Norvell for his guidance and for seeing potential in me even before I could see it myself. I would also like to thank my committee, Ron Ryel and Kimberly Sullivan. I would be amiss if I did not mention the wonderful people that worked as my field crew. I am very grateful for the hard work they did in collecting the data and making the field work enjoyable. I am also grateful for all of the support I received from the Utah Division of Wildlife Resources not just as an agency, but the people with whom I work. Through the respect they have shown me, I have learned much and they have become more than just colleagues. Lastly, I would like to thank all my fellow students, classmates, and peers. I am proud to call them my friends.

Adam Brewerton

CONTENTS

LIST OF TABLES

LIST OF FIGURES

BACKGROUND

Disturbances as Necessary on the Landscape

Disturbances are relatively discrete events that cause a change in the environment or resource availability, and that can create patches on the landscape and increase the landscape heterogeneity (Pickett &White 1985). Heterogeneity across a landscape influences the landscape in different ways, such as, the spread of other disturbances or alternating regional or biodiversity. Risser et al. (1984) noted that landscape heterogeneity often retards the spread of disturbance across a landscape. Landscape heterogeneity also provides variation of habitats for different species of wildlife and for various habitat requirements of individual species, like winter and summer habitats for mule deer, or breeding and migratory habitats for birds. This increased heterogeneity often leads to increased species richness (Atauri & Lucio 2001).

While heterogeneity on a landscape has certain benefits it can also have disadvantages. In some cases it can enhance the spread of disturbances and can reduce the abundance of certain species (Knick & Rotenberry 1995; Turner et al. 2001). The optimal level of heterogeneity, and therefore of disturbance, is different for different landscapes. Disturbances, particularly their spatial and temporal patterns, are of great importance to landscape function, pattern, and the level of heterogeneity (Turner et al. 2001). This spatial and temporal pattern of disturbances is referred to as a disturbance regime and is central to the concept that plants and animals native to a landscape have adapted to historical disturbance regimes (Rood 2006). As long as a disturbance occurs within the historical regime, the landscape is assumed to be able to recover to conditions similar to its pre-disturbed state.

State and transition models have been used to describe the relationship between various vegetation types, the disturbance regime and landscape heterogeneity (Stringham et al. 2003). When an area is disturbed, and the disturbance occurs at a low enough intensity, the vegetation type can change but will eventually recover and the system is maintained within the state. However, a disturbance that occurs outside of the natural regime, often called a catastrophic disturbance, can cause the system to cross a threshold and transition to different state (Rood 2006). Disturbances that cause a state change can be either single catastrophic disturbances or the cumulative effect of a shift in the disturbance regime (Turner et al. 2001). For example, over-grazing livestock by itself may or may not cause a state change but, when invasion of exotic plants and drought are combined, that may be enough to push the system past a threshold into a different state. Once a state change has occurred it can be difficult to reverse, and can require a greater input of energy to restore.

Wildfire and Cheatgrass

Wildfire is a major disturbance type in the arid shrubsteppe of the Great Basin, although historically it was likely less prominent (Baker 2006). Baker (2006) has noted that *Artemisia* spp. (sagebrush) does not exhibit adaptations normally associated with fire driven systems, like regeneration from root or a prolific seed bank. Sagebrush is therefore dependant on surviving plants or nearby unburned seed sources for recovery. It has been estimated that the interval between fires in the shrubsteppe is anywhere from 20 to 100 years (West 1999; Baker 2006).

Where landscapes have changed due to inputs like livestock grazing and invasive exotics such as *Bromus tectorum* (cheatgrass), fires can provide the last catalyst for a transition across a threshold (West 1999; Stringham et al. 2003). Cheatgrass as an invasive species also has the property of changing the fire regime in a positive feedback phenomenon (Young & Evans 1978; D'Antonio & Vitousek 1992). When cheatgrass is interspersed among shrubs and a fire burns through, cheatgrass provides a very volatile fuel source that ignites readily and burns fast and hot. It often dominates other species for establishment in the newly opened area of the fire (Whisenant 1990). As cheatgrass becomes established in a landscape, fire frequency increases, resulting in a change in the disturbance regime itself (Whisenant 1990). Restoration efforts are then used following wildfires to attempt to break this cycle.

Species Descriptions

For this study, we examined the responses of five avian species to restoration treatments following a catastrophic wildfire. These five species are *Amphispiza belli* (Sage Sparrow), *Spizella breweri* (Brewer's Sparrow) and *Oreoscoptes montanus* (Sage Thrasher), *Eremophila alpestris* (Horned Lark) and *Pooecetes gramineus* (Vesper Sparrow). The Brewer's Sparrow, Sage Sparrow, and Sage Thrasher were selected as species identified as shrub obligates, closely associated with shrubsteppe habitats primarily dominated by *Artemisia* spp (sagebrush; Knick et al. 2003; Rotenberry & Wiens 2009). These species show a range wide population decline largely attributed to habitat degradation and loss (Knick & Rottenberry 1995; Knick et al. 2003; Rich et al. 2005). The Horned Lark and Vesper Sparrow were selected as grassland associated species; they benefit from sagebrush removing disturbances (Wiens & Rotenberry 1985; Jones and Cornely 2002). They use areas of shrubsteppe that have been opened by disturbance and are known to be some of the first to colonize following disturbance (Wiens & Rotenberry 1985; Wiens et al. 1987; Rotenberry & Wiens 2009).

The Brewer's Sparrow is a non-descript sparrow. It is about 12.5 to 15 cm long and about 9 to 12 g in weight. It is fairly typical sparrow (*Spizella*) in overall shape. While its appearance is somewhat "non-committal," its song is quite distinct with buzzy trills. It ranges throughout western North America in shrubsteppe habitat. It is found throughout the Great Basin, and in shrubsteppe habitat in eastern Oregon and Washington, Montana, Wyoming and western Colorado. It can also be found in shrubsteppe habitat north in British Columbia and Yukon. It winters in Arizona, New Mexico, western Texas and Mexico. Throughout its range, it is often the most common bird species in shrubsteppe habitat. Notwithstanding, it has seen population declines due largely to loss of suitable habitat (Rotenberry et al. 1999).

The Sage Sparrow is a more distinctive bird with a brown body with white streaks on the outer tail feathers and wings and a gray head and nape with white and black markings around the face. It is about 15 to 19 g in weight. Its song is somewhat short and abrupt with simple, clear, high pitch tinks and buzzes. Its range matches that of the Brewer's Sparrow, but does not extend north into Canada. It also winters in Arizona, New Mexico, western Texas and Mexico, but some areas of western California and northern Arizona have year-round residents. Though it can be common, it is somewhat inconspicuous as it tends to hop along the ground from shrub to shrub. Like the Brewer's Sparrow, it has seen declines due to habitat loss and degradation (Martin & Carlson 1998).

The Sage Thrasher is brown-streaked bird with brown and dark brown streaks on back and wings, with buff and brown-streaked breast. It is medium sized, 20 to 23 cm long and 40 to 50 g in weight, though with relatively short beak and tail for a thrasher. Much like the other two shrub obligate species, it ranges throughout the Great Basin and shrubsteppe habitats of Montana, Wyoming, Colorado and eastern Washington. Also like its shrubsteppe counterparts, it winters in Arizona, New Mexico, western Texas and Mexico. The Sage Thrasher is not uncommon but is more dependent on large shrubs and large areas of intact sagebrush. Habitat degradation is as much a concern as complete loss (Reynolds et al. 1999).

The Horned Lark, like its name suggests, has feathered horns atop its head. It is pale brown overall with lighter breast. Its face has a black mask that extends through the horns with yellow highlights and throat. It is 16 to 20 cm long and 28 to 40 g in weight. It is holarctic in distribution. In North America it is found continent-wide. Although it is widely distributed and commonly found, it is actually quite specialized in its habitat, preferring open bare areas with low to no cover. This specialization on the open has allowed it to thrive where many other species cannot. It is able to take advantage of disturbed areas, like fires, grazing pastures, and airport runways (Beason 1995).

The Vesper Sparrow is another brown sparrow but with distinct white markings around the eye and white outer tail feathers. It is about 15 cm long and 24 to 25 g in weight. It ranges across North America in dry grasslands with sparse shrub or other similar structure. As shrublands have been turned to grasslands and forests to agriculture fields, it has been able to expand to areas within its range that were previously unsuitable. It often uses areas of shrubsteppe that have been recently opened to a more grassland type (Jones & Cornely 2002).

