The Grouse & Grazing Project:
Effects of cattle grazing on sage-grouse demographic traits

2018 Annual Report

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TABLE OF CONTENTS

LIST OF FIGURES

EXECUTIVE SUMMARY

We completed the 5th year of field work on the Grouse & Grazing project. In 2018, we conducted field work at 5 study sites: Big Butte, Brown's Bench, Jim Sage, Pahsimeroi Valley, and Sheep Creek. We had 32 people working full-time conducting field work on the project in 2018, and 2 new graduate students started on the project in 2018. We conducted field work in 21 BLM grazing pastures that are part of the grazing experiment at the 5 study sites, as well as dozens of BLM grazing pastures adjacent to the 21 experimental pastures. Two fires burned all or parts of 3 of the 21 experimental pastures (at 2 study sites) in 2018. We captured and collared 123 female sage-grouse in 2018 and we followed an additional 66 hens that were caught and radio-collared in previous years. We documented 34 mortalities of radio-collared hens in 2018. We located and monitored 116 sage-grouse nests and apparent nesting success was 32% in 2018. Nesting propensity was 90-100%, re-nesting propensity was 16%, and apparent nesting success of renesting attempts was 40%. We monitored 32 sage-grouse broods and apparent survival of broods was 30%.

We conducted vegetation measurements at 487 plots in 2018 (102 nest plots and 385 random plots). We measured grass height, percent biomass removed, and other metrics on 22,681 grass plants within those 487 plots. We walked transects throughout the 21 experimental study pastures to estimate utilization and measure grass metrics at 3,934 plots along those transects. In 2018, we initiated short-eared owl surveys in collaboration with the WAfLS project (https://www.avianknowledgenorthwest.net/citizen-science/short-eared-owls) to assess the impact of our experimental grazing treatments on occupancy and abundance of short-eared owls. We also finished the 2nd year of songbird point count surveys in all experimental treatment pastures. We conducted invertebrate sampling at 178 plots and collected 2,544 pitfall samples and 1,730 sweep-net samples at those 178 plots. We also conducted ant mound surveys and measured the distance to (and size of) 269 ant mounds along transects at the 178 plot locations. Thus far, we have counted, identified, and measured 45,725 arthropods from 424 pitfall trap samples.

We started the grazing treatments at our Big Butte study site in 2018 and collected the first year of post-treatment data at Big Butte. At our Brown's Bench and Jim Sage study sites, 2018 was the 3rd year of post-treatment data collection. At our Pahsimeroi Valley study site, 2018 was the second year of pre-treatment data collection. In fall of 2018, we assigned pastures to the 4 grazing treatments and 2019 will be the first year of post-treatment data collection at our Pahsimeroi Valley site. At our Sheep Creek study site, 2018 was the second year of post-treatment data collection.

INTRODUCTION

The distribution of the greater sage-grouse (hereafter sage-grouse; *Centrocercus urophasianus*) has contracted (Schroeder et al. 2004) and abundance of males attending leks throughout the species' range has decreased substantially over the past 50 years (Garton et al. 2011, 2015; Western Association of Fish & Wildlife Agencies 2015). Livestock grazing is a common land use within sage-grouse habitat, and livestock grazing has been implicated as one of numerous factors contributing to sage-grouse population declines (Beck and Mitchell 2000, Schroeder et al. 2004). However, there are also numerous mechanisms by which livestock grazing might benefit sage-grouse (Beck and Michell 2000, Crawford et al. 2004). Livestock grazing on public lands is often managed as to limit negative effects on populations or habitats of plants and animals (including sage-grouse), but we lack experimental studies that have explicitly examined the effects of livestock grazing on sage-grouse. The objective of the Grouse & Grazing Project is to document the relationship between cattle grazing and sage-grouse demographic traits, nest-site selection, and habitat features. We focus particularly on spring cattle grazing because spring is thought to be the time when livestock grazing is most likely to adversely affect sage-grouse (Neel 1980, Pedersen et al. 2003, Boyd et al. 2014).

STUDY AREA

Our field work thus far (2014-2018) has occurred at 5 study sites in Owyhee, Twin Falls, Cassia, Butte, and Custer counties, Idaho (Fig. 1). Our study sites are located in Sage-Grouse Management Zone IV: The Snake River Plain (Knick 2011). Elevations at our 5 study sites range from 1400 m to 1900 m. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) is common in the overstory at all sites. Other overstory shrub species include little sagebrush (*Artemisia arbuscula*), black sagebrush (*Artemisia nova*), three-tip sagebrush (*Artemisia tripartita*), rubber rabbitbrush (*Ericameria nauseosa*), and green rabbitbrush (*Chrysothamnus viscidiflorus*). The most common understory grasses include Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Elymus elymoides*), bluebunch wheatgrass (*Pseudoroegneria spicata*), western wheatgrass (*Pascopyrum smithii*), and needlegrass (*Achnatherum spp* and *Hesperostipa spp*).

