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AGENCY:	**Fish, Wildlife & Parks**
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Annual Report

Sage-Grouse Grazing Evaluation

July 1, 2015 – June 30, 2016

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EXECUTIVE SUMMARY

In September 2015, the US Department of Interior Fish and Wildlife Service determined that the greater sage-grouse did not need to be listed for protection under the Endangered Species Act because of the collaborative conservation efforts among agencies and private landowners. The Sage-Grouse Initiative (SGI) implemented by the US Department of Agriculture Natural Resources Conservation Service formed a large part of those conservation efforts that contributed to this decision. These conservation efforts must be maintained because the status of greater sage-grouse will be re-evaluated in 2020. Information on the impacts of grazing to greater sage-grouse and their habitat will provide support for conservation efforts. Thus a goal of our study is to evaluate the effectiveness of SGI in improving greater sage-grouse habitat and how SGI impacts greater sage-grouse vital rates and resource selection. However, this is a long-term study in its 6th year, with 4.5 yrs of data collection left. Therefore not all long-term project deliverables are completed. Herein we present preliminary results from years 1 – 6 of the project (years 2011 – 2016).

We collected data to estimate greater sage-grouse vital rates including adult female (hen) survival, nest success, and chick survival using radio telemetry. We also used radio telemetry to collect locations of hens, nests, and chicks for resource selection analyses. We measured several habitat variables to ascertain their relationship with each vital rate and resource selection. We measured herbaceous vegetation based on line-intercept methods at a set of stratified random field plots on both SGI-enrolled and non-participating ranches (Non-SGI) to test for differences in indicators of habitat quality across the project area. We measured vegetation data at greater sage-grouse nests and random points within nesting habitat using line-intercept and Robel pole methods to evaluate nest site selection and nest success of hens. We also used landscape-scale habitat variables measured from remotely sensed data in GIS layers in nest site selection and nest success analyses.

We used linear mixed effects models to test for grazing system and rest effects on vegetation metrics while accounting for variation across years and ranches. Likelihood ratio tests indicated that live grass height, residual grass height, bare ground, and litter all differed between SGI and Non-SGI ranches. Live and residual grass heights were taller on SGI than Non-SGI ranches, and bare ground cover was lower on SGI ranches. Visual obstruction and herbaceous vegetation cover did not differ between grazing systems. However, after accounting for grazing system

effects, the effect of pasture rest was negligible and non-significant for all variables tested. In addition, these grazing system effect sizes between SGI and Non-SGI ranches were small relative to annual variation. Nest site selection by hens was assessed using Bayesian methods to fit logistic regression models relating measured covariates to the probability that a site was a nest versus a randomly sampled available site. At the smaller scale of the nest, analyses indicated that females selected shrubs with greater volume. At the plot scale, analyses indicated that females selected for greater sagebrush cover. At the patch scale, analyses indicated that females selected gentler terrain and more even stands of sagebrush. Females preferred to locate nests farther from county roads and highways but closer to two-track roads, and avoided landscapes with greater amounts of non-cropland anthropogenic disturbance. We speculate that this preference may reflect the tendency for 2-track roads to traverse terrain preferred by sage- grouse for nesting, e.g., areas of gentle topography.

Annual apparent survival estimates of greater sage-grouse hens from 2011 – 2015 ranged from 57 – 82%. We used a Kaplan-Meier survival function to evaluate hen and chick survival with a staggered entry design and right censored individuals with unknown fates, dropped transmitters, or that survived until their transmitters expired. The Kaplan-Meier mean survival time estimate for 300 marked hens monitored from March 2011 – September 2015 is 2.98 yrs and the median is 2.35 yrs. Annual apparent nest success during 2011 – 2015 ranged from 30 – 64%. The effects of covariates on nest success were analyzed using Bayesian methods to fit logistic regression models relating measured covariates to daily nest survival rate. These analyses suggested that greater amounts of rainfall over a 4-day period prior to the occurrence of nest fates were associated with lower daily nest survival. Results indicated some support for greater nest success for nests farther away from county roads and highways. Annual apparent survival estimates for greater sage-grouse chicks during 2011 – 2016 ranged from 12 – 22%. Preliminary results of chick survival analyses using Kaplan-Meier survival estimates and log-rank tests indicate no difference in survival of greater sage-grouse chicks among years during 2011 – 2015. Low chick survival indicated that this vital rate may be an important focus for future conservation and management efforts.

BACKGROUND

The greater sage-grouse (*Centrocercus urophasianus*; hereafter "sage-grouse") is a large, ground-dwelling bird that is endemic to semi-arid sagebrush (*Artemisia* spp.) habitats in western North America (Schroeder et al. 1999). This species uses the sagebrush steppe year-round for most of its life history needs (Crawford et al. 2004) because sagebrush is often the only food available during certain times of the year such as winter. Sage-grouse are not the only species that rely on sagebrush. Sagebrush systems also provide important habitat for songbird species including Brewer's sparrow (*Spizella breweri*; Dreitz et al. 2015), elk (*Cervus elaphus*), mule deer (*Odocoileus hemionus*), and pronghorn (*Antilocapra americana*; Connelly et al. 2004). More than 600 species of conservation concern that depend upon sagebrush ecosystems have been identified (Rich et al. 2005). Thus, efforts to sustain sage-grouse populations are likely to benefit a variety of other wildlife species.

The loss and degradation of the sagebrush habitats upon which these several species depend has led to the extirpation of sage-grouse from over half of its original range (Schroeder et al. 2004). In September 2010 the US Department of Interior Fish and Wildlife Service (USFWS) listed the sage-grouse on the candidate list for threatened and endangered species protection under the Endangered Species Act (ESA; USFWS 2010) due to several petitions for listing. In September 2015 the USFWS determined that sage-grouse did not need to be listed because current efforts by state and federal agencies as well as other partners were adequate for the conservation of this species and its habitat (USFWS 2015). However, the conservation efforts must be maintained because the status of sage-grouse will be re-evaluated in 2020. Information on the impacts of grazing to sage-grouse and their habitat will provide support for conservation efforts.

Declines in sage-grouse populations are attributed to habitat loss from a variety of sources including increasing oil and gas development (Naugle et al. 2011), conversion to cropland (Connelly et al. 2004, Smith et al. 2016), conifer invasion (Crawford et al. 2004, Beck et al. 2012), rural sprawl (Leu and Hanser 2011), and disease (i.e., West Nile virus; Walker and Naugle 2011). A top priority of sage-grouse conservation is preventing further habitat loss and fragmentation from these many sources (e.g., Smith et al 2016, USFWS 2013). The USFWS, in partnership with several state agencies, has outlined range-wide conservation objectives for sage-grouse (USFWS 2013). USFWS (2013) has delineated management zones (Fig. 1) with specific conservation needs for each zone. Our project falls within management zone 1, where agricultural conversion (USFWS 2013, p. 48) is identified as the biggest threat to sage-grouse habitat. USFWS (2013, p.48) has outlined four conservation actions for management zone 1 that are focused on incentivizing landowners to conserve sage-grouse habitat (Table 1). Current progress towards these actions includes the sodsaver provision of the 2014 Farm Bill that was signed into law in February 2014 and is intended to decrease conversion of native sagebrush and grasslands to tilled crops, and the US Department of Agriculture Natural Resources Conservation Service's (NRCS) Sage-Grouse Initiative (SGI) that the NRCS has implemented across the range of sage-grouse. These are intended to keep working ranches on the landscape and prevent further reduction of sage-grouse habitat. Further, in September 2014 the Governor of Montana signed executive order 10-2014 establishing the Montana Sage

Grouse Oversight Team (MSGOT) and the Montana Sage Grouse Habitat Conservation Program. The Montana Greater Sage-grouse Stewardship Act was passed by the 2015 Montana