INTRODUCTION

Disturbance regimes are essential to the structure and function of landscapes (Attiwill 1994). Disturbances themselves are relatively discrete events that alter the environment or resource availability, often by creating (or eliminating) patches on the landscape and consequently altering landscape heterogeneity (Pickett and White 1985). While disturbance can alter local areas, the larger scale spatial and temporal pattern of disturbances shapes a landscape (Turner et al. 2001). This spatial and temporal pattern of disturbances is referred to as a disturbance regime and is central to the concept that plants and animals native to a landscape have adapted to historical disturbance regimes (Rood 2006). Therefore, as long as disturbances occur within historical bounds, the landscape is assumed to be able to recover to conditions similar to its pre-disturbed state. However, high intensity disturbances can occur outside these historical bounds. These so-called "catastrophic" disturbances can initiate a transition to an alternate state (Rood 2006) which then requires a greater input of energy to restore the area to its original state.

Just as different landscapes can be shaped by different disturbance regimes, they are also shaped by different disturbance types. Floods, winds, and storms can all disturb a landscape by removing patches of the present vegetation. In the arid shrubsteppe of the Great Basin of the western United States, wildfire is currently a major disturbance type, although its historical effect is questionable (Baker 2006). Shrubsteppe habitat is characterized by large arid expanses of mixed shrubs, mostly *Artemisia* spp. (sagebrush), and perennial bunchgrasses (West 1999). It represents a gradient of shrub cover, from dense sagebrush to open patches of grassland, with different proportions of shrub cover and grasses comingled in a mosaic landscape. The historical fire regime in the shrubsteppe is estimated to be 20 – 100 year intervals, with the sparse vegetation causing burns to leave patches of unburned shrub (West 1999; Baker 2006). With the invasion of exotic plant species, namely *Bromus tectorum* (cheatgrass), fires have been more intense and more frequent. Fire suppression practices allow for greater accumulation of fuel loads, thereby creating an environment where large fires can burn and facilitate the expansion of cheatgrass. As the fire regime changes, invasive annual grasses increase their establishment and in turn make an area more prone to fire resulting in a positive feedback loop (D'Antonio & Vitousek 1992; Baker 2006). Fire restoration efforts are proposed and often used to restore native grasses and shrubs, and halt or reduce the conversion of shrubsteppe to a state dominated by annual grasses (West 1999).

In the summer of 2007 a large wildfire burned approximately 137,000 ha of Great Basin shrubsteppe in west-central Utah. Called the Milford Flat Fire, it was the largest catastrophic fire recorded in the Great Basin ecoregion; the second largest was the Winters Fire of 2006 in Nevada at about 97,000 ha (USDOI 2007a, 2007b). Concern exists that the Milford Flat Fire would lead to a state change from shrubsteppe to an annual grassland dominated by cheatgrass. To prevent this change, vegetation reseeding treatments were applied immediately post-fire. The treatments consisted of three different mechanical applications; rangeland drill, aerial seeding followed by chaining, and aerial seeding only, and two seed mix types; one with shrub seed component and the other without. These treatments were applied with the assumptions that they were necessary to prevent the state change, and that by preventing the change the system was set on a trajectory back towards pre-fire conditions. The restoration treatments had the objectives of stabilizing the soil, establishing native vegetation, and restoring wildlife habitat. Given these objectives, it was assumed that if the restoration treatments are beneficial to the vegetation, they would be beneficial to wildlife.

Shrubsteppe habitat is important to many species of wildlife, such as shrubsteppe songbirds, raptors, *Centrocercus urophasianus* (Sage Grouse), small mammals like rabbits, and microtines, and ungulates like *Antilocapra americana* (pronghorn antelope), *Odocoileus hemionus* (mule deer), and *Cervus canadensis* (elk). Our work examined the effect of the wildlife habitat restoration treatments on five shrubsteppe associated songbirds. The first three species included *Amphispiza belli* (Sage Sparrow), *Spizella breweri* (Brewer's Sparrow) and *Oreoscoptes montanus* (Sage Thrasher). We chose these species due to their high association with sagebrush, mainly *Artemisia tridentata* (big sagebrush; Knick et al. 2003; Rotenberry & Wiens 2009). These bird species currently show population declines throughout their range, much of which is attributed to habitat loss and degradation (Knick & Rottenberry 1995; Knick et al. 2003; Rich et al. 2005). We also looked at two species that prefer the more open shrubsteppe and grasslands, *Eremophila alpestris* (Horned Lark) and *Pooecetes gramineus* (Vesper Sparrow; Rotenberry & Wiens 1980; Wiens et al. 1987). Both these species benefit from sagebrush removing disturbance, like fire (Wiens & Rotenberry 1985; Jones and Cornely 2002). While they use unburned habitat, they are known to be some of the first to colonize disturbed areas with open, shorter vegetation, particularly the Horned Lark (Wiens & Rotenberry 1985; Wiens et al. 1987; Rotenberry & Wiens 2009).

While we expected to have a direct effect from the fire itself on the bird species, our specific research objective was to investigate how these five shrubsteppe associated birds responded to fire restoration treatments. These treatments were: (i) aerial reseeding with shrub; (ii) chain without shrub; (iii) chain with shrub; and (iv) drill without shrub. We asked the specific question: How do the four fire restoration treatments affect bird densities? We evaluated this question in two parts. Because it is assumed that the restoration treatments are necessary to prevent a state change, we first expected that the treatments would reduce the effects of the fire on our study birds. This would be seen as an increase in density of the shrubsteppe obligate birds, and a decrease in density of the grassland birds when compared to the no treatment areas. In other words, the treated areas would be more similar to the reference than the no treatments areas. In the second part, we were interested in evaluating if any of the treatment methods were more (or less) effective than the others. Given that the assumptions of the restoration treatments were true, namely that the restoration treatments were necessary and effective at restoring the vegetative habitat, we hypothesized the treatments to have similar effects.

METHODS

Study Area

The Milford Flat Fire was ignited by lightning in the summer of 2007 and burned 137,000 ha from its ignition point just northeast of the town of Milford, Utah. From there it burned east (approximately 30 km) and north (approximately 70 km) towards the Interstate-15 corridor and toward the town of Fillmore, Utah. The fire burned mostly public land under the jurisdiction of the Bureau of Land Management. As there are no pre-fire data, we included a 50 km buffer around the outside of the fire to approximate pre-fire conditions. This buffer area is referred to as reference, not as a reference of ideal shrubsteppe habitat, but as a representation of the pre-disturbance conditions. Because the 50 km buffer would extend to the east into a different ecoregion, outside of the Great Basin, the buffer area is clipped on the east by the boundary of the Great Basin ecoregion (Fig. 1).

Restoration Treatments

The restoration treatments consisted of three mechanical applications of two seed mix types (Table 1). These treatments were two seed mix types, with or without a shrub component, and three mechanical applications, drill seeding, aerial seeding followed by chaining, and aerial seeding only. Both seed mixes included the following grasses and forbs: *Medicago stiva* (alfalfa), *Pseudoroegneria spicata* (bluebunch wheatgrass), *Elymus elymoides* (bottlebrush squirreltail), *Agropyron cristatum* (crested wheatgrass), *Kochia*

