Evaluating Sage-Grouse and Habitat Responses to Sage-Grouse Friendly Livestock Grazing Strategies.

3-yr Preliminary Findings

MFWP Upland Game Bird Enhancement Program

Conservation Innovation Grants

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Executive Summary

The greater sage-grouse (*Centrocercus urophasianus*) is a sagebrush-obligate species that was designated as warranted for protection under the Endangered Species Act (ESA) in 2010 but precluded due to higher priority species. The loss and degradation of the sagebrush habitats has led to its extirpation from half of its original range. In 2015 the U.S. Fish and Wildlife Service will make a final listing decision for the sage-grouse. To help avoid the listing of the greater sage-grouse, the U.S. Department of Agriculture – Natural Resources Conservation Service (NRCS) recently implemented the Sage-Grouse Initiative (SGI) program, which provides incentives to private landowners within key areas to help them modify their ranches and grazing systems to improve sage-grouse habitat and populations. This study evaluates the effectiveness of the SGI program and the direct effects of grazing management on greater sage-grouse and their habitat.

We monitored adult female sage-grouse and chicks with radiotelemetry to obtain vital rate and habitat use data. We measured vegetation data using line intercept and Robel pole techniques at (1) stratified random points in non-SGI pastures, grazed SGI pastures, and rested SGI pastures; and (2) sage-grouse nests and random points within nesting habitat. Residual grass height in both rested and grazed pastures enrolled in SGI was greater than in non-SGI pastures.

Hens in both areas showed a preference for intermediate-high sagebrush canopy cover, greater residual grass height, and more forb canopy cover at nest sites. The proportions of adult female sage-grouse ("hens") that survived annually in non-SGI areas during 2011 and 2012, respectively, were 59% (13/22) and 74% (32/43; 2013 data still being collected). The proportions of hens that survived annually in SGI areas during 2011 and 2012, respectively were 57% (45/79) and 61% (42/69; 2013 data still being collected). Contrary to expectations for a species that has typically high winter survival, hens in our study population had the lowest seasonal survival during the winter (Nov-Mar) in 2011-12 in both non-SGI and SGI areas. The proportions of hens that survived each season in non-SGI areas in 2011, 2012, and 2013 respectively were: spring = 100% (22/22), 86% (37/43) and 94% (34/36); summer = 82% (18/22), 95% (35/37) and 97% (33/34); fall = 94% (17/18), 86% (30/35), and 100% (33/33); and winter = 76% (13/17) and 83% (25/30; 2013 data not yet collected). The proportions of hens that survived each season in SGI areas in 2011, 2012, and 2013 respectively were: spring = 85% (67/79), 83% (57/69), and 93% (54/58); summer = 94% (63/67), 91% (52/57), and 89% (48/54); fall = 89% (56/63), 88% (46/52), and 96% (46/48); and winter = 80% (45/56) and 76% (35/46; 2013 data not yet collected). The proportion of nests that were successful (hatched ≥1 chick) during 2011, 2012, and 2013, respectively were 12% (3/25), 61% (23/38), and 36% (12/33) in non-SGI areas and 36% (28/77), 49% (26/53), and 42% (22/52) in SGI areas. Using an information theoretic approach in program MARK, the top-ranked nest success model showed that grass height was an important factor out of the variables in our *a priori* models, where an increase in grass height at the nest positively affected nest success. There did not appear to be differences in nest survival between enrolled lands and non-enrolled lands except in 2011, where overall low nest survival seems to have been driven by very low survival on non-enrolled lands. We speculate that it is possible that we have not yet observed a difference in nest success between SGI and non-SGI systems because of variation in the data due to weather. The study area experienced average to above average precipitation during the first and third years of the study (2011 and 2013) and below average precipitation during the second year (2012). Resource selection modeling showed that hens were more likely to nest where residual grass was taller, and box plots of vegetation data showed that SGI pastures (both rested and grazed) appeared to have taller residual grass than non-SGI pastures. The proportions of chicks that survived in non-SGI areas during 2011, 2012, and 2013, respectively in non-SGI areas were 20% (1/5), 9% (3/34), and 23% (3/13) and in SGI areas were 21% (4/19) , 11% (5/47), and11% (5/44). The survival rate of chicks appeared to improve at one month post-hatch.

We highlight that the results in this report are preliminary results from the first three years of a long-term study that will continue for at least ten years. Changes in habitat conditions and sage-grouse vital rates in response to grazing management will likely show a “lag” effect and not be observed for a few years. This should be considered when drawing inferences from this report. However, this preliminary look at the first three years of data suggests that SGI pastures exhibited taller residual grass than non-SGI pastures. Also, nesting hens were selecting for taller residual grass at nest sites and nest success was positively influenced by grass height around the nest. We predict that we will begin to see a difference in nest success rates in favor of SGI pastures in the next few years if landowners continue the SGI grazing systems. With further analyses we will attain a more in-depth look at the effects of environmental and vegetation variables on all vital rates and habitat selection.

PROJECT DESCRIPTION

Background

Private lands constitute 30% of the 48 million ha of greater sage-grouse (*Centrocercus urophasianus*; hereafter "sage-grouse") habitat, with Montana (MT) among the states with the most sagebrush in private control (Connelly et al. 2004). Of the land within 75% of the highest density breeding sites in MT, 59% is private whereas in other states 33% is typically private (Doherty et al. 2010). For species that range over large areas such as sage-grouse, private lands conservation and maintaining "working landscapes" has become a major means by which conservation and management occurs (Raven 1990, Brunson and Huntsinger 2008). The Natural Resources Conservation Service (NRCS), as part of their new Sage-Grouse Initiative (SGI) program, has designed rotational grazing systems that improve vegetative cover on potential sage-grouse habitat through a mixture of rest and deferment. Though implementation of SGI grazing systems has begun, their effectiveness as a management tool for maintaining or enhancing sage-grouse populations and their habitat has not been quantified.

The Sage-Grouse Initiative (SGI) Program

Grazing systems designed under the relatively new SGI program (started in 2010) focus on improving livestock production and rangeland health while simultaneously alleviating threats to and improving habitat for greater sage-grouse (NRCS pers. comm., Boyd et al. 2011). Landowners enrolling in the SGI program 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 in MT (see **Study Area, Fig. 1)**. These systems are tailored to each ranch, and may vary with the needs of the landowner or the condition of the rangelands.

To achieve improved rangeland health and sage-grouse habitat, SGI grazing systems are designed as rotational systems that rest 20% of enrolled lands that contain potential sage-grouse habitat for an average of 15.5 months during the three year contract or use a deferred grazing system. Deferred grazing systems for this program are defined as systems where at least one pasture is grazed and then left alone until after seed set the following year. In addition, the season of use for each pasture is rotated annually. Pastures that are "rested" are not used for ≥ 15 months. All systems also set stocking rates to minimize the impacts of livestock on rangelands. This benefits rangeland by leaving residual grass to capture moisture, reducing temperature and evaporation through shading of the soil, and providing organic matter to the soil.

The SGI grazing systems are designed to leave more residual vegetation cover for the following year's nesting season (April-June) as well as improve 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.). This 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.

Sage-grouse

Sage-grouse are endemic to semi-arid sagebrush habitats in western North America (Schroeder et al. 1999). Sage-grouse populations have declined over the past century and currently inhabit 56% of their historic distribution (Schroeder et al. 2004). This decline in sage-grouse populations precipitated the recent listing of this species as "warranted but precluded" from protection under the federal Endangered Species Act (United States Department of the Interior – Fish and Wildlife Service 2010). Declines in sage-grouse populations are attributed to increasing oil and gas development (Naugle et al. 2011), conversion to cropland (Walker et al. 2007), disease (i.e., West Nile virus; Walker and Naugle 2011), conifer invasion into sagebrush habitat (Crawford et al. 2004, Beck et al. 2012), and rural sprawl (Leu and Hanser 2011) in sagebrush landscapes (Knick et al. 2013). In addition, improper livestock grazing management may contribute to declines in this species by altering the vegetation structure and composition of sagebrush habitats (Beck and Mitchell 2000). A combination of these factors, and probably additional unknown factors, have likely brought about the decline in sage-grouse and other prairie grouse populations (Crawford et al. 2004).

Recent research by Taylor et al. (2012) shows that hen survival, nest success, and chick survival are the three most important vital rates influencing sage-grouse population growth across all of the published vital rate studies—more influential than, for example, nest initiation dates or clutch sizes. In addition, range-wide population declines of sage-grouse are attributed to declining production, of which chick survival is an important component (Dahlgren et al. 2010). Thus, we focus on monitoring hen survival, nest success, and chick survival and habitat use associated with these vital rates for this study.

Objectives

More than 700 producers and > 2 million acres have been enrolled in SGI programs across sage-grouse habitat in several western states since SGI began in 2010. The threats to sage-grouse populations vary across their range (e.g., conifer invasion in Oregon, energy development in Wyoming, tillage of sagebrush to crops in MT). Consequently SGI programs implement a variety of actions to improve rangelands such as conifer removal in Oregon, fence-marking in multiple states, and grazing systems in MT. Our goal is to evaluate the effects of SGI grazing systems on sage-grouse vital rates, distribution, and habitats using a focal sage-grouse population in central MT, and to inform NRCS's grazing programs by recommending modifications (if needed) that can benefit sage-grouse. We are focusing on a representative sage-grouse population and network of SGI-enrolled land in central MT. To achieve our goal, we outlined the following objectives:

1. Determine the impact of individual cattle grazing treatments including timing and duration of rest-rotation grazing systems on critical sage-grouse habitat features.
2. Document how sage-grouse select nest and brood rearing sites with respect to a suite of habitat features within SGI and non-SGI grazing systems.
3. Document the effects of habitat features within SGI and non-SGI grazing systems on sage-grouse population vital rates, including adult female survival, nest success, and chick and brood survival, in the context of vegetation and environmental factors.
4. Determine how sage-grouse population dynamics within different cattle grazing treatments and management systems are related to spring lek counts to facilitate transfer of results to other areas where lek counts are the only readily available data.
5. Transfer knowledge of the impacts of cattle grazing management systems on sage-grouse habitat and populations to livestock producers, landowners, NRCS and federal land management staff, and wildlife management agencies.

This report documents the first three years of this long-term study which is designed to monitor and evaluate these grazing systems for at least ten years.

Study Area

The intent of the SGI program is to improve rangeland health on private lands in order to help conserve sage-grouse and eliminate the need to list them on the threatened or endangered species list. Therefore the program is focused on land where there are potential threats to sage-grouse populations but these threats have not yet been realized (e.g., eastern MT prairies are threatened by conversion to cropland, but conversion to cropland has not yet occurred in many places with core sage-grouse populations). Within MT, the NRCS focused SGI conservation easements and grazing systems within sage-grouse "core areas". These core areas were delineated by FWP as areas that include 25% of the highest densities of male sage-

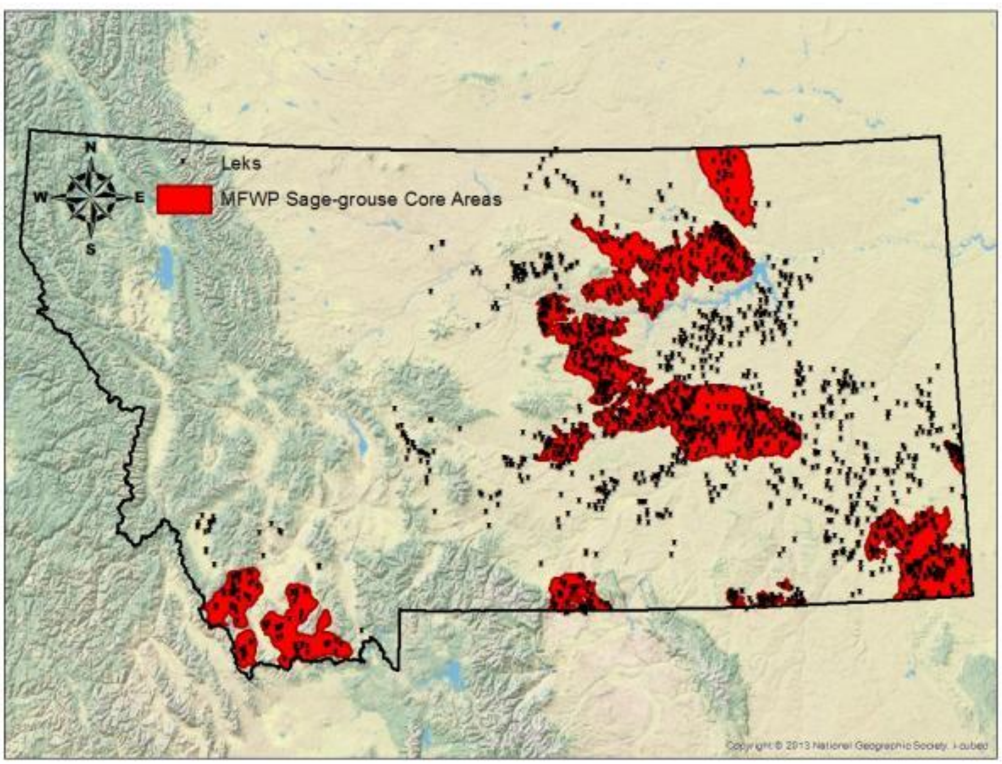


Figure 1. *Greater sage-grouse leks and core areas in MT as defined by Montana Fish, Wildlife, and Parks.*

grouse on leks and associated habitats that are important to sage-grouse distribution (**Fig. 1**).