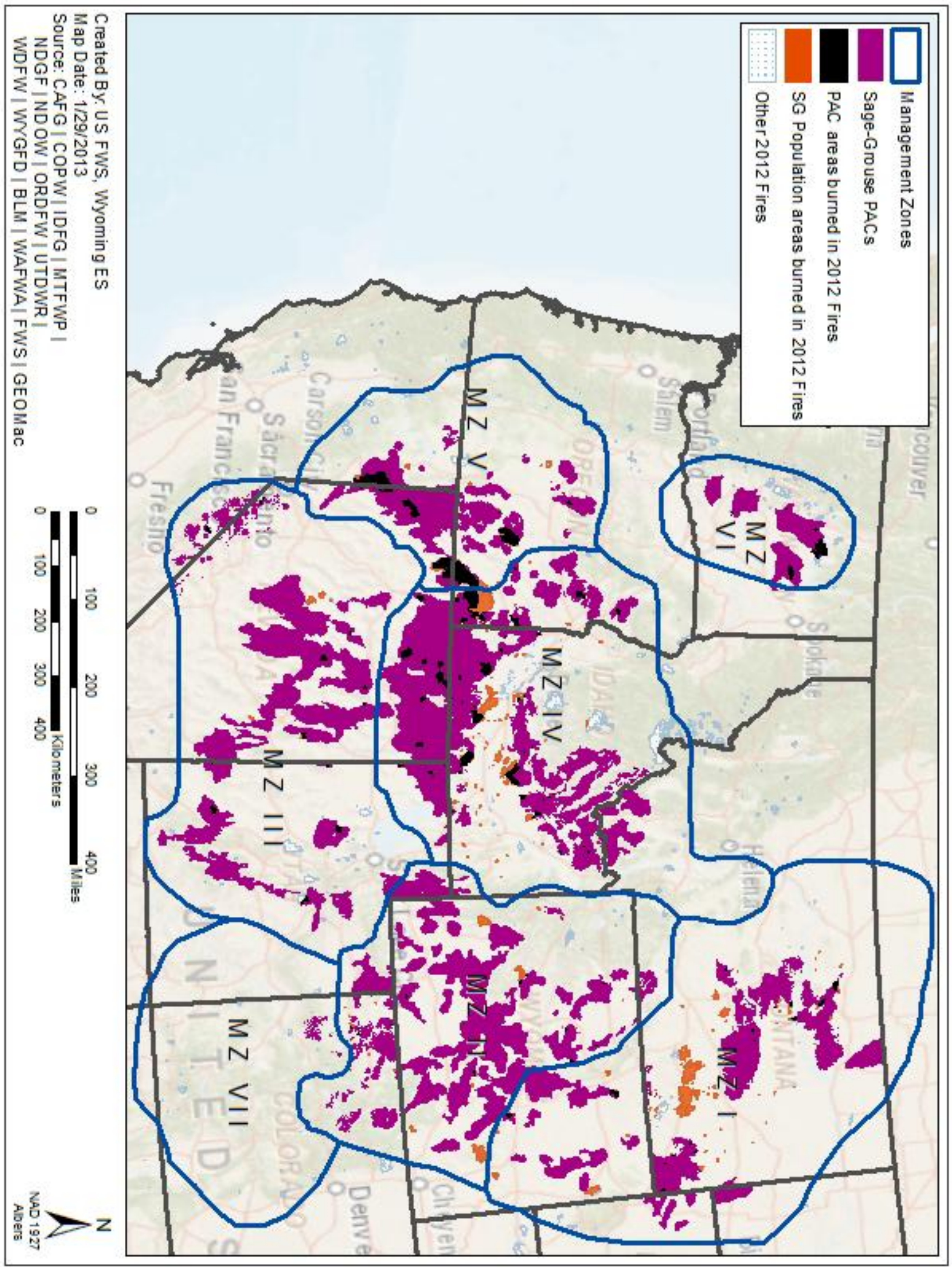

*Figure 1. The location of Management Zones (MZ) and Priority Areas for Conservation (PAC) across the range of the greater sage-grouse. Figure taken from: U.S. Fish and Wildlife Service. 2013. Greater sage-grouse (*Centrocercus urophasianus*) Conservation Objectives: Final Report. U.S. Fish and Wildlife Service Denver, CO, February 2013.*

Table 1. Conservation options for greater sage-grouse habitat in management zone 1 from the U.S. Fish and Wildlife Service report: U.S. Fish and Wildlife Service. 2013. Greater sage-grouse (Centrocercus urophasianus) Conservation Objectives: Final Report. U.S. Fish and Wildlife Service Denver, CO. February 2013, p. 48.

Conservation Action	Description
1	Revise Farm Bill policies and commodity programs that facilitate ongoing conversion of native habitats to marginal croplands (e.g., through the addition of a 'Sodsaver' provision), to support conservation of remaining sagebrush-steppe habitats.
2	Continue and expand incentive programs that encourage the maintenance of sagebrush habitats.
3	Develop criteria for set-aside programs which stop negative habitat impacts and promote the quality and quantity sage-grouse habitat.
4	If lands that provide seasonal habitats for sage-grouse are taken out of a voluntary program, such as CRP[a] or SAFE[b], precautions should be taken to ensure withdrawal of the lands minimizes the risk of direct take of sage-grouse (e.g., timing to avoid nesting season). Voluntary incentives should be implemented to increase the amount of sage-grouse habitats enrolled in these programs.

[a] *Conservation Reserve Program*
[b] *State Acres for Wildlife Enhancement*

Legislature, which provided $10 million for MSGOT to implement the Sage Grouse Habitat Conservation Program and for competitive grant funding to establish mechanisms for voluntary, incentive-based conservation measures to benefit sage-grouse and their habitat (Montana Legislature 2015). Other states such as Idaho and Wyoming have taken similar actions.

The next step after preventing habitat reduction is to manage current habitat to sustain the various uses that it supports. Livestock grazing is the largest land management practice in the world (Krausman et al. 2009) and is the dominant land management practice in sagebrush habitat, impacting 70% of land in the western United States (Fleischner 1994). Thus livestock grazing is an important consideration in managing the sagebrush habitat that is currently left. Livestock grazing impacts sagebrush habitat by altering its vegetation structure, composition, and productivity (Beck and Mitchell 2000). This grazing can have negative impacts, but it also can be managed to achieve desired habitat conditions (Fuhlendorf and Engle 2001). The third action outlined by USFWS (2013) in their conservation objectives report is to ("develop criteria for set-aside programs which stop negative habitat impacts and promote the quality and quantity of sage-grouse habitat" (Table 1). Our study makes progress towards this action by evaluating the effectiveness of SGI grazing systems intended to improve sage-grouse habitat, how timing of grazing impacts sage-grouse and their habitat, and how grazing in SGI or other systems may be improved when managing habitat for sage-grouse.

The Sage-Grouse Initiative (SGI) Program

SGI grazing systems focus on improving livestock production and rangeland health while simultaneously alleviating threats to and improving habitat for sage-grouse (NRCS pers. comm., Boyd et al. 2011). SGI grazing systems are implemented on ranches that contain potential sage-grouse habitat. The program is voluntary with contracts lasting 3 years. Landowners enrolling in SGI agree to implement a grazing system in collaboration with an NRCS range conservationist who may suggest rest or deferment, installment of water sources or fences to change the distribution of livestock or the size of pastures, respectively, or to change the number of animal units in the grazing system in pastures within potential sage-grouse habitat. NRCS defines potential sage-grouse habitat based on topography and sagebrush canopy cover ≥5% (NRCS pers. comm.) with a focus on sage-grouse core areas (Fig. 2). SGI grazing systems are tailored

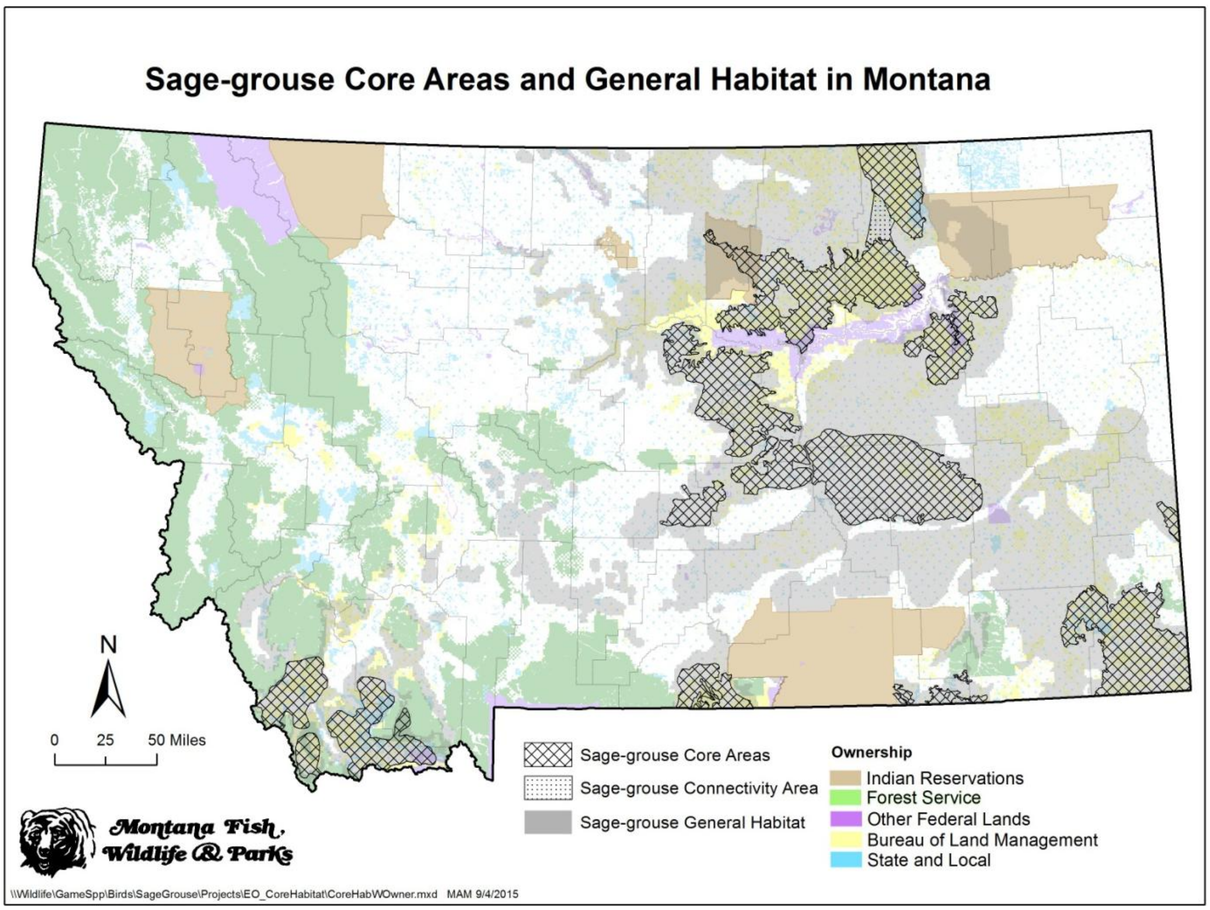

Figure 2. Greater sage-grouse core areas in Montana, USA.

to each ranch, and may vary with the needs of the landowner or the condition of the rangelands. Season of use for enrolled pastures is rotated annually, and 20% of enrolled pastures that contain sage-grouse habitat are rested or deferred from grazing. Pastures that are "rested" are not used for ≥ 15 months. All systems also set stocking rates to minimize the impacts of livestock on rangelands (utilization of less than 50%). This benefits rangeland by leaving residual grass to capture moisture, reducing temperature and evaporation from the soil through shading, and providing organic matter to the soil. An increase in residual grass increases potential nest cover for sage-grouse during the following year's nesting season (April-June) and also improves plant productivity by allowing plants to complete their reproductive cycle and set seed (Hormay 1970; Natural Resources Conservation Service, pers. comm.). In addition, plant growth can be stimulated and plants can grow larger if grazing is managed properly (NRCS pers. comm.), which increases forage for cattle and cover for wildlife. Plant growth is enhanced by alternating the timing of grazing in each pasture among years. For example, if a pasture is grazed April 1 – April 15 during year 1, grazing in that pasture in year 2 must be deferred by 20 days, such that grazing does not occur before May 5th.

GRAZING STUDY

The goal of this study is to evaluate the effects of NRCS's SGI grazing strategies on sage-grouse vital rates and habitat. Taylor et al. (2012) showed that adult female (hen) survival, nest success, and chick survival are the three most important drivers of population growth in sage-grouse populations. Therefore the goal of our project is to investigate the impacts of grazing on these vital rates. We are also monitoring the habitat use of hens and chicks, nest site selection of hens, and vegetation response to grazing, as well as investigating how habitat use links with vital rates. We are comparing these variables between SGI-enrolled and non-participating ranches (Non-SGI).