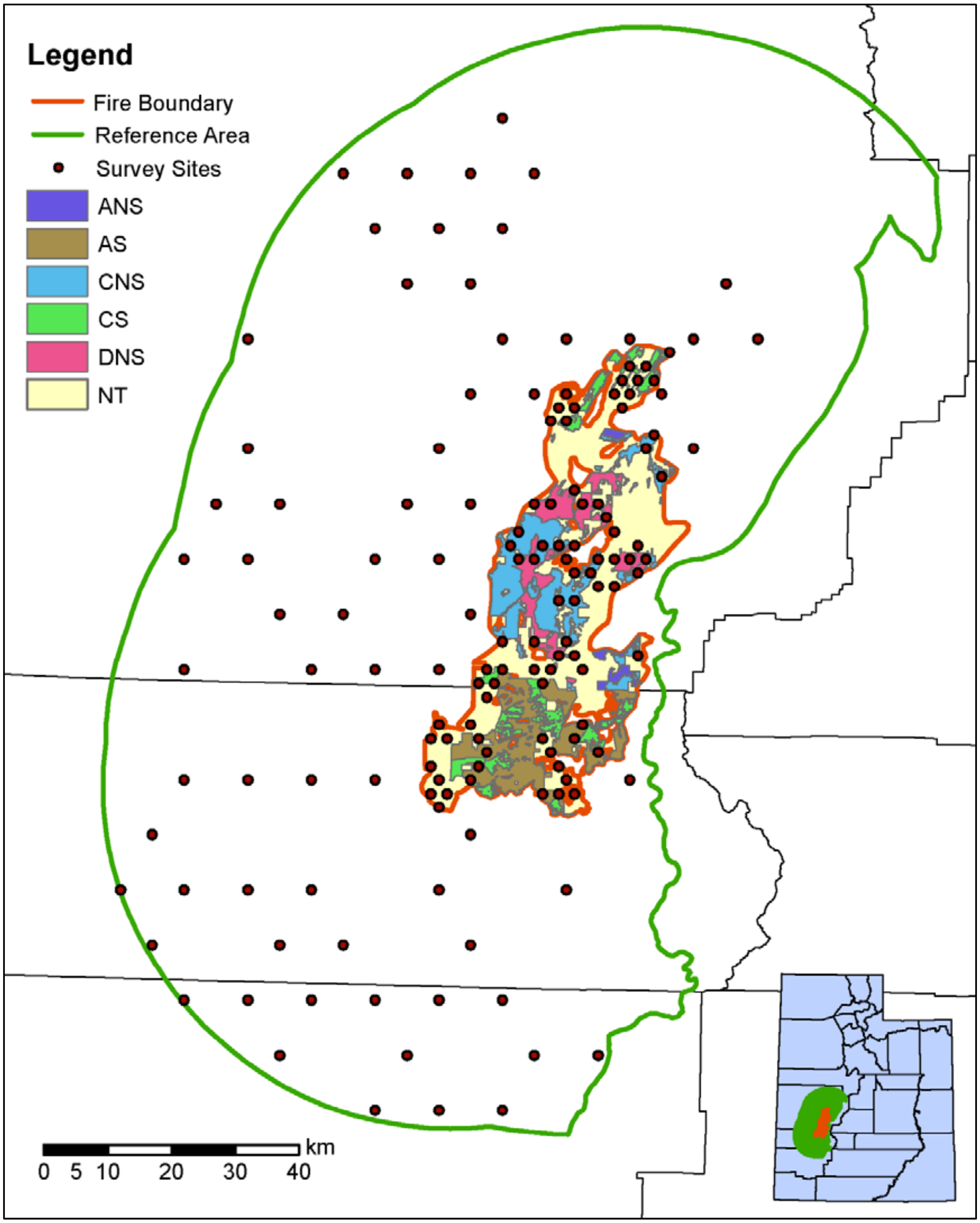

Figure 1. Map of Milford Flat Fire study area. Map shows survey sites, treatments, reference area, and locality in the state of Utah. See Table 1 for treatment abbreviations. Black lines represent county borders.

prostrata (forage kochia), *Elymus cinereus* (Great Basin wildrye), *Oryzopsis hymenoides* (indian ricegrass), *Thinopyrum intermedium* (intermediate wheatgrass), *Linum lewisii* (Lewis flax), *Bromus marginatus* (mountain brome), *Dactylis glomerata* (orchardgrass), *Penstemon palmeri* (Palmer's penstemon), *Agropyron trichophorum* (pubescent wheatgrass), *Psathyrostachys juncea* (Russian wildrye), *Onobrychis* sp. (sainfoin), *Sporobolus cryptandrus* (sand dropseed), *Poa secunda* (Sandberg's bluegrass), *Agropyron fragile* (Siberian wheatgrass), *Sanguisorba minor* (small burnet), *Bromus*

Table 1. Reseeding treatments applied 2007 on the Milford Flat Fire, Utah with number of sample sites per treatment.

Treatment	Abbreviation	*n*	Description[1]
Aerial with Shrub	AS	11	Seed applied aerially, seed mix included shrub seed component.
Chain without Shrub	CNS	16	Seed applied aerially, followed by chaining for turning seed into topsoil, seed mix did not include shrub seed component.
Chain with Shrub	CS	8	Seed applied aerially, followed by chaining for turning seed into topsoil, seed mix included shrub seed component.
Drill without Shrub	DNS	8	Seed applied with rangeland drill, seed mix did not include shrub seed component.
No Treatment	NT	53	Area within the fire that burned but was not reseeded.
Reference	REF	96	Reference area within the 50 km buffer around the fire, it was not burned nor treated.

[1]See methods section for list of species used in seed mixes.

inermis (smooth brome), *Elymus wawawaiensis* (Snake River wheatgrass), *Thinopyrum ponticum* (tall wheatgrass), *Elymus lanceolatus* (thickspike wheatgrass), *Pascopyrum smithii* (western wheatgrass), *Melilotus officinalis* (yellow sweet clover). In addition to the grass and forb seed, the seed mix that included shrubs contained seed for *Purshia tridentata* (antelope bitterbrush), *Artemisia tridentata* ssp. *wyomingensis* (Wyoming big sagebrush), *Artemisia tridentata* ssp. *vaseyana* (mountain big sagebrush), *Atriplex canescens* (fourwing saltbrush). Two of the treatment combinations were unavailable, the drill with shrub and the aerial without shrub. The drill with shrub combination was not applied and the aerial without shrub combination were in areas too small to be surveyed, comprising less than 12 ha of the sample site.

Treatments were applied non-randomly by the Bureau of Land Management (BLM) throughout the burn area. To control for this, we included elevation, year (annual variation) and density of surviving big sagebrush as covariates to better estimate treatment effects and capture the non-random application effects. The treatments follow a latitudinal pattern which corresponds to a general elevational gradient of higher elevations in the south and lower elevations in the north. The aerial with shrub treatments were applied to the southern, higher elevation sites. The chaining and drill without shrub treatments were applied to mid elevation, mid-latitude sites. The chaining with shrub treatments were applied to the northern, lower elevation sites; one exception to this general pattern is that the chaining with shrub treatment was also applied to southern, lower elevation sites (Fig. 2). The treated areas were compared with untreated

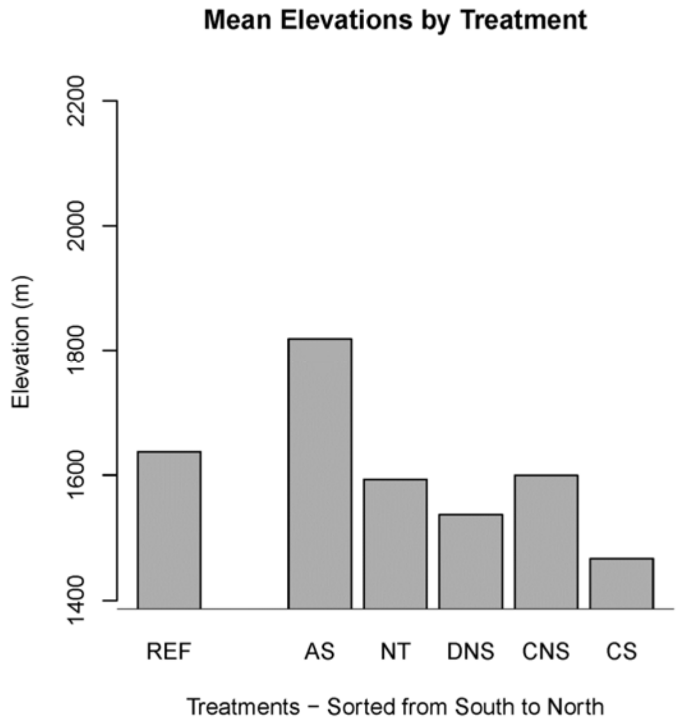

Figure 2. Mean elevations of reseeding treatments on the Milford Flat Fire, Utah arranged from south to north, representing a general elevation gradient by latitude. See Table 1 for treatment abbreviations.

areas within the fire, referred to as “no treatment,” and untreated areas outside the fire representing pre-fire conditions, referred to as “reference.”

Sampling Design and Field Methods

We randomly selected sample points from a hexagonal design grid (Stevens & Olsen 2004) that has been generated for the state of Utah and used in other studies (Norvell 2008). Grids were available at various spacing densities characterized by the distance between grid points. We used a grid point spacing of 5,000 m for burned areas, both treated and not treated, and a spacing of 10,000 m for the reference area. Points were selected in the fire for the four different treatment areas, the no treatment areas, and in the buffer area outside the fire for the reference area (Fig. 1). In each treatment, the number of survey sites were proportional to the area of each treatment (*n* = 8-16). The number of samples in the no treatment areas (*n* = 53) approximately matched the total of the treated (*n* = 43). We also selected a matching number of reference sites to the total number of sites within the fire (*n* = 96). In total, 192 sites were sampled (See Table 1).

These survey sites were visited twice, first during May and June to conduct bird counts, and second during July and August for vegetation data collection. Bird counts and vegetation data collection were conducted over two summer field seasons, 2009 and 2010. At each selected point, a set of four transects was established, such that the original grid points acts as an anchor to the randomly oriented set of transects. A 400 m transect was extended along a random bearing. Three more transects were then set parallel and 100 m removed. The transects were oriented such that the second and fourth transects are running opposite the first and third, making an out and back setup covering an area of approximately 12 ha. The coordinates of the start and end points were calculated by trigonometry and fed into handheld GPS units that were used to navigate along the line transects.

