Seasonal Resource Selection and Habitat Treatment Use by a Fringe Population of Greater Sage-Grouse

Rhett Boswell
Utah State University

Follow this and additional works at: https://digitalcommons.usu.edu/gradreports

Part of the Behavior and Ethology Commons, Biostatistics Commons, Natural Resources and Conservation Commons, Natural Resources Management and Policy Commons, Other Ecology and Evolutionary Biology Commons, Population Biology Commons, Statistical Models Commons, and the Terrestrial and Aquatic Ecology Commons

Recommended Citation
https://digitalcommons.usu.edu/gradreports/1192
SEASONAL RESOURCE SELECTION AND HABITAT TREATMENT USE BY A FRINGE POPULATION OF GREATER SAGE-GROUSE.

by

Rhett Boswell
6 November 2017

A capstone report submitted in partial fulfillment of the requirements for the degree of

MASTER OF NATURAL RESOURCES

Committee Members:
Frank Howe, Chair
Shandra Nicole Frey
Shannon Wing Belmont

UTAH STATE UNIVERSITY
Logan, Utah
2017
ABSTRACT

Movement and habitat selection by Greater Sage-grouse (*Centrocercus urophasianus*) is of great interest to wildlife managers tasked with applying conservation measures for this iconic western species. Current technology has created small and lightweight GPS (Global Positioning Systems) transmitters that can be attached to sage-grouse. Using GIS software and statistical programs such as Program R, land managers can analyze GPS location data to assess how sage-grouse are geospatially interacting with their habitats. Within the Panguitch Sage-Grouse Management Area (SGMA) thousands of acres of land have been restored or manipulated to enhance sage-grouse habitat; this usually involves removal of pinyon pine (*Pinus* spp.) and juniper (*Juniperus* spp.). A foundational aspect of this study is to assess what resources sage-grouse are selecting for and if it includes habitat treatments. For this study I used over 12,000 GPS locations from 13 individual sage-grouse (4 female, 9 male) in the Panguitch SGMA. I analyzed the point locations using a “used/available” 3rd order Resource Selection Function (RSF). The RSF design for this study is a variation of a logistic regression (generalized linear mixed effect model) designed to approximate the relative probability of use within the specified home range while accounting for random effects. I ran four separate RSFs based on seasonal use and sex (Winter Female, Winter Male, Brooding and Nesting Female, Brooding and Nesting Male). The RSF design provided coefficient estimates for a set of anthropologic, topographic, and vegetative landscape predictor variables. All four RSF models indicate that sage-grouse are strongly selecting for areas with low tree cover and low ruggedness values and selecting against areas classified as Pinyon and Juniper woodland. Results also indicate that female sage-grouse are selecting for areas near habitat treatments during winter as well as during brooding and nesting. Male sage-grouse exhibited a slight avoidance of habitat treatments with low positive coefficient estimates in both seasons. Using the results of the RSF models, I generated distinct heat maps that display probability of use geospatially within the study area. My RSF models can be used to better inform land managers when planning habitat treatments, updating seasonal habitat maps, identifying mitigation opportunities, and preparing state, federal, and local management plans.

INTRODUCTION

Problem Statement

Populations of Greater Sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) are scattered throughout southern Utah, with most of their breeding area locations (i.e., lekking sites) well known by local state wildlife biologists. However, seasonal movement patterns and resource selection of sage-grouse are not well described throughout the whole of southern
Utah. With the exception of a Parker Mountain population, sage-grouse habitat in southern Utah is considerably fragmented (Dahlgren et al. 2016). The state of Utah has identified 11 different sage-grouse management areas (SGMAs) including 4 in southern Utah. This report focuses on sage-grouse with GPS transmitters in the lower half of the Panguitch SGMA, which includes the southernmost population of the species. The Panguitch SGMA is on the edge of Greater Sage-grouse range and as a whole has relatively low densities of sage-grouse that could be considered peripheral or fringe populations (Dalhgren et al. 2016, S. N. Frey, Bureau of Land Management report, Utah State University, unpublished data).

Sage-grouse and other wildlife species at the edge of their ranges may exhibit atypical habitat selection behavior due to limited habitat and other pressures such as predation, wildfire, and invasive plants that lead to local adaptations (Connelly et al. 2000, Burnett 2013, Frey et al. 2013). Conservation actions for peripheral populations are important because those populations could represent resilient strongholds that may have adapted to anthropogenic disturbance or other pressures (Channell and Lomolino 2000, Steen and Barrett 2015). By comparing resource selection between a peripheral and central population, we may gain insight into the habitat quality tolerance threshold of sage-grouse.

With limited amount of habitat available in southern Utah for sage-grouse, land managers must identify habitat characteristics that are most important to this sensitive native species. Use of Global Positioning System (GPS) transmitters to track sage-grouse movement can provide data for which a resource selection probability can be calculated along with an understanding of explanatory variables that factor into habitat use by sage-grouse. By understanding habitat preferences and avoidances, land managers can act to protect, create, or improve habitat through vegetation treatment projects. In addition, local biologists can use tracking data to better refine habitat maps, which are vital impact analysis tools needed for addressing threats to sage-grouse.

In the Panguitch SGMA, thousands of acres have been treated for sage-grouse, most of which cleared encroaching pinyon pine (Pinus edulis and P. monophylla) and juniper (Juniperus osteosperma and J. scopulorum ) woodland (UWRI 2016). Federal, state, and private entities have spent millions of dollars on large-scale sage-grouse habitat treatments in Utah (UWRI 2016). However, more research is needed to better understand how effective these treatments are in providing useable habitat for sage-grouse. By using highly resolved geospatial location data to inform a resource selection model, land managers can assess the effectiveness of these habitat treatment projects. Managers may use these results to justify economic feasibility and social acceptability of large-scale habitat treatments for a single species. Managers may also use these data to assess the temporal factor of treatment implementation, as some treatments
may require time to move into a successional class that sage-grouse select for (Boyd et al., 2016).

**Background**

The sage-grouse is a large gallinaceous bird of the western United States that relies on broad expanses of sage brush (Artemisia spp.) for food and cover (Schroeder et al. 2004, Connelly et al. 2011). Sage-grouse have experienced steep population declines across the west due to loss of habitat from development (Knick et al. 2004, Connelly et al. 2011). In 2010, the USFWS recommended a listing under the Endangered Species Act (ESA) based largely on the lack of regulatory mechanisms on federal lands. In 2015, the USFWS decided not to list the Greater-Sage-grouse due to the unprecedented conservation effort put forth by federal, state, and local governments as well as private landowners (USFWS 2015). The threat of a sage-grouse ESA listing had a major impact on the federal and state resource agencies in Utah. By 2015, the BLM and USFS amended their land use plans in Utah to address threats to sage-grouse. These federal plan amendments resulted in tighter regulations and specific guidelines for sage-grouse related actions on public lands. The state of Utah also reacted to the threat of listing and created the Utah Conservation Plan for Greater Sage-grouse (Utah Governor’s Office 2013). Currently, management jurisdiction for sage-grouse in Utah remains with the UDWR, which uses the state conservation plan as guidance. State and federal conservation plans have some substantial differences however, which results in logistic and jurisdictional challenges for state and federal land managers.