This study is designed as a 10 year study because the effects of grazing on habitat (and hence, sage-grouse) may exhibit a "lag" effect and may be tempered by the confounding effects of habitat, weather, and other variables. Some impacts of grazing management may be observable or fully realized only after several years. In addition, multiple years of data are needed to obtain enough sampling replicates of pastures within each grazing treatment for analyses and inferences. The study's duration also helps ensure that we obtain good estimates of sage-grouse population vital rates and their habitats despite annual fluctuation in these measures due to weather and other influences.

This project has the following long-term objectives (beyond the dates covered by this agreement):

1. Measure the vegetation response in pastures receiving different grazing and resting treatments, relative to published sage-grouse habitat needs;

2. Identify movements by sage-grouse between grazed and rested pastures to quantify use of treatments proportional to habitat availability and other drivers of sage-grouse resource selection;
3. Create habitat-based measures of fitness which can be compared among grazing treatments by measuring individual vital rates known to impact population growth in sage-grouse and relating estimated vital rates directly to habitat variables and other important drivers;
4. Create a habitat-linked population model to:
    a. evaluate and forecast the benefits of treatments within a rotational grazing system on sage-grouse populations in the context of other drivers of sage-grouse vital rates, so as to put the influence of grazing management on population dynamics in context, and
    b. identify current areas that are most important to sage-grouse to prioritize locations where habitat management will have the most benefit to populations;
5. Quantify the population-level response of grazing treatments by indexing lek counts to our population modeling results, then by comparing lek counts within the Roundup study area to surrounding populations. To the extent that lek counts represent population changes reflected in population models, bird response to grazing might be forecasted in other areas where only lek count data are available; and
6. Generate spatially-explicit maps for areas with high quality seasonal habitat. Specifically we will produce maps that delineate areas with habitat attributes that define relative probability of use and that have a positive influence on vital rates during the nesting, brood-rearing, and winter periods, and extrapolate to similar landscapes to the extent that these models validate well.

We have successfully completed 5.5 yrs of data collection towards these objectives. Data from the 2016 season is still being collected and entered. We are halfway through our 6th season of data collection, and the funding provided by this agreement covered 1 year (half each of years 5 and 6: Jul 1, 2015 to Jun 30, 2016). Thus we have not yet completed all of the objectives listed above. We will report on the objectives that have been completed thus far.

OBJECTIVES 1 AND 2:

1. **Measure the vegetation response in pastures receiving different grazing and resting treatments, relative to published sage-grouse habitat needs.**
2. **Identify movements by sage-grouse between grazed and rested pastures to quantify use of treatments proportional to habitat availability and other drivers of sage-grouse resource selection.**

Vegetation Response to Grazing (Objective 1): 2012 – 2015 **2016 data not compiled yet*

We use herbaceous vegetation measurements at a set of stratified random field plots among grazing treatments to test for differences in indicators of habitat quality across the project area. In 2012 we sampled field plots on both SGI and Non-SGI pastures; these data were then used to parameterize a power analysis to develop a sampling scheme for subsequent field seasons. We identify pastures rested each season and sample an appropriate number of field plots in grazed SGI pastures, rested SGI pastures, and Non-SGI pastures to test for differences in vegetation structure among these treatments. Rangelands are highly dynamic and spatially heterogeneous and assessing their condition over large areas has always been a logistical challenge (West 2003). We use ArcGIS (ESRI Inc., Redlands, CA) and program R (R Core Team 2011) to generate stratified random points using the criteria in Table 2. Local-scale vegetation plots measured in the field are centered on a random point and extend 15 m in each cardinal direction ("spokes"). Along each spoke we estimate visual obstruction using a Robel pole (Robel et al. 1970) at 1, 3 and 5 m from the random point. Using Daubenmire frames (Daubenmire 1959) at 3, 6, and 9 m from the random point along each spoke we measure the grass height (maximum droop height with and without the influorescence for both current year's and residual grass) and estimate percent cover of native and nonnative live (current year) grass, residual (previous year's or dead) grass, native and nonnative forbs (herbaceous flowering plants), litter (detached dead vegetation), lichen, moss, bare ground, rock, and cowpies. In each Daubnemire frame, we also identify forb species and the number of each species is recorded to measure forb species diversity and abundance. Additionally, we measure distance to water as well as the four most dominant herbaceous species in the plot.

Table 2. Criteria for inclusion of sampling plots used to measure vegetation response to grazing systems.

Variable	**Acceptable Range**	**Data Source**
Slope	0 – 5 degrees	10 m DEM (National Elevation Dataset)
Soil Type[1]	60C, 60D, 64A, 64B, 68C	NRCS SSURGO Database[3]
Distance to Water[2]	200 – 1500 m	Local NRCS records, National Hydrography Dataset[4]

[1]Soil map units chosen for inclusion are salty clay loams that typically support sagebrush in the study area.
[2]Field checked.
[3]http://soildatamart.nrcs.usda.gov
[4]http://nhd.usgs.gov

We used linear mixed effects models to test for grazing system and rest effects (fixed effects) on vegetation metrics while accounting for variation across years and ranches (random effects). Our years are defined as Apr 1 – Mar 31. For example, year 2012 in our report is defined as Apr 1, 2012 – Mar 31, 2013. We define "rest" as any pasture rested for 12 consecutive months. Linear mixed effects models were fit using the lme4 package (Bates et al. 2015) in program R.

Significance of fixed effects was assessed with likelihood ratio tests, by comparing models with and without a fixed effect for grazing system.

We sampled 353 vegetation plots on Non-SGI ranches and 510 vegetation plots on SGI ranches during 2012-2015 (Fig. 3). Likelihood ratio tests indicated that live grass height ($\chi^2 = 9.4$, $df = 1$, $p = 0.002$), residual grass height ($\chi^2 = 5.3$, $df = 1$, $p = 0.021$), bare ground ($\chi^2 = 4.9$, $df = 1$, $p = 0.027$), and litter ($\chi^2 = 6.6$, $df = 1$, $p = 0.010$) all differed between Non-SGI and SGI ranches.

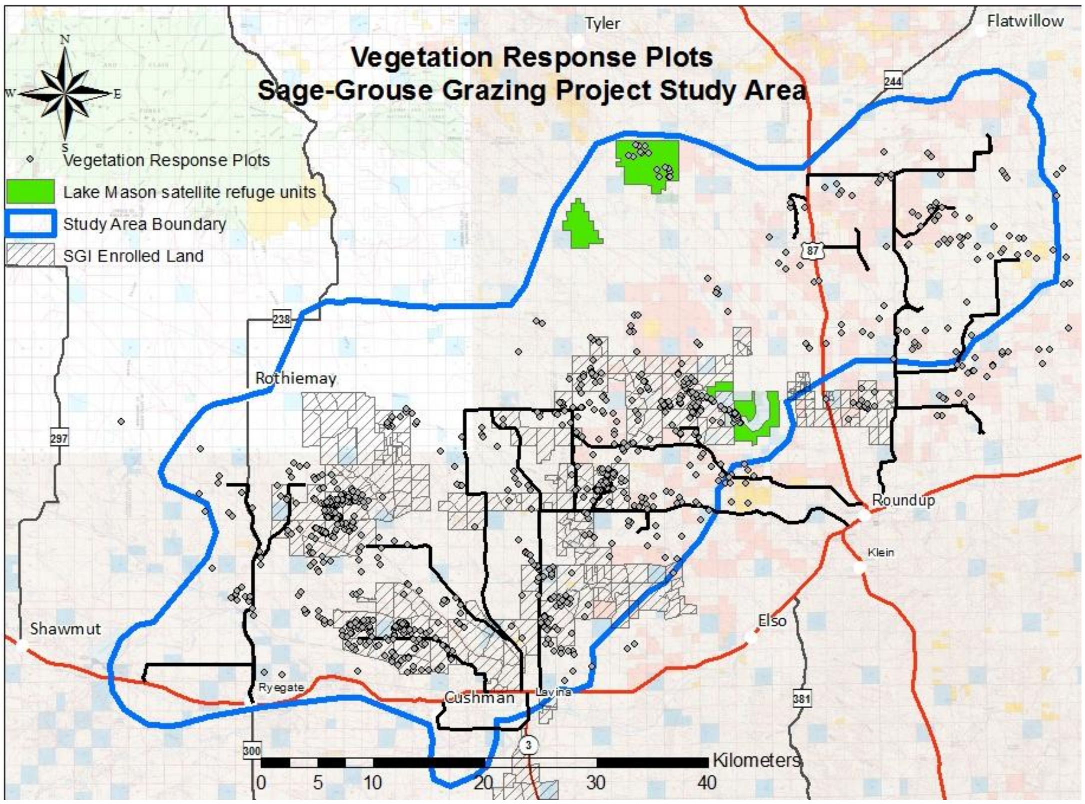

Figure 3. Locations of vegetation response plots measured during 2012 – 2015 to evaluate the effects of Sage Grouse Initiative (SGI) rotational grazing systems and grazing systems of non-enrolled ranches (Non-SGI) on greater sage-grouse habitat in Musselshell and Golden Valley Counties, Montana, USA. The Lake Mason units are satellite units of the Charles M Russell National Wildlife Refuge. The SGI-enrolled land shown includes the original participating ranches in 2011 - 2013. Enrolled land is dynamic, with different contracts ending and starting each year.

Visual obstruction ($\chi^2 = 0.22$, $df = 1$, $p = 0.642$) and herbaceous vegetation cover ($\chi^2 = 0.27$, $df = 1$, $p = 0.605$) did not differ between grazing systems (Fig. 4). After accounting for grazing system effects, the effect of pasture rest was negligible and non-significant for all variables tested. Grazing system effect sizes, however, were small relative to annual variation: live grass height was 1.50 cm (SE 0.467 cm) greater on SGI ranches, residual grass height was 1.04 cm (SE 0.432 cm) greater on SGI ranches, bare ground cover was 6.05% (SE 2.695%) lower on SGI ranches, and litter cover was 4.52% (SE 1.762%) higher on SGI ranches.