Data were collected by trained observers walking at a slow, steady pace along the transect recording every bird seen or heard. The observers also recorded the perpendicular distance of the detection from the transect as obtained from a laser rangefinder, following standard distance sampling procedures (Buckland et al. 2001).

Each bird was identified to species and, when possible, as male, female, or juvenile. Counts started at local sunrise and stopped at 1100 hrs.

Vegetation data on shrub cover and density, native and non-native grass and forb cover, and vegetation height was collected along the first 50 m of each line transect. A modified method of the Daubenmire frame was used to estimate grass and forb cover (Daubenmire 1959). A Wiens pole was used for vertical structure (Wiens 1969). The Daubenmire frame and Wiens pole was placed at the beginning and end of each 50 m section. A line intercept method was used to estimate shrub cover (Canfield 1941). The line intercept covered the full 50 m transect.

Analysis

Data were analyzed on five bird species, Brewer's Sparrow (BRES), Sage Sparrow (SAGS), Sage Thrasher (SATH), Horned Lark (HOLA), and Vesper Sparrow (VESP). This combination of species affords a comparison of responses between species that would be expected to be negatively affected by the loss of shrubland habitat (Brewer's Sparrow, Sage Sparrow, Sage Thrasher), and those expected to be positively affected (Horned Lark and Vesper Sparrow). We analyzed the response at three different ecological levels; by each of the five species, by guild (grassland species and shrubland species), and for overall bird density.

Program Distance (Thomas et al. 2010) was used to derive density estimates by calculating detection probabilities for each species at each survey site for each year. To verify the accuracy of our detection probability estimates, we compared our estimates with those derived from a long term dataset consisting of 10 years of shrubsteppe bird surveys by the Utah Division of Wildlife Resources in the vicinity of our study. Our detection probabilities were comparable for three of our five species; Horned Lark, Brewer's Sparrow, and Sage Sparrow. However, we had too few observations for our other two species; Sage Thrasher, and Vesper Sparrow. Therefore, we combined those two species with the long term dataset to get more accurate estimates of detection probabilities and densities of those species.

Once the detection probabilities and density estimates were calculated, we performed a two step analysis. We first constructed an extirpation model that evaluated the presence/absence response of the birds to the fire and post-fire restoration treatments. The second step was to make a density model in which we looked at the effect on the densities of the bird species when they were present. We ran the extirpation model using a binomial logit link in a generalized linear model. We modeled the presence of the birds at the three ecological levels, species, guild, and overall, in response to the restoration treatments (Table 1). Elevation, year and density of *Artemisia tridentate* (ARTR) were treated as covariates. The density model considered bird densities as a function of treatment effects (Table 1), with elevation, density of *Artemisia tridentata* (ARTR), and year effects included as covariates. Because we are testing a response that is recovery from zero density, we used a one-sided test in the analysis of variance. We fit a generalized linear model for each test, and ran both a full model with all interactions included and a reduced model without interactions. Both the full and reduced models yielded similar results and none of the interactions were significant. We therefore opted to use the simpler, more parsimonious model without interactions. In addition to bird densities, we performed a one-way ANOVA test on the sagebrush density covariate, where sagebrush density is a function of treatment. All analysis was done with the car package in program R (Fox & Weisberg 2011).

RESULTS

We had 2,124 bird detections for the five species; 1,599 Horned Larks, 376 Brewer's Sparrows, 99 Sage Sparrows, 32 Sage Thrashers, and 18 Vesper Sparrows. The estimated probabilities of detection were 0.571 for Horned Larks, 0.547 for Brewer's Sparrows, 0.745 for Sage Sparrows, 0.576 for Sage Thrashers, and 0.557 for Vesper Sparrows. Densities for each bird species were calculated using program Distance for each of the 192 sample sites (Table 2; Fig 3; Thomas et al. 2010).

Extirpation Model

Our extirpation model compared the odds ratio of the birds being more or less likely to be present in any of the fire areas, both treated and not treated, as compared to the reference area. We saw a significantly higher odds ratio for all birds in the no treatment area (Fig 4). At the guild level, we saw significant odds ratios for the no treatment and for the chaining without shrub seed treatment (Fig 4). The no treatment was higher for both the shrubland and grassland guilds. The chaining without shrub seed treatment was higher for the grassland guild but lower for the shrubland guild. At the species level, only the two more common species, Brewer's Sparrow and Horned Lark, showed significant results (Fig 5). The other three species were either not able to be modeled due to low sample size, or were not significant without even trending to any pattern. Brewer's Sparrows showed a significantly higher occurrence in the no treatment area. Horned Larks showed higher occurrence in all areas except the chaining with shrub seed treatment. At the species level, the odds ratios in the drill without shrub seed

Table 2. Mean (± 1 SD) of bird densities by reseeding treatment applied in 2007on the Milford Flat Fire, Utah.

Species Group	Treatments[1]					
	Seed with Shrub		Seed without Shrub		Reference	
	AS	CS	CNS	DNS	NT	REF
All Birds	26.68 (24.10)	25.34 (34.41)	30.50 (40.61)	63.01 (38.76)	37.39 (50.57)	29.43 (34.07)
Guild						
Shrub	11.43 (17.31)	3.04 (0.52)	8.46 (2.59)	0.00 (0.00)	10.22 (11.79)	19.99 (26.11)
Grass	34.30 (24.01)	40.21 (37.98)	35.15 (43.41)	63.01 (38.76)	56.09 (58.1)	38.3 (38.22)
Species[2]						
BRES	13.07 (19.54)	3.23 (0.46)	8.81 (3.05)	0.00 (0.00)	13.12 (12.59)	23.43 (26.33)
SAGS	4.87 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	11.37 (11.26)	18.62 (29.22)
SATH	0.00 (0.00)	2.47 (0.00)	7.04 (0.00)	0.00 (0.00)	1.69 (0.74)	3.73 (4.19)
HOLA	37.66 (22.83)	47.54 (37.48)	36.65 (44.15)	63.01 (38.76)	59.07 (58.22)	41.8 (38.59)
VESP	4.03 (0.00)	3.58 (0.00)	8.07 (0.00)	0.00 (0.00)	1.63 (0.45)	5.48 (2.42)

[1]See Table 1 for treatment abbreviations.
[2]Species abbreviations: BRES = Brewer's Sparrow, SAGS = Sage Sparrow, SATH = Sage Thrasher, HOLA = Horned Lark, VESP = Vesper Sparrow