Despite challenges arising from different visions, federal, state and private partners have come together in Utah to improve and expand sage-grouse habitat on a large scale. Consequently, more funds were made available for sage-grouse related projects such as habitat restoration and research, with the majority of federal agency actions for sage-grouse taking the form of habitat restoration. Most of these restoration projects for sage-grouse in Utah occur as pinyon and juniper removal or reduction from sagebrush or potential sagebrush areas. These treatments that identify sage-grouse as a primary benefactor are expensive and can have dramatic ecological and aesthetic effects on the landscape. As such, researchers and land managers have been interested in determining the efficacy of these habitat treatments in providing ecosystem services and to better understand the public’s perception of these projects.

In the Panguitch SGMA, the number and size of habitat treatment projects have drastically increased over the past ten years. As of 2016, over fifty thousand acres have been treated for sage-grouse in the Panguitch SGMA alone (UWRI 2016). Previous research in the Panguitch SGMA suggested that on a local level, sage-grouse were targeting areas where trees had been recently removed (Frey et al. 2013). Frey et al. (2013) also hypothesized that the lack of suitable
habitat may be a limiting factor in the Panguitch SGMA and that sage-grouse were using areas with less than ideal habitat conditions. Similar results have been found in other research in southern Utah where sage-grouse have been observed using newly treated or recently burned areas (Burnett 2013, Dahlgren et al. 2016, Hansen 2016). An initial study on GPS transmitter equipped sage-grouse in the Panquitch SGMA confirmed preference for sagebrush habitat, compared home range sizes between sexes, and provided evidence that sage-grouse are using habitat treatments (S. N. Frey, unpublished data). I expand on this project by developing a resource selection function on the same GPS monitored sage-grouse in the Panguitch SGMA.

**Goals and Objectives**

The primary goal of this project is to understand the combination of variables sage-grouse are selecting for in the Panguitch SGMA and if habitat treatments are an essential part of that equation. Sage-grouse typically select for sagebrush (*Artemisia spp.*), but we do not know what other specific ecological or anthropological factors influence their behavior or habitat selection in the project area.

The objective of this project was the development of a resource selection function model for a sample of sage-grouse from the Panguitch SGMA. To achieve this goal, I completed the following:

- Obtained data from previous research in the Panguitch SGMA (S. N. Frey, Bureau of Land Management report, Utah State University, unpublished data).
- Prepared a list of explanatory variables (based on similar studies) that may be influencing resource selection.
- Performed a literature review to choose an appropriate resource selection probability model.
- Analyzed data in Geographic Information System (GIS) and Program R (created home range estimates, estimated habitat availability in the project area, converted explanatory variables to appropriate feature class types, ran generalized linear mixed model).
- Interpreted results of Generalized Linear Mixed Models as a Resource Selection Function for each sex and season.

**METHODS**

**Study Area**

The study area is in the southern half of the Panguitch SGMA and is the minimum extent of all the individual home ranges of the GPS tagged sage-grouse locations. The Panguitch SGMA is
approximately 607,210 acres (2457 km²) and is the southernmost population of sage-grouse across its entire range. This study area is approximately 393,273 acres (1592 km²) and is in central southern Utah within Garfield and Kane counties (Figure 1). State Highway 89 bisects the study area and provides access to several rural communities such as Panguitch, Hatch, and Alton, Utah. The study area is primarily comprised of sagebrush-steppe habitat, Pinyon (Pinus edulus and P. monophylla) and Juniper (Juniperus osteosperma and J. scopulorum) woodland (PJ), and agriculture in the form of pasture grassland and irrigated cropland. The sagebrush-steppe habitat is characterized by big sagebrush (Artemisia tridentata var. tridentata and var. vaseyana), black sagebrush (Artemisia nova), and antelope bitterbrush (Purshia tridentata). The PJ woodland is widespread in the study area and is considered native or in various phases of encroachment into sagebrush habitats. The irrigated cropland consisted primarily of alfalfa (Medicago sativa) and the pasturelands consisted primarily of Kentucky bluegrass (Poa pratensis), timothy (Phleum pratense), crested wheatgrass (Agropyron cristatum), intermediate wheatgrass (Thinopyrum intermedium) and several species of sedges (Carex spp.). In addition to the dominant habitat types, spruce (Picea spp.), fir (Abies spp.), quaking aspen (Populus tremuloides), and curl-leaf mahogany (Cercocarpus ledifolius) communities were found at higher-elevation areas throughout the study area.
Figure 1. Study Area relative to Utah SGMAs and rangewide distribution of sage-grouse habitat. Points in lower right map are GPS tagged sage-grouse locations used to inform the RSF models.
Source of Data

I analyzed a set of data collected by Dr. Nicki Frey from 2013 to 2016, which consisted of over twelve thousand GPS locations of sage-grouse. The GPS transmitters weighed approximately 0.78 ounces (22 grams) and were attached by a harness to the individual birds (22g Model PTT-100, Microwave Telemetry Inc., Columbia, MD). Each transmitter collected 4 locations per day at ± 60ft (18m) accuracy through the Argos data collection system (Argos System, CLS America, Lanham, MD). These data are from 13 different sage-grouse (4 female, 9 male) trapped at various locations in the study area. Of the 13 individual sage-grouse used in this study, 6 males were captured in Sage Hen Hollow, 5 (1 male, 4 females) were captured in Sink Valley, 1 male was captured at Hoyt’s Ranch, and 1 male was captured at Panguitch Airport. Each of the capture locations are associated with an active breeding area except for Panguitch Airport.