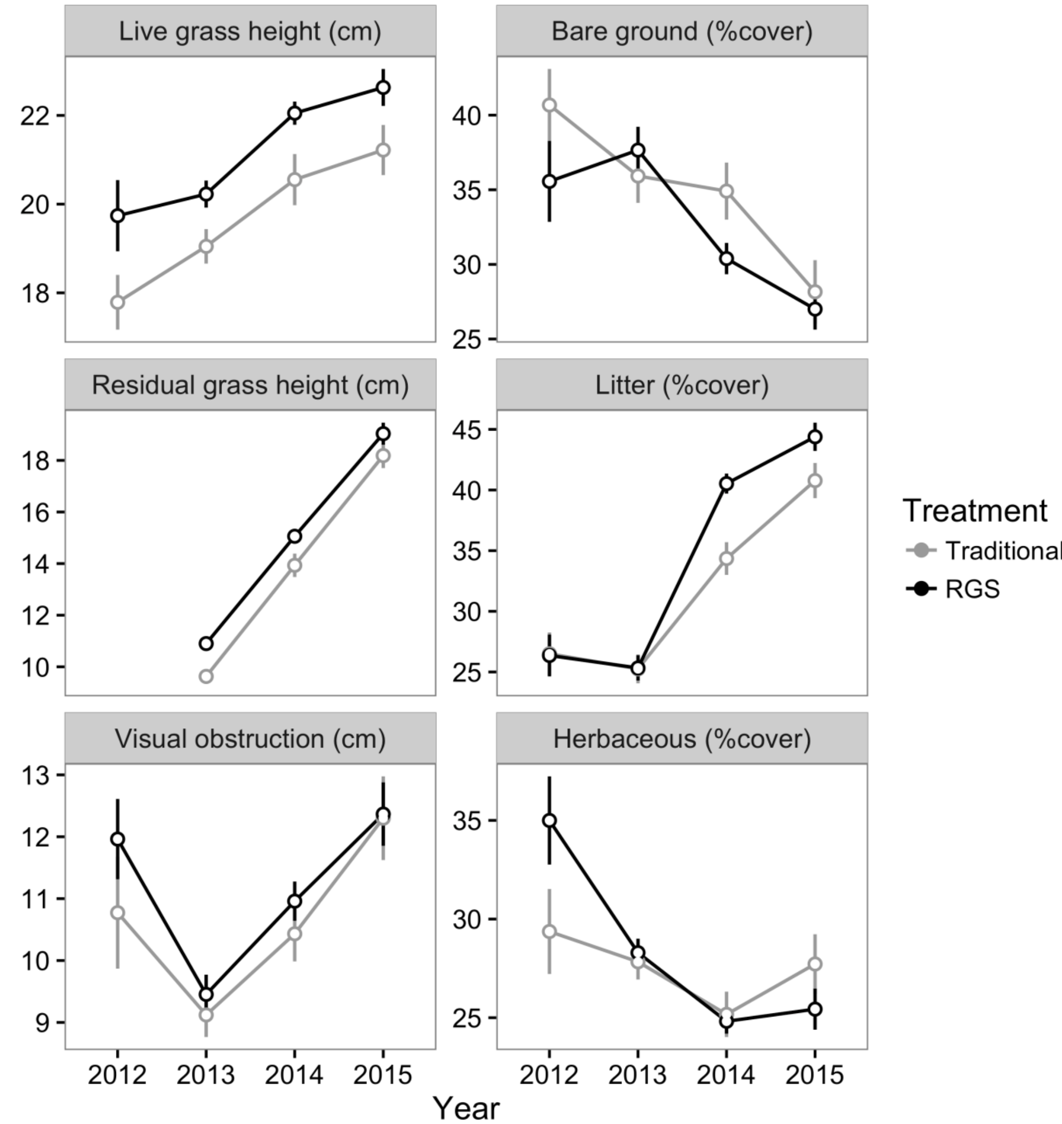

Figure 4. Means and standard errors of vegetation metrics measured at vegetation response plots on ranches enrolled in Sage Grouse Initiative (SGI) rotational grazing systems (labeled "RGS" in this figure) and on non-enrolled (Non-SGI) ranches (labeled "Traditional" in this figure) in Golden Valley and Musselshell Counties, Montana, USA during 2012 – 2015. Likelihood ratio tests revealed that live grass height, residual grass height, bare ground cover, and litter cover all differed significantly between SGI and Non-SGI ranches. Estimated effect sizes were small, however, relative to annual variation.

Nest Site Selection (Part of Objective 2): 2011 – 2015 **2016 data not compiled yet*

We collect location data on adult sage-grouse hens and sage-grouse chicks marked with radio transmitters to assess (1) seasonal resource selection by adult hens, (2) nest site selection by adult hens, and (3) resource selection by hens with broods or marked chicks. We are currently in our 6th year of data collection and herein report preliminary results for nest site selection from 2011-2015. We are currently working on data analyses for resource selection by hens and chicks and these will be completed outside of the time period for this agreement.

Nests are found by monitoring hens marked with radio transmitters via radiotelemetry. To evaluate the effects of vegetation on nest success and nest-site selection, we sample vegetation at nests as well as stratified random points within potential nesting habitat. We use ArcGIS and program R (R Core Team 2011) to generate random points that are constrained to be within 6.4 km of leks, not in cropland, and in a sagebrush-dominated land cover. Nest plots are measured after nests have reached their estimated hatch date (for failed nests) or after the nests successfully hatch. Plots at random points are measured during the same week as nest plots that are in the same area. Local-scale vegetation plots measured in the field are centered on the nest bowl or a random shrub (the shrub nearest to a random point and >35 cm in height) and extend 15 m in each cardinal direction ("spokes"). Much of our protocol for sampling vegetation follows the procedure outlined in Doherty (2008). At the nest or random shrub we measure grass height (maximum droop height with and without the influorescence, current year's and residual [previous year's] grass); the top two dominant cover species of grass; height, width, species, and percent vigor of the nest or random shrub; and visual obstruction using a Robel pole (Robel et al. 1970). Along each spoke we estimate visual obstruction at 0, 1, 3, and 5 m from the nest or random shrub. Using Daubenmire frames (Daubenmire 1959) at 3, 6, and 9 m from the nest or random shrub along each spoke we measure the height of the nearest shrub; measure the grass height (maximum droop height with and without the influorescence, for both current year's and residual grass); and estimate percent cover of native and non-native live (current year) grass, residual (previous year's or dead) grass, native and non-native forbs (herbaceous flowering plants), litter (detached dead vegetation), lichen, moss, bare ground, rock, and cowpies. In each Daubenmire frame, forbs are identified to species and the number of each species is recorded to measure forb species diversity and abundance. For each spoke we also measure sagebrush canopy cover and density using line-intercept and belt transect methods (Canfield 1941; Connelly et al. 2003). Additionally, we measure an index of livestock utilization in each local-scale vegetation plot by measuring the percent of the plot that has been grazed and counting the number of cowpies (both from the current and previous year) in each plot. These data enhance the information we obtain from NRCS and landowners on the grazing history in specific pastures.

In addition to collecting local-scale vegetation data, vegetation and other habitat data (e.g., distance to roads, Table 3) are measured using remote sensing data from geographic information systems (GIS) layers (e.g., Table 3) for evaluating landscape-scale variables that may impact nest site selection and nest success of hens. We use a combination of GIS layers to obtain landscape-level variables (e.g., the most recent versions of Landsat landcover data and NDVI data), as well as a GIS of our project area generated by Open Range Consulting (Park City, UT; http://www.openrangeconsulting.com/index.php; Open Range Consulting 2013, Sant et al. 2014) that allows us to measure habitat variables in finer detail (1m resolution) including fine-

Table 3. Covariates considered in building nest success and nest-site selection functions.

Variable	Abbreviated Variable Name	Transformation
Landscape Covariates (0 - 1.61 km from nest)		
Distance to major road (county, highway)	DIST TO ROAD[a,b]	Logarithmic[a,b]
Distance to two-track road	DIST TO 2TRACK[a,b]	Logarithmic[a,b]
Distance to cropland	DIST TO CROPLAND[a,b]	Logarithmic[a,b]
Distance to mesic vegetation	DIST TO MESIC[a,b]	Quadratic[a]; Logarithmic[b]
Proportion of landscape disturbed (non-cropland)	PROPORTION DISTURBED[a,b]	
Proportion of landscape in cropland	PROPORTION CROPLAND[a,b]	
Proportion of landscape in sagebrush landcover (≥5%)	PROPORTION SAGE[a,b]	
Patch (0 - 100 m from nest) Covariates		
Topographic roughness	ROUGHNESS[a]	
Sagebrush cover	SAGEBRUSH COVER[a,b]	
Standard deviation of sagebrush cover	SAGE HETEROGENEITY[a,b]	
Plot (0-15 m from nest) Covariates		
Live grass height	GRASS HEIGHT[a,b]	
Residual grass height	RESIDUAL HEIGHT[a,b]	
Total herbaceous cover	HERBACEOUS COVER[a,b]	
Bare ground	BARE GROUND[a,b]	Quadratic[a]
Residual herbaceous cover	RESIDUAL COVER[a,b]	
Litter cover	LITTER COVER[a,b]	
Visual obstruction (Robel pole)	VISUAL OBSTRUCTION[a,b]	
Shrub height	SHRUB HEIGHT[a,b]	
Sagebrush cover	SAGEBRUSH COVER[a,b]	Quadratic[a]
Total shrub cover	SHRUB COVER[a,b]	Quadratic[a]
Shrub cover * residual grass height		
Shrub cover * total herbaceous cover		
Nest Shrub Covariates		
Maximum live grass height at nest	GRASS HEIGHT[a,b]	
Maximum residual grass height at nest	RESIDUAL HEIGHT[a,b]	
Visual obstruction (Robel pole)	VISUAL OBSTRUCTION[a,b]	
Nest shrub volume	NEST SHRUB SIZE[a,b]	
Nest substrate (other = 0, sagebrush = 1)	NEST SUBSTRATE[b]	
Grazing Covariates		
Pasture grazed during nesting	GRAZED DURING[b]	
Livestock use index, current year	LIVESTOCK INDEX (CURRENT)[a,b]	

Variable	Abbreviated Variable Name	Transformation
Livestock use index, historical	LIVESTOCK INDEX (PAST)[a,b]	
Grazing system (Other = 0, SGI RGS = 1)	SGI RGS[b]	
Precipitation Covariate (Daily)		
Predicted total rainfall in last 4 days	RAINFALL 4DAY[b]	
Other Covariates		
Hen age (juvenile = 0, adult = 1)	HEN AGE[b]	
Nest attempt (1st = 0, 2nd or 3rd = 1)	NEST ATTEMPT[b]	

[a] Variable or transformation was considered as a candidate in nest selection model
[b] Variable or transformation was considered as a candidate in nest survival model

scale categories of sagebrush canopy cover. We collect data on precipitation each year from the Oak Ridge National Laboratory Distributed Active Archive Center, a data center of the National Aeronautics and Space Administration's Earth Observing System Data and Information System (<https://daymet.ornl.gov/>).