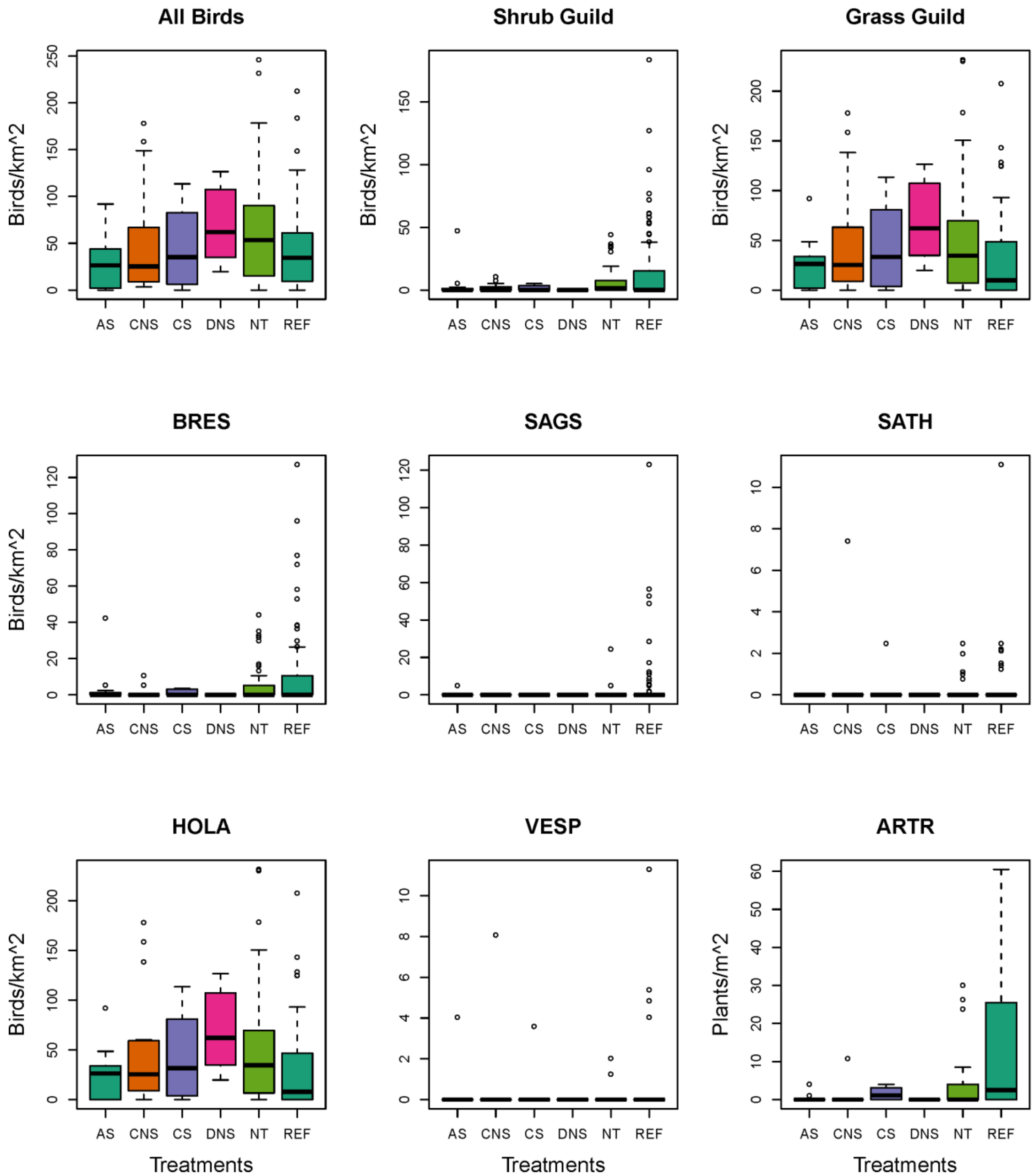

Figure 3. Boxplots of bird densities (Bird/km^2) by treatment with plot of sagebrush (*A. tridendata*) density (Plants/m^2) by treatment. See Table 1 for treatment abbreviations and Table 2 for species abbreviations.

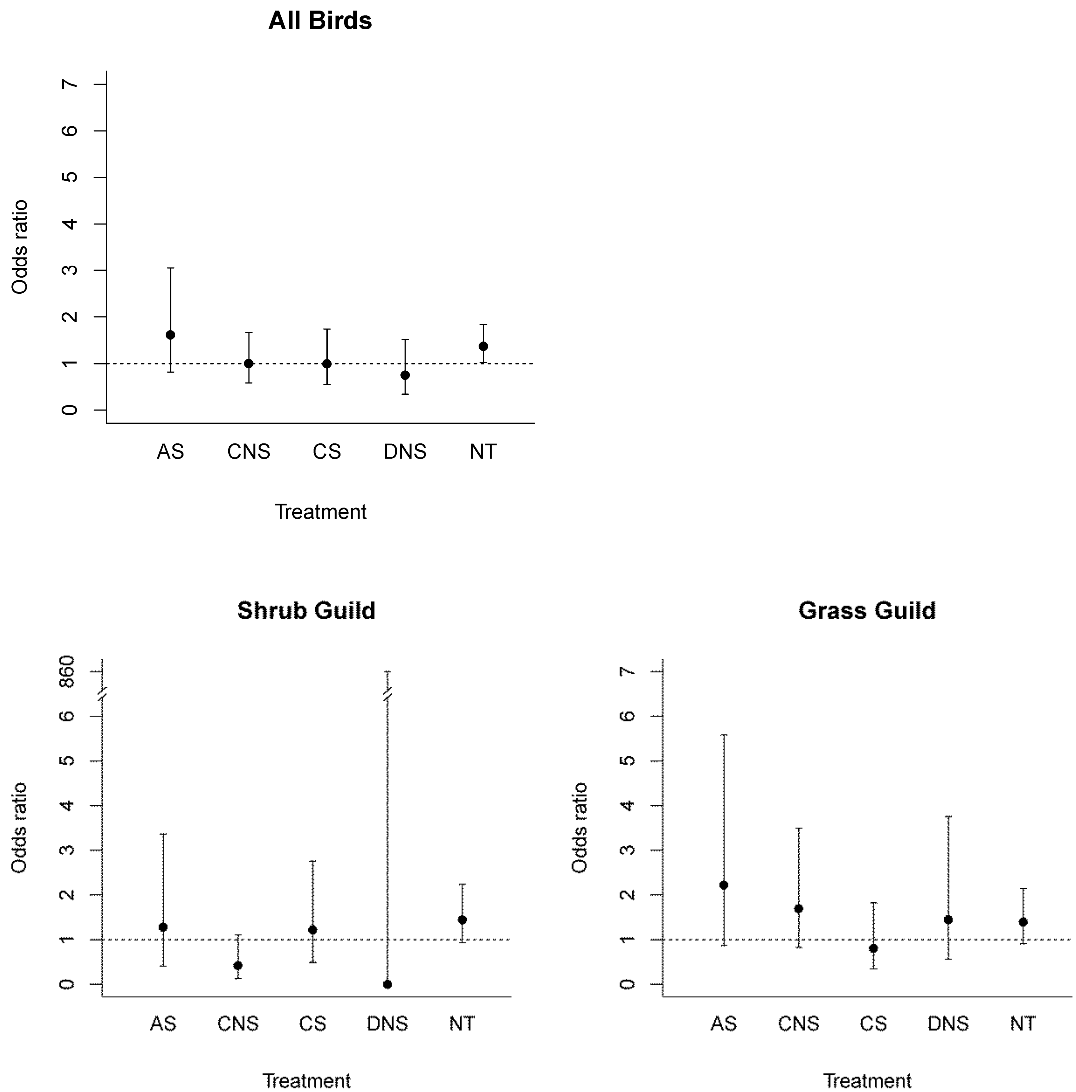

Figure 4. Odds plot for all birds, and guilds (shrubland and grassland) comparing treatments to reference. Dashed line at 1 represents no different from reference, values greater than 1 are more likely to be present in that given treatment than reference and values less than 1 are less likely to be present. See Table 1 for treatment abbreviations.