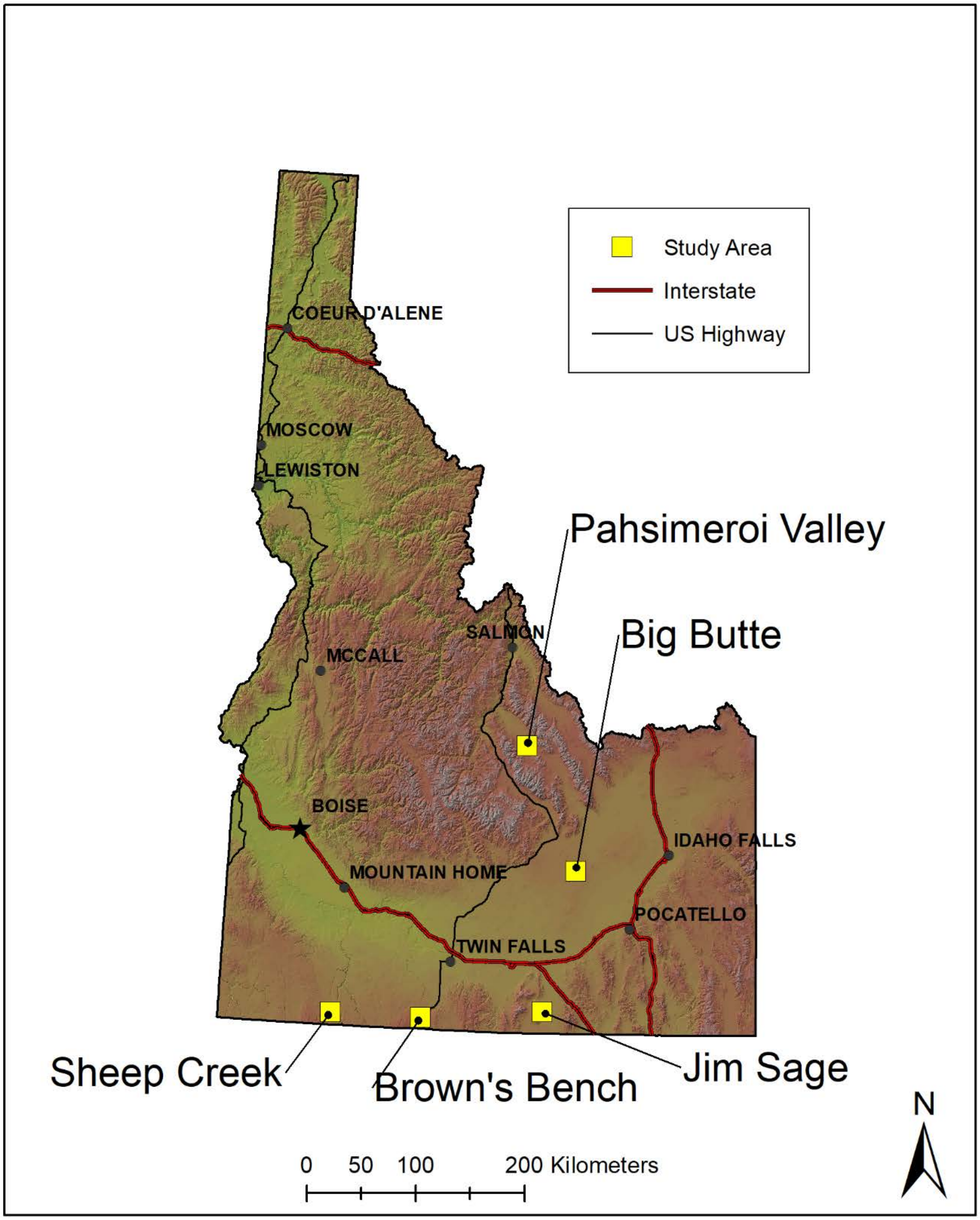

Figure 1. Five study sites in southern Idaho where field work has been conducted for the Grouse & Grazing Project.

METHODS

Experimental Design

We began field work at two study sites in 2014 (Brown's Bench, Jim Sage), two more in 2015 (Big Butte, Sheep Creek), and a fifth in 2017 (Pahsimeroi Valley). Our initial study plan included a goal of 9 study sites but additional funding would be needed to add more study sites (or to add more treatments per study site). Additional replicates of the grazing treatments would help to ensure sufficient sample sizes in each of the 4 experimental grazing treatments (see below). Each study site was selected based on the following characteristics:

1. ≥15% overhead sagebrush cover, including at least some *Artemisia tridentata wyomingensis* in the overstory
2. Herbaceous understory that is dominated by native grasses and forbs
3. At least one sage-grouse lek of ≥25 males
4. Adequate road access in spring
5. Cooperative permittees
6. ≤15 inches (38 cm) of annual precipitation
7. ≥5,700 acres (23 km^2) of sagebrush grassland with minimal infrastructure development (i.e., few wind turbines, powerlines)
8. Spring cattle grazing occurs in the allotment(s), or is at least allowed under the current grazing permit

For this project, we are applying a paired Before-After-Control-Impact (BACI) experimental design with spatial and temporal replication and a staggered-entry approach to evaluate the effects of cattle grazing on sage-grouse demographic traits and habitat characteristics. Paired BACI designs that include both spatial and temporal replication are considered one of the most rigorous experimental designs to assess the effects of a treatment or management action (Green 1979, Bernstein and Zalinski 1983, Stewart-Oaten et al. 1986). We plan to gather data at each study site for ≥6 years (≥2 years before experimental changes in grazing intensity and ≥4 years after experimental changes in grazing intensity). We are using a 'staggered-entry' design so that experimental changes in grazing intensity are not initiated at all study sites in the same year. Precipitation and temperature can have large effects on biomass of grasses and forbs and on sage-grouse demographic traits (Skinner et al. 2002, Moynahan et al. 2007, La Pierre et al. 2011, Hovick et al. 2015) and the staggered-entry design will help us differentiate responses caused by the experimental changes in grazing intensity versus those caused by annual variation in weather. For example, this design ensures that all of the experimental changes in grazing intensity won't occur during a particularly wet or dry year (i.e., it allows separation of a 'year effect' from a 'treatment effect').