We used Bayesian methods to fit logistic regression models relating measured covariates (Table 3) to the probability that a site was a nest (1) versus a randomly sampled available site (0). We used indicator variables paired with each model coefficient to assess variable importance and produce model-averaged coefficient estimates (Kuo and Mallick 1997). We performed an initial screening of variables by fitting univariate nest site selection models to each candidate variable and rejecting variables when 85% credible intervals for coefficients overlapped zero. Of the 16 variables passing variable screening, seven were supported with Bayes factors ≥ 3 (Fig. 5). These were nest shrub volume, plot-scale (15 m) sagebrush cover, patch-scale (100 m) roughness, patch-scale sagebrush heterogeneity, distance to county roads and highways, distance to two-track roads, and proportion of the landscape (1.61 km) disturbed. At the scale of the nest substrate, females selected shrubs with greater volume. At the plot scale, females selected for greater sagebrush cover. At the patch scale, females selected gentler terrain and more even stands of sagebrush. Finally, females preferred to locate nests farther from county roads and highways but closer to two-track roads, and avoided landscapes with greater amounts of non-cropland anthropogenic disturbance. We do not have a not have a clear biological interpretation of selection of nest sites closer to 2-track roads. We speculate that this preference may reflect the tendency for 2-track roads to traverse terrain preferred by sage-grouse for nesting, e.g., areas of gentle topography. We found no evidence of selection with respect to herbaceous vegetation metrics, current-year's livestock use intensity, or density of previous-years' cow pats.

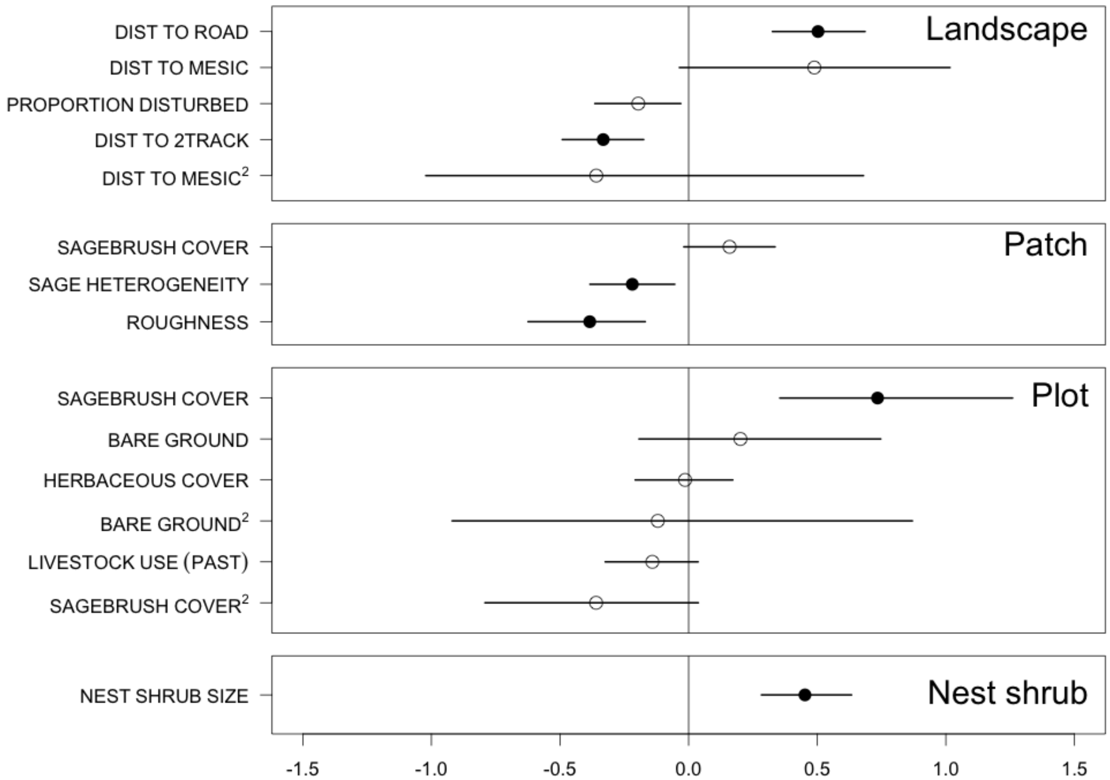

Figure 5. Coefficient estimates from a logistic regression model describing variables influencing the selection of nest sites (n=322) by sage-grouse in Golden Valley and Musselshell Counties, Montana, USA from 2012 to 2015. Filled circles identify variables supported by Bayes factors and error bars represent 95% credible intervals. Selection of nest sites was driven not by herbaceous vegetation characteristics but by preference for greater shrub cover (SAGECOV) and size (N_SHRUBVOL), gentle topography (P_ROUGH), avoidance of county roads and highways (D_MROAD), and avoidance of non-cropland anthropogenic disturbance at the landscape scale (L_DISTURB).

OBJECTIVE 3:

Create habitat-based measures of fitness which can be compared among grazing treatments by measuring individual vital rates known to impact population growth in sage-grouse and relating estimated vital rates directly to habitat variables and other important drivers.

We collect data on sage-grouse vital rates including hen survival, nest success, and chick survival each year and are currently in our 6th year of data collection. Herein we report preliminary results for nest success with respect to habitat variables. We also report preliminary survival analyses of hens and chicks, but we have not yet related these two vital rates to habitat variables. These analyses will be completed outside the time period of this agreement.

<u>Hen Survival: 2011 – 2016</u>

We maintain 100 hens marked with radio transmitters in our marked population each year. We typically capture and mark hens at the start of the breeding season each spring to replace hens that died in the previous year. Hens are captured on or near leks using night-time spotlighting (Giesen et al. 1982), one of the most common and safe methods of capture. Hens are fitted with 22 g necklace style VHF radio transmitters (Model A4060, Advanced Telemetry Systems, Isanti, MN), measured, weighed, and released. Yearling females captured during our study have a mean weight of 3.5 lbs (standard error of the mean [SE] = 0.02), and adult females have a mean weight of 4.0 lbs (SE = 0.01). A 22 g radio transmitter is 1.4% of the body weight for a 3.5 lb yearling female, 1.2% for a 4 lb adult female, and lasts 434 to 869 days (1.2 – 2.4 yrs). The transmitters have a mortality switch on-board that is activated when the transmitter has been motionless for at least 4 hrs. We attempt to recapture hens at 2 yrs after initial capture to replace old transmitters with new ones before the old transmitter batteries expire. In this way we attempt to monitor individual hens as long as possible. This population of sage-grouse is not migratory and can be monitored continuously within the study area. We monitor marked hens from March through August from the ground with the help of seasonal field technicians each year who obtain at least two locations per hen each week. During September through March we monitor the hens via aerial telemetry once per month.

Our annual survival estimates of hens are measured from Apr 1st at the start of nesting season through March 31st each year. Apparent annual survival estimates (number of hens alive at the end of the monitoring period / total number of hens alive at the start of the monitoring period) during 2011 – 2015 ranged from 57 – 82% (Table 4). Our annual survival estimates

Table 4. Apparent seasonal and annual survival (number of hens still alive at the end of the season / total number of hens monitored at the start of the season) of radio-marked greater sage-grouse hens in Golden Valley and Mussellshell Counties, Montana, USA during 2011 – 2016 for both SGI and Non-SGI areas combined. We measure annual survival from Apr 1 – Mar 31.

Year / Season	Apr-May (Spring)	Jun-July (Summer)	Aug – Oct (Fall)	Nov – Mar (Winter)	Annual
2011	88%	91%	90%	79%	57%
2012	84%	93%	89%	82%	82%
2013	93%	86%	90%	89%	67%
2014	91%	100%	79%	98%	75%
2015	95%	98%	96%	78%	77%
2016	84%	Still entering data	Not complete	Not complete	Not complete

are comparable to those observed in other studies across the range of sage-grouse (Table 5), though we caution that the apparent survival estimates in Table 4 do not represent formal survival analyses. We have defined seasons to represent biologically meaningful separations *sensu* Blomberg et al. (2013; Table 4). There are few published seasonal survival estimates

Table 5. Summary of annual adult female greater sage-grouse survival estimates from several studies across the greater sage-grouse range.

Survival Estimate	Location	Reference
75 – 98%	Central Montana, our study area	Sika 2006
48 – 78%	Wyoming	Holloran 2005
48 – 75%	Idaho	Connelly et al. 1994
57%	Alberta	Aldridge and Brigham 2001
61%	Colorado	Connelly et al. 2011
37%	Utah	Connelly et al. 2011

available for sage-grouse hens. We have slightly different definitions for our seasons than Sika (2006), but our apparent hen survival estimates are comparable to what Sika (2006) observed during similar time periods. Sika (2006) measured seasonal hen survival on our study area during 2004-2005. Monthly survival from April to June was 94%. July survival during 2004-05 was 99% to nearly 100% each year, and August survival was 94% and 84% in 2004 and 2005, respectively. Our apparent seasonal survival rates are lower relative to seasonal survival estimates measured by Blomberg et al. (2013) in a Nevada population of greater sage-grouse. Again we caution that our annual rates are apparent estimates and Blomberg et al.'s (2013) are estimated using formal survival analyses. Blomberg et al. (2013) monitored hen survival for 328 hens from 2003-2011. Their seasonal survival estimates, represented here as mean survival ± standard error (SE) were: spring = 0.93 (93%) ± 0.02; summer = 0.98 ± 0.01; fall = 0.92 ± 0.02; and winter = 0.99 ± 0.01. Blomberg et al. (2013) found very little annual variation in hen survival, allowing them to pool seasonal estimates among years (above). Our seasonal rates appear more variable among years. We have yet to evaluate inter-annual variation in seasonal survival rates formally and thus present our rates by year.