Landscape Classification

I classified predictor variables as vegetative, anthropogenic, or topographical. To create, visualize, manipulate, and analyze landscape predictor variables, I used ArcMap (ArcMap; [GISsoftware]. Version 10.4.1 Redlands, CA: Environmental Systems Research Institute, Inc., 1999 - 2017) and Program R (Program R; R version 3.4.1, www.r-project.org, accessed 1 July 2017). To assess conifer cover, I used a remotely sensed conifer cover map which classified total conifer cover in six classes: 1) 0-1%, 2) 1 - 4%, 3) 4 – 10%, 4) 10 – 20%, 5) 20 – 50%, and 6) >50% (Falkowski et al., 2013). Calculated home range areas within the Panguitch SGMA did not contain any class “6” conifer cover. The measure of conifer cover was a continuous value between one and five. Using Utah’s Watershed Restoration Initiative (WRI) treatment polygons I created treatment maps for the study area and calculated Euclidean distance to treatment based on used and available sage-grouse locations (UWRI 2016). From the WRI database, I extracted treatments that occurred between 2006 to 2015 and had a tree removal component or identified sage-grouse as a direct beneficiary. Pinyon Juniper woodland, low sagebrush, and big sagebrush polygons were extracted from LANDFIRE Existing Vegetation Type data (LANDFIRE 2013) to create individual vegetation datasets. I developed Euclidean distance rasters measuring distance between the refined LANDFIRE vegetation data and the location of the used and available sage-grouse locations. Temporal adjustments were made to account for the availability of treatments to sage-grouse based on the timing of treatment relative to the time the location point was recorded for individual sage-grouse (e.g., treatments completed in 2016 could not be used or available for grouse prior to 2016). I also applied temporal adjustments to the Pinyon-Juniper predictor variable to account for tree removal treatments being subtracted geospatially relative to the treatment timing and sage-grouse location time stamp. I derived anthropogenic landscape variables from a remotely sensed baseline disturbance map that quantifies anthropogenic disturbances in Utah’s SGMA's (Gifford et al.
The anthropogenic variables considered for analysis were major roads (>45mph/72 kmph speed limit), minor roads (<45mph/72 kmph speed limit), Agriculture (Irrigated and non-irrigated rangeland and pasture), and Development (urban, non-urban, mines, pipelines, and miscellaneous anthropogenic structures or developments). For the topographical landscape variables, I used a Digital Elevation Model (DEM, 10 m resolution; Utah Automated Geographic Reference Center, 2013) to develop elevation, slope, and ruggedness values. I used Riley et al.’s (1999) Total Ruggedness Index to develop a ruggedness raster from our DEM in ArcMap. All the predictor variables considered for analysis are continuous variables. For the DEM based variables and the conifer cover variable, the value used in the RSF analysis is the value of the raster cell (10m) where it intersects the used and available sage-grouse locations. The remaining variables are all continuous distance-based metrics calculated in ArcMap as the distance (m) from the used and available sage-grouse locations. For a summary of the predictor variables considered for analysis and their attributes, see Table 1. Before the selection of the final landscape predictor variables to use for the RSF analysis, I standardized the continuous values and assessed pairwise correlations using Program R.
Table 1. Candidate predictor variables and their metrics considered for a resource selection model in Panguitch SGMA study area.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Type (Resolution)</th>
<th>Description(units)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vegetation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>LSB_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to low sagebrush derived from LANDFIRE existing vegetation type (m)</td>
</tr>
<tr>
<td><em>BSB_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to big sagebrush derived from LANDFIRE existing vegetation type (m)</td>
</tr>
<tr>
<td><em>MastPJ_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to Pinyon Juniper derived from LANDFIRE existing vegetation type and updated using WRI treatment data(m)</td>
</tr>
<tr>
<td><em>MasterTDIS</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to WRI available habitat treatments (m)</td>
</tr>
<tr>
<td><em>TCC</em></td>
<td>Continuous (10m)</td>
<td>Conifer cover class (1-5) derived from Falkowski et al. (2013)</td>
</tr>
<tr>
<td><strong>Anthropogenic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>AG_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to Agriculture areas derived from Gifford et al. 2014 (m)</td>
</tr>
<tr>
<td><em>DEV_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to Developed areas derived from Gifford et al. 2014 (m)</td>
</tr>
<tr>
<td><em>MinR_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to minor roads ≤ 72 km/hr (m)</td>
</tr>
<tr>
<td><em>MajR_Dist</em></td>
<td>Euclidean distance raster (10m)</td>
<td>Distance to major roads &gt; 72 km/hr (m)</td>
</tr>
<tr>
<td><strong>Topographic</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>SLOPE</em></td>
<td>Continuous (10m)</td>
<td>Slope calculated from 10 m DEM</td>
</tr>
<tr>
<td><em>ELEV</em></td>
<td>Continuous (10m)</td>
<td>Elevation derived from 10 m DEM</td>
</tr>
<tr>
<td><em>RUG10</em></td>
<td>Continuous (10m)</td>
<td>Riley’s Terrain Ruggedness Index calculated from 10 m DEM</td>
</tr>
</tbody>
</table>

*Variables not used in final RSF models due to correlation or other spatial issues*
I removed slope and elevation because they were highly correlated in all datasets and relatively uniform across the home ranges. Major roads and agriculture were also highly correlated in one or more datasets. I removed major roads from the final analysis because I was more interested in the role of agriculture in sage-grouse selection. I also removed development from the final models because it had correlation issues with roads and agriculture in one or more datasets. Finally, I removed development because upon visual inspection of the actual grouse locations in relation to development, I found a novel problem: a disproportionate number of sage-grouse locations fell within or close to the coal mine in Sink Valley. Many of the sampled sage-grouse (1 male, all 4 females) were captured near the coal mine area and some never strayed far from it. This phenomenon caused a large amount of used points to fall within the reclaimed mining area, which is geospatially identified as development. Throughout the rest of the study area, sage-grouse locations were not concentrated on any other development feature. I therefore removed development as a variable because it may provide misleading selection data relative to the study area as a whole. The predictor variables I removed for correlation problems or other spatial issues in any one dataset were removed from all datasets so each of the four RSFs had identical predictor variables.

**Data Analysis**

I used a Resource Selection Function (RSF) framework comparing third-order selection (Johnson 1980) of habitat used by sage-grouse to available habitat in the study area. Third order RSFs typically use a variation of a logistic regression to approximate the relative probability of use within a specified area such as calculated home ranges (Manly et al. 2002, Hosmer et al. 2013). To capture variation in sage-grouse habitat use across seasons and sexes, I generated subsets of data by the winter season (November to February), the nesting and brooding season (May–October), and by sex, resulting in four separate RSF models (*Winter Females*, *Winter Males*, *Nesting and Brooding Females*, *Nesting and Brooding Males*). I based our seasonal delineations on sage-grouse life history, data availability, and movements as demonstrated in previous research in Southern Utah (Burnett 2013, Frey et al. 2013, Dahlgren et al. 2016, Hansen 2016). I used package ‘adehabitatHR’ (Calenge and Fortmann-Roe, 2013) in Program R to calculate 99% Kernel Density Estimate (KDE) based home ranges for each individual. The final “available” home range habitat subset was further refined geospatially in ArcMap relative to the Panguitch SMGA boundary then aggregated by season. Within the seasonal available habitat, I generated the “available” points using a stratified random approach at a 10X sampling intensity relative to the number of used points.

To interpret RSF results at the population level while accounting for the random effects of individual and year (‘BirdYear’), I used a generalized linear mixed effect model (GLMM). The GLMM used is a variation of a logistic regression that constrains the response variable value
between 0 and 1 (1 = used, 0 = available/non-used) and allows for specification of a random effects component. I performed all RSF analyses using the statistical package lme4 (Bates et al., 2015) in Program R. I standardized \((x - \text{mean}(x))/\text{standard deviation}(x)\) all continuous predictor variables values prior to model runs to maximize model convergence. I used the ‘glmer’ function within lme4 to run each RSF and assigned ‘binomial’ to the family argument. The general model structure for each RSF as an equation is as follows:

\[
RSF = \text{glmer}(\text{Response Variable} \sim \text{Predictor Variables} + (1|\text{Random Effect}))
\]

Program R input equation:

\[
xRSF = \text{glmer}(\text{Used} \sim \text{LSB\_Dist} + \text{BSB\_Dist} + \text{MasterTDIS} + \text{MastPJ\_Dist} + \text{AG\_Dist} + \text{DEV\_Dist} + \text{RUG10} + \text{TCC} + \text{MinR\_Dist} +(1|\text{BirdYear}), \text{data} = x, \text{family} = '\text{binomial}')
\]

I created heat maps to visualize the RSF outputs geospatially using the raster calculator tool in ArcMap. To make the heat maps, I applied calculations to the raster values that were associated with each data point (used and available). The raster value for each predictor variable was the continuous number (e.g. distance in meters, ruggedness value, tree cover class) assigned to each point based on where they intersected geospatially. I standardized the raster values of predictor variables in ArcMap so the coefficient values from the RSF output matched the predictor variable raster values in ArcMap. To characterize the results of the RSF outputs geospatially, I ran the standardized predictor variable raster values and their corresponding RSF coefficient values through a logistic regression:

\[
RSF = \frac{\text{Exp}((\beta_1 + \text{Raster Value}_1) + \ldots + (\beta_8 + \text{Raster Value}_8))}{\text{1} + \left(\text{Exp}((\beta_1 + \text{Raster Value}_1) + \ldots + (\beta_8 + \text{Raster Value}_8))\right)}
\]

I divided the output raster of each heat map RSF regression by its max value to scale displayed map values between 0 and 1 (1 = highest probability of use and 0 = lowest probability if use). Final heat maps are presented in Appendix 1a - 1e.