At each study site, we gather baseline data (e.g., nest locations, nest success, brood survival, etc.) for $\geq$2 years prior to experimental changes in grazing intensity (Fig. 2). These initial years of field work and data collection allow us to identify grazing pastures that are appropriate for inclusion in the experiment (based on discussions with permittees and BLM managers and the presence of nesting sage-grouse) and they provide the “Before” measures of demographic traits for the BACI design. In the spring of the 3^{rd} year of sampling at each study site, we experimentally alter the grazing regime in 4 pastures per study site and begin grazing those pastures according to 1 of 4 grazing treatments: 1) spring-only grazing in odd years, 2) spring-only grazing in even years, 3) no grazing, and 4) alternating years of spring-only grazing and fall-only grazing (Fig. 2). We define spring grazing as 1 March through 15 June and fall grazing as 1 September through 15 December.

<table>
<tr><th>Treatment</th><th>Year 1</th><th>Year 2</th><th rowspan="5">Implement Grazing Treatments</th><th>Year 3</th><th>Year 4</th><th>Year 5</th><th>Year 6</th></tr>
<tr><td>Spring Odd Years</td><td>Current grazing</td><td>Current grazing</td><td>Spring Grazing</td><td>No Grazing</td><td>Spring Grazing</td><td>No Grazing</td></tr>
<tr><td>Spring Even Years</td><td>Current grazing</td><td>Current grazing</td><td>No Grazing</td><td>Spring Grazing</td><td>No Grazing</td><td>Spring Grazing</td></tr>
<tr><td>No Grazing</td><td>Current grazing</td><td>Current grazing</td><td>No Grazing</td><td>No Grazing</td><td>No Grazing</td><td>No Grazing</td></tr>
<tr><td>Spring and Fall</td><td>Current grazing</td><td>Current grazing</td><td>Spring Grazing</td><td>Fall Grazing</td><td>Spring Grazing</td><td>Fall Grazing</td></tr>
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Figure 2. Experimental design to evaluate potential effects of cattle grazing on sage-grouse demographic traits and habitat features.

Capture and Radio-collaring

We searched experimental treatment pastures at night with spotlights and used hand nets (Wakkinen et al. 1992) to capture female sage-grouse in February and March of each year. We also used rocket-nets (Giesen et al. 1982) occasionally to capture sage-grouse on a few leks. We recorded the capture location, body weight, and age of each bird captured. We used plumage characteristics to assign captured sage-grouse to one of two age classes: yearling and adult (Braun and Schroeder 2015). We attached a 23.7 - 25.2 g necklace-type VHF radio transmitter (Advanced Telemetry Systems, Isanti, MN) to all female sage-grouse that we captured.

Nest Searching and Monitoring

We used VHF telemetry to locate radio-collared sage-grouse hens every 2-3 days. We monitored hens that moved to the periphery of the study sites less frequently (approximately once per week depending on accessibility) because information on hens outside the 4 experimental pastures is not as useful for the BACI study. Once a radio-collared female became localized (consistent location for 2-3 consecutive visits), we approached the area cautiously to confirm if she was nesting and find the location of the nest. We followed an explicit protocol for locating and monitoring nests that ensured minimum disturbance to nesting hens (i.e., we attempted to never flush a hen off her nest and to minimize the number of times we walked within 100 m of each nest). We used telemetry equipment to identify potential nest shrubs and we sometimes confirmed a nest was present if we obtained a visual confirmation with binoculars (Aldridge and Brigham 2002). If we could not obtain a visual confirmation but thought we were close to the nesting hen, we identified a cluster of shrubs from where the telemetry signal was emanating and assumed that cluster was the location of the nest (i.e., we avoided flushing a hen off her nest while trying to locate/confirm a nest). If the hen was found in the same location on subsequent visits, we assumed it was nesting within that cluster of shrubs, even if we did not obtain a visual confirmation of the hen on the nest. To monitor nests, we established two monitoring points using small rock cairns (Dahlgren et al. 2016) $\geq$100 m from the nest (Connelly et al. 1991) at which we listened for the telemetry signal of the radio-collared hen every 2-3 days. The 2 monitoring points were 90^{o} to 150^{o} apart from each other. If the hen was located at consistent bearings from the 2 monitoring points, we assumed she was incubating a clutch of eggs. If the bearings indicated the hen was not located on the nest during any of our 2-3 day monitoring visits, we walked into the area and searched the cluster of shrubs to locate the actual nest and documented its status and its precise location. If we located the nest bowl but no eggs were present, we determined the fate of the nest (hatched or failed) based on the condition/presence of eggshells (Connelly et al. 1991). We estimated minimum clutch size by searching the area surrounding the nest bowl for eggshells and estimated the number of eggs based on the eggshell fragments (Schroeder 1997).

Nesting Propensity

We calculated nesting propensity as the number of radio-collared hens that initiated at least one nesting attempt divided by the number of radio-collared hens tracked (i.e., that we monitored closely) during the nesting period. Past studies have not clearly defined a “tracked bird” (i.e., the denominator used in calculating nesting propensity). Selecting an explicit definition of a ‘tracked bird’ is particularly important for this project because we do not put forth the same tracking effort on all collared hens (i.e., we monitor the hens that stay within the 4 experimental pastures closely whereas we largely ignore hens that completely leave the study area). Hence, we used 2 approaches to define a “tracked bird” and calculated 2 measures of nesting propensity based on these 2 approaches: 1) a tracked bird = any hen that we either found a nest or we did not find a nest but obtained a location on the hen at least 1 time per week between 1 April and 15 June, and 2) a tracked bird = any hen that we either found a nest or we did not find a nest but we obtained a location on the hen for >50% of the weeks (i.e., located her at least once during 50% of the weeks) between her capture date and 1 June. The range of dates that we used for approach #1 (1 Apr and 15 Jun) were based on the earliest and latest nest initiation dates by hens in previous years of the study (2014-2017). We chose these two definitions for a tracked bird because they represent a more conservative definition (approach #1; should yield less tracked hens) and a more liberal definition (approach #2; should yield more tracked hens) of a tracked hen.