We used Kaplan-Meier survival functions to formally estimate the overall survival of hens during 2011 – 2015. The Kaplan-Meier estimator measured the survival of individuals over a series of monitoring occasions, producing a survival function of cumulative survival through the monitoring period (Kaplan and Meier 1958, Cooch and White 2013). We used package "survival" (Therneau 2016) in program R to run Kaplan-Meier analyses. The Kaplan-Meier mean survival time estimate for all marked hens monitored from March 2011 – September 2015 was 1,091 days (2.98 yrs; standard error [SE] = 68.2 days; 95% confidence interval = 745 – 1,375 days or 2.04 – 3.77 yrs) and the median was 856 days (2.35 yrs; Fig. 6). These estimates included 300 hens and we used a staggered-entry design to account for marking individuals at different times throughout the study period. We used right censoring for individuals with unknown fates, dropped transmitters, and for individuals that survived until their transmitters expired. Thus our Kaplan-Meier survival estimates were conservative. For these estimates we pooled data across all years.

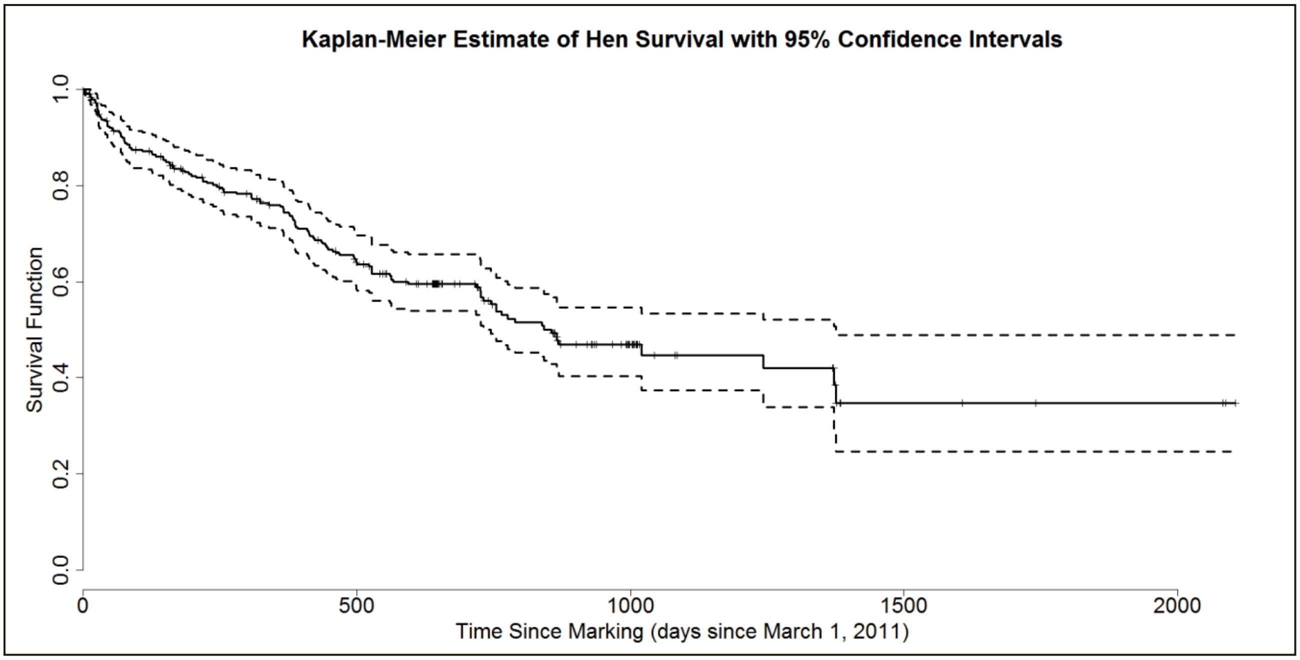

Figure 6. The Kaplan-Meier survival curve (solid line) and 95% confidence intervals (dashed lines) for greater sage-grouse hens monitored from 2011 – present in Golden Valley and Musselshell Counties, Montana, USA.

Nest Success: 2011-2016

Nests are found by monitoring hens via radio telemetry and are monitored every other day until they fail or hatch (defined as at least one chick successfully hatching and leaving the nest). Annual apparent nest success (number of monitored nests that hatched at least one chick / total number of nests monitored) during 2011 – 2015 ranged from 30 – 64% (Table 6). The number of marked hens that attempted at least one nest each year ranged from 64 – 78% (Table 7). Nest success varies from 14 – 86% across the entire range of sage-grouse (including

Table 6. Apparent nest success (number of monitored nests that hatched at least one chick / total number of nests monitored) of our marked population of greater sage-grouse hens in Golden Valley and Mussellshell Counties, Montana, USA during 2011 – 2015 (SGI and Non-SGI areas combined). Total number of nests monitored are presented as well as number of nests per nest attempt. Nest success for 1st nests = # successful 1st nests / total 1st nests attempted; 2nd nests = # successful 2nd nests / total 2nd nests attempted; 3rd nests = # successful 3rd nests / total 3rd nests attempted.

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Overall Apparent Nest Success	30%	54%	39%	64%	51%	36%
Total Number of Nests	103	91	84	74	76	85
Number of 1st Nests / Nest success	79 / 28%	82 / 52%	69 / 39%	68 / 63%	69 / 54%	68 / 35%
Number of 2nd Nests / Nest success	22 / 41%	9 / 67%	15 / 40%	6 / 67%	8 / 38%	17 / 41%
Number of 3rd Nests / Nest success	1 / 0%	–	1 / 100%	–	–	–

studies from Oregon, Colorado, and Idaho; Connelly et al. 2004). The average nest success across the range is 46% (Connelly et al. 2011). Nest success observed during all years of our study is within the range expected for sage-grouse.

Table 7. Percent of our marked population of greater sage-grouse hens that attempted at least one nest in Golden Valley and Mussellshell Counties, Montana, USA during 2011 – 2015 (SGI and Non-SGI areas combined).

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Total number of marked hens, start of nesting season	101	112	93	106	100	101
Hens attempting to nest / all marked hens	78% (79/101)	73% (82/112)	76% (71/93)	64% (68/106)	66% (66/100)	Not compiled yet

We used Bayesian methods to fit logistic regression models relating measured covariates to daily nest survival rate. As with nest site selection models, we used indicator variables paired with each model coefficient to assess variable importance and produce model-averaged coefficient estimates, and performed an initial variable screening step, rejecting variables (i.e., Table 3) when 85% credible intervals for coefficients overlapped zero. We included separate intercepts for each year and a random effect for individual females, as we monitored from one to seven nests for each female (all nests for an individual from 2011-2015) and fates of nests from the same female may not be independent if females differ in 'quality' with respect to their ability to successfully incubate a nest.

Of the 11 variables passed to the final model only precipitation was supported with a Bayes factor ≥ 3, with greater amounts of rainfall over a 4-day period associated with lower daily nest survival (Fig. 7). Distance from county roads and highways received some support from a 95% credible interval that did not overlap zero, suggesting greater survival farther from these features. Grazing system (Non-SGI vs SGI), presence or absence of livestock in the pasture during nesting, current year's grazing intensity, and density of previous-years' cow pats were all unrelated to daily nest survival.

Chick Survival: 2011 – 2016

Consistent monitoring of females that are initiating nests makes it possible to estimate hatch dates to within one day. Sage-grouse chicks of marked hens are captured by hand 2 to 8 days after hatching, with most captured no later than 5 days old. We capture the entire broods of these hens by homing in on the hen with telemetry just after sunset when the hen broods all of the chicks underneath her, allowing us to get close enough to capture the chicks. The hen might flush or walk away a short distance, but usually remains within 50 – 100 m of us

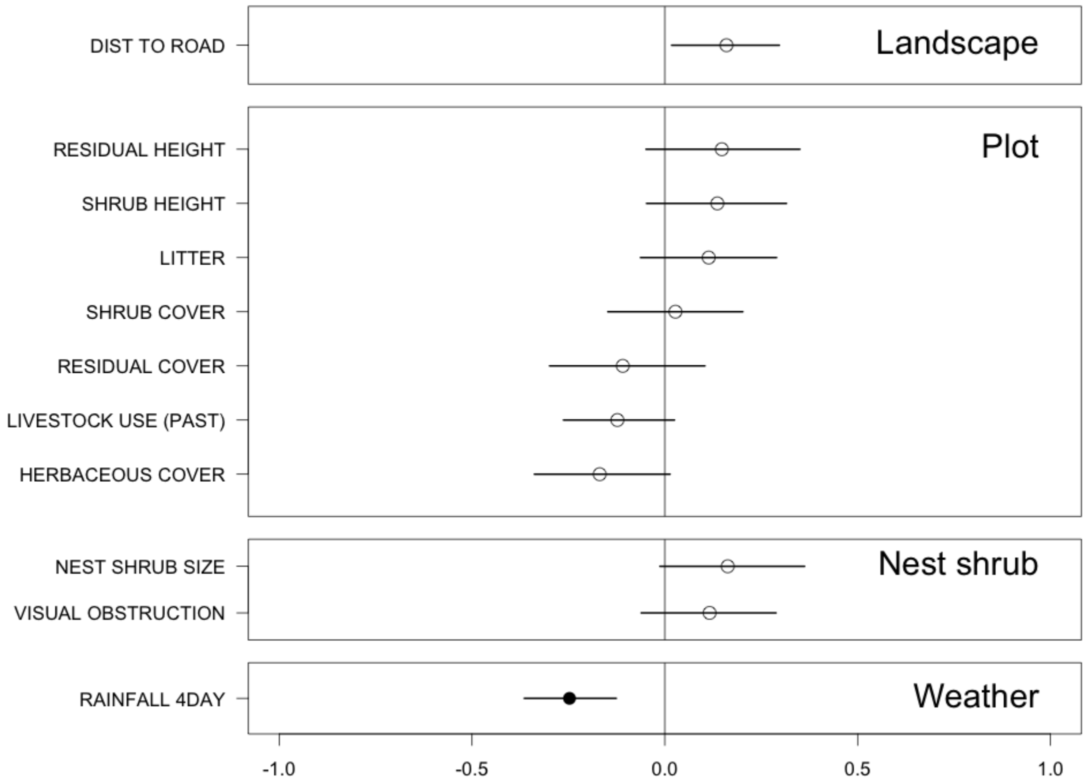

Figure 7. Coefficient estimates from logistic regression model describing variables influencing daily nest survival of sage-grouse nests (n=412) in Golden Valley and Musselshell Counties, Montana, USA from 2011 to 2015. Filled circles identify important variables supported by Bayes factors and error bars represent 95% credible intervals.