**RESULTS**

Results of the four RSF models are presented here as log-odds, odds ratios, and heat maps. Raw coefficient estimates from the GLMM reveal the log-odds and are interpreted relative to zero. Positive coefficients indicate selection where negative coefficients indicate avoidance. For distance-based metrics, a negative coefficient indicates avoidance of the predictor as distance from it increases. When a distance based predictor variable yields a positive coefficient, it signals selection of distances further from that variable. For non-distance based predictors (e.g. ruggedness, tree canopy cover), a negative coefficient estimate indicates avoidance of high
predictor variable values and selection for lower values. All variables were continuous in this study so the log-odds interpretation assessed the log probability of use for every one unit change in data. Data were standardized to maximize model convergence; in this case, one standard deviation from the mean was one unit change in data. To interpret the coefficient as an odds-ratio, I divided the coefficient estimate by the standard deviation and exponentiated. For distance-based predictors, I multiplied the standard deviation divided coefficient by a distance value that was a good fit for the scale of the study area before exponentiating. Distance measurement units were in meters, but one meter was too small for a meaningful distance interpretation for a landscape species. For our distance-based odds ratio interpretation, I used 500m as one unit change. Odds ratios are a measure of percent change in respect to one unit change for continuous data, and ratios are interpreted in respect to one; values greater than one indicate selection and values less than one indicate avoidance.

I produced heat maps to provide a visual and geographical representation of RSF outputs. Heat maps were created in ArcGIS by back transforming standardized predictor variable raster data values (raster value-mean of raster value/standard deviation of raster value) then applying a logistic regression using respective coefficient estimates from the RSF output. I created a separate heat map for each season/sex RSF model and a composite heat map of all four models.

**Winter Season Females RSF (WFRSF)**

For the winter season female RSF, I analyzed 2,008 “Used” points and 20,127 “Available” points using the generalized linear mixed model (GLMM) in Program R. All eight predictor variables in the final model had highly significant P values (<0.001). The two non-distance based predictors, ruggedness (RUG10) and tree canopy cover (TCC) had the highest negative coefficient values (β = -0.88, 95% CI: -0.97, -0.79 and β = -0.79, 95% CI: -0.87, -0.71) indicating a strong avoidance to high ruggedness and high canopy cover values. Of the remaining distance based predictors, distance to treatment (MasterTDIS) had the highest negative coefficient (β = -0.64, 95% CI: -0.74, -0.55) indicating that hens are selecting for areas near habitat treatments in winter. The odd-ratio (i.e. probability) calculation for distance to treatments indicates that for every 500m increase in distance from treatments probability of use decreases by 48% (Exp(β / β sd * 500)-1)). Results also indicate that sage-grouse hens are selecting for areas near big sagebrush (BSB_Dist) and agriculture (AG_Dist) in the winter months (β = -0.33, 95% CI: -0.41, -0.24 and β = -0.18, 95% CI: -0.23, -0.13). The strongest avoidance from hens in winter was to areas near low sagebrush (β = 0.46, 95% CI: 0.4, 0.52) followed by distance to pinion/juniper and distance to minor roads (β = 0.34, 95% CI: 0.29, 0.40 and β = 0.14, 95% CI: 0.08, 0.21). A coefficient estimate plot for the winter season female RSF is shown in Figure 2. To assess variability across years and between individual sage-grouse, the GLMM includes a test for random effects.
because sample size varied by individual across years. Data for the winter season female RSF included three individuals and spanned from 2014 to 2016. The random effect considered for the RSF is “BirdYear” and was a data field that combined the individual bird ID with the year for each GPS data point. Random effect variability was measured as it related to the intercept from the GLMM. Some variability was evident in “BirdYear” for the winter season female RSF (Figure 3.) The cause of this variability may be due to differences in sample size or home range size across years and requires further analysis beyond the scope of this study.

Figure 2. Coefficient plot for winter season female RSF. Points indicate Beta estimates of RSF model. Negative coefficients indicate selection and positive coefficients indicate avoidance. As distance from 0.0 increases (-/+), selection/avoidance is greater. Horizontal lines indicate 95% confidence interval range. Confidence intervals that overlap 0.0 indicate non-significant parameters.
Fig 3. Random effects plot for winter season females. Points represent random effect intercept estimates and horizontal lines represent 95% confidence intervals. “BirdYear” was the random effect assigned to the RSF and the plot illustrates variation in resource selection for each individual for each year.

**Brooding and Nesting Season Females RSF (BFRSF)**

For the BFRSF, I analyzed 1,243 “Used” points and 12,322 “Available” points using a GLMM in Program R. Seven of the eight predictor variables returned highly significant P values (<0.001) while the coefficient estimate for the ruggedness variable had a P value of < 0.05, which is also significant. The two strongest predictor variables for sage-grouse hens during the brood rearing and nesting season were tree canopy cover (β = -0.84, 95% CI: -0.95, -0.73) and distance to treatment (β = -0.70, 95% CI: -0.90, 0.52), which have overlapping confidence intervals (Figure 4). These high negative coefficient values indicate that hens are selecting areas with very low tree canopy cover and selecting areas near habitat treatments. The odds ratio calculation for distance to treatments indicated that for every 500m increase in distance to treatment, probability of use decreases by 27% (Exp(β / β sd * 500)-1). Results from the GLMM also indicated that hens select distances closer to agriculture (β = -0.39, 95% CI: -0.50, -0.27) and for
areas with low ruggedness values ($\beta = -0.12$, 95% CI: -0.23, -0.01) during the brood rearing and nesting season. Interestingly, results of the RSF indicate that hens select against areas near both big and low sagebrush ($\beta = 0.45$, 95% CI: 0.38, 0.52 and $\beta = 0.10$, 95% CI: 0.03, 0.17). Positive coefficient estimates for distance to minor roads ($\beta = 0.43$, 95% CI: 0.36, 0.50) and distance to Pinyon/Juniper ($\beta = 0.11$, 95% CI: 0.05, 0.17) indicate hens select against areas near these features. Data for the BFRSF included three individuals and spanned from 2014 to 2016. Substantial variability was evident in “BirdYear” for the BFRSF for a hen identified as “Shandra” in 2014 and 2016 (Figure 5.) The cause of this variability may be due to differences in sample size or home range size across years and requires further analysis beyond the scope of this study.

![Figure 4](image.png)

**Figure 4.** Coefficient plot for brooding and nesting season female RSF. Negative coefficients indicate selection and positive coefficients indicate avoidance. As distance from 0.0 increases (-/+ selection/avoidance is greater. Horizontal lines indicate 95% confidence interval range. Confidence intervals that overlap 0.0 indicate non-significant parameters.
Figure 5. Random effects for brooding and nesting season female RSF. Points represent random effect intercept estimates and horizontal lines represent 95% confidence intervals. “BirdYear” was the random effect assigned to the RSF and the plot illustrates variation in resource selection for each individual for each year.