Nest Success

We used 2 approaches to quantify sage-grouse nest success: apparent nest success and daily nest survival. Apparent nest success is a simple ratio of the number of hatched nests divided by the number of total nests whereas daily nest survival is a model-based estimate that accounts for biases inherent in apparent nest success estimates. To estimate daily nest survival, we needed the date the nest was first found and the date that it attained its final fate (failed or hatched). Additionally, we wanted to estimate the date that each nest was initiated to determine if daily nest survival changes throughout the nesting cycle. To do so, we used all information available to generate unbiased estimates of 3 critical dates for each nest: nest initiation date, date of onset of full incubation, and estimated hatch/fail date. Below is a summary of the information we used to estimate each of these 3 critical dates for each nest.

Nest Initiation Date

Sage-grouse typically lay 1 egg every 1.5 days (Schroeder et al. 1999) and average clutch size is approximately 7 eggs in Idaho (Wakkinen 1990, Schroeder et al. 1999, Connelly et al. 2011). Therefore, we estimated the date of the first egg laid by subtracting 10.5 days (based on an average clutch size of 7 eggs and a laying interval of 1.5 days) from the estimated clutch completion date. If we found evidence for >7 eggs in the nest, we used the number of eggs observed in our calculation for that individual nest (i.e., we subtracted more than 10.5 days). We did not adjust our calculation if we detected eggshells suggesting fewer than 7 eggs because our estimate of minimum clutch size was based on eggshell fragments after the nest was no longer active (and may be lower than the actual clutch size).

Date of Onset of Full Incubation

The average incubation period for sage-grouse is 27 days (range 25-29 days; Schroeder 1997, Schroeder et al. 1999). For hatched nests, we subtracted 27 days (median of reported incubation period) from the estimated hatch date to estimate the date of onset of full incubation (i.e., date of clutch completion). If the estimate of the date of onset of full incubation was later than the date that we first confirmed the nest, we assumed we had found the nest while the hen was laying because sage-grouse hens are known to occasionally sit on their nests during the laying period (Schroeder 1997). If we had information on nest contents during laying (e.g., the hen was accidentally flushed, the hen was off the nest during a nest monitoring visit and the observer inspected the nest, etc.), we estimated the date of clutch completion such that it was consistent with those observations. For failed nests, we determined the range of possible dates of onset of full incubation based on the number of days we observed the nest and we used the midpoint of this range as our estimate for the date of onset of full incubation.

Fate Date (Hatched and Failed Nests)

For hatched and failed nests, we estimated the date of its fate by calculating the midpoint between the date the hen was first documented off the nest (i.e., no longer incubating eggs) and the last date the hen was detected on the nest. For hatched nests, we further refined the estimated hatch date if we had additional information (e.g., eggshells were still wet when we inspected the nest, etc.) that suggested the hatch day was something other than the midpoint. For failed nests, we determined the range of possible projected hatch dates based on the estimated date that incubation began and the number of days we observed the nest, and then we used the midpoint of this range as our estimate of the projected hatch date (i.e., the estimated hatch date if the nest had not failed). If we observed a failed nest for more than 27 days, we estimated the projected hatch date by adding 1 day to the estimated fail date (i.e., we assumed that the nest would have hatched the next day had it not failed).

Brood Survival

We used 3 methods to document the fate of each brood and, hence, to estimate brood survival: daytime flush count surveys, fecal pellet surveys at nighttime roost sites, and nighttime spotlight surveys. Below is a summary of these 3 methods for monitoring brood fate.

Brood Flush Count Surveys

For nests that hatched, we used a handheld telemetry antenna to walk out to the hen and then conducted a brood flush count survey on 4 occasions: 7, 14, 28, and 42 days after the estimated hatch date of her nest. We occasionally deviated from this timeframe when we were unable to locate a hen because of long-distance movements or because of logistical reasons (e.g., we did not conduct a scheduled flush count in inclement weather so as not to cause stress to the chicks). We conducted these brood flush count surveys >2 hours after sunrise and >2 hours before sunset (i.e., we avoided crepuscular hours) so as not to disturb broods while foraging during the critical early morning and late evening hours. Our objective on the first three brood flush counts (at 7, 14, and 28 days post-hatch) was to confirm that the brood was either alive or dead and, hence, we didn’t always flush the hen and brood. If we saw $\geq$1 chick, we left the area without flushing them. On the fourth and final brood flush count, we attempted to flush the hen and all chicks and get a complete count of chicks that survived to 42 days. On each brood flush count survey, we approached the radio-collared sage-grouse hen by homing with telemetry equipment and attempted to locate the radio-collared hen and any chicks present. If we observed chicks without flushing the hen on the first three surveys, we backed out of the area so as to not cause any further disturbance. If we could not see any chicks on a brood flush survey, we flushed the hen and searched the 15-m radius area around where the hen flushed. On the fourth and final brood flush count, we purposefully flushed the hen and chicks and counted the number of chicks that flushed and searched the surrounding 15 m from the approximate location where the hen flushed to look for chicks that did not flush. We also estimated the distance that the hen flushed (i.e., the distance from where the hen flushed to where she landed).