We focused our study in a core area in central MT, located in Golden Valley and Musselshell counties immediately north of Lavina and Roundup, MT (**Fig. 2**). For comparison, we also

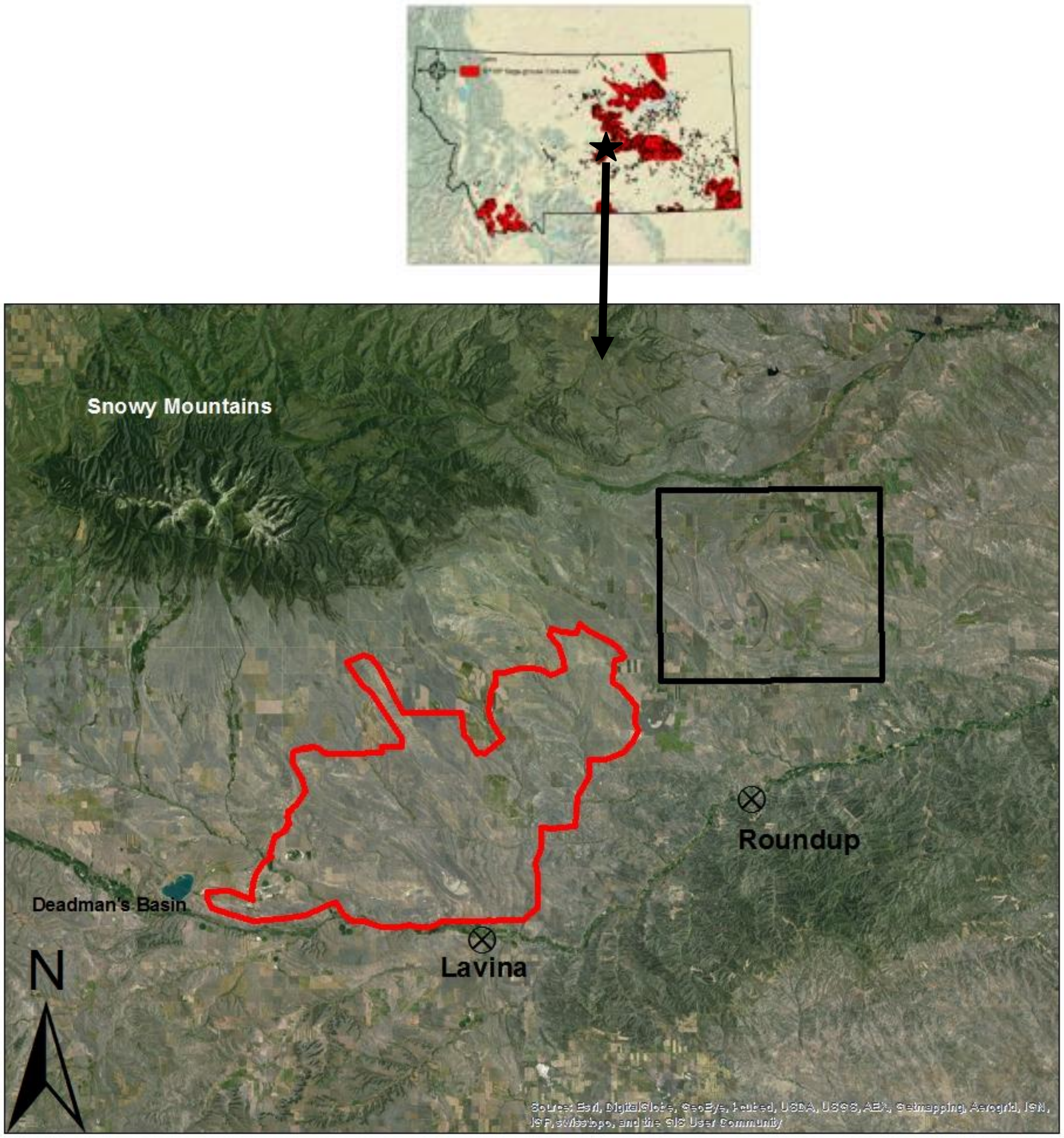


Figure 2. *A map of the study area north of Lavina, MT, and north and west of Roundup, MT, in Golden Valley (western portion) and Musselshell (eastern portion) Counties. The study area includes a sage-grouse core area (red boundary) delineated by FWP where SGI grazing systems have been implemented and an area 25 mi north of Roundup (black border) where no SGI systems have been implemented.*

included sage-grouse and their habitats near leks located 25 mi north of Roundup, MT where no SGI systems have yet been implemented. This area included both public and private lands. Grazing systems were used in this area, but they were not SGI systems.

From April 1, 2011 (the start date for implementing the first SGI grazing systems) through September 10, 2013 (the end of the funding period for this grant), NRCS enrolled 12 ranches in this area into SGI three-year grazing contracts, totaling ~40,468 hectares (~100,000 acres). However, not all land within the core area was enrolled in SGI. Thus any sage-grouse hens, nests, or chicks located in areas not enrolled in the SGI program were categorized as "non-SGI". We evaluated the vital rates of marked sage-grouse that used SGI-enrolled lands (hereafter "SGI") versus non-SGI lands (hereafter "non-SGI"). This population of sage-grouse was not migratory; thus land management affected their entire life cycle and we monitored vital rates and habitat use continuously throughout the study period.

Objective 1. Determine the impact of individual cattle grazing treatments, including timing, duration, and stocking rates, and rest-rotation grazing systems on critical sage-grouse habitat features.

In 2012 we collected a preliminary sample of vegetation data at 99 field plots. Several factors unrelated to grazing management are known to affect vegetation structure in rangelands. We reduced the heterogeneity in our samples caused by non-treatment effects by requiring randomly sampled plots to conform to the following criteria. Plots were selected from areas with similar slope and soil type to reduce topographic and edaphic effects on vegetation structure. Plots were also restricted based on distance from surface water, as livestock utilization of forage is directly and inversely related to distance from water. Sites less than 200 m from a water source are expected to experience high levels of trampling and herbivory by cattle which tend to congregate around water, especially in hot weather. Conversely, sites more than 1500 m from a water source likely experience infrequent use by livestock. Distances between these bounds are likely to show the greatest response to alteration of grazing management. We eliminated any sites dominated by non-native vegetation or deemed by observers to have been altered by past management activities such as shrub treatment, cultivation, or recent burning. Plots were selected by randomly generating points across the study area using the criteria shown in **Table 1.1** and were further evaluated with respect to

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 silty clays and silty clay loams that typically support sagebrush in the study area.
[2]: Field checked.
[3]: http://soildatamart.nrcs.usda.gov
[4]: http://nhd.usgs.gov

Table 1.1. *Criteria for inclusion of sampling plots used to measure vegetation response to grazing systems.*

vegetation type by field observers. Locations of field plots measured in 2012 are shown in **Fig. 1.1**. At each field plot we measured vertical (areal) cover, height, and visual obstruction of

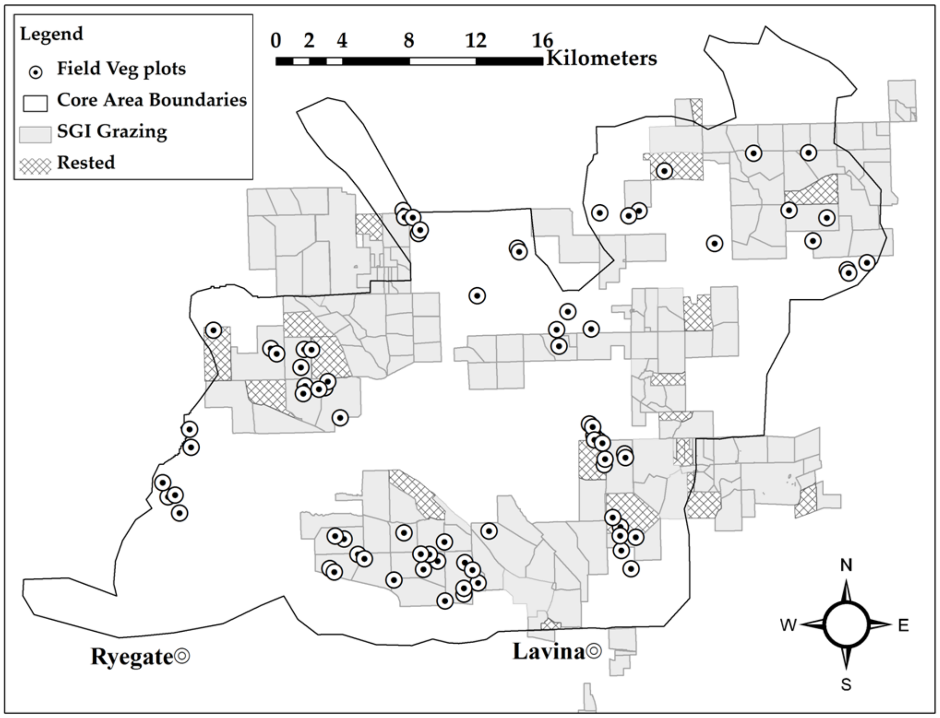


Figure 1.1. *Location of field plots measured in 2012. An incomplete map of rested pastures is displayed, with rested pastures shown with hash marks. Complete grazing records will be available in April following each grazing season. Data from these plots were used to parameterize the power analysis.*

herbaceous vegetation. We estimated areal coverage of herbaceous vegetation, litter (detached dead vegetation), lichen and moss, and bare ground and rock using twelve 0.2×0.5 m quadrats (Daubenmire 1959) placed at 3, 6, and 9 m from the center of the point in each of the four cardinal directions. Estimated cover was recorded in 1% intervals. Droop height of herbaceous vegetation was also recorded in each quadrat by measuring the height of the grass or forb plant nearest the center of each quadrat. Areal coverage and droop height values were averaged among all quadrats to estimate average coverage and height values for each plot. Visual obstruction was measured using a Robel pole (Robel et al. 1970) placed at 0, 1, 3, and 5 m from the center of the plot in each of the four cardinal directions for a total of 16 measurements. Vegetation obstructing the pole was categorized and recorded as herbaceous or shrub by the observer. Visual obstruction readings were also averaged to obtain a total visual obstruction and an herbaceous visual obstruction value for each plot. We used the preliminary sample to parameterize a power analysis for more intensive field sampling in 2013.

Only an incomplete list of rested pastures could be acquired before preliminary analysis, so only differences between non-SGI and SGI pastures were examined. In the preliminary sample, differences in means of all vegetation metrics of interest (grass height, herbaceous cover, bare ground, and visual obstruction of grass) between non-SGI and SGI pastures in 2012 were in the expected direction; SGI pastures had slightly higher grass, slightly greater areal cover of herbaceous vegetation and litter, less bare ground, and slightly greater visual obstruction provided by herbaceous vegetation. We conducted power analyses to assess the necessary sample sizes of plots required for each vegetation metric to detect statistically significant differences between SGI and non-SGI pastures. We simulated 10% differences between non-SGI and SGI pastures, as this seemed to be a reasonable expectation based on personal observation and the differences observed between non-SGI and SGI pastures. Sample sizes required to detect differences between non-SGI and SGI pastures at $\alpha = 0.05$ for each metric varied from *N=50-150* these four metrics (**Fig. 1.2)**. Power to detect differences between non-SGI and grazed SGI pastures with our initial sample of 99 plots was generally low (~0.2 – 0.6) for all parameterizations and is not shown. This is expected early on in grazing system implementation; at the time of measurement, grazing system pastures range from just grazed to having gone many months without grazing. Nevertheless, we sample from SGI pastures that are not currently rested, as data gathered soon after grazing system implementation may be

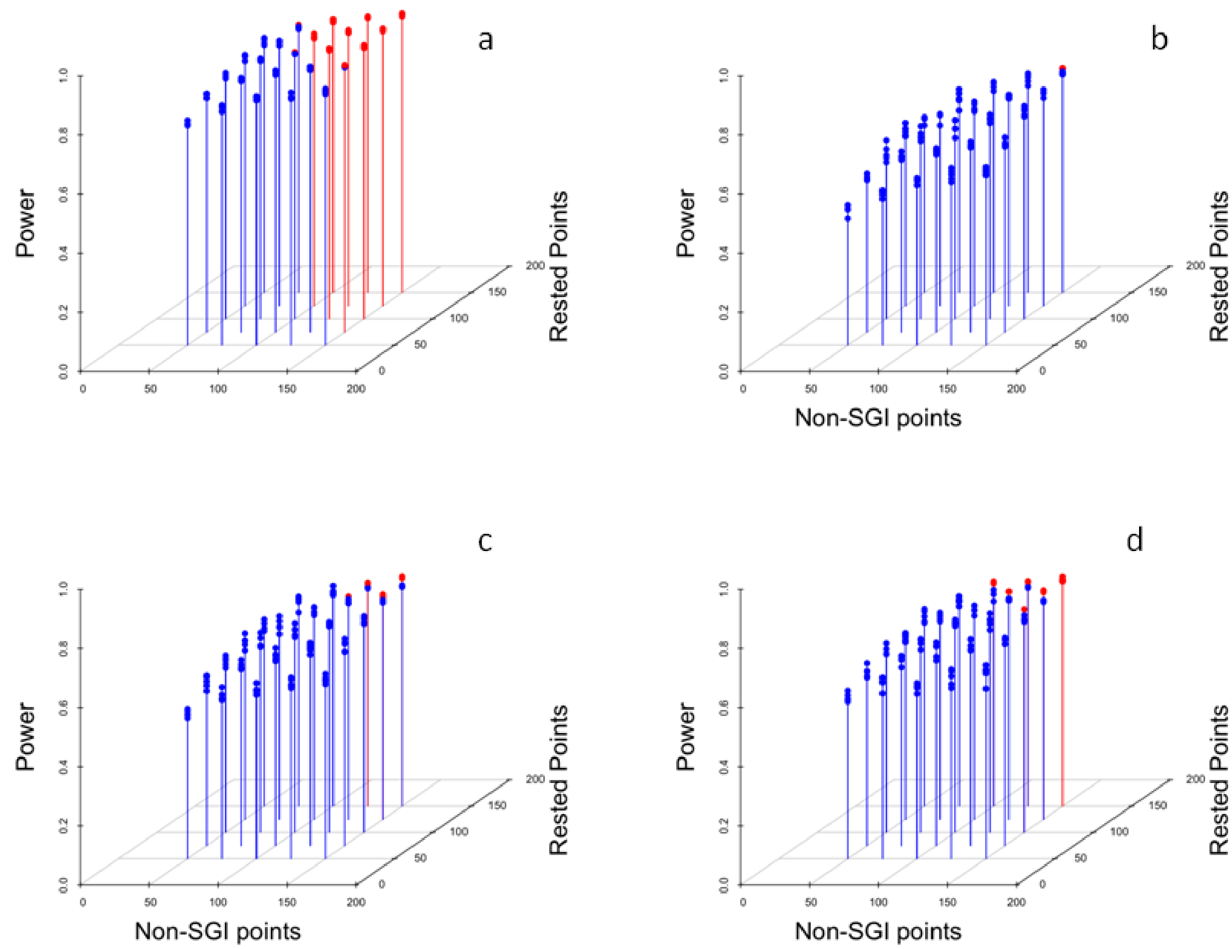


Figure 1.2. *Power analyses of four herbaceous vegetation metrics. Each panel indicates the power to detect significant differences between non-SGI and SGI rested pastures at the α = 0.05 level using a t-statistic. All combinations of sample sizes of 50, 75, 100, 125, and 150 from each treatment were considered. (a): Power to detect a 10% increase in grass height in SGI rested pastures, with power > 0.9 shown in red; (b) power to detect a 10% increase in total herbaceous areal cover in SGI rested pastures, with power > 0.75 shown in red; (c) power to detect a 10% decrease in bare ground cover in SGI rested pastures, with power > 0.75 shown in red; (d) power to detect a 10% increase in grass visual obstruction (height-density) in SGI rested pastures, with power > 0.75 shown in red.*