**Winter Season Males RSF (WMRSF)**

The WMRSF dataset included 2,476 “Used” points and 23,927 “Available” points that were analyzed with a GLMM in Program R. All eight predictor variables in the final model had highly significant P values (<0.001). The driving predictor variable for winter male grouse in this study area was tree canopy cover (β = -1.15, 95% CI: -1.25, -1.05) followed by the other non-distance based predictor, ruggedness (β = -0.59, 95% CI: -0.69, -0.50). These high negative coefficient estimates indicate a selection for areas with very low tree canopy and ruggedness values. Of the distance based predictors, male grouse selected for areas near low sagebrush (β = -0.38, 95% CI: -0.48, -0.31) and near minor roads (β = -0.22, 95% CI: -0.28, -0.16). Pinyon and Juniper woodland was the distance variable male grouse most strongly avoided in winter (β = 0.56, 95% CI: 0.55, 0.60). The odds-ratio calculation for distance to PJ indicates that for every 500m
increase in distance from PJ, probability of use increases by $3075\% \ (\text{Exp}(\beta / \beta \text{ sd} * 500)-1))$. Male sage-grouse in this study also relatively avoided areas near treatments ($\beta = 0.15$, 95% CI: 0.08, 0.21), agriculture ($\beta = 0.18$, 95% CI: 0.12, 0.24), and big sagebrush ($\beta = 0.29$, 95% CI: 0.23, 0.34) during the winter. A coefficient estimate plot for the WMRSF is presented in Figure 6. The random effect considered for the WMRSF is also “BirdYear” as the data for the WMRSF included six individuals and spanned from 2013 to 2016. The random effect variability was measured as it related to the intercept from the GLMM. A small amount of variability was evident in “BirdYear” for the WMRSF (Figure 7.) The cause of this variability may be due to differences in sample size across years or home range size and requires further analysis beyond the scope of this study.

Figure 6. Coefficient plot for winter season male RSF. Negative coefficients indicate selection and positive coefficients indicate avoidance. As distance from 0.0 increases (-/+), selection/avoidance is greater. Horizontal lines indicate 95% confidence interval range. Confidence intervals that overlap 0.0 indicate non-significant parameters.
Figure 7. Random effects plot for winter season males. Points represent random effect intercept estimates and horizontal lines represent 95% confidence intervals. “BirdYear” was the random effect assigned to the RSF and the plot illustrates variation in resource selection for each individual for each year.

Brooding and Nesting Season Males RSF (BMRSF)

For the BMRSF, I analyzed 4,428 “Used” points and 42,794 “Available” points using a GLMM in Program R. Six of the eight predictor variables returned highly significant P values (<0.001), while coefficient estimates for distance to low sagebrush and distance agriculture were not significant. Results strongly suggest that male sage-grouse select areas with very low tree canopy cover values during the brood rearing and nesting season ($\beta = -0.85$, 95% CI: -0.91, -0.80). Male sage-grouse also select for low ruggedness ($\beta = -0.35$, 95% CI: -0.41, -0.30) and for areas near big sagebrush ($\beta = -0.10$, 95% CI: -0.14, -0.06). Slightly positive coefficient estimates for distance to treated areas, PJ, and minor roads indicate that males avoid areas near those variables. A coefficient estimate plot for the WMRSF is presented in Figure 8. The random effect considered for the BMRSF is “BirdYear,” as the data for the BMRSF included nine individuals and spanned from 2013 to 2016. The random effect variability was measured as it relates to the
intercept from the GLMM. A moderate amount of variability was evident in “BirdYear” for the BMRSF (Figure 10.) The cause of this variability may be due to differences in sample size across years or home range size and requires further analysis beyond the scope of this study (Figure 9).

Figure 8. Coefficient plot for brooding and nesting season male RSF. Negative coefficients indicate selection and positive coefficients indicate avoidance. As distance from 0.0 increases (-/+) selection/avoidance is greater. Horizontal lines indicate 95% confidence interval range. Confidence intervals that overlap 0.0 indicate non-significant parameters.
Figure 9. Random effects plot for brooding and nesting season males. Points represent random effect intercept estimates and horizontal lines represent 95% confidence intervals. “BirdYear” was the random effect assigned to the RSF and the plot illustrates variation in resource selection for each individual for each year.

DISCUSSION

My results suggest that sage-grouse within the study area strongly select for very low conifer cover values and low ruggedness across sexes and seasons. The selection of low tree canopy cover is consistent with research that suggests conifer expansion into sagebrush habitats is detrimental to sage-grouse populations during nesting (Doherty et al. 2010), breeding (Casazza et al., 2011), and during winter (Doherty et al., 2008). Dalhgren (2016) described much of Utah’s sage-grouse habitat as highly fragmented and confined to mainly areas of open sagebrush habitat. The Panguitch SGMA exemplifies fragmented sage-grouse habitat having relatively narrow patches of open sagebrush areas fragmented by geographic features such as rugged cliffs and anthropogenic features such as a highway that bisects the length of the SGMA.
The RSF models in this study suggest that in the Panguitch SGMA, sage-grouse are limited by habitat availability and rely on areas with low conifer cover and low ruggedness. Connelly and Knick (2011) suggest sage-grouse require large contiguous tracks of sagebrush habitat, which is not a defining characteristic of the habitat found in the Panguitch SGMA (with only some exceptions). As suggested by Frey (2013), sage-grouse in the Panguitch SGMA may be selecting less than optimal habitats – such as small patches of sagebrush or low tree canopy cover areas – as they are space limited. This result fits initial visual inspection in ArcGIS of the “used” points relative to the tree canopy cover and ruggedness raster data.

A major limiting factor that contributes to further habitat fragmentation in the Panguitch SGMA is the amount PJ that is encroaching into open sagebrush ecological types (Frey 2013). Our results suggest male and female sage-grouse universally avoid PJ habitat in winter and during the nesting and brood-rearing period. Local resource managers have long suspected that encroaching PJ is a limiting factor for sage-grouse in the Panguitch SGMA. The local sage-grouse working group (Color Country Adaptive Resource Management team or CCARM, 2013) identified conifer encroachment as well as nest predation and wildfire as major threats to sage-grouse in the Panguitch SGMA.

A foundational aspect of this study is assessing the use of habitat treatments by sage-grouse. Over the past 11 years, PJ removal has occurred in the Panguitch SGMA costing millions of dollars (UWRI 2016). For this analysis, I included all WRI treatments with sage-grouse benefits in the Panguitch SGMA from 2006 to 2016 as a predictor variable (n=44,511 acres). Of the total acres used in the analysis, approximately 80% of those occurred from 2012 to 2016 (36,735 acres) and approximately 50% of all treatments used in this analysis occurred from 2014 to 2016 (~23,201 acres). Therefore, the majority of treatments available to the sampled population are recent and relatively new, ecologically speaking.