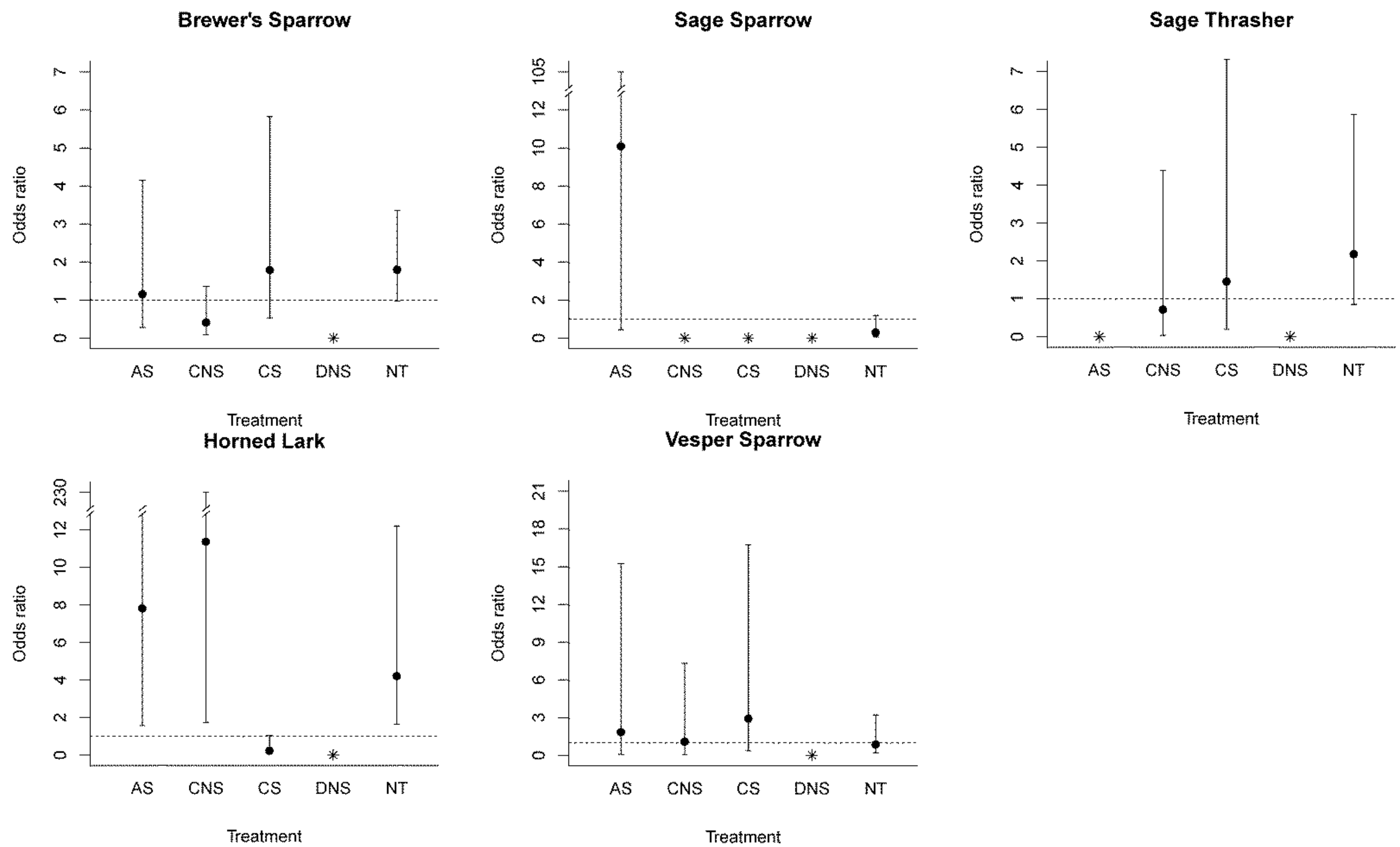

Figure 5. Odds plot for the five study species, Brewer's Sparrow, Sage Sparrow, Sage Thrasher, Horned Lark and Vesper Sparrow, comparing treatments to reference. Dashed line at 1 represents no different from reference, values greater than 1 are more likely to be present in that given treatment than reference and values less than 1 are less likely to be present. See Table 1 for treatment abbreviations.

treatment were not estimable as it had 100% occurrence of Horned Larks and no other species present. The lack of variation in this treatment did not lend to statistical analysis, but a pattern this strong does not necessarily need statistics.

Density Model

We did not see any significance for the test of treatment effects on bird densities; *p* values all greater than 0.10 (Tables 3, 4 & 5). The lack of treatment effect suggests no simple fire effect, as the comparison of reference to any of the fire treatments is included in that test. Even though the ANOVA test failed to show any treatment effects, we could see that any differences in bird density between treatments are confounded by the large variances in the data (Table 2). Elevation ($p = 0.01$) and year ($p = 0.02$) were significant for overall bird density (Table 3). At the level of guilds, the shrub guild had significant effects from sagebrush density ($p<0.001$) and year ($p<0.001$; Table 4). The grass guild had significant effects from elevation ($p<0.001$) and sagebrush density ($p = 0.01$; Table 4). At the species level, the main influences came from significant differences due to elevation for Horned Larks ($p<0.001$) and Vesper Sparrow ($p = 0.08$), sagebrush density for Brewer's ($p<0.001$) and Sage Sparrows ($p<0.001$) and Horned Larks ($p = 0.01$), and year effects for all except Horned Larks, though Horned Larks approached significant ($p = 0.19$; Table 5).

Table 3. ANOVA table for overall bird density on the Milford Flat Fire, Utah.

Source	*Type III SS*	*df*	*F*	*p* value
Treatment	13728	5	1.652	0.15
Elevation	1676	1	1.008	0.32
Shrub Density	10990	1	6.611	0.01
Year	2667	1	1.605	0.21
Error	581857	350		

Table 4. ANOVA table for bird density by guild on the Milford Flat Fire, Utah.

Source	Shrub Guild			
	Type III SS	*df*	*F*	*p* value
Treatment	646	4	0.428	0.79
Elevation	656	1	1.736	0.19
Shrub Density	4349	1	11.515	<0.01
Year	518	1	1.373	0.24
Error	52872	140		
Source	Grass Guild			
	Type III SS	*df*	*F*	*p* value
Treatment	18866	5	1.863	0.10
Elevation	245	1	0.121	0.73
Shrub Density	29960	1	14.791	<0.01
Year	4545	1	2.244	0.14
Error	409175	202		

Table 5. ANOVA table for bird species densities on the Milford Flat Fire, Utah.

Species[1]	Source	*Type III SS*	*df*	*F*	*p* value
BRES	Treatment	1122	4	0.728	0.58
	Elevation	57	1	0.149	0.70
	Shrub Density	3829	1	9.936	<0.001
	Year	276	1	0.717	0.40
	Error	35458	92		
SAGS	Treatment	293.2	2	0.244	0.79
	Elevation	1534.2	1	2.548	0.13
	Shrub Density	481.5	1	0.800	0.38
	Year	499.1	1	0.829	0.38
	Error	10237.1	17		
SATH	Treatment	9.084	3	0.694	0.57
	Elevation	57.339	1	13.143	<0.001
	Shrub Density	52.61	1	12.059	<0.001
	Year	0	1	0.000	0.99
	Error	78.532	18		
HOLA	Treatment	18024	5	1.738	0.13
	Elevation	959	1	0.462	0.50
	Shrub Density	27030	1	13.032	0.00
	Year	3215	1	1.550	0.21
	Error	385787	186		
VESP	Treatment	31.0015	4	7.383	0.01
	Elevation	24.9712	1	23.786	0.00
	Shrub Density	5.134	1	4.890	0.06
	Year	1.4072	1	1.340	0.28
	Error	8.3986	8		

[1]See Table 2 for species abbreviations.

We also tested sagebrush density, which showed significant treatment effects ($p<0.001$). The pair wise comparisons show that sagebrush density was significantly reduced from reference in all of the fire treatments except for the chain with shrub and the drill without shrub treatments, although the lack of significance for the drill without shrub is likely due to the lack of variance resulting from zeros rather than any actual similarity in sagebrush density (Table 6; Fig. 3). Sagebrush were completely removed from the drill without shrub seed treatment and nearly completely removed from the chaining without shrub seed treatment. The chaining with shrub seed and aerial with shrub seed treatments had the least sagebrush removal and the no treatment areas had patches of surviving sagebrush, lending to the decision not to treat those areas.

Table 6. The *p* values from pairwise comparisons of sagebrush density by treatment[1].

	AS	CNS	CS	DNS	NT
CNS	1	-	-	-	-
CS	1	1	-	-	-
DNS	1	1	1	-	-
NT	1	1	1	1	-
REF	0.0471	0.0205	0.2321	0.1078	0.0014

[1]See Table 1 for treatment abbreviations.

While statistical significance was not always seen, a pattern does become apparent; that the shrub obligate species are more abundant where there are higher densities of sagebrush and the grassland species are less abundant at higher sagebrush densities (Figs. 3 & 6). However, this not a very precise predictor (Fig. 6) and other variables, like annual variation, are still providing much of the variation. This pattern is most apparent in the proportion occupied of the treatments (Fig. 7) and the occurrence odds ratios (Figs. 4 & 5). All the treatments show a decrease in the shrub guild species and an increase in the grass guild species. The drill without shrub treatment shows the most drastic change, a loss of all species except for Horned Larks.

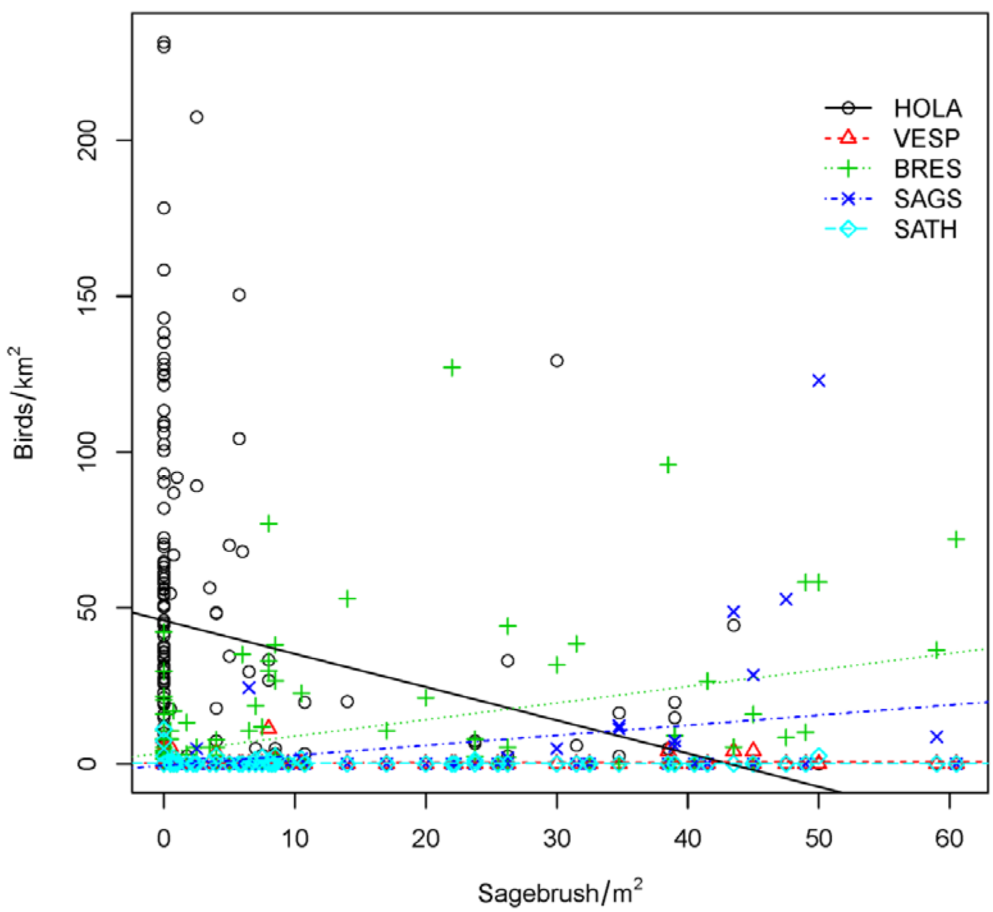

Figure 6. Bird densities (Birds/km^2) by species plotted by sagebrush density (Plants/m^2). See Table 2 for species abbreviations.