useful for future assessment of vegetative response. Following these initial stages of data collection and analyses, our sampling goal in 2013 was increased to 350 – 400 plots per year, larger than the sum of the two horizontal axes in **Fig. 1.2.** We were able to collect field measurements of herbaceous vegetation structure as described above in both grazed and rested SGI pastures as well as non-SGI pastures during mid-summer in 2013 on 279 plots.

The residual grass height at random plots appeared greatest in rested / deferred (≥15 months) SGI pastures, but appeared to be greater in both grazed and rested SGI pastures than in non-SGI pastures (**Fig. 1.3**). We are in the process of compiling data for other vegetation variables that were selected by nesting hens (see **Objective 2**).

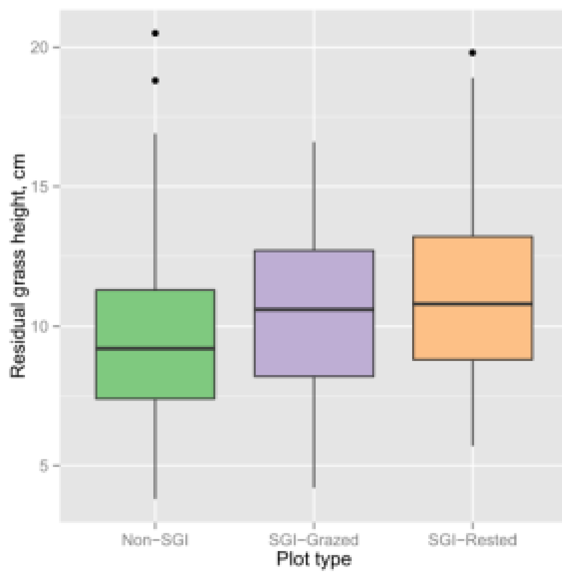
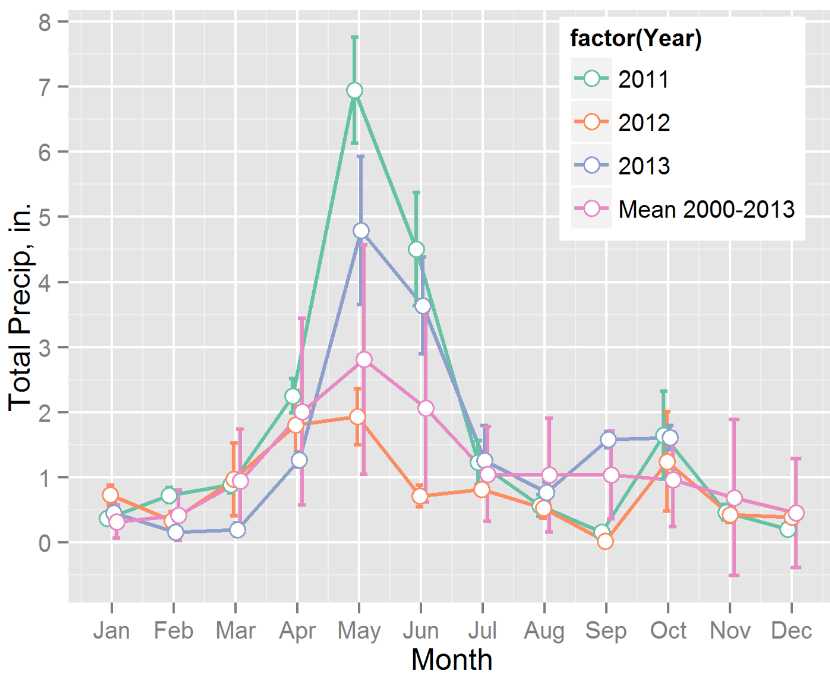


Figure 1.3. *Residual grass height at vegetation response plots on non-SGI pastures (n = 117), SGI pastures grazed in the past year (n = 47), and SGI pastures that had been rested from grazing since the previous nesting season (n = 114). All plots were measured in July 2013.*

We obtained total monthly precipitation data from the National Climatic Data Center (National Oceanic and Atmospheric Administration 2013). The nearest NCDC weather observation stations for our study area were located in Ryegate, Roundup, and Lavina, MT in Golden Valley and Musselshell counties. We speculate that the variation we observed in vegetation and possibly hen nest site selection data (see **Objective 2**) likely reflected, in part, variation in weather each year (for example monthly total precipitation, **Fig. 1.4**). Annual weather fluctuations, particularly of precipitation, are a major driver of the vegetative structure and



Alternate Figure 1.4
Monthly total precipitation at weather stations in Ryegate, Roundup, and Lavina. Open circles indicate means and error bars extend one standard deviation from the mean, indicating spatial variation in precipitation among stations. Mean and standard deviation of monthly total precipitation from 2000 – 2013 is shown to indicate normal precipitation patterns.

composition of rangeland ecosystems (Gillen and Sims 2006). Weather effects are powerful enough that they can negate effects of grazing or act in concert with grazing to determine the succession of plant communities (Gillen and Sims 2006). Thus, long-term data is needed to tease out the effects of grazing versus weather on sage-grouse and their habitats. We are doing further analyses to determine how much variation in the data is explained by weather variables such as precipitation, which will be necessary to fully quantify the effect of the SGI grazing programs.

Objective 2. Document how sage-grouse select nest and brood rearing sites relative to habitat features within different cattle grazing treatments and management systems.

We measure a suite of vegetation and environmental data at three types of sampling locations within the study area: 1) nest locations documented through observation of radio-marked hens, 2) telemetry locations characterizing movement of hens and chicks beyond those at nests, and 3) random locations characterizing general availability of habitat throughout the study area. For details on capturing and monitoring hens and chicks, see **Objective 3**. Each year nest sites had slightly greater residual grass height than random sites. The box plots in **Fig. 1.5** show the median, upper and lower quartiles, and outliers for our residual grass (defined as standing dead grass from the previous year) height data at nest sites of great sage-grouse hens versus random points within potential nesting habitat. Sika (2006) found that 98% of 215 nests were within 4.8 km of active leks and 83% were within 4.8 km of the nearest lek to the hen's capture site. Thus we considered potential nesting habitat to be sagebrush habitat within 5 km of active leks where hens were captured. Given resources and time, we measure as many additional random points as possible to increase the power of our evaluation. The random points are generated in ArcGIS v 9.3.1 (ESRI Inc., Redlands, CA) using the Geospatial Modeling Environment v 0.3.2 Beta (Beyer 2010).

Much of our protocol for collecting nest and random point vegetation data follows the

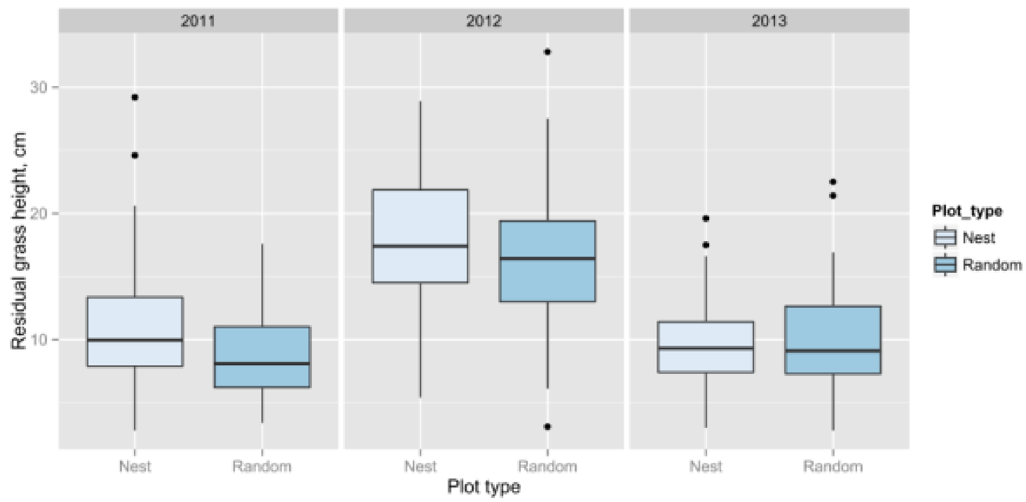
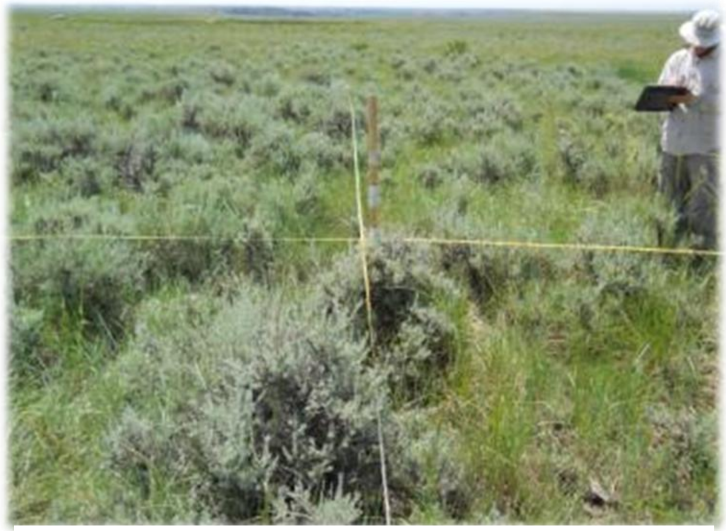


Figure 1.5. *Box plots of residual grass heights measured at both greater sage-grouse nests and random points within potential nesting habitat in Musselshell and Golden Valley counties, Montana from 2011-2013.*

procedure outlined in Doherty (2008). Vegetation plots at nests or random points are centered on the nest bowl or a random shrub (the shrub nearest to a random point and >35 cm in height) and extend 15m in each cardinal direction ("spokes"). At the nest or random shrub we measure grass height (maximum droop height with and without the inflorescence; distinct measurements are obtained for both current-year and residual grass); the top two dominant cover species of current-year grass; height, width, species, and percent vigor of the nest or random shrub; and visual obstruction to the nearest half-decimeter using a Robel pole (Robel et al. 1970). Along each spoke we estimate visual obstruction at 0, 1, 3 and 5m from the nest or random shrub. Using Daubenmire frames (Daubenmire 1959) at 3 and 6 m from the nest or random shrub along each spoke we measure the height of the nearest shrub, grass height (maximum droop height with and without the inflorescence; distinct measurements are obtained for both current-year and residual grass), proportion herbaceous cover (with native and non-native grass and forb cover estimated separately), proportion litter cover, and proportion bare ground. 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 index livestock use in each local-scale vegetation plot by measuring the proportion of plants that have been grazed and counting the number of cowpies (current and past year's) in each plot as well as the visual presence of livestock in the pasture (a variable also noted at each location of sage-grouse hens, chicks, and nests). These data enhance the information we obtain from NRCS on history of grazing in specific pastures as well as record livestock use immediately around nests and random points.



Vegetation sampling plot near Roundup, MT.

In addition to fine-scale field-based measurements, we also use Geographical Information Systems (GIS) to characterize the conditions surrounding nest, telemetry, and random locations at a larger scale. The GIS is computer-based software that can be used to measure vegetation variables including percent cover of bare ground, grass, litter, and sagebrush canopy cover at a larger scale than we can measure in the field. We also obtain distance to and proportion of cropland, grazing treatment of adjacent pastures, and distance to road variables from the GIS at hen, chick, or brood locations. Our GIS sources are the USDA National Agricultural Statistics Service, 2011-2014 Cropland Data Layers; LANDFIRE 1.1.0 Existing vegetation type layer, USGS (http://landfire.cr.usgs.gov/viewer/); Census 2010 TIGER/Line shapefile (http://www.census.gov/geo/www/tiger/shp.html); Open Range Consulting Landcover map (Simonds et al. in prep); Open Range Consulting continuous cover map (Simonds et al. in prep); and the MT Bureau of Mines and Geology.