Brood Pellet Count Surveys

We conducted brood fecal surveys to test whether this is a less invasive but accurate method to document brood status and survival. Brood fecal surveys were part of Ian Riley’s graduate thesis research. Ian explicitly compared brood fecal pellet surveys, spotlight surveys, and flush surveys regarding their utility for estimating brood survival. Ian will defend his thesis and graduate in Spring 2019.

Brood Spotlight Surveys

We conducted brood spotlight surveys as a third approach for estimating brood survival at 42 days (i.e., to estimate detection probability of the 42-day flush count surveys). We conducted brood spotlight surveys at nighttime roost sites >1 hour after sunset and >1 hour before sunrise. We conducted brood spotlight surveys 42 days after hatch, randomly choosing which survey we conducted first: the 42-day brood spotlight survey or the 42-day brood flush count survey. The two 42-day brood surveys for the same hen (flush count survey and spotlight survey) were conducted >6 hours but <24 hours apart. We sometimes conducted the 42-day brood surveys slightly earlier or slightly later than 42 days when we were unable to locate a hen because of long-distance movement or because of logistical reasons (e.g., inclement weather). We used telemetry equipment to get approximately 10-20 m from the radio-collared hen and then cautiously circled the hen while scanning the surrounding area with a spotlight. We counted the number of chicks present within 15 m of the hen. We also revisited the roost site after sunrise to conduct brood pellet counts (see above).

Avian Point-Count Surveys

From 1 May to 30 June, we conducted point-count surveys for all bird species at 20 random points within each treatment pasture at all 5 study sites (these are the same random points at which we conducted vegetation sampling; see below). We made 4 visits to each point during spring/summer 2018, which resulted in a total of 80 point-count surveys per pasture (4 counts at each of 20 points in each pasture). Point-count surveys were conducted during the time period of 15 minutes before sunrise and 4 hours after sunrise. We only conducted these counts during low wind (<16 km/hour or 10 miles/hour) and non-rainy days. Each point-count survey lasted for exactly 5 minutes, during which we recorded species and distance from observer for each bird detected. We recorded all birds seen or heard and whether each of these individuals were detected during each of five 1-minute intervals.

Vegetation Sampling

From 2014-2018, we have measured vegetation at three types of plots: nest plots, dependent non-nest plots (100-200 m from each nest), and random plots. Nest plots were centered on sage-grouse nests. Each dependent plot was 100-200 m from a sage-grouse nest (in a random direction) and was centered on a sagebrush shrub suitable to contain a nest (based on height and diameter of nest shrubs). However, we did not measure dependent non-nest plots in 2018 (only nest plots and random plots) due to lack of funding. Random plots were centered on sagebrush shrubs and randomly located within experimental grazing pastures. We conducted vegetation surveys at nest and random plots from 5 May 2018 to 3 July 2018 and the vegetation surveys consisted of 6 components: a set of photographs to estimate percent nest concealment, measurements of the nest shrub (or the patch of shrubs), two line-intercept transects to estimate percent shrub cover, estimates of grass height and grazing intensity (by species) along the line transects, Daubenmire plots to estimate percent cover, and a count of herbivore fecal droppings along the line transects. Some of the 2015-2016 data from the intensive vegetation sampling was used in Janessa Julson's graduate thesis (Julson 2017).

Plot Placement

We selected random plots within each study pasture. We conducted vegetation sampling at a minimum of 20 random plots in each pasture (except at Pahsimeroi Valley because we monitored 7 pastures and did not have the personnel to complete 20 per pasture; we completed 10-15 per pasture instead). Random plot locations were moved if the randomly generated location had ≥1 of the following criteria:

- A visual estimate suggested <10% sagebrush cover in the 50-m radius surrounding the point

- A visual estimate suggested >10% tree canopy cover (e.g., willow thicket, juniper stand, Douglas fir/aspen stand) in the 50-m radius surrounding the point.
- A point was <15 m from the edge of a maintained road.
- The point was <15 m from a fence

We centered all random plots on a focal shrub (because all nest plots were also centered on a shrub) and spread two 30-m tapes that intersected at the 15-m mark in each cardinal direction (Fig. 3).