throughout the entire process. The chicks are captured and placed into a cooler containing a hot water bottle that keeps them warm while we are working. We affix a 1.3 g backpack VHF radio transmitter (Model A1065, Advanced Telemetry Systems, Isanti, MN) to two randomly selected chicks per brood (mean number of chicks hatched per nest in our study has been seven to eight) via two small sutures on the lower back (similar to the suture technique described in Dreitz et al. [2011]). This method is the most successful (<1% accidental death rate) and common method used to attach radio transmitters to sage-grouse chicks (Burkepile et al. 2002, Dahlgren et al. 2010) and has been successful with other galliforms (Dreitz et al. 2011). The mean weights (SE) of 2 to 5 day old chicks on our study range from 41.6 g (SE = 0.86) to 51.7 (SE = 2.2), respectively. A 1.3 g radio transmitter lasts 49 to 98 days and is 3.1% of the body weight of a 2d old chick and 2.5% of a 5 d old chick. The tagging procedure typically lasts 20 – 30 min per brood, and then we release all chicks together under sagebrush cover. We monitor the hen to ensure she is nearby when we release the chicks, and follow-up the next morning to monitor chick survival and determine if the hen and chicks are still together. We monitor chicks every other day for the first two weeks, and at least twice per week thereafter until the chicks die or their tags expire.

Annual apparent survival estimates (number of marked chicks known to be alive at the end of the monitoring period / number of marked chicks known to be alive at the start of the monitoring period) for sage-grouse chicks during 2011 – 2016 ranged from 12 – 22% (Table 8). We are still cleaning up data, thus these are preliminary results that may be adjusted. Only

Table 8. Apparent survival of greater sage-grouse chicks (number of marked chicks known to be alive at the end of the monitoring period / number of marked chicks known to be alive at the start of the monitoring period) in Golden Valley and Musselshell Counties, Montana, USA, during 2011 – 2016 that were known to survive until their transmitter battery failed.

	2011	**2012**	**2013**	**2014**	**2015**	**2016**
Apparent Chick Survival	22%	10%	14%	12%	19%	22%
Number Surviving Chicks	5	8	8	9	11	10
Total Number of Marked Chicks	23	81	57	75	58	45

chicks that were known to survive until their transmitter battery expired were considered to survive until the end of the monitoring period. These estimates are conservative because chicks whose signals were lost and their fates unknown were not considered alive for these estimates. Chick transmitters were guaranteed to last 60 days, and most lasted 75 to 100 days. Thus the "Number of Surviving Chicks" is the number of chicks that survived two to three months.

We used package "survival" (Therneau 2016) in program R to run the following Kaplan-Meier survival analyses. With data pooled across years, the Kaplan-Meier mean survival time for sage-grouse chicks marked with radio transmitters during 2011 – 2015 was 25 d (SE = 2.67 d), and the median survival time was 13 d (95% confidence interval [CI] = 10 – 16 d; Fig. 8). Individuals whose signals were lost or had unknown fates were censored from the analysis at the last time they were successfully monitored. Thus our Kaplan-Meier survival estimates were conservative.

In the following preliminary analyses, we used log-rank tests to look for differences in survival of marked chicks related to year (2011 – 2015) or grazing treatment of the pastures where chicks hatched (SGI or Non-SGI). Chick survival was not significantly different among years (χ^2 = 5, *df* = 4, *p* = 0.292; Fig. 9). The SGI status of the pastures in which chicks hatched did not impact chick survival during the remaining monitoring period (data for all years pooled; χ^2 = 0.5, *df* = 2, *p* = 0.784) or when evaluating the same relationship with respect to year (log-rank test stratified by year: χ^2 = 3.1, *df* = 2, *p* = 0.21). However, this analysis only evaluated where chicks spend their first few days post-hatch. Chicks often move between SGI and Non-SGI pastures throughout the monitoring period, and a different analysis will be conducted to estimate survival with respect to grazing status of pastures instantaneously during each monitoring interval, allowing the grazing status of pastures to change as needed. These analyses will be

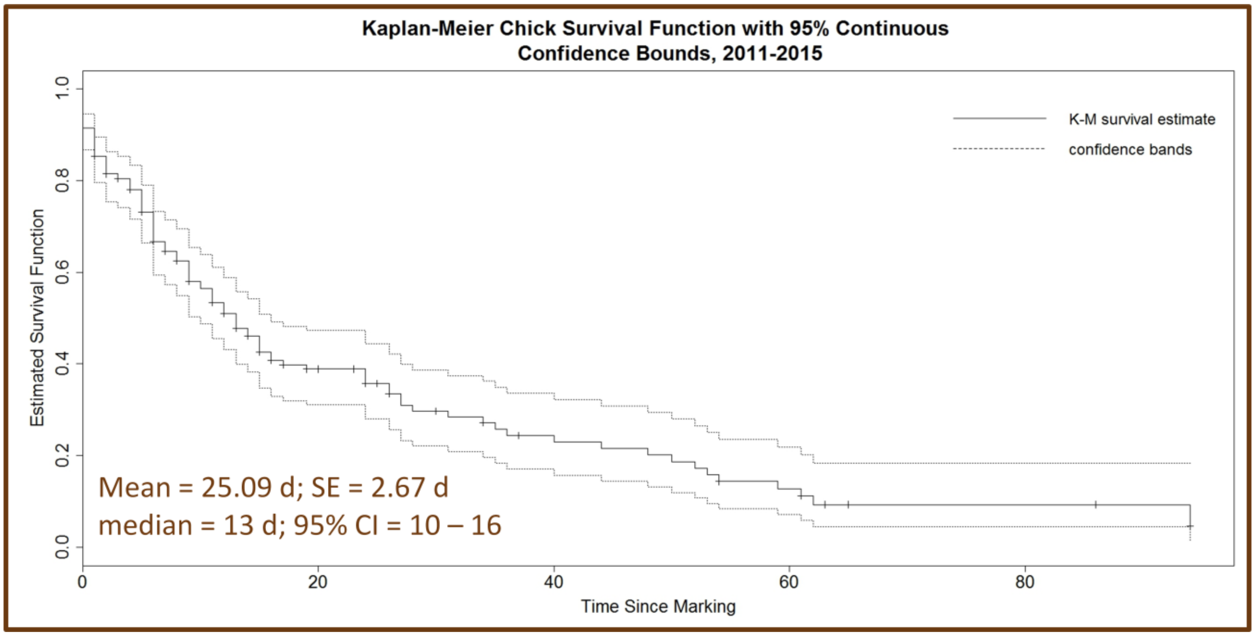

Figure 8. Kaplan-Meier survival curve and 95% confidence bounds for greater sage-grouse chicks marked with radio transmitters in Golden Valley and Musselshell Counties, Montana, USA during 2011 – 2015. Mean survival time for marked chicks was 25 days (SE = 2.67 days), while the median survival time was 13 days (95% confidence interval = 10 – 16 days).

completed outside of the period covered by this agreement.

Weather conditions during the sensitive post-hatch time, which peaks in early June for many prairie grouse, may have a large impact on chick survival (Flanders-Wanner et al. 2004). For example, chicks cannot thermoregulate during their first week post-hatch and rely on the hen to keep them warm. Many chicks get chilled and die in heavy rain events during the post-hatch period (Horak and Applegate 1998). We have not yet formally analyzed the effects of weather and other habitat variables on chick survival. Previous studies have shown chick survival to be variable and range from 12-50% during the first few weeks after hatching (Aldridge and Boyce 2007, Gregg et al. 2009, Dahlgren et al. 2010, Guttery et al. 2013). However, caution should be used when comparing estimates among studies because the duration of monitoring periods differ. For example, Gregg et al. (2009) and Dahlgren et al (2010) monitored sage-grouse chicks for 28 and 42 days, respectively, whereas we are able to monitor chicks up to 100 days due to the recent availability of smaller, lighter radio transmitters with longer battery life. In addition, some studies measure "brood" survival (at least one chick from a brood lives) or unmarked chicks rather than monitoring individually marked chicks.