Year	Plot Type	
	Nest	*Random*
2011	74	102
2012	89	181
2013	80	118

Table 2.1. *Nest and random plots for which a complete set of measurements were available for RSF model selection (Table 2).*

Resource selection functions were used to test for effects of local vegetation attributes on nest site selection during 2011 – 2013 using program R version 2.15.2 (R Core Team 2012). Sample sizes of nest (used) and random (available) plots used to estimate resource selection functions are shown in **Table 2.1**. Plots were only included if measurements were available for all covariates included in the candidate models in **Table 2.2**.

Model description	n	K	df	Log(*L*)	AIC	ΔAIC	*w*
%ARTR + Nshrub_ht + Pshrub_ht + PForb + Presid_ht + (Ngrass_ht | Year)	644	9	635	-364.77	747.5	0.0	0.377
%ARTR + Nshrub_ht + Pshrub_ht + PForb + Nresid_ht + (Ngrass_ht | Year)	644	9	635	-365.18	748.4	0.9	0.241
%ARTR + %ARTR^2 + Nshrub_ht + PForb + Presid_ht + (Ngrass_ht | Year)	644	9	635	-365.5474	749.1	1.6	0.170
%ARTR + %ARTR^2 + Nshrub_ht + PForb + Nresid_ht + (Ngrass_ht | Year)	644	9	635	-366.05	750.1	2.6	0.103
%ARTR + Nshrub_ht + PForb + Nresid_ht + (Ngrass_ht | Year)	644	8	636	-367.89	751.8	4.3	0.044
%ARTR + %ARTR^2 + Nshrub_ht + PForb + Presid_ht + (Pgrass_ht | Year)	644	9	635	-367.15	752.3	4.8	0.034
%ARTR + Nshrub_ht + Pshrub_ht + PForb + Presid_ht + (Pgrass_ht | Year)	644	9	635	-367.58	753.2	5.7	0.022
%ARTR + Nshrub_ht + PForb + Presid_ht + (Pgrass_ht | Year)	644	8	636	-369.70	755.4	7.9	0.007
%ARTR + %ARTR^2 + Nshrub_ht + Pshrub_ht + PForb + (1 | Year)	644	7	637	-372.54	759.1	11.6	0.001
%ARTR + %ARTR^2 + Nshrub_ht + Pshrub_ht + PForb + Presid_ht + (1 | Year)	644	8	636	-371.99	760.0	12.5	0.001
%ARTR + Nshrub_ht + Pshrub_ht + PForb + (1 | Year)	644	6	638	-374.86	761.7	14.2	0.000
%ARTR + Nshrub_ht + Pshrub_ht + PForb + Presid_ht + (1 | Year)	644	7	637	-374.28	762.6	15.1	0.000
%ARTR + %ARTR^2 + Nshrub_ht + Pshrub_ht + (1 | Year)	644	6	638	-376.86	765.7	18.2	0.000
%ARTR + Nshrub_ht + Pshrub_ht + (1 | Year)	644	5	639	-379.46	768.9	21.4	0.000
%ARTR + Nshrub_ht + (1 | Year)	644	4	640	-381.86	771.7	24.2	0.000
%ARTR + (1 | Year)	644	3	641	-405.74	817.5	70.0	0.000

Table 2.2. *Candidate models for nest site selection (2011 – 2013). %ARTR = percent sagebrush canopy cover; %BG = percent bare ground; %Tforb = percent total forb canopy cover (native and nonnative combined); Pshrub_ht = plot-level mean of shrub height (all shrub species combined); PForb = plot-level mean forb height (all forb species combined); Pgrass_ht = plot-level mean of grass height, excluding inflorescence; Presid_ht = plot-level mean of residual grass height; Nshrub_ht = nest shrub height; Ngrass_ht = maximum height of grass at the nest, excluding inflorescence; Nresid_ht = maximum height of residual grass at nest.*

Hence, a total of 29 nests (23 in 2011, 2 in 2012, and 4 in 2013) and 14 random plots (5 in 2011, 8 in 2012, and 1 in 2013) were excluded due to missing data. Candidate RSF models are ranked in **Table 2.2**. All models included a random intercept for year to accommodate differences in used/available ratios among years. Models including random coefficients for the effects of grass height at the plot- and nest-levels were used to include effects of grass height on nest site selection. We did not include these covariates as fixed effects because differences in spring weather among years resulted in substantial variation in the timing and rate of herbaceous vegetation growth relative to the onset of nesting. For the sake of simplicity, this analysis was restricted to the effects of selected local vegetation metrics on nest site selection; future analyses will test for effects of landscape composition, rangeland condition at larger spatial scales (derived from imagery analysis), anthropogenic disturbance, and grazing treatments. Consistent with previous studies, parameter estimates in our most supported nest site RSF model indicate that hens show a preference for higher sagebrush canopy cover with some support for a quadratic term (two models within 3 AIC units of the top model included a quadratic term, indicating selection for intermediate-high sagebrush canopy cover; **Fig. 2.1**), greater residual grass height at the plot level and/or at the nest shrub (effect of plot-level residual grass height shown in **Fig. 2.2**), and greater forb canopy cover than was found at random plots (**Fig. 2.3**).

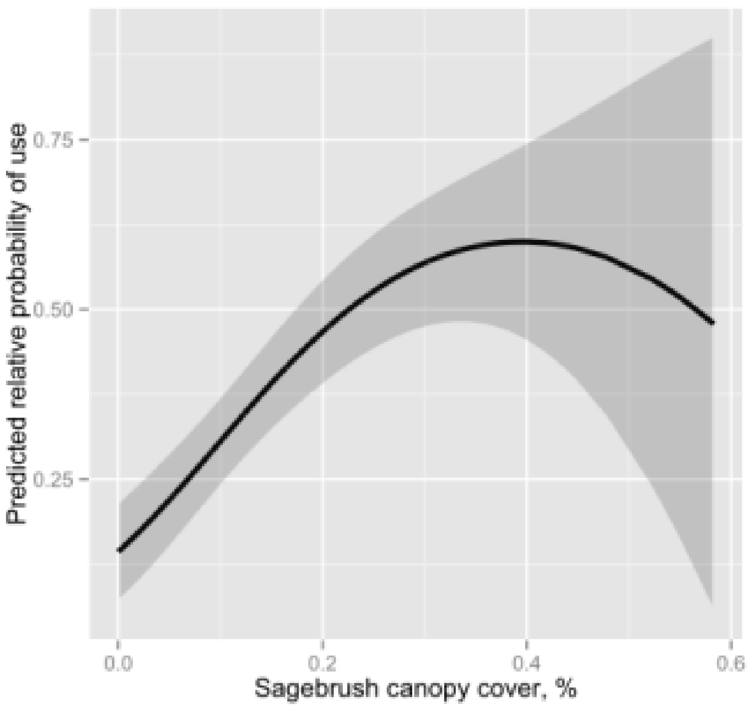


Figure 2.1. *Predicted relative probability of use as a function of sagebrush (Artemisia tridentata) canopy cover within 15 m of the nest shrub (measured in the field) from top RSF model. Predictions are made with all other covariate values held at their mean value. Shaded gray area is the 95% confidence region calculated using the delta method as implemented using the predictSE.mer() function in the AICcmodavg package in program R.*

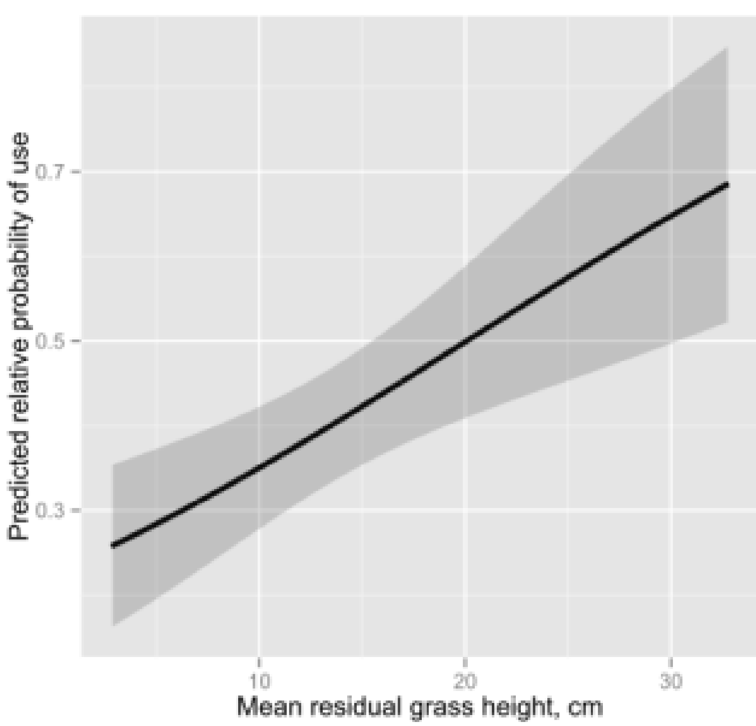


Figure 2.2. *Predicted relative probability of use as a function of residual grass height (excluding inflorescence) within 6 m of the nest shrub from top RSF model. Predictions are made with all other covariate values held at their mean value. Shaded gray area is the 95% confidence region calculated using the delta method as implemented using the predictSE.mer() function in the AICcmodavg package in program R.*

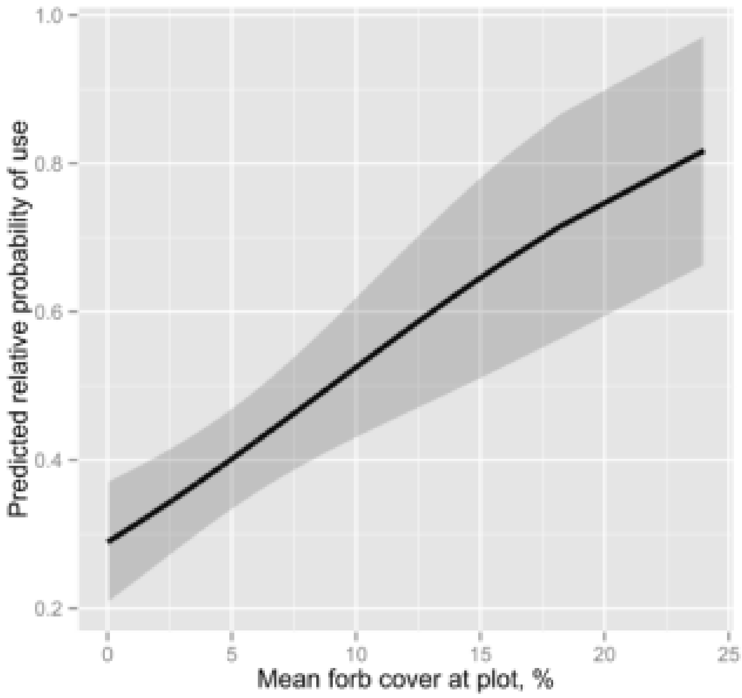


Figure 2.3. *Predicted relative probability of use as a function of forb canopy cover (native and non-native combined) within 6 m of the nest shrub from top RSF model. Predictions are made with all other covariate values held at their mean value. Shaded gray area is the 95% confidence region calculated using the delta method as implemented using the predictSE.mer() function in the AICcmodavg package in R.*

Further exploratory data analysis will include areal herbaceous cover, sagebrush canopy cover, and percent bare ground at a range of spatial scales using the continuous cover maps produced by Open Range Consulting; at the time of this preliminary analysis we are still conducting quality checks of these data. Final analysis will also test for effects of grazing treatments and SGI enrollment on nest site selection. We stress that these are only preliminary insights into patterns of nest site selection; additional years of data collection will improve our estimates of the average strength of selection for various vegetation attributes (fixed effects), while the multi-level structure of these models may allow us to assess how selection strength and/or direction vary with the wide fluctuations in habitat availability associated with the variable weather that is characteristic of sage-grouse habitat.

Objective 3. Document the effects of habitat features within different cattle grazing treatments and management systems on sage-grouse population vital rates, including adult female survival, nest success, and chick and brood survival, in the context of other important factors.

3.1. Hen Survival

Adult female sage-grouse are captured near leks using night-time spotlighting (Giesen et al. 1982). Sage-grouse hens roost in the open on the ground in upland sagebrush habitat near leks and in nesting habitat (L. Berkeley, pers. obs.). Spotlighting is one of the most common and safest methods for capturing these birds. During this method, spotlights are used to find and distract hens. Hens are captured with hoop nets and fitted with a 22 g necklace style very high frequency (VHF) transmitter (Model A4060, Advanced Telemetry Systems, Isanti, MN). A 22 g transmitter is ~1.6% of body weight for a 3-pound yearling female, 1.2% for a 4-pound adult female, and lasts 434 to 869 days.

This population of sage-grouse is not migratory and can be monitored continuously within the study area. Hens are monitored once per month from September through the end of March each year using aerial telemetry, which yields locations that are usually accurate to within ¼ mi (we can determine what pasture and therefore grazing system they are using). Ground

Greater sage-grouse hen just after capture by spotlighting and newly marked with radio-transmitter.

monitoring occurs April – August each year, and hens are monitored 1-2 times per week. Thus we obtain data on seasonal and annual survival and habitat use of hens.

Sage-grouse differ from other prairie grouse in that they are relatively long-lived with higher adult survival and low annual production relative to other grouse species (Connelly et al. 2004). Annual survival of adult female sage-grouse ("hens") ranges 37-78% across the species' range (**Table 3.1**). A variety of predators have been recorded for adult and older juvenile sage-grouse including red fox (*Vulpes vulpes*), coyote (*Canis latrans*), American badger (*Taxidea taxus*), bobcat (*Lynx rufus*), domestic cat, weasels, and a variety of raptor species (Connelly et al. 2011). The annual survival of hens in our study population is comparable to those of other

Survival Estimate	**Location**	**Reference**
75 – 98%	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

Table 3.1. *Summary of annual adult female greater sage-grouse survival estimates from several studies across the greater sage-grouse range.*

studies, ranging from 55 - 64% among years and whether they use SGI or non-SGI lands (**Fig 3.1**). However, hen survival from our study is much lower than the 75 - 98% hen survival observed in this population from 2004-05 (Sika 2006; **Table 3.1**) before SGI implementation. The reasons for this difference in survival rates between our study and that of Sika 2006 are as yet unknown.