This study’s RSF analysis suggests a marked difference in use of treatments by sage-grouse across sexes, with females selecting for and males avoiding treatments in both study seasons. Females strongly selected for distances near treatments during the nesting and brood rearing season second only to tree canopy cover but with overlapping confidence intervals (Figure 7). Sanford et al (2016) had similar results from an RSF study in which nesting success increased as distance to treatment decreased. Severson (2017) also found a preference for nesting in or near treatments; noting that nesting preference increased over time in conifer removal areas compared to control areas. Many of the large-scale treatments in the current study area happened recently; the benefits for nesting grouse may only increase as these landscape scale changes in habitat mature. The current study’s sampled female sage-grouse also selected for distances close to treatments in winter. Sage-grouse hens may be using these treatment areas for much of the year as they are providing new or alternate resources such as early succession
grass and forb communities or important shrub communities that were, until recently, suppressed by encroaching PJ. Treatment areas may also be refuge from predation due to the reduction of trees for perching predators (Manzer and Hannon, 2005). Frey (2013) observed sage-grouse shifting preference from local agricultural areas in Sink Valley to newly treated areas. This shift may be tied to resource availability, predator avoidance, or a combination of the two. Relative home range size of individual female grouse was substantially smaller than that of the male grouse sampled in this study. All of the female grouse in this study (n =4) were captured in the same area (Sink Valley) and despite thousands of location data points (n=2008 in Winter, n = 1243 in Nesting and Brood Rearing), they spent the majority of their time relatively close (<15 km) to where they were captured, save a few forays. These minimal movements are contradictory to research that suggests sage-grouse found in more fragmented habitat make longer movements on average compared to grouse in large continuous tracts of habitat (Dahlgren, 2016). The high selection for treatment areas may be influenced by the fact that several treatments are centered in Sink Valley and the yearling female grouse have high fidelity to the area for all their life history needs. Future efforts to better understand the benefit of habitat treatments to female grouse in the Panguitch SGMA will require larger sample sizes and more heterogeneous capture locations.

In this study, male grouse did not select distances near treatments in either season studied. The broader home ranges and capture areas of the male grouse in relation to treatment locations may imply a more diverse use of habitat by male grouse. The benefits of early successional vegetation communities may not be as beneficial to males as it is to females, especially females with broods (Casazza 2011). Because many of these large-scale treatments were relatively new, they may not have matured enough to provide the sagebrush resources preferred by male grouse for cover and forage. Based on the overall preference for low tree canopy cover, it is reasonable to predict that treatments sited near open sagebrush areas of known sage-grouse use will eventually become suitable and selected for by male sage-grouse, especially if the treatment area is a sagebrush ecological type. Further analysis is needed to qualify the different treatment types in relation to use by sage-grouse in the area. For this study, treatments were not split into categories based on methods or current/desired conditions; they were billed as a benefit to sage-grouse. However, the majority of the treatments used in the RSF involved conifer removal at various phases (of encroachment as a main component (Miller et al. 2005, UWRI 2016).

Agriculture was a common landscape feature within the study area. Female sage-grouse selected for areas near agriculture in winter and slightly more so during the nesting and brood rearing period. All hens in this study were captured near the Sink Valley lek area, which is surrounded by agriculture. The hens sampled in this survey were all yearlings or juvenile when captured, with only one hen (‘Shandra’ 2014 to 2016) reaching breeding age while the
transmitter was active. Resident female grouse may be using the agricultural areas in Sink Valley for brood-rearing diet needs, with these yearling hens having been reared in these agricultural areas thus exhibiting fidelity. The proximity and association of agricultural areas in relation to the Sink Valley lek, treatment areas, areas with low canopy cover, low ruggedness, and sagebrush habitat may all contribute to selection by sage-grouse hens. Frey et al. (2013) observed sage-grouse shifting use from irrigated pasture to nearby treated areas in the Sink Valley area, which may indicate that the surrounding treated areas have influenced sage-grouse resource selection. To better understand female sage-grouse use of agriculture in the Panguitch SGMA, larger sample sizes and further qualification of agriculture types and level of use are warranted. Our sampled male sage-grouse clearly selected against areas near agriculture across seasons, suggesting that male grouse find resources elsewhere and do not target the type of resources that agriculture provides. Alternatively, males avoid potential threats near agriculture such as predation.

Sagebrush habitats are inextricably tied to sage-grouse in the western US (Knick and Connelly, 2011, Connelly et al. 2000). The GPS location data of this study’s sampled sage-grouse strongly support that notion with 92% of the “Used” locations (n=10,155) falling within 100 meters of sagebrush (low and big) and 85% falling within 50 meters. However, the RSF dataset indicates that use of these sagebrush habitats by sage-grouse may differ between sexes and across seasons. In this study, male grouse selected for big sagebrush during the nesting and brood-rearing seasons and for low sagebrush in winter. The latter selection is surprising because low sagebrush is often covered by snow in the winter months, especially at high elevations. However, low sagebrush may provide vital nutrition and males may actively seek lower elevations or southern-facing slopes where low sagebrush is available in the winter months. Further analysis using snow depth records and elevation data may provide insight on seasonal use of sagebrush type by male sage-grouse in the Panguitch SGMA.

The RSF suggests year-round sagebrush selection by male sage-grouse and avoidance of treated areas. A large majority of the habitat treatments in the Panguitch SGMA has occurred recently and may not yet contain adequate sagebrush resources for male sage-grouse. This study’s results indicate a strong selection for big sagebrush and avoidance of low sagebrush by female sage-grouse in the winter. The sample consisted of yearling or young female grouse, and these grouse may target taller sagebrush in winter months due to availability based on snow cover. Counterintuitively, the results of the RSF analysis indicated the sampled female grouse were not selecting for low sagebrush or big sagebrush in the study area during the nesting and brood-rearing season. Physical inspection of the “Used” female data points indicate confirmed presence in sagebrush but the limited sample size and small home ranges may not yield a distinction between use of sagebrush between the “Used” and “Available” points. Another possible explanation is that the many treatments in the area are actually now sagebrush sites.
but not identified by LANDFIRE (2013) as such. Temporal adjustments were made to account for treatment and PJ availability but not for sagebrush. It was reasonable to adjust LANDFIRE PJ vegetation type using treated area polygons (e.g. digitally updating the PJ layer based on timing of treatment) but not feasible to call all treated areas sagebrush habitat based on a LANDFIRE classification system. Upon visual inspection of aerial imagery, many of the treated areas used by the sampled female grouse were sagebrush areas, but it is beyond the scope of this study and irresponsible to assume that we could classify the amount of low and big sagebrush in all of the treated areas. Future analysis warrants a new RSF run using an updated LANDFIRE vegetation dataset that accounts for the substantial habitat treatment work since 2013. Future RSF studies should also consider the effect of treatment age relative to selection by sage-grouse to determine at what stage the treatment is the most beneficial or detrimental.

The strong selection for treatments and low conifer cover values by female sage-grouse during the nesting and brood rearing season could indicate that much of the treated area is a sagebrush ecological site that has experienced significant conifer encroachment. Overall, the universal selection of low conifer cover, low ruggedness, and avoidance of PJ sites coupled with evidence of treatment and sagebrush use provides compelling evidence to resource managers to continue efforts in removing encroaching conifer and enhancing sagebrush habitats in the Panguitch SGMA.