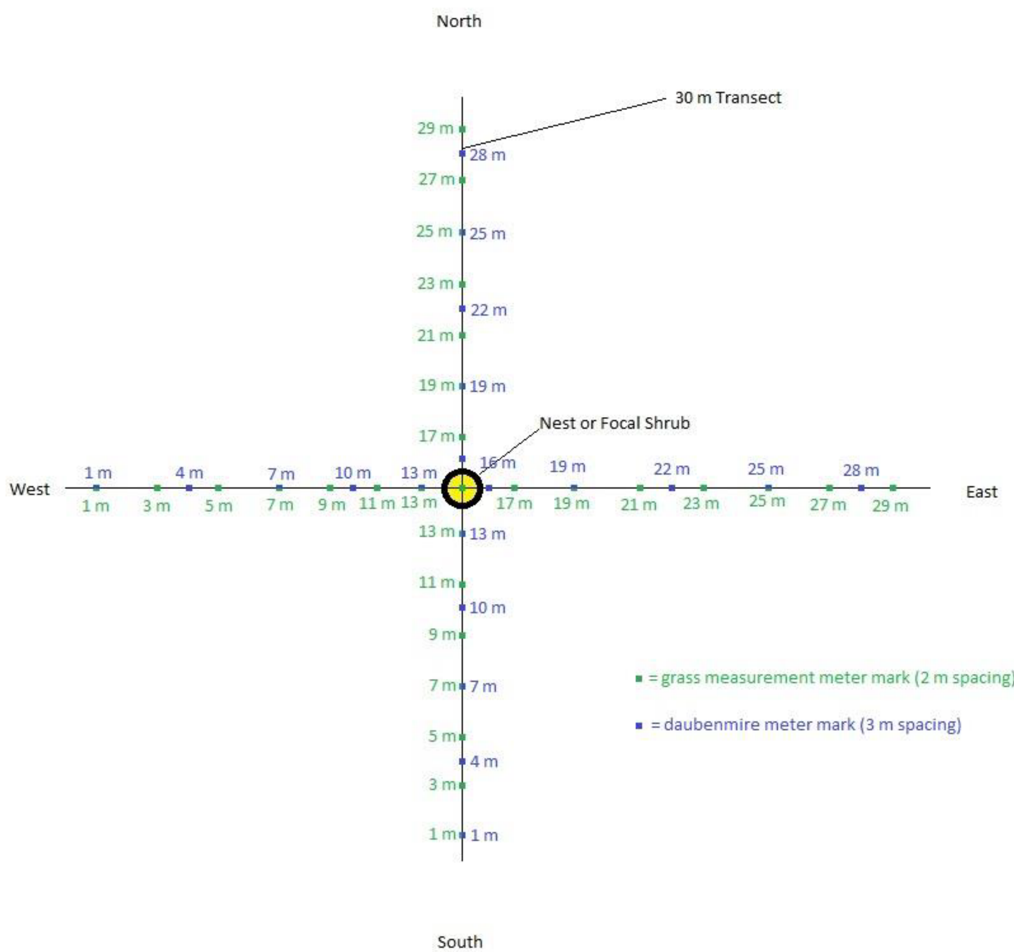

Figure 3. Visual depiction of the placement of two 30-m tapes stretched to conduct vegetation sampling at nest plots and random plots for the Grouse & Grazing Project in southern Idaho, 2014-2018.

Concealment

We placed a 4187-cm^3 (20-cm or ~8-inch diameter) pink ball on top of each sage-grouse nest bowl (or in the most concealed location of the focal shrub for random plots). We took photographs of the pink ball from 3 m away in each of the four cardinal directions and from directly above the nest. For the 4 pictures in the 4 cardinal directions, we took the picture with the camera 1 m above the ground. We took a 5th photo directly above pink ball with the camera 1 m above the ground to estimate overhead concealment. We are processing these images to estimate the percent of the pink ball (and hence the nest area) concealed by vegetation. We will average the 5 estimates to obtain a concealment value for each plot.

Focal Shrub Patch

The focal shrub was the center of the vegetation plot and was the shrub that contained the nest (at nest plots) or the shrub that was closest to the randomly selected point that was large enough to support a sage-grouse nest (at random plots). The focal shrub consisted of a single shrub or multiple shrubs with an intertwined and continuous canopy. We identified the shrub species (and subspecies for sagebrush), and measured the height, the maximum length, and the width (measured perpendicularly to the maximum length) of each focal shrub.

Shrub Cover

At each vegetation plot, we used the line-intercept method to measure shrub cover (Stiver et al. 2015). We used two 30-m transects that intersected at the focal shrub. One transect was oriented from north to south and the other transect was oriented from east to west.

Grass Height

We collected information on height and grazing intensity of perennial grasses along the two 30-m line transects that intersected at the nest or focal shrub. Every 2 m along transects and within 1 m of each respective meter mark, we identified the nearest individual perennial grass of up to 3 grass species. For each of the 3 individual perennial grasses, we measured 5 traits: droop height, droop height sans flower stalk, effective height (i.e., vertical cover; Musil 2011), whether the grass was under a shrub canopy, and an ocular estimate of percent biomass removed by herbivores (Coulloudon et al. 1999).

Daubenmire Canopy Cover

At each vegetation sampling plot, we also collected canopy cover data within 20 Daubenmire (1959) frames along the two 30-m transects that intersected at the nest or focal shrub. We placed a 50-cm x 20-cm Daubenmire frame at every 3rd meter mark along the 2 line transects at each vegetation sampling plot (nest or random plot). We estimated ground cover by using 6 pin drops along the outer edges of each of the 20 Daubenmire frames. These 6 measurements were taken in each of the 4 corners of the frame and at the midpoints on the long edges of each frame (yellow squares in Fig. 4). At each of the 6 pin drops, we recorded if the pin hit litter (any dead unattached vegetation lying on the ground), bare ground, rock (>0.5

cm diameter), biological soil crust, or live vegetation. We also visually estimated the percent canopy cover of shrubs, forbs, and grasses to the nearest 5% within each 50-cm x 20-cm Daubenmire frame. We averaged the percent cover readings from the 20 Daubenmire frames to estimate percent cover for each plant species/forb group at each vegetation plot (Table 1).