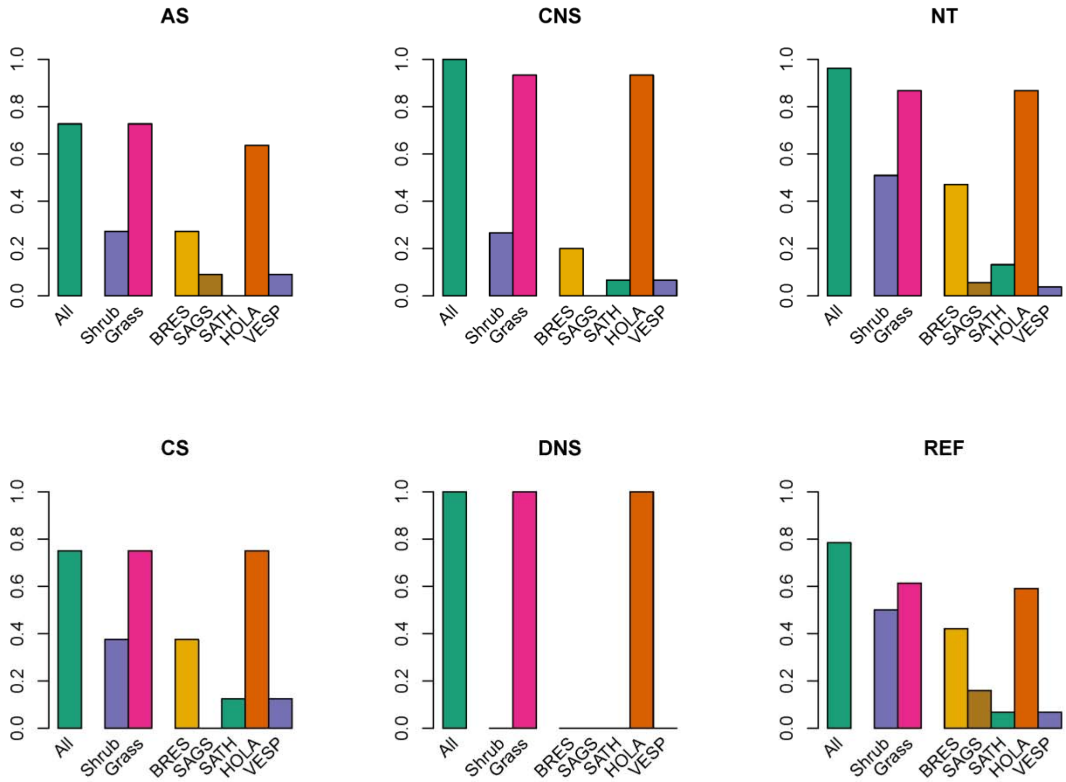

Figure 7. Proportion of treatment occupied for all bird species, guilds and our five study species. See Table 1 for treatment abbreviations.

DISCUSSION

We found no statistically significant effect of restoration treatments on bird densities in our study region. However, we did find some significant effects on the presence/absence response. Any of the significance we found in our extirpation model is likely driven by the remaining habitat from the fire and not from any direct effects of the restoration treatments due to the confounding nature of the non-random treatment application.

Bird species that are associated with habitats that are frequently disturbed would be expected to respond positively to a disturbance (Brawn et al. 2001). We expected that the shrub obligate species would have been negatively affected by the fire and the grassland associated species to be positively affected (Knick et al. 2005). Brewer's Sparrows, in particular, have been reported to respond negatively to fire (Castrale 1982; Bock & Bock 1987; Petersen & Best 1987; Knick & Rotenberry 1999; Reinkensmeyer 2000; McIntyre 2002; Welch 2002; Holmes 2007). Responses for Sage Sparrows have been negative (Petersen & Best 1987; Knick & Rotenberry 1999; Reinkensmeyer 2000; McIntyre 2002; Welch 2002) while Sage Thrashers have reports of all types of responses; negative to none to positive (Castrale 1982; Petersen & Best 1987; McIntyre 2002; Welch 2002; Holmes 2007). For the grassland species, reported responses of Horned Larks and Vesper Sparrows have been both neutral and positive (Castrale 1982; Petersen & Best 1987; Reinkensmeyer 2000; McIntyre 2002; Welch 2002; Holmes 2007).

Of the five species we examined, the Horned Lark was expected to benefit most from the fire, due to its catastrophic effect on shrubs. Even though we recorded very high numbers of Horned Larks, the differences in density between the treated areas and no treatment and even reference were not significant. The three shrub obligate species also did not show density related responses as expected. While the response of bird densities was not significant, we did see some significance and a definite pattern in the occurrences in the treatments, especially the drill without shrub seed treatment where sagebrush removal was so complete.

It is also important to note that our study is limited to short term effects; to examine long term effects of the restoration, if any, would require a longer study. The absence of a short term response is similar to findings of Wiens and Rotenberry (1985) who found no short term effects of habitat alterations. They attributed this lack of short term response to site fidelity causing a potential time lag. Petersen and Best (1987) also found no or mixed response of shrubsteppe birds to fire that burned less than 50% of the shrub cover in a mosaic pattern. Knick et al. (2005) note that while fire should negatively affect shrub obligate species, such short term effects are moderated by strong site fidelity and wildfire that does not remove all shrub cover. Thus, the disturbance (wildfire) does not alter the landscape characteristics sufficient for these species to respond. However, we had expected that the Milford Flat Fire was sufficiently large and severe enough to cause a response in the shrub obligate species, such as that found by Earnst et al. (2009) on this same assemblage of species in south-central Washington. They noted increases in grassland species and a decrease in shrubland species, and that regional population trends were congruent with the local responses of the shrubsteppe bird species. It is possible that the lack of pre-fire data for our study is confounded by regional population changes and may be responsible for the non-significant responses.

Following Knick et al. (2003), Knick and Rotenberry (1995) and Baker (2006) shrubsteppe habitats throughout the west are threatened by invasive exotics, changing disturbance regimes, and anthropogenic impacts like poorly managed grazing, energy development for oil and gas and even renewable energies like geothermal, wind and solar, and off road recreation. The reference area of our study was not intended to be a reference of pristine shrubsteppe, but rather an approximation of pre-fire conditions. Bird densities, for many survey sites in our reference area, were zero. It is possible that the lack of fire effect is due to reference conditions showing already decreased numbers and not due to a lack of effect from the fire itself.

Where no effects were seen on the bird densities, the proportion of each of the treatments occupied by the five study species did show a pattern. All the treatments are relatively similar to the reference except for the drill without shrub treatment. This treatment also suffered the most complete removal of sagebrush. The severity of the fire was not uniform across all treatments. The greater response in that treatment follows the greater severity of the disturbance as seen in other studies (Petersen & Best 1987; Smucker et al. 2005).

In the event of a catastrophic disturbance, like a rare, large, high intensity wildfire, restoration efforts are often required. However, those restoration efforts will inevitably require a significant input to match the scope and scale of the disturbance itself. To make restoration efforts more effective, and to make the monitoring of the recovery more valuable, we can take some lessons from this study.

When applying restoration treatments, it is important to remember the value of control areas. These control areas should be areas that meet the criteria to be treated but are left untreated. While the application methods are often limited by logistics on the ground, a tractor can only drive on a hill so steep, use of experimental design in prescribing the treatments can make the restoration more valuable for future restorations. Our reference areas were not representative of ideal shrubsteppe habitat, but merely an approximation of pre-fire conditions. While we can compare what might have been using this approach, it is no substitute for having pre-disturbance data nor for having larger scale regional data. General population monitoring in critical areas can provide both a regional standard as well as provide for pre-disturbance data in the event of a disturbance where a monitoring project is already running.