This species is unique among grouse species because sage-grouse typically have low winter mortality (82-100% overwinter survival; Connelly et al. 2011) and relatively high annual survival (Connelly et al. 2011). Some studies show variable survival rates that contrast with the observations reported above, but all of these studies coincided with outbreaks of West Nile Virus in the populations which were often followed by harsh winters (e.g., Moynahan et al. 2006, Sika 2006, Tack 2009). Blomberg et al. (2013) found that monthly survival of hens was greatest in winter (November – March) and summer (June – July) and lower during nesting (April – May; also Connelly et al. 2000) and fall (August - October). The seasonal survival rates of hens in our study are shown in **Fig. 3.1**. We have defined seasons to represent biologically meaningful separations *sensu* Blomberg et al. (2013): spring (Apr-May) includes the nesting period (the time of highest vulnerability for adult females), summer (Jun-Jul) includes the end of nesting and the brood-rearing period; fall (Aug-Oct) includes the period when broods break-

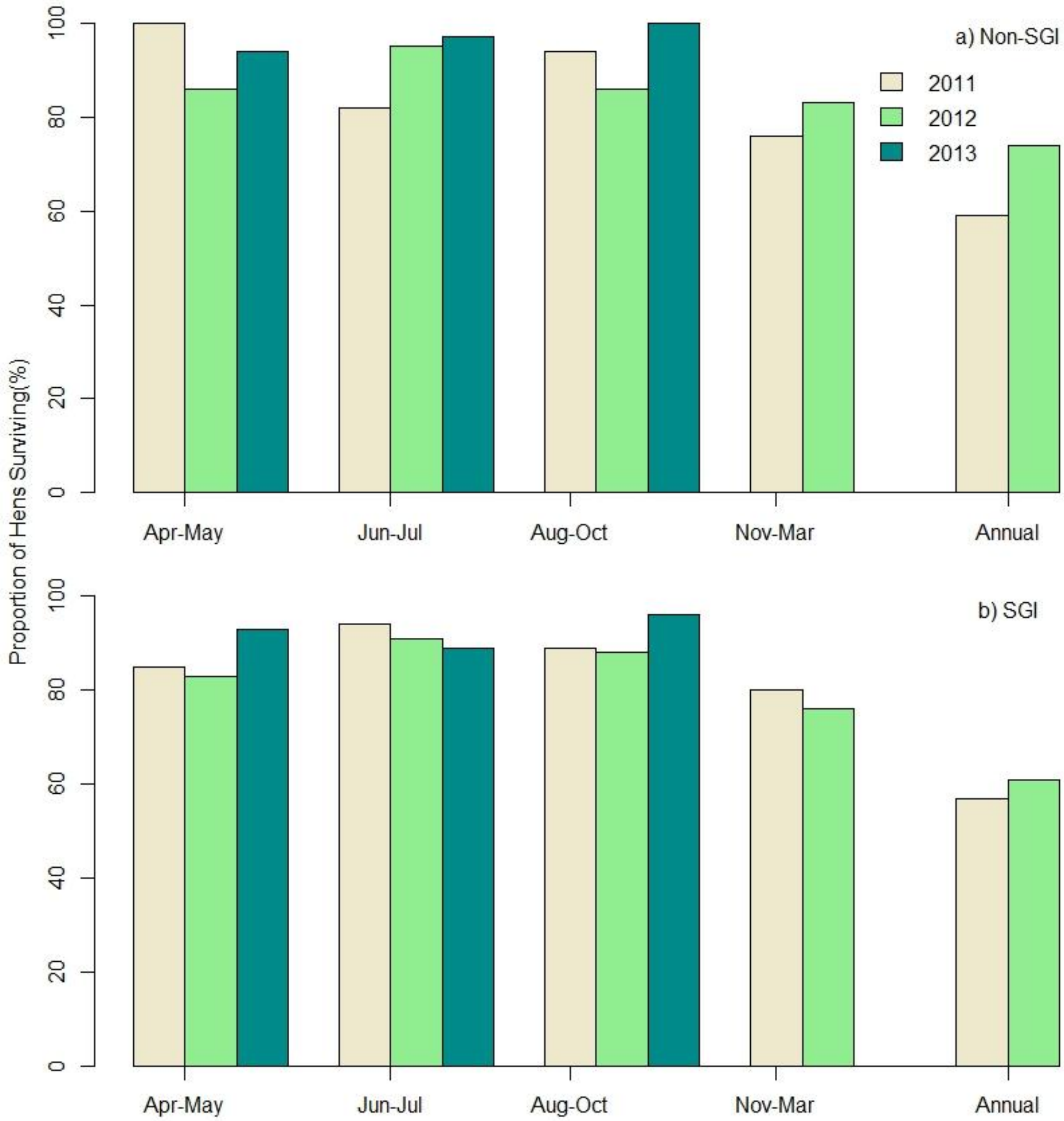


Figure 3.1. *The proportion of radio-marked greater sage-grouse hens surviving each season and year in (a) SGI versus (b) non-SGI areas in Musselshell and Golden Valley counties, MT from 2011-2013. There are no 2013 bars for Fall (Aug-Oct) or winter (Nov-Mar) because this report was prepared before collection of these data. The proportion of hens surviving annually for 2013 thus far are presented, but data are still being collected as the year is not yet complete. The sample sizes of hens marked with radio transmitters at the start of the breeding season (1-Apr) during 2011-2013, respectively, were 22, 43, and 36 in non-SGI areas and 79, 69, and 58 in SGI areas.*

up and individuals begin moving to wintering areas; and winter (Nov-Mar) includes winter survival. The proportion of hens that survived each season was calculated using the number of hens still alive at the end of each season divided by the number of hens alive at the start of each season. The sample sizes of hens marked with radio transmitters at the start of the breeding season (1-Apr) during 2011, 2012, and 2013, respectively were 101, 112, and 95: 22, 43, and 36 hens in non-SGI areas and 79, 69, and 58 hens in SGI areas. The proportions of hens that survived annually in non-SGI areas during 2011 and 2012, respectively, were 59% (13/22) and 74% (32/43; 2013 data still being collected). The proportions of hens that survived annually in SGI areas during 2011 and 2012, respectively were 57% (45/79) and 61% (42/69; 2013 data still being collected). Hens from our study had the lowest seasonal survival during the winter (Nov-Mar) in 2011-12 in both non-SGI and SGI areas. The proportions of hens that survived each season in non-SGI areas in 2011, 2012, and 2013 respectively were: spring = 100% (22/22), 86% (37/43) and 94% (34/36); summer = 82% (18/22), 95% (35/37) and 97% (33/34); fall = 94% (17/18), 86% (30/35), and 100% (33/33); and winter = 76% (13/17) and 83% (25/30; 2013 data not yet collected). The proportions of hens that survived each season in SGI areas in 2011, 2012, and 2013 respectively were: spring = 85% (67/79), 83% (57/69), and

93% (54/58); summer = 94% (63/67), 91% (52/57), and 89% (48/54); fall = 89% (56/63), 88% (46/52), and 96% (46/48); and winter = 80% (45/56) and 76% (35/46; 2013 data not yet collected).

Annual survival during the study period was the highest in 2013. Contrary to the high winter survival rates typical of this species and observed in other studies, winter in our study area appears to have the lowest seasonal survival rate for our population in 2011 – 2012; this report was prepared before the end of fall and the winter of 2013, thus we do not have those rates yet for comparison.

3.2. Nest Success

Nests are found by monitoring hens via radiotelemetry and the nests are monitored every other day until the nest fails or hatches (defined as at least one chick hatching). Crawford et al. (2004) suggested that despite their high reproductive potential, hens rarely realize this potential and have relatively low annual reproduction and nest success. Infrequent successful production years lead to fluctuations in abundance that have been suggested to resemble cycles (Rich 1985, Crawford et al. 2004). However, Connelly et al. (2011) suggest that nest success for sage-grouse is comparable and even relatively high compared to other grassland / shrubland species. Nest success rates have been reported at 50-72% for sharp-tailed grouse (Connelly et al. 1998, Connelly et al. 2011) and 22-65% for greater prairie chickens (Schroeder and Robb 1993, Connelly et al. 2011). Studies report nest success rates of sage-grouse


Greater sage-grouse nest near Roundup, MT.

populations vary between 14.5 - 86.1% (Connelly et al. 2004). Out of 29 telemetry studies, the mean nest success was 46% (Connelly et al. 2011). A study on our focal population in 2004-05 (before SGI implementation) observed nest success rates of 47 and 37%, respectively (Sika 2006). Common nest predators include common ravens (*Corvus corax*), gulls (*Larrus* spp.), red fox, coyote, American badger, and ground squirrels (Spermophilus spp; Connelly et al. 2011).

Fig. 3.2 shows a summary of sage-grouse nest fates by year and treatment (“Non-SGI” and “SGI”). A nest is considered successful (“hatched”) if at least one chick successfully hatches from the nest. An “abandoned” nest means that the female left and did not return to finish incubating the eggs. “Predation” means that the nest was destroyed by a predator. “Unknown” means that the fate of the nest could not be determined. For example, if a hen was suspected of nesting, but days later she had moved and there was no evidence of a nest that could be found. “Hen.Predation” means that the nest was intact, but the hen was eaten while she was off of the nest and consequently the nest failed. The sample sizes of nests during 2011, 2012, and 2013, respectively were 102, 91, and 85: 25, 38, and 33 nests in non-SGI areas and 77, 53, and 52 nests in SGI areas. The proportion of successful nests (hatched ≥1 chick) during 2011, 2012, and 2013, respectively were 12% (3/25), 61% (23/38), and 36% (12/33) in non-SGI areas and 36% (28/77), 49% (26/53), and 42% (22/52) in SGI areas. Nest success was low and many more nests were destroyed in 2011. We speculate that this decreased nest success is due to the extremely wet spring that year. When it rains, hens seem to be easier for predators to locate, probably using scent (L. Berkeley, M. Szczypinski, J. Smith pers. obs.), and we have observed hen and nest predation increasing after

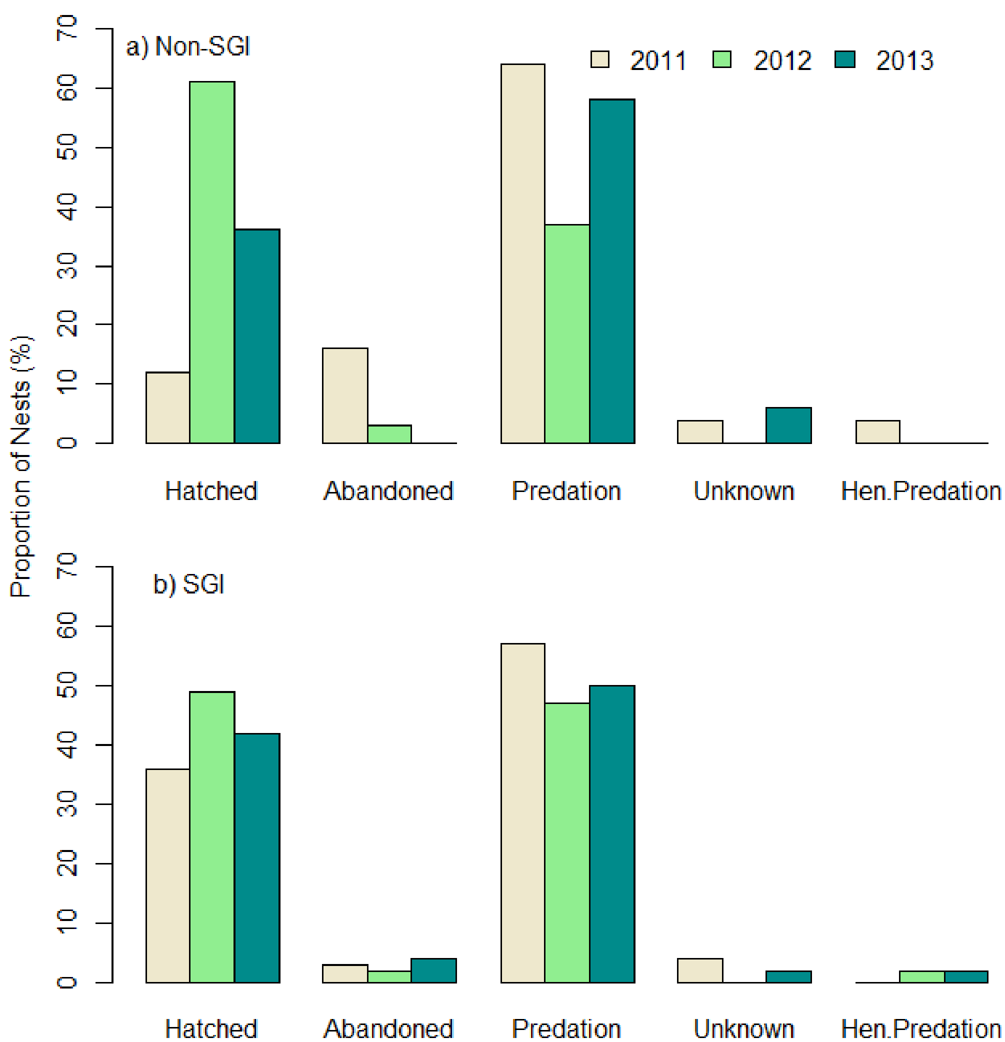


Figure 3.2. *The proportion of greater sage-grouse nests and their fates of in (a) non-SGI versus (b) SGI areas in Musselshell and Golden Valley counties, Montana from 2011-2013. The sample sizes of nests during 2011-2013, respectively were 25, 38, and 33 nests in non-SGI areas and 77, 53, and 52 nests in SGI areas.*

rain events. A nest success summary over all nests, for first nests, and for renests each year is given in **Table 3.2**. The proportion of renests (second and third nests; there were only two hens that made third nest attempts throughout the study) by hens whose first nests failed was higher during high precipitation years, and the success rates of renests was higher than for first nests each year. Presumably there are greater food resources available for longer periods of

	2011	**2012**	**2013**
Total Number of Nests	102	91	85
Total Successful Nests	30%	54%	40%
Renest Rate	23%	10%	19%
Successful First Nests	28%	52%	39%
Successful Renests	39%	67%	44%

* 2013 data is only January through June.