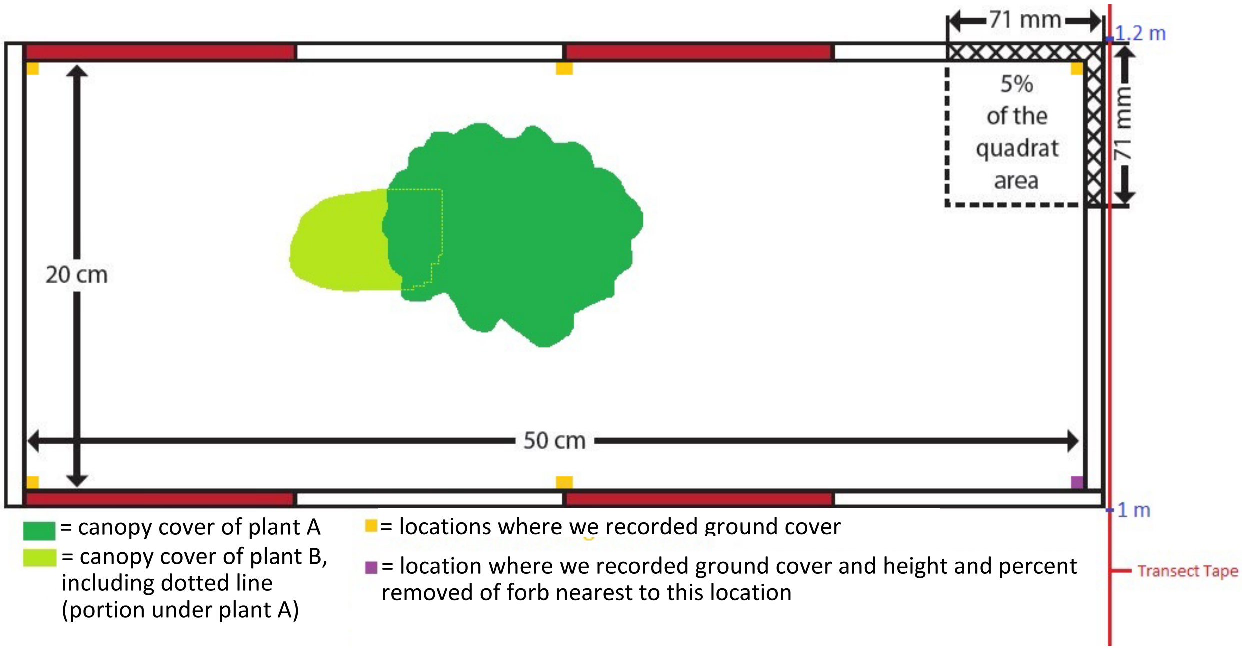

Figure 4. Example of Daubenmire frame cover measurements. Canopy cover of plant A would be an estimate of the percent of the frame the dark green colored area encompasses when looking from above the frame. Canopy cover of plant B would be an estimate of the percent of the frame the light green colored area encompasses including the area encompassed by the light green dotted line. The light green dotted line represents a portion of plant B protruding underneath plant A. Small orange squares represent where ground cover would be recorded (6 pin drops).

Herbivore Droppings

We searched for herbivore fecal droppings within 5 m (2.5 m from either side of the tape) of the two 30-m line transects at each vegetation sampling plot. We counted the number of current-year cattle fecal piles and the number of past-year cattle fecal piles. We also recorded the presence or absence of elk, rabbit, and mule deer/pronghorn antelope fecal pellets (we pooled deer and antelope because of the similarities between mule deer and pronghorn antelope fecal pellets).

Table 1. We estimated percent cover for each of the forb groups below within the Daubenmire frames at each vegetation sampling plot.

Forb Group	Common Name	Plants species, genera, or tribes included.
ACH	Yarrow	*Achillea millefolium*
AGOS	Dandelion, Prairie	*Agoseris and Microseris*
ANT	Pussytoes	*Antenaria spp.*
ASTRAG	Milkvetch	*Astragalus spp.*
CAST	Indian Paintbrush	*Castilleja spp.*
C-COMP	Course Composite	*Anaphalis, Antennaria, Arctium, Carduus, Centaurea, Circium, Cnicus, Crupina, Echinops, Filago, Gnaphalium, Hieracium, Inula, Layia, Machaeranthera, Madia, Micropus, Onopordum, Psilocarphus, Saussurea, Stylocline (Tribes: Cynareae, Inuleae)*
C-FORB	Course Forb	*Boraginaceae, (coarse genera, Amsinckia, Cryptantha, Mertensia, Lithosperumu), Brassicaceae (Sisymbrium), Ranunculaceae, Cleomaceae (Cleome), Linaceae (Linum), Euphorbiaceae, Hypericaceae, Onagraceae, Asclepidaceae, Convolvulaceae, Lamiaceae (Monarda), Solanaceae, Santalaceae (Comandra), Orobanchaceae, Hypericaceae, Chenopodiaceae*
CREP	Hawksbeard	*Crepis spp.*
DAIS	Daisies, Aster, Erigeron (non-milky sap)	*Adenocaulon, Arnica, Aster, Balsamorhiza, Bidens, Blepharipappus, Chaenactis, Coreopsis, Conyza, Chryopsis, Crocidium, Enceliopsis, Echinacea, Erimerica, Erigeron, Eriophyllum, Gallardia, Haplopappus, Helenium, Helianthella, Helianthus, Hulsea, Hymenoxys, Iva, Ratibida, Rubeckia, Senecio, Solidago, Tetradymia, Townsendia, Xanthium, Wyethia*
ERIO	Buckwheats	*Eriogonum*
GUMMY	Yellow Gummy Composite	*Ambrosia, Anthemis, Brickellia, Chrysanthemum, Eupatorium, Grindelia, Liatris, Matricaria, Tanacetum (Tribes: Anthemideae, Eupatorieae [except Artemisia]).*
LACT	Prickly lettuce	*Lactuca serriola*
LEGUME	Tender Legumes (Not Lupine)	*Dalea, Lathyrus, Vicia, Medicago, Melilotus, Trifolium, Hedysarum, Lotus, etc.*
LILY	Lily	*Calochortus, Fritillaria*
LOMAT	Desert Parsley	*Lomatium, Cymopterus, Perideridia*
OPF	Other Preferred Forbs	*Listed as Preferred in appendix B, but not in group above.*
OTHER	Other NOT Preferred Forbs	*Not listed as preferred in appendix B as preferred, all other forbs*
PENS	Penstemons	*Penstemon spp*
PHLOX	Phlox	*Gilia, Linanthus, Microsteris, Phlox*
TARAX	Dandelion, Common	*Taraxacum officinale*
TOX-LEG	Toxic Legume - Lupine	*Glycyrrhiza, Lupinus, Psoralea*
TRAG	Salsify	*Tragopogon spp*
UAF	Unknown Annual Forb	
UPF	Unknown Perennial Forb	

Utilization

We used 3 methods to estimate the percent of above-ground perennial grass biomass removed by herbivores (i.e., % utilization).