**MANAGEMENT RECOMMENDATIONS (by MNR Core Competency)**

**Human Dimensions**

The sage-grouse has become the symbol of wildlife conservation in the western United States. Conservation efforts put towards sage-grouse in the last 10 years have been unprecedented (USFWS 2015). The perceived threat of a sage-grouse listing to human interests such as ranching, housing development, and energy development spurred a conservation paradigm shift in the west in which sagebrush became the focal point. Stakeholders came together to be sure their interests were considered in the various federal and state management plans being developed to protect sage-grouse. In Utah, and particularly southern Utah, fragmented sage-grouse populations are associated with small rural communities that typically have interests in livestock operations in sage-grouse habitats. The majority of sage-grouse habitat in our study area is designated as federal multiple-use land or private property. Recently, efforts to improve or protect sage-grouse habitat have resulted in a drastic change in the look of these rangelands through conifer removal treatments. This study has shown that these treatments are used by sage-grouse and are therefore beneficial. However, perception of these habitat treatments may
vary greatly across stakeholder groups and the general community. This study can add to the evidence that tree removal is beneficial to sage-grouse, and resource managers can use the RSF results as justification for continued tree removal in appropriate areas. During this study, we developed a questionnaire (see Appendix 1f) to gain a better understanding of public perception of not only sage-grouse, but of habitat treatments for sage-grouse. This questionnaire targeted the residents within the Panguitch SGMA and surrounding communities. The results of this human-dimension inquiry are outside scope of this report. Our human dimensions report will be available in a separate report that can supplement this study’s findings.

Ecological

This study represents a glimpse into the ecological needs of sage-grouse in the Panguitch SGMA. As such, the RSF model is informed using biologically relevant predictor variables based on local knowledge and literature. The primary interest of this study is the use of habitat treatments by sage-grouse; results show that hens are selecting for treated areas. However, the overall strong selection for low canopy cover and low ruggedness may be the primary drivers of these models. I recommend that managers continue tree removal in areas with low ruggedness value and evidence of conifer encroachment in the Panguitch SGMA. These treatments contribute to the aggregate of areas with low tree density and will likely be used if adjacent-to-used areas or as ecological succession matures.

The majority of the recent habitat treatments in the Panguitch SGMA are funded because they are billed as a project that will benefit sage-grouse. One concern with landscape level ecological change for a single species centers around the effects on other local native species. I recommend that resource managers carefully execute sage-grouse habitat projects in appropriate ecological sites such as sagebrush habitat that has experienced conifer encroachment. Holmes et al., (2017) found that conifer removal projects in Oregon that were designed to improve sagebrush, forb, and grass communities benefited other species such as Brewer’s Sparrow (*Spizella breweri*), vesper sparrow (*Pooecetes gramineus*), and green-tailed towhee (*Pipilo chlorusus*). However, the latter species are ground-nesting passenires and the same study found a decline in treated areas for gray flycatcher (*Empidonax wrightii*), which is a tree nesting species. Impacts of conifer removal on tree nesting species warrants further research. It could be argued that large-scale tree removal influences nesting habitat for several tree nesting species but it could also be argued those species have a surplus of nesting strata based on the expanse of encroaching conifer in the west.
Economic

In the Panguitch SGMA, most recent large-scale habitat restoration efforts are channeled through the WRI. The WRI is a clearinghouse that appropriates federal, state, and private funding sources via peer-reviewed ranking for projects that benefit wildlife habitat and watershed health. Big game habitat has historically been the focus of most WRI channeled treatment projects in southern Utah (pers. comm. G. Bezzant). Recently, sage-grouse have joined with big game as the focus of habitat restoration funding. Once the threat of a federal listing became a reality, many new sources of federal monies became available from agencies such as the Bureau of Land Management (BLM) and the Natural Resource Conservation Service (NRCS). I recommend that resource managers consider using this study’s findings and similar research when planning treatment projects. For example, the heat maps produced within this study could be used to target areas that need conifer removal or areas adjacent to high use areas that could quickly expand useable habitat for sage-grouse. The RSF model further provides a method of justification for effective treatment placement, thus maximizing funding efficiency.

A major concern of local government in the Panguitch SGMA has been the perceived impact that sage-grouse conservation could have on the local economy. In particular, concerns over sage-grouse habitat protections center around the limitation of federal grazing leases and hindrance to a local private coal mine operation in Sink Valley. However, the recent increase in large-scale habitat treatment work on federal land may create an increase in available forage for livestock and native wildlife. Many federal grazing allotments have extensive areas of Phase II and III encroached conifer, which provide very little forage in the form of forbs and grasses. The subsequent seeding of these treated areas has provided a net gain in forage throughout much of the Panguitch SGMA.

A private coal operation in Sink Valley was a major concern for local resource managers regarding sage-grouse. The mine is located essentially on top of a lekking area on private land and once operations started, lek counts drastically dropped based on historic averages (pers. comm. D. Schiable, UDWR). However, state and federal managers focused treatment projects in Sink Valley due to the presence of the mine in hopes that sage-grouse would find useable habitat as an alternative. This resulted in extensive conifer encroachment removal in and around Sink Valley. The local sage-grouse found a new area to lek and started using treated areas near the mine (Frey 2013). Since the mining operation began, lek counts have trended back upwards to levels equal to pre-mining conditions. The local sage-grouse in sink valley returned to the original lek site in 2016, which is approximately 9 years since the mining operations began. This study’s RSF models reveal high fidelity to the Sink Valley area near the mine, which means that the targeted treatments in the area held the birds in spite of significant
disturbance. Major efforts from multiple stakeholders helped identify threats and mitigation strategies for offsetting the impacts from the small private coal operation, and many of the stakeholders involved with the sage-grouse in Sink Valley are active members of a sage-grouse local working group. The persistence of the Sink Valley grouse population in the presence of a strip mine surprised many members of the local working group. However, the resiliency of the Sink Valley sage-grouse to a strip mine is novel and should not be generalized range-wide. Currently, the existing mining in Sink Valley is located on private property, but coal resources are present on adjacent federal land. The presence of sage-grouse habitat on that federal land has complicated efforts by the BLM to offer a lease by application in Sink Valley. The extractive energy industry is likely impacted economically by restrictions on federal surface disturbance in sage-grouse habitat range-wide.

**Policy and Administration**

A large portion of existing and potential sage-grouse habitat in the Panguitch SGMA is on federal land. Regional and localized land use plans in BLM field offices and USFS ranger districts (e.g. Resource Management Plans for the BLM and Forest Plan for the USFS) provide policy-based guidance for sage-grouse management on those federal lands. In response to the USFWS designating the sage-grouse as a candidate for listing in 2010, these land use plans were amended to provide more robust protections for sage-grouse. Land use plan amendments were completed range-wide and provide more robust regulatory mechanisms for federal land management agencies regarding sage-grouse (USFWS 2015). Current research including RSF models should inform Federal sage-grouse policy. This study’s RSF can inform future amendments to federal policies relevant to the Panguitch SGMA. In addition to federal policies, state wildlife agencies have management plans specific to sage-grouse. Updates to Utah’s state sage-grouse management plan occur every 5 years. To create more accurate seasonal-use maps and identify key conservation and mitigation areas, I recommend that my RSF models inform future iterations of the state plan specifically in the Panguitch SGMA.