Last, we found that the restoration treatments were largely ineffective at restoring habitat for these five bird species in the short term. This speaks to two points. First, that restoration treatments aimed at soil stabilization and vegetation restoration does not necessarily translate into habitat restoration. Second, when implementing a restoration plan, it is important to have a sense of the time frame in which the desired response can be seen. For this fire, sagebrush is an important component of the habitat and the restoration of that habitat should include some a greater input than that of soil stabilization. To evaluate the effectiveness of the restoration, monitoring should be conducted around the time frame needed to restore sagebrush, not the short time frame that is usually done.

LITERATURE CITED

Atauri, J. A., and J. V. Lucio. 2001. The role of landscape structure in species richness distribution of birds, amphibians, reptiles and lepidopterans in Mediterranean landscapes. Landscape Ecology **16**: 147-159.

Attiwill, P. M. 1994. The disturbance of forest ecosystems: the ecological basis for conservative management. Forest Ecology and Management **63**:247-300.

Baker, W. L. 2006. Fire and restoration of sagebrush ecosystems. Wildlife Society Bulletin **34**:177-185.

Beason, R. C. 1995. Horned Lark (Eremophila alpestris) in A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, New York. URL http://bna.birds.cornell.edu/bna/species/195 [accessed on 29 August 2011]

Brawn, J. D., S. K. Robinson, and F. R. Thompson III. 2001. The role of disturbance in the ecology and conservation of birds. Annual Review of Ecology and Systematics **32**:251-276

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, New York.

Bock, C. E., and J. H. Bock. 1987. Avian habitat occupancy following fire in a Montana shrubsteppe. Prairie Naturalist **19**:153-158.

Canfield, R. H. 1941. Application of the line intercept method in sampling range vegetation. Journal of Forestry **39**:388-394.

Castrale, J. J. 1982. Effect of two sagebrush control methods on nongame birds. Journal of Wildlife Management **46**:945-952.

D'Antonio, C. M., and P. M. Vitousek. 1992. Biological invasions by exotic grasses, the grass/fire cycle, and global change. Annual Review of Ecology and Systematics **23**:63-87.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Science **33**:43-64.

Earnst, S. L., H. L. Newsome, W. L. LaFramboise, and N. LaFramboise. 2009. Avian response to wildfire in interior Columbia Basin shrubsteppe. The Condor **111**:370-376.

Fox, J., and S. Wiesberg. 2011. An R companion to applied regression, second edition. Sage, Thousand Oaks, California. URL http://socserv.socsci.mcmaster.ca/jfox/Books/Companion

Holmes, A. L. 2007. Short-term effects of a prescribed burn on songbirds and vegetation in mountain big sagebrush. Western North American Naturalist **67**:292-298.

Jones, S. L., and J. E. Cornely. 2002. Vesper Sparrow (Pooecetes gramineus) in A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, New York. URL http://bna.birds.cornell.edu/bna/species/624 [accessed on 29 August 2011]

Knick, S. T., D. S. Dobkin, J. T. Rotenberry, M. A. Schroeder, W. M. Vander Haegen, and C. Van Riper III. 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. The Condor **105**:611-634.

Knick, S. T., A. L. Holmes, and R. F. Miller. 2005. The role of fire in structuring sagebrush habitats and bird communities. Studies in Avian Biology **30**:63-75

Knick, S. T., and J. T. Rotenberry. 1995. Landscape characteristics of fragmented shrubsteppe habitats and breeding passerine birds. Conservation Biology **9**:1059-1071.

Knick, S. T., and J. T. Rotenberry. 1999. Spatial distribution of breeding passerine bird habitats in southwestern Idaho. Studies in Avian Biology **19**:104-111.

Martin, J. W. and B. A. Carlson. 1998. Sage Sparrow (Amphispiza belli) in A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, New York. URL http://bna.birds.cornell.edu/bna/species/326 [accessed on 29 August 2011]

McIntyre, K. K. 2002. Species composition and beta diversity of avian communities in burned, mixed, and unburned sagebrush steppe habitat at Sheldon National Wildlife Refuge, Nevada. Master's thesis. Sul Ross University, Alpine, Texas.

Norvell, R. 2008. Disturbance as restoration in the intermountain sagebrush-steppe: effects on non-target bird species. Ph.D. dissertation. Utah State University, Logan.

Petersen, K. L., and L. B. Best. 1987. Effects of prescribed burning on nongame birds in a sagebrush community. Wildlife Society Bulletin **15**:317-329.

Pickett, S. T., and P. S. White. 1985. Patch dynamics: a synthesis. Pages 371-384 in S. T. Pickett, and P. S. White, editors. The ecology of natural disturbances and patch dynamics. Academic Press, New York.

Reinkensmeyer, D. P. 2000. Habitat associations of bird communities in shrub-steppe and western juniper woodlands. Master's thesis. Oregon State University, Corvallis.

Reynolds, T. D., T. D. Rich and D. A. Stephens. 1999. Sage Thrasher (Oreoscoptes montanus) in A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, New York. URL http://bna.birds.cornell.edu/bna/species/463 [accessed on 29 August 2011]

Rich, T. D., M. J. Wisdom, and V. A. Saab. 2005. Conservation of priority birds in sagebrush ecosystems. PSW-GTR-191. United States Forest Service, Washington D. C.

Risser, P. G., J. R. Karr, R. T. T. Forman. 1984. Landscape ecology: directions and approaches. Illinois Natural History Survey, Champaign, Illinois.

Rood, S. B. 2006. Unusual disturbance: forest change following a catastrophic debris flow in the Canadian Rocky Mountains. Canadian Journal of Forest Research **36**:2204-2215.

Rotenberry, J. T., M. A. Patten, and K. L. Preston. 1999. Brewer's Sparrow (Spizella breweri) in A. Poole, editor. The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, New York. URL http://bna.birds.cornell.edu/bna/species/390 [accessed on 29 August 2011]

Rotenberry, J. T., and J. A. Wiens. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. Ecology **61**:1228-1250.

Rotenberry, J. T., and J. A. Wiens. 2009. Habitat relation of shrubsteppe birds: a 20-Year retrospective. The Condor **111**:401-413.

Smucker, K. M., R. L. Hutto, and B. M. Steele. 2005. Changes in bird abundance after wildfire: importance of fire severity and time since fire. Ecological Applications **15**:1535-1549.

Stevens Jr., D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. Journal of the American Statistical Association **99**:262-278.

Stringham, T. K., W. C. Krueger, and P. L. Shaver. 2003. State and transition modeling: an ecological process approach. Journal of Range Management **56**:106-113.

Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: design and analysis of distance sampling surveys for estimating population size. Journal of Applied Ecology **47**:5-14.

Turner, M. G., R. H. Gardner, and R. V. O'Neill. 2001. Landscape ecology in theory and practice. Springer Science+Business Media, Inc., New York.

USDOI (United States Department of the Interior), Bureau of Land Management Nevada State Office. 2007a. URL http://www.blm.gov/nv/st/en/prog/more_programs/geographic_sciences/gis/geospatial_data.html [accessed 6 October 2011]

USDOI (United States Department of the Interior), Bureau of Land Management Utah State Office. 2007b. URL http://www.blm.gov/ut/st/en/prog/more/geographic_information/gis_data_and_maps.html [accessed 6 October 2011]

West, N. E. 1999. Synecology and disturbance regimes of sagebrush steppe ecosystems. Sagebrush Steppe Ecosystems Symposium. Boise State University. Idaho.

Welch, B. L. 2002. Bird counts in stands of big sagebrush and greasewood. RMRS-RN-16, United States Department of Agriculture, Forest Service. Ogden, Utah.

Whisenant, S. G. 1990. Changing fire frequencies on Idaho's Snake River plains: ecological and management implications. In E. D. McArthur, E. M. Romney, S. D. Smith, and P. T. Tueller editors. Proceedings of a symposium on cheatgrass invasion, shrub die-off, and other aspects of shrub biology and management. 1989. General Technical Report INT-276. Ogden, Utah.

Wiens, J. A. 1969. An approach to the study of ecological relationships among grassland birds. Ornithological Monographs **8**:1-93.

Wiens, J. A., and J. T. Rotenberry. 1985. Response of breeding passerline birds to rangeland alteration in a North American shrubsteppe locality. Journal of Applied Ecology **22**:655-668.

Wiens, J. A., J. T. Rotenberry and B. Van Horne. 1987. Habitat occupancy patterns of north American shrubsteppe birds: the effects of spatial scale. Oikos **48**:132-147.

Young, J. A., and R. A. Evans. 1978. Population dynamics after wildfires in sagebrush grasslands. Journal of Range Management **31**:283-289.