Table 3.2. *Summary of the proportion of nests each year that were second or third nests, their success rate (%), and the mean total annual precipitation (obtained from National Climatic Data Center weather observation stations in Ryegate, Roundup, and Lavina) for greater sage-grouse nests in Musselshell and Golden Valley counties, Montana from 2011 – 2013.*

time during the summer to support renesting efforts during wet years – we are currently working on analyzing food availability data. We observed comparable nest success to that of Sika (2006) who studied this sage-grouse population before SGI implementation in 2004 and 2005 (**Fig. 3.3**). The proportions of nests lost to particular fates also closely mirror those observed by Sika (2006).

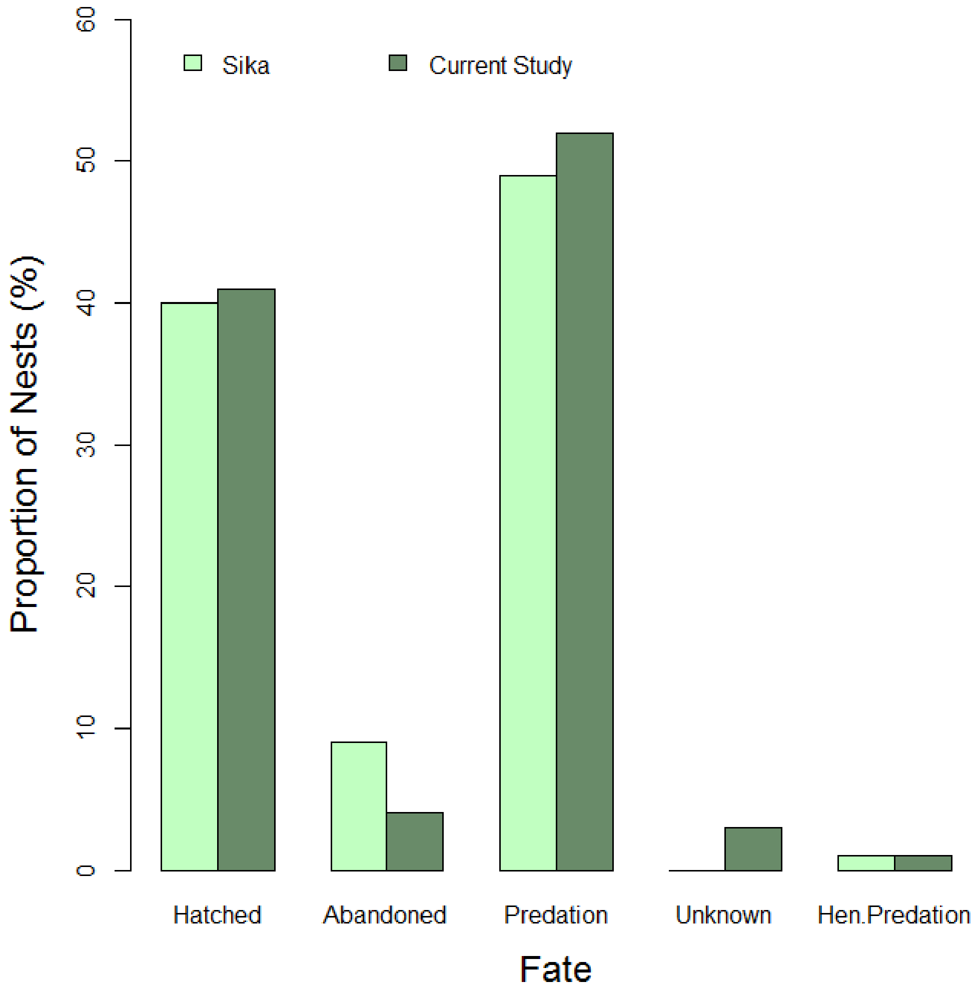


Figure 3.3. *A summary of the fates of greater sage-grouse nests over the entire study area in the Sika (2006) study (Musselshell and Golden Valley counties, MT from 2004-2005) before SGI implementation and the current study (after SGI implementation in Musselshell and Golden Valley counties, MT from 2011-2013).*

From 2011-13 the largest monthly total precipitation was observed during May (**Objective 1, Fig. 1.4**; though our 2013 data only ranges from January - June), which corresponds to the peak of hatch for first nests of the season (**Fig. 3.4**; second and third nest hatches peak in June). This timing of nests hatching during the month when the study area experiences its highest

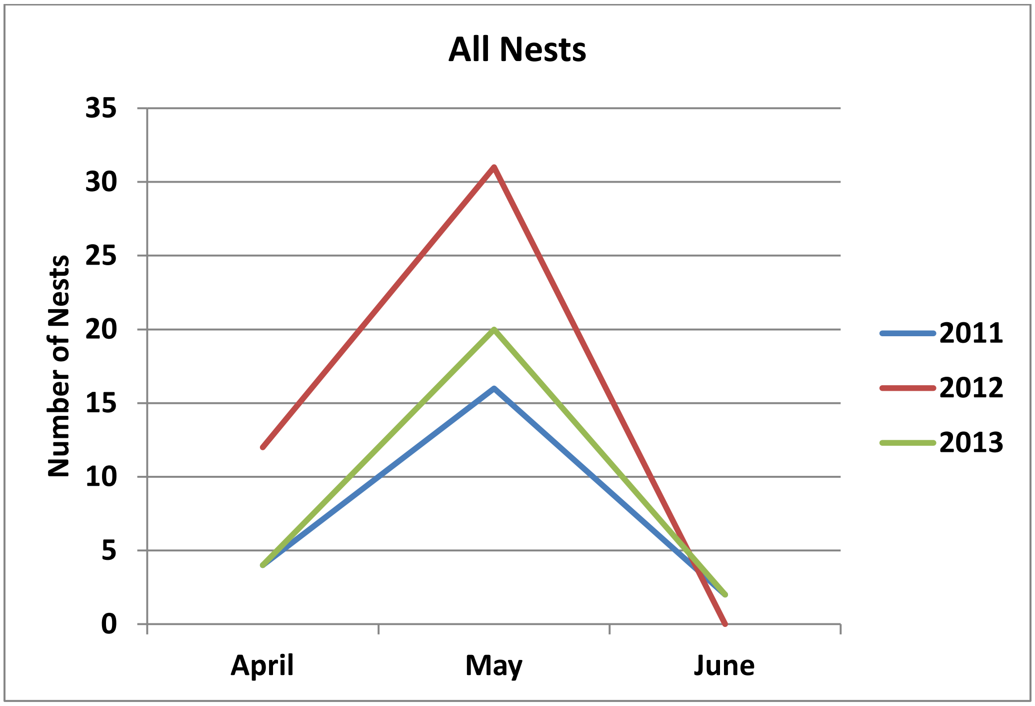


Figure 3.4. *A summary of the number of greater sage-grouse nests successfully hatching each month in Musselshell and Golden Valley counties, MT from 2011-2013.*

precipitation could have negative effects on nest and chick survival in the short-term, but could also have positive effects on these vital rates the following year via increased vegetation growth. Wallestad (1975) found that rain during nesting can result in poor production, but showed that spring rains can result in an overall increased production. Either way weather is probably an important driver of the variation in vital rate data that we observe each year. Effects of weather on vital rates along with other environmental factors are In the process of being examined.

We estimated nest daily survival rates (DSR) and tested for effects of local vegetation covariates on DSR using the nest survival models implemented in Program Mark. Candidate nest survival models are shown and ranked in **Table 3.3**. **Fig 3.5** shows the relationship between grass height and DSR in the top model. The top-ranked model includes an additive term for year, an interaction between year and season day (DSR increased as a function of season day in 2012 and decreased as a function of season day in 2011 and 2013; the reason for this is not yet clear to the authors), and a positive term for plot-level grass height (**Fig. 3.5**). Daily nest survival rates

Model description	K	AIC	ΔAIC	*w*
{S(Year + Year*SeasonDay + Pgrass_ht)}	7	635.56	0.0	0.96
{S(Year + Year*SeasonDay)}	6	644.72	9.2	0.01
{S(Year + Year*SeasonDay + Nresid_ht)}	7	645.67	10.1	0.01
{S(Year + Year*SeasonDay + Nshrub_ht)}	7	645.80	10.2	0.01
{S(Year + Year*SeasonDay + Adult)}	7	646.08	10.5	0.00
{S(Year + Year*SeasonDay + SGI)}	7	646.13	10.6	0.00
{S(Year + Year*SeasonDay + %ARTR)}	7	646.27	10.7	0.00
{S(Year + Year*SeasonDay + Presid_ht)}	7	646.59	11.0	0.00
{S(Year + Pgrass_ht)}	4	651.86	16.3	0.00
{S(.)}	1	653.69	18.1	0.00
{S(Year + SeasonDay)}	4	654.30	18.7	0.00
{S(Year + SGI)}	4	654.86	19.3	0.00
{S(Year + SGI + Adult)}	5	655.77	20.2	0.00

Table 3.3. *Candidate daily survival rate models for sage-grouse nests, 2011 – 2013. SeasonDay = days since 1st day of nesting season (i.e., 1st day a hen was verified to be on a nest); %ARTR = percent sagebrush canopy cover; Nshrub_ht = nest shrub height; Pgrass_ht = plot-level mean of grass height, excluding inflorescence; Presid_ht = plot-level mean of residual grass height; Nresid_ht = maximum height of residual grass at nest.*

were low in 2011, rose substantially in 2012, and fell again slightly in 2013 (**Fig. 3.7**). For purposes of illustration, the model (S(*Year* + *Year**SGI*)) was used to generate this figure. Differences in nest survival between enrolled lands and non-enrolled lands appear nonexistent with the possible exception of 2011, where overall low nest survival seems to have been driven by very low survival on non-enrolled lands. However, 2011 and 2013 were wet years. In addition, hens were more likely to nest where residual grass was taller (see **Objective 2, Fig. 2.2**), and SGI pastures (both rested and grazed) appeared to have taller residual grass than non-SGI pastures (see **Objective 1, Fig. 1.4**). If there is a difference between grazing systems, we speculate that it is possible there is an effect between systems that has not yet been realized. Alternatively, sage-grouse may exhibit a lag effect in response to management, where it may take a few years for vital rates to show a response after a management action has been implemented. For example, nest site fidelity of hens may cause hens to select nest sites in locations that are not ideal for survival. In addition, hens may be using cues other than grass height to select nest sites, such as selecting habitat at a larger spatial scale before settling on a nest site. We are currently examining habitat selection at a spatial scale larger than the nest-site to examine this alternative. We have not yet analyzed responses of vital rates and vegetation to specific grazing treatments in each pasture, but this will be forthcoming. Grazing treatment will be included with local vegetation, large-scale vegetation, and disturbance covariates in future modeling efforts.

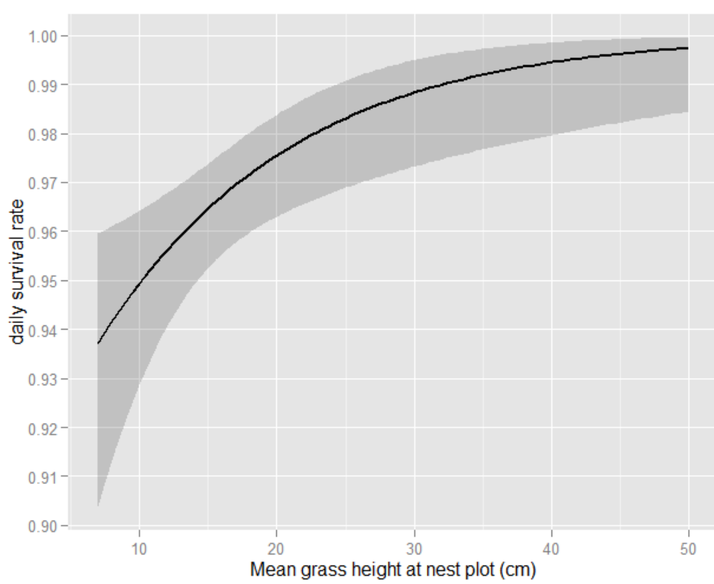


Figure 3.5. *Daily survival rate of greater sage-grouse nests as a function of average grass height within 6 m of the nest shrub in Golden Valley and Musselshell counties, MT from the top-ranked model of daily survival rate (Year + Year*SeasonDay + Pgrass_ht); predicted DSRs are based on a nest midway through the 2013 nesting season.*

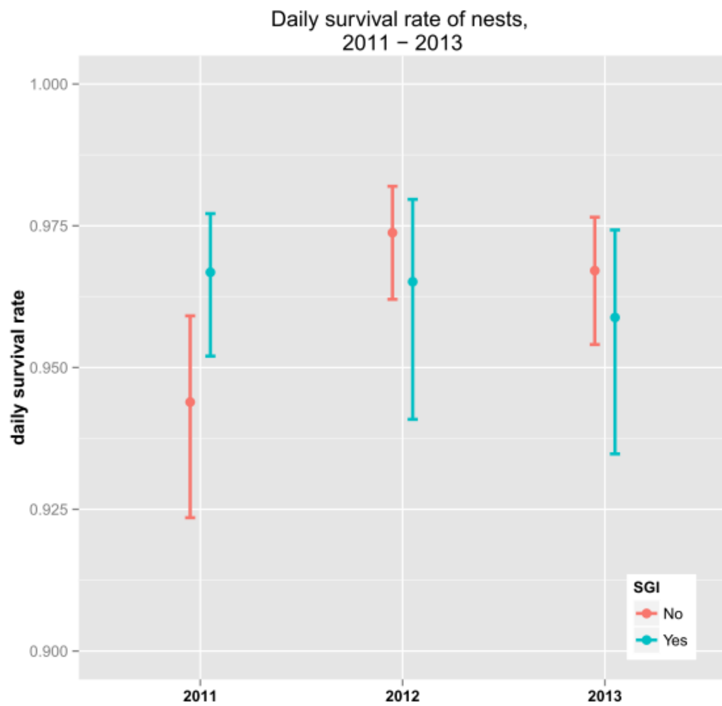


Figure 3.6. *Daily survival rate of greater sage-grouse nests, 2011 – 2013, on non-SGI and SGI land in Golden Valley and Musselshell counties, MT.*

3.3. Chick Survival

Fewer data have been collected regarding chick survival than hen survival or nest success because it is a relatively difficult vital rate to document (Connelly et al. 2004, Crawford et al. 2004). In previous work, low sample sizes and other difficulties have made testing potential variables that may influence chick survival difficult (Connelly et al. 2004). 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. 2007, Dahlgren et al. 2010, Guttery et al. 2013). The average from several studies of chick survival from hatch to breeding age is 10% (Crawford et al. 2004, Connelly et al. 2011).