In the western U.S., sage-grouse conservation and research has become a fixture in the daily work of many federal and state land managers. Multiple agencies have staff that administer sage-grouse specific programs. For example, many BLM and USFS offices within sage-grouse range have specialists that ensure the provisions in the sage-grouse plan use amendments that are being included in actions requiring assessment under the National Environmental Policy Act (NEPA). A specific provision required by the sage-grouse land use amendment is the explicit consultation of federal agencies with state wildlife agencies that have management jurisdiction over sage-grouse. RSF models provide a geospatial reference for state biologists, federal land managers, and ultimately NEPA decision makers. RSF models can inform impact analysis,
identify key habitats for protection, and justify actions that conserve and expand sage-grouse populations and habitats. RSF models also can be projected across large areas, which will expand our understanding of the scale and space required by a landscape scale species such as the sage-grouse. Sage-grouse do not consider administrative boundaries when selecting a resource. The RSF is a useful tool that may blur the administrative lines and foster the continued multi-agency cooperative approach to sage-grouse conservation and management.
REFERENCES


Appendix 1a. Winter female sage-grouse heat map in Panguitch SGMA study area.
Appendix 1b. Winter male sage-grouse heat map in Panguitch SGMA study area.
Appendix 1c. Nesting and brooding female sage-grouse heat map in Panguitch SGMA study area.
Appendix 1d. Nesting and brooding male sage-grouse heat map in Panguitch SGMA study area.
Appendix 1e. Composite heat map of all four RSF models.
Dear Respondent,

You have been identified as a survey participant because of your place of residence and/or activity - property ownership, agricultural practices, grazing leases, etc. - within the Panguitch Sage Grouse Management Area (SGMA: See map attached). Your identity will remain confidential. We are asking the following questions to gain information on the perceptions and attitudes towards Greater-Sage Grouse (*Centrocercus urophasianus*) and federal land management in the local communities within or nearby the Panguitch SGMA. Data from this survey will be used to help state and federal resources agencies make informed decisions that include public input. This survey should take less than 5 minutes to complete. Once finished, please use the pre-addressed, postage-paid envelope to return the survey to Dr. Nicki Frey, at Utah State University.

For each question, please circle THE ONE RESPONSE that best fits your opinion or knowledge.

1. Which of the following best describes your attitude towards Greater Sage-grouse?
   a. They are an important part of the ecosystem and efforts should be made to protect their populations and their habitats.
   b. They are an important part of the ecosystem and deserve protection AND they are valuable as an upland game species providing a unique hunting opportunity.
   c. They are only valuable as a game species.
   d. I do not find any value in Greater-Sage grouse.
   e. I do know much about Greater-Sage grouse and do not have an opinion.

2. Which of the following best describes your experience or familiarity with Greater-Sage grouse?
   a. I regularly encounter sage grouse and have hunted them.
   b. I regularly encounter sage grouse but have never hunted them.
   c. I rarely encounter sage grouse but have hunted them.
   d. I rarely encounter sage grouse and do not hunt them.
   e. I have never encountered a sage grouse.

3. One threat to Greater sage-grouse is the presence of trees in their sagebrush habitats. In southern Utah, these trees are often Pinyon Pines and Junipers. We are interested in public opinion regarding Pinyon and Juniper trees. Please rate the statements below based on your level of agreement:
I strongly agree | I agree | Neutral | I Disagree | I Strongly Agree
---|---|---|---|---
Pinyon and Juniper trees are encroaching into sagebrush habitats and reducing the value of the land for wildlife and livestock use
Pinyon and Juniper trees are not encroaching into other habitats they are where they are supposed to be.
Fire suppression is a major cause of Pinyon and Juniper encroachment.

4. Millions of federal, state, and private dollars have been spent to improve sage grouse habitats in Southern Utah. A large number of these treatments have occurred on federal land near the communities of Panguitch, Hatch, and Alton. Most of these treatments involve the removal or thinning of Pinion Pine and Juniper trees to facilitate more sagebrush and grassland habitats. Which of the following best describes your opinion regarding these habitat treatments?

a. These treatments are improving sage grouse habitat, big game, habitat, livestock forage, and improving fire resiliency.
b. These treatments are very destructive and are removing native woodlands that are valuable to wildlife and the public.
c. Pinion and Juniper have encroached in many areas but they are removing too many trees at a time. They are not leaving enough tree cover for big game species and are displacing native wildlife.
d. These treatments are a waste of money and we should let nature take its course.
e. I am unfamiliar with these habitat treatments and have no opinion.

5. Which of the following best describes your land ownership in or near the Panguitch SGMA?

a. I live in the community but do not own property.
b. I am a homeowner in the community but I do not own more than 100 acres.
c. I live in the community and own more than 100 acres not used for agriculture.
d. I live in the community and own more than 100 acres used for agricultural purposes.
e. I own more than 1000 acres in the community.

6. The Panguitch SGMA and surrounding area is mostly comprised of public land managed by the Bureau of Land Management and the U.S. Forest Service. People often value their public lands for different reasons. Please rate the statements below based on your level of agreement:

| I strongly agree | I agree | Neutral | I Disagree | I Strongly Agree |
---|---|---|---|---|
I value the public lands for recreation including any of the following: hunting, fishing, camping, wildlife watching, and ATV
riding AND I support grazing, logging, mining, and other development on these lands.

I value the public lands for recreation including any of the following: hunting, fishing, camping, wildlife watching, and ATV riding AND I DO NOT support grazing, logging, mining, and other development on these lands.

The primary value of federal land is for livestock grazing, mining, logging, and other development.

7. Which of the following best describes your opinion on federal land management?
   a. The federal government controls too much land in my community and is hindering economic growth in the local communities.
   b. Federal land belongs to the public and provides opportunities for multiple uses including but not limited to: hunting, fishing, wildlife watching, timber, energy development, and livestock grazing.
   c. Federal agencies are not managing the federal land to its potential and federal policies should be revised to allow for fewer development restrictions on federal land.
   d. Federal agencies are not managing the federal land to its potential and the state should have control of the federal lands.
   e. The federally controlled lands around my community provide the rural communities with the economic benefit of tourism and outdoor recreation.

8. How healthy do you consider the vegetation on the public lands in and around your community? If you have no basis for judgment, please select “no opinion”.
   a. Very Healthy
   b. Moderately Healthy
   c. Needs Improvement
   d. In Poor Condition
   e. No Opinion

9. How often do you spend time on public lands?
   a. Once a week or more on average.
   b. Once a month on average.
   c. A couple of weeks per year.
   d. A weekend or two per year.
   e. I spend very little time on public lands.

10. What wildlife and/or domestic animal species do you value on public lands?
    a. Big Game, Upland Game, Sport Fish, Native Wildlife, and Domestic Livestock.
    b. Big Game, Upland Game, Sport Fish, and Domestic Livestock.
c. Native Wildlife Species Only.
d. Big Game, Upland Game, and Sport Fish Only.
e. Domestic Livestock Only.

11. What is your education level?

a. Doctorate Degree.
b. Master’s Degree.
c. Bachelor’s Degree.
d. High School Diploma or equivalent.
e. Less than High School Diploma.

12. Which of the following best describes your involvement with grazing on public or state lands (BLM, Forest Service, and SITLA).

a. I have a grazing permit on public or state lands.
b. I am not a livestock owner.
c. I am a livestock operator on private lands only.

13. Please use the space below to for additional comments or opinions you feel like sharing related to Greater-Sage grouse and land management practices in and around your community.

_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
_______________________________________________________________________
Map of the Panguitch SGMA

Courtesy of the State of Utah’s Conservation Plan for Greater-Sage Grouse