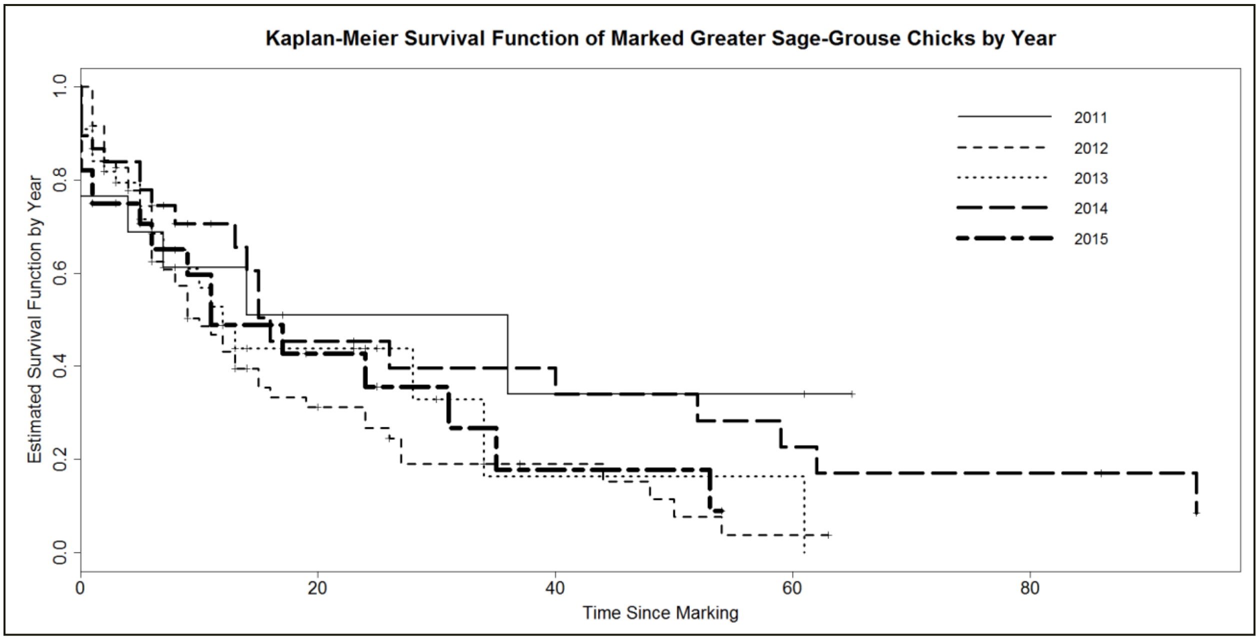

Figure 9. Kaplan-Meier survival curve by year for greater sage-grouse chicks marked with radio transmitters in Golden Valley and Musselshell Counties, Montana, USA during 2011 – 2015. The 95% confidence bounds are not shown in order to make the survival curves easy to see. Chick survival was not different among years ($\chi^2 = 5$, df = 4, p = 0.292).

Unmarked chicks are difficult to observe and monitor, and brood mixing may occur that results in broods containing chicks not parented by a particular hen. Thus there are limitations when comparing unmarked chick or brood survival estimates with telemetry survival estimates. The low chick survival observed during our study suggests a focus for future research and conservation efforts. We are working on chick resource selection and survival analyses to determine how habitat variables impact survival and resource selection in order to help guide management for this life phase. We are also evaluating hen survival, nest success, chick survival, and the habitat needs for these life phases together to identify priority areas for conservation efforts.

OBJECTIVES 4 – 6:

4. **Create a habitat-linked population model to:**
    a. **evaluate and forecast the benefits of treatments within a rotational grazing system on sage-grouse populations in the context of other drivers of sage-grouse vital rates, so as to put the influence of grazing management on population dynamics in context, and**
    b. **identify current areas that are most important to sage-grouse to prioritize locations where habitat management will have the most benefit to populations.**
5. **Quantify the population-level response of grazing treatments by indexing lek counts to our population modeling results, then by comparing lek counts within the Roundup study**

area to surrounding populations. To the extent that lek counts represent population changes reflected in population models, bird response to grazing might be forecasted in other areas where only lek count data are available.

6. **Generate spatially-explicit maps for areas with high quality seasonal habitat. Specifically we will produce maps that delineate areas with habitat attributes that define relative probability of use and that have a positive influence on vital rates during the nesting, brood-rearing, and winter periods, and extrapolate to similar landscapes to the extent that these models validate well.**

Our preliminary results presented above represent progress on these objectives. These are long-term objectives which will be completed at the end of the study in 2021-2022.

DELIVERABLES

Technical Reports

Agency	Reports	Delivery Dates
NRCS and USFWS Interagency Agreement # 60181BJ653 facilitated via the Intermountain West Joint Venture and Pheasants Forever	Biannual progress reports; final comprehensive report covering funding period of May 1, 2013 – Jun 30, 2016.	Oct 31, 2015; Apr 31, 2016; Aug 5, 2016
US Bureau of Land Management Grant and Cooperative Agreement # LI5AC00097	Annual progress report.	Mar 31, 2016
US Fish and Wildlife Service CFDA program Cooperative Agreement Award F14AC01224	Annual progress report.	Dec 31, 2015

Professional Meetings

Meeting	Description	Delivery Dates
Annual Oversight Committee Meeting	Hosted this meeting in Helena and presented updates on the sage grouse project to the committee and solicited their feedback on our schedule for planned publications.	Feb 9, 2016
Multi-state Sage-Grouse Research Meeting	Hosted a meeting in Helena with research groups from Idaho, Utah, and Montana that are doing sage-grouse grazing studies. Made plans for collaboration.	Nov 4-5, 2015

Presentations

Presentation	Description	Delivery Dates
Invited talk: National SGI SWAT training	Gave a presentation to several agency representatives from USFWS, BLM, NRCS, etc as well as the SGI SWAT biologists working in all states across the range of sage-grouse – Lewistown, MT.	Jun27-29, 2016
Invited talk: Yellowstone Valley Audubon	Gave a presentation presentation on sage-grouse grazing project to the Yellowstone Valley Audubon, Billings, MT.	Apr 18, 2016
Invited talk: Rocky Mountain College	Gave a presentation on our sage-grouse grazing project to Wildlife Conservation class undergraduate students at Rocky Mountain College, Billings, MT.	Mar 23, 2016
Invited talk: Sagebrush Conservation Conference	Gave a presentation on our sage-grouse grazing project at the Sagebrush Conservation Conference in Salt Lake City, UT.	Feb 25, 2016
Invited talk: University of Montana	Gave a presentation on our sage-grouse grazing project to Wildlife Habitat Conservation & Management class undergraduate students at the University of Montana, Missoula.	Nov 16, 2015
Invited talk: Montana WILD	Montana Fish, Wildlife, and Parks – Montana WILD Living with Wildlife Series.	Nov 9, 2015
Presentation for Big Hole Watershed Working Group meeting	Prepared presentation on our sage-grouse project for the local Area Biologist.	Nov 2016

Outreach

Description	Delivery Dates
Landowner appreciation dinner	Jul 14, 2016
Landowner appreciation dinner	Jul 29, 2015

PARTNERSHIPS

We have had ongoing communication with landowners and project partners. We have continued our partnership that we began in 2014 with USFWS to expand our habitat sampling to the Lake Mason satellite units of the Charles M. Russell (CMR) National Wildlife Refuge in Musselshell County. Data collected from plots on these units provide important variation in our data and comparisons between grazed and un-grazed pastures because these units have not been grazed in several years. We will include these units when we map relative probability of sage-grouse use across our study area.

It is increasingly important to evaluate grazing effects at an ecosystem level; grazing systems will not only impact sage-grouse but the sage-steppe community. We have leveraged the infrastructure and landowner relationships that we have built by establishing other, concurrent projects in our location: (1) "Migratory song birds- grazing study" (P-R grant W-165-R-1 to FWP; Dreitz et al. 2015), and (2) "Determining the impacts of grazing prescriptions on food availability for grouse species" (P-R grant W-164-R-1 to FWP). These multi-year projects are designed to overlap our sage-grouse grazing study by occurring during the same years and on the same study area. These projects dovetail with our sage-grouse work to look at impacts of grazing on migratory songbird species as well as insects (ties into food availability for sage-grouse) in the sage-steppe and surrounding grassland communities. We anticipate a collaborative report among the three projects in the next three to five years in which we will assess grazing impacts on sage-grouse, songbirds, and insects, and connection among these components of the sagebrush ecosystem.

We have partnered also with MSU on a project evaluating the impacts of grazing on the demography, population dynamics, and habitat selection of sharp-tailed grouse (*Tympanuchus phasianellus*); densities and demographic performance of the grassland bird communities; and the predator community in Richland County, Montana, USA (P-R grant W-162-R-1 to FWP). This project is very similar in design to our sage-grouse grazing study and will provide a comparison of the impacts of grazing among related species and ecosystems. This project focuses on a 3-pasture, rest-rotation grazing system managed by FWP, and we should be able to make some comparisons among this system, SGI, and more traditional season-long systems. This collaborative approach is essential to understand multiple facets of the impacts of grazing on rangelands and wildlife, and it further leverages funding contributions for this project. It is also a unique and critical opportunity to determine the long-term impacts of changes in land-use practices at the ecosystem level.

To put our project into context within the bigger picture of grazing and sage-grouse across their entire range, we are collaborating with research groups from Utah, Idaho, and western Montana that are conducting greater sage-grouse grazing studies. We met with these groups on Nov 4-5, 2015 and identified potential areas for collaboration in order to evaluate grazing and its impacts on sage-grouse and their habitat across the sage-grouse distribution.

ACKNOWLEDGEMENTS

We thank the Intermountain West Joint Venture (IWJV) and Pheasants Forever for all of your support (NRCS and USFWS Interagency Agreement # 60181BJ653 facilitated by IWJV and Pheasants Forever). In addition, we thank our current funders including Montana Fish, Wildlife, and Parks (FWP license sale funds), US Fish and Wildlife Service (Pittman-Robertson funds administered by the USFWS; CFDA program Cooperative Agreement Award F14AC01224), and the US Bureau of Land Management (Grant and Cooperative Agreement # LI5AC00097). We also thank additional previous funders including the Natural Resources Conservation Service (Conservation Innovation Grants program Agreement # 69-3A75-10-151, Conservation Effects Assessment Project); Montana Fish, Wildlife, and Parks (Upland Game Bird Enhancement Program); and the Big Sky Upland Bird Association. We thank all of the private landowners that have allowed us to access their land for this work. We are appreciative of several seasonal technicians who have helped collect the data used for this report including A.J. McArthur, Alan Harrington, Alison Gabrenya, Amanda Reininger, Amanda Smith, Amber Swicegood, Amelia Hirsch, Amy Bardo, Brandon Sandau, Caleb Deitz, Charles Black, Charles Sandford, Cody Cole, Colten Harner, Dana Jansen, Daniel Madel, Derek White, Emily Gilbreath, Emily Luther, Erik Fortman, Ethan Chaddick, Ethan Young, Heather Brower, Jacob Decker, Janelle Badger, Landon Moore, Loni Blackman, Luke Hawk, Mary Schvetz, Michael Yarnall, Ryan Keiner, Shawna Sandau, Theresa Doumitt, and William (Jack) Medlicott. We are also appreciative of several people that have volunteered on this project. We thank the partners that participate in an oversight committee that oversees the direction of our research including representatives from Montana Fish, Wildlife, and Parks; the Natural Resources Conservation Service; US Bureau of Land Management; the Montana Department of Natural Resources and Conservation, and the University of Montana.

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