Sage-grouse chicks were captured by hand two to five days after hatching. Consistent, intensive monitoring of females that were initiating nests made it possible to estimate hatch

Suturing a radio-transmitter onto a greater sage-grouse chick.

date to within one day. We captured chicks just after sunset when the radio-marked hen was brooding them to keep them warm for the night and we knew that the chicks would likely be within five meters of her. We moved in carefully to flush the female and capture all chicks in the brood, which were then placed in a cooler with a hot water bottle to keep them warm during handling. A maximum of two chicks per brood were randomly selected (average number of chicks hatched is six to seven; Tack 2009), weighed, and fitted with a 1.3g backpack radio-transmitter (Model A1065, Advanced Telemetry Systems, Isanti, MN), that lasted 49 to 100 days. A 1.3g transmitter is ~4% of body weight on a newly hatched chick; body weight increasing rapidly thereafter (Burkepile et al. 2002). Backpack VHF transmitters were attached via two small sutures on the lower back (Dahlgren et al. 2010). This method has been the most successful (<1% accidental death rate) and common method used to attach radio-transmitters to sage-grouse chicks. Sage-grouse chicks were monitored every other day for the first two weeks, and then at least twice per week until they died or their radio-transmitters failed; UTM coordinates were obtained on each visit (coordinates within 30m of their actual location to avoid flushing them).

We examined chick survival up to 80 days post-hatch (until chicks died or their radio-transmitters failed) using nest success models in program MARK (White and Burnham 1999). We used the nest success rather than known fate models to assess chick survival because the exact mortality dates of some chicks were not known and chicks were not all monitored simultaneously. These models were used to estimate the variation in survival due to chick age and year (**Table 3.3**). We used an information theoretic approach to assess which models best fit the data. Individuals whose signal was lost or their fate could not be determined (e.g., dropped tag versus death) were removed from the analysis; thus our estimates of survival and the variables that influence it are probably conservative. We found that variation in chick survival was best explained by a model including age-specific differences, with a model including age and year as the only competing model (**Table 3.4, Fig. 3.7**). Examination of the

Model Number	Model Description	AIC_c[a]	ΔAIC_c[b]	K[c]	w_i[d]
1	Age	580.57	0	2	0.73
2	Year + Age	582.55	1.98	3	0.27
3	Constant[e]	626.05	45.48	1	0
4	Year	628.05	47.48	2	0

[a] Akaiki Information Criterion for small sample sizes
[b] Difference in AIC_c values between model *i* and the top-ranked model (model with the lowest AIC value)
[c] Number of parameters
[d] AIC weights
[e] Assuming a constant survival rate for the entire monitoring period

Table 3.4. *Akaiki's Information Criterion for small sample sizes was used to rank survival models for radio-marked sage-grouse chicks monitored north of Roundup and Lavina, MT in 2012 (n = 80) and 2013 (n = 50).*

effects of other variables on chick survival (e.g., weather, vegetation factors) is in progress. Chick mortality was highest during the first month after hatching (**Fig. 3.7**). This result is comparable to survival observed in other studies of sage-grouse and other prairie grouse chicks. The primary causes of mortality during the first few weeks after hatching are typically exposure to cold or wet weather, predation, lack of food, and poor condition of the chick or female (Kirol 2012). Based on the observed range of daily survival rates during the study (93-

99%), the survival rate from hatching to 80 days old was 0.13 (SE = 0.03, 95% CI = 0.079 – 0.21) each year.

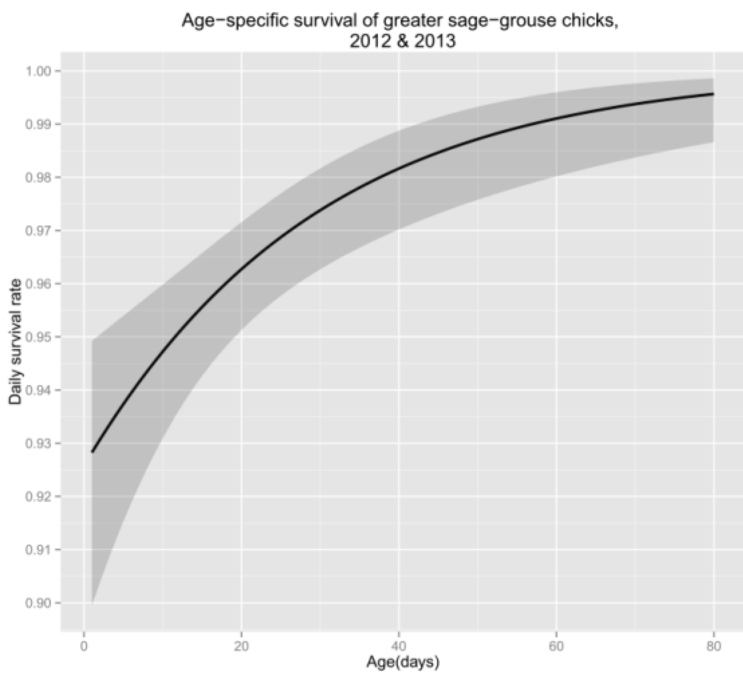


Figure 3.7. *Survival curve showing the effect of chick age on daily survival rate for greater sage-grouse chicks in Musselshell and Golden Valley counties, Montana from 2012-2013.*

Fig. 3.8 shows a summary of sage-grouse chick survival by year in SGI versus non-SGI areas. "Survived" means the chick survived until its radio-transmitter battery expired. We do not know its fate after that (except for four chicks that we re-captured and fitted with adult radio-transmitters). "Predation" means that the transmitter and remains of the chick were found – the loss was determined to be from a predator. "Exp / Disease" means that the radio-marked chick was found dead with its body intact. The cause of death is unknown, but is likely exposure or disease. "Dropped Tag" means the radio-transmitter was found in good condition (no marks consistent with predation) with no evidence of a dead chick (e.g., plucked feathers). This typically happens within the first week after the chick was marked. "Unknown" means the fate could not be determined with enough confidence to assign it to one of the other categories. For example, a chick's fate would be assigned to "Unknown" if a signal from a chick's radio-transmitter was lost soon after the chick was marked. It is too early for the

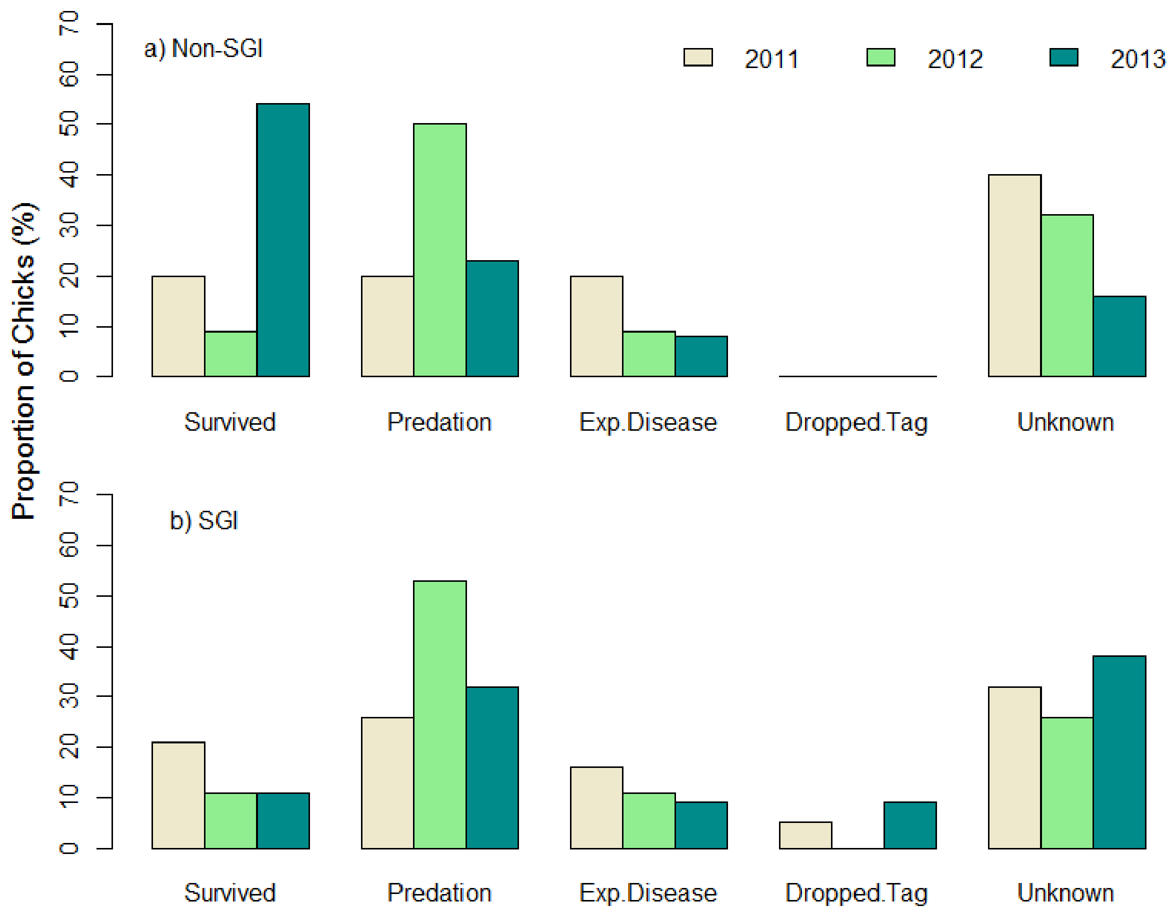


Figure 3.8. *A summary of the fates of radio-marked greater sage-grouse chicks in (a) non-SGI versus (b) SGI areas in Musselshell and Golden Valley counties, Montana from 2011-2013. The sample sizes of nests in non-SGI areas each year were: 2011=5; 2012=34; 2013=13. The sample sizes of nests in SGI areas each year were: 2011=19; 2012=47; 2013=44.*

transmitter to expire but there is no evidence to determine if it was lost due to predation or some other fate. The chick could be dead, but its transmitter might have simply failed as well.

For this analysis, we categorized chicks as part of SGI or non-SGI by the pasture in which they hatched ("natal pastures"). Broods remained in natal pastures for varying periods of time with, for example, some remaining in these pastures for a month or more and some leaving these pastures after a week. We are currently working on an analysis that will address movement among pastures and the varying SGI versus non-SGI status of the pastures.

We marked 23, 80, and 57 chicks in 2011, 2012, and 2013, respectively: 5, 34, and 13 chicks in non-SGI areas and 19, 47, and 44 chicks in SGI areas. In 2011 and 2013, we were precluded from marking more chicks due to wet, cold weather. Chicks cannot regulate their own body temperature during the first week after hatching. They rely on the hen to "brood" them under her to keep them warm. Thus it is too dangerous to separate chicks from the hen when the weather is cold (our criteria is <50°F) or the ground is wet from recent precipitation. The proportions of chicks that survived in non-SGI areas during 2011, 2012, and 2013, respectively in non-SGI areas were 20% (1/5), 9% (3/34), and 23% (3/13) and in SGI areas were 21% (4/19) , 11% (5/47), and11% (5/44; **Fig. 3.8**). We send recovered chick carcasses for necropsy and West Nile Virus tests to the United Stated Geological Survey - National Wildlife Health Center in Madison, WI (<http://www.nwhc.usgs.gov/>). The center has found no evidence of West Nile Virus in the carcasses (of both chicks and adults) we have collected. Several factors have been suggested to affect juvenile survival including gender, food availability, habitat quality, harvest rates, age of the brood hen and weather (Connelly et al. 2011). We will explore these further in future analyses. Predators of young chicks include common ravens, gulls, red fox, coyote, badger, western rattlesnake (*Crotalus viridus*), and possibly bull snake (Pituophis catenifer; Connelly et al. 2011). Predators of older juveniles are the same as for adult hens (see **3.1. Hen Survival** above). In 2013, chick survival appears to be much higher in non-SGI versus SGI pastures. We do not know the cause of this difference. However, as mentioned above, we categorized SGI and non-SGI chicks based on their natal pasture. SGI chicks may have moved among pastures during the summer that were in both SGI and non-SGI. Thus the entire contribution of SGI to chick survival is not clear yet; we are currently working on analyses to deal with movements among pastures of varying SGI status.

Objective 4. Determine how sage-grouse population dynamics within different cattle grazing treatments and management systems are related to spring lek counts, to facilitate transfer of results to other areas where lek counts are the only readily available data.

Lek counts have been the most widely-used (Emmons and Braun 1984) and logistically feasible method for monitoring sage-grouse populations. These counts have been used as an index to population size (Jenni and Hartzler 1978, Walsh et al. 2004) and to monitor trends in populations over time (Walsh et al. 2004). Because lek counts are the only monitoring tool available for many agencies, a goal of this project is to compare and calibrate data from lek count data within our study area and surrounding populations to those from our population modeling of marked animals. With only three years of data, it is not yet possible to correlate sage-grouse vital rates or population models to lek counts. However, we are in process of compiling data to evaluate these relationships.

During mid-March - May of 2011-2013 we assisted the Roundup Area Biologist for FWP in conducting intensive male counts on leks in both SGI and non-SGI areas. Sixteen of the largest and most consistently active leks (FWP defined Adaptive Harvest Management [AHM] leks) on our study area in Musselshell and Golden Valley counties are counted every year and used by FWP to monitor the population and manage the sage- grouse harvest each fall. Mean male counts on the AHM leks were ~13% lower in 2012 than in 2011 (2013 lek counts are currently being compiled). **Fig. 4.1** shows lek counts on our study area over the past 40 years: the solid line represents the 16 AHM leks, and the dashed line represents 4 leks that have been consistently counted annually since 1972**.**

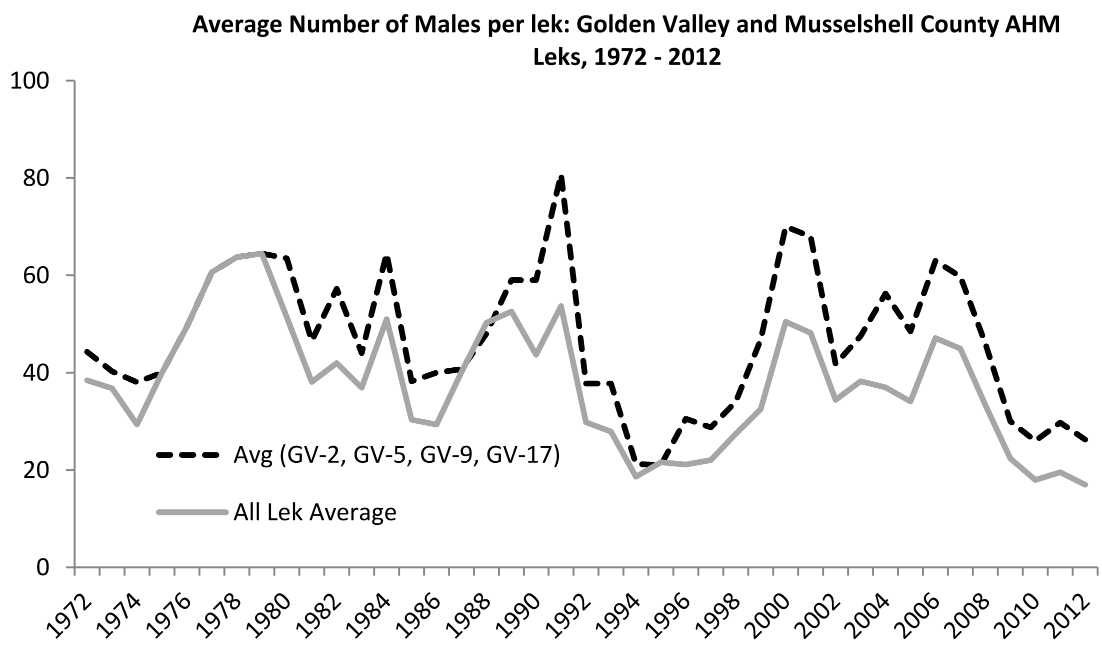


Figure 4.1. *The mean number of greater sage-grouse males counted on adaptive harvest management leks (largest and most consistently active leks on the study area) each year in Musselshell and Golden Valley counties from 1972-2012. The solid line represents 16 adaptive harvest management leks, and the dashed line represents 4 leks that have been consistently counted annually since 1972.*

Objective 5. Transfer knowledge of the impacts of cattle grazing management systems on sage-grouse habitat and populations to livestock producers, landowners, NRCS and federal land management staff, and wildlife management agencies.

Our activities related to sharing our research with livestock producers, landowners, NRCS and federal land management staff, and wildlife management agencies during the funding period are listed below.

Collaborations

We are currently collaborating with Montana State University and the University of Montana on two separate and independently funded projects regarding (1) insect diversity and abundance in grazed versus rested pastures on our study area, and (2) songbird diversity and abundance in sage-grouse habitat, respectively. These collaborations will provide data on food availability for sage-grouse (particularly hens and chicks during nesting and brood-rearing) as well as knowledge of the effects of grazing systems on other avian species within or near sage-grouse habitat. This will increase the overall knowledge base of the sagebrush ecosystem with regard to rest-rotation grazing systems.

Collaborations (continued)

Activity	Description
Montana State University	Partnering on a study in the Centennial Valley, MT : "Landscape Collaborative Grazing and Greater Sage-grouse Survival" study. Principal Investigators: Bok Sowell and Michael Frisina, MSU Range Sciences Department.
Montana State University	Partnering with Principal Investigator Hayes Goosey, MSU Range Sciences Department, on a study in our Roundup / Lavina study area that is concurrent with and will provide data for our study: "Modeling the Response of Food Insects of Sage-Grouse to Rest-Rotation Grazing"
University of Montana	Partnering with Principal Investigator Victoria Dreitz, UM Wildlife Biology Program, on a study in our Roundup / Lavina study area and concurrent with our study: "Assessing Land Use Practices on the Ecological Characteristics of Sagebrush Ecosystems: Multiple Migratory Bird Responses"

Progress Reports

Activity	Description	Delivery Dates
Pheasants Forever and Intermountain West Joint Venture (3)	We submit biannual progress reports to the Intermountain West Joint Venture and Pheasants Forever.	2012, 2013
Landowners and Oversight Committee (multiple)	We produce at least 2 progress reports per year for landowners and our interagency (NRCS, MFWP, BLM, UM, and MT DNRC) oversight committee.	2011, 2012, 2013

Education / Outreach

Activity	Description	Delivery Dates
Oral Presentation - Governor's Sage-grouse Citizen's Advisory Council	Presented an overview and preliminary findings from our study to the Governor's Sage-Grouse Citizen's Advisory Council.	July 2013
Oral Presentation / Outreach – Charles M. Russell National Wildlife Refuge	Met with the manager at Charles M. Russell National Wildlife Refuge to present an overview of this project and discuss collaboration (they are interested in implementing rest-rotation grazing, working with landowners surrounding the refuge, and documenting effects of grazing on sage-grouse).	Mar 2013
Outreach – Landowner Meetings	Met with SGI enrolled landowners to give them an update on our project, and also to gain access for related research on which we are collaborating: "Assessing Land Use Practices on the Ecological Characteristics of Sagebrush Ecosystems: Muliple Migratory Bird Responses".	Feb 2013
Oral Presentation – Last Chance Audubon Society	Presented overview of project to the Last Chance Audubon Society in Helena, MT: "Berkeley, L. I. and J. T. Smith. The plight of the greater sage-grouse – can better grazing systems improve the species' status in Montana? Invited oral presentation to the Last Chance Audubon Society, Helena, MT, 9-Oct-2012."	October 2012
Field Tour	Field tour of SGI in Roundup for Joe Montoni (NRCS's examiner at the White House Office of Management and Budget).	August 2012
Montana Governor's Range Tour, Roundup / Lavina, MT	Presented overview and update of project to landowners and other participants.	April 2011
Oral Presentation	Overview of research to teachers in the Montana Fish, Wildlife, and Park's Hunter's Education group in Billings, MT.	April 2011

Landowner Appreciation

Activity	Description	Delivery Dates
Landowner Appreciation Potlucks	We host a potluck that includes local NRCS employees, landowners whose land we access to monitor birds, and our field crew to thank the landowners and give them updates on our project at the end of each field season.	2011, 2012
Landowner Appreciation Dinner, Lavina, MT	Update for the Landowner Appreciation dinner hosted by the local Roundup NRCS office.	Sep 2013

Meetings

Activity	Description	Delivery Dates
NRCS Partner Meetings	Updates of research progress at annual Montana NRCS Partner Meetings.	April 2012, 2013
Annual Oversight Committee Meetings (4); Field tour 2013	We discuss design and provide research updates to our oversight committee on an annual basis. In 2013 we hosted the committee meeting in Roundup and included a field tour where we demonstrated data collection techniques.	March 2011; Sep 2011, 2012, 2013
Matador Ranch Science and Land Management Symposium	3rd Annual Matador Ranch Science and Land Management Symposium: Berkeley, L. I., J. T. Smith, and M. Szczypinski. The plight of the greater sage-grouse – can better grazing systems improve the species' status in Montana? Invited oral presentation at the 3rd Annual Matador Ranch Science and Management Symposium, Matador Ranch, Zortman, MT, 19-Jun-2013.	June 2013
MFWP Region 5 Meeting	Berkeley, L. I., J. T. Smith. Evaluating the effects of a rotational grazing system on greater sage-grouse and their habitat. Invited oral presentation to Region 5 employees of Montana Fish, Wildlife, and Parks, Pictograph Caves State Park, Billings, MT, 26-Jun-2012.	June 2012

Activity	Description	Delivery Dates
Western Agencies Grouse Meeting	28th Western Agencies Sage and Columbian Sharp-tailed Grouse Workshop in Steamboat Springs, Colorado: Berkeley, L. I. and J. T. Smith. Evaluating the effects of a rotational grazing system on greater sage-grouse and their habitat. Oral presentation at the 28th Western Agencies Sage and Columbian Sharp-tailed Grouse Workshop, Steamboat Springs, CO, Jun 2012.	June 2012
MFWP Wildlife Manager's Meeting	Berkeley, L. I. Evaluating the effects of treatments in a rotational grazing system on greater sage-grouse and their habitat. Oral presentation at the Montana Fish, Wildlife, and Parks Annual Manager's Meeting, Roundup, MT, 4-Apr-2012.	April 2012
Montana Bird Conservation Partnership	Montana Bird Conservation Partnership, Lewistown, MT: Berkeley, L. I. Evaluating the response of sage-grouse to rest-rotation grazing. Oral presentation at the Montana Bird Conservation Partnership 2011 Fall Meeting, 15-Sep-2011.	September 2011
Northern Great Plains Joint Venture	Invited oral presentation to give an overview of project to Northern Great Plains Joint Venture board meeting, Billings, MT: "Berkeley, L. I. Evaluating the response of sage-grouse to rest-rotation grazing. Oral presentation at the Northern Great Plains Joint Venture board meeting, 24-Aug-2011."	August 2011

Media

Activity	Description	Delivery Dates
TV	Participated in TV show "Out on the Land" (sponsored b y Dow Agrosciences) hosted by Dr. Larry Butler and airing on RFD-TV that highlighted the SGI program (Season 2, episode 23). We interviewed for the show, toured them around the study area, and tracked a sage-grouse to help them obtain footage for the show. Link to show: http://outontheland.com/season-2-episode-23/	Filmed 27-Jun-2013; show aired September 2013
Popular Magazine Article	Interviewed for article on the Sage-Grouse Initiative for the magazine Montana Outdoors, published by Montana Fish, Wildlife, and Parks; author is Tom Dickson, and the article will be published in Oct/Nov 2013.	Interviewed Sep 2013; article will be published in Oct/Nov 2013
TV	Participated in Montana Fish, Wildlife, and Parks news story about our sage-grouse grazing evaluation study (interview and took Communication Education specialist in the field to get footage of trapping hens and radio-marking chicks): http://www.youtube.com/watch?v=0KkKLNY1t6w	June 2013
Photography	We coordinated with professional photographer, Kenton Rowe, a consultant with FWP who came out to document our research.	May 2012
News Article	Worked with Deborah Richie who produced an article about our research on the NRCS / SGI website (Richie 2012).	April 2012
Video	Participated in a sage-grouse video being produced by Jeremy Roberts for the Natural Resources Conservation Service	September 2011
Newspaper Article	Interviewed about sage-grouse research by a local newspaper: Brett French, 2011. A sage plan: groups cooperate to build wildlife habitat, save greater sage grouse. Billings Gazette. 12-Mar-2011; State and Regional news section: Montana. On-line article available at http://billingsgazette.com/news/state-and-regional/montana/article_d21ef200-0315-5614-949c-049696ce47d4.html.	April 2011

Additional Funding

Description	Amount	Delivery Dates
Conservation Innovation Grants from the Natural Resources Conservation Service.	$170,000	2011-13
We received additional funds during 2011-12 from Pittman-Robertson funds. The MT legislature approved placing this study into the FWP annual budget. Thus we began receiving regular funds in July 2013 from FWP license sale funds and matching Pittman-Robertson funds administered by the USFWS.	$5,000 - $10,000 each year 2011-2012; $133,000 2013 - present	2011 - present
The University of Montana - CEAP	$50,000	2011
We have received funds from the FWP Upland Game Bird Enhancement program each year.	$15,000 in 2011; $14,000 each year 2012-13	2011 - 2013
We received a grant from the Big Sky Upland Bird Association in 2012.	$1,000	2012

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