Ocular Estimate Method

We sampled approximately 20 random vegetation sampling plots within each of our 20 experimental pastures, and we sampled each of them on 2 occasions: 1) from 7 May to 3 July to coincide with hatch dates of sage-grouse nests (described above under "Vegetation Sampling"), and 2) from 19 July to 10 August (to estimate percent utilization at the end of the growing season). As described in the "Grass Height" subsection above, we made several height measurements of perennial grasses along two 30-m line transects (at each vegetation sampling plot). For each individual perennial grass measured, field technicians also made an ocular estimate of percent of the above-ground biomass consumed or destroyed by herbivores (Coulloudon et al. 1999). Field technicians were trained on how to visually estimate percent biomass removed at the outset of the sampling.

Landscape Appearance Method

We used the landscape appearance method (Coulloudon et al. 1999) to estimate utilization in experimental pastures (and potential experimental pastures at sites where the experimental pastures had not been selected yet). We used ArcGIS to randomly place a grid of north-south transects in experimental pastures (and potential experimental pastures at Pahsimeroi Valley). If the pasture was grazed by livestock during spring/summer 2018, we placed transects 300 m apart and sampled at every 200 m along each transect. If the pasture was not grazed by livestock during spring/summer 2018, we instead placed transects 500 m apart and sampled at every 200 m (because we expected minimal utilization in pastures that did not have cows in them). At 200-m intervals along each transect, an observer estimated utilization according to the utilization classes in Coulloudon et al. (1999) (Table 2) within a 15-m radius half-circle in front of them. Each observer also estimated the percent cover of cheatgrass (*Bromus tectorum*) and the most dominant overstory shrub and the most dominant perennial grass within the same 15-m radius half-circle in front of them at each sample point (i.e., every 200m along the transect).

Percent Height Reduction

In 2016-2018, we measured grass height for up to 16 grass plants at every 3rd point along the landscape appearance transects (i.e., every 600 m) to improve our utilization estimates. At every 3rd point, we measured heights of grasses and recorded evidence of grazing. We took 3 measurements for 4 grass plants within 1 m of the point (1 plant for each of 4 species). If there were <4 different plant species then we took measurements on the closest individual plant from each species present. For each grass plant measured, we recorded 3 measurements: whether the grass plant had been grazed, the droop height, and the average height of all grazed stems (if there was evidence of grazing). After measuring grass heights at this initial location, we moved 2 paces (~3 m) forward and repeated this procedure (i.e., we measured the 3 traits above for each of 4 more grasses).

Table 2. Utilization classes that we used to estimate percent utilization along landscape appearance transects (based on Coulloudon et al. 1999).

Utilization Class	Description
0-5%	The rangeland shows no evidence of grazing or negligible use.
6-20%	The rangeland has the appearance of very light grazing. The herbaceous forage plants may be topped or slightly used. Current seed stalks and young plants are little disturbed.
21-40%	The rangeland may be topped, skimmed, or grazed in patches. The low value herbaceous plants are ungrazed and 60 to 80 percent of the number of current seedstalks of herbaceous plants remain intact. Most young plants are undamaged.
41-60%	The rangeland appears entirely covered[a] as uniformly as natural features and facilities will allow. Fifteen to 25 percent of the number of current seed stalks of herbaceous species remain intact. No more than 10 percent of the number of low-value herbaceous forage plants are utilized. (Moderate use does not imply proper use.)
61-80%	The rangeland has the appearance of complete search[b]. Herbaceous species are almost completely utilized, with less than 10 percent of the current seed stalks remaining. Shoots of rhizomatous grasses are missing. More than 10 percent of the number of low-value herbaceous forage plants have been utilized.
81-94%	The rangeland has a mown appearance and there are indications of repeated coverage. There is no evidence of reproduction or current seed stalks of herbaceous species. Herbaceous forage species are completely utilized. The remaining stubble of preferred grasses is grazed to the soil surface.
95-100%	The rangeland appears to have been completely utilized. More than 50 percent of the low-value herbaceous plants have been utilized.

[a] “covered” means that foraging ungulates have passed through the area.

[b] “complete search” means that foraging cattle have spent considerable time foraging in the area and were not just passing through.

Weather and Climate Monitoring

We obtained precipitation and temperature data at each study site. We used Remote Automatic Weather Stations (RAWS) and National Weather Service (NWS) station to obtain weather data at each of our 5 field sites over the course of the entire year. Data were collected daily at these stations. We obtained these data because precipitation and temperature impact sage-grouse demographic traits (Connelly et al. 2000) and grass productivity (Kruse 2002). For this report, we summarized monthly rainfall by year and average monthly maximum temperature by year. We also included 30-year local averages of rainfall and temperature for comparison.

Insect Sampling

We sampled insects at a subset of 10 of the random vegetation sampling points in a subset of pastures at all 5 study sites in 2018. We established the center of insect sampling plots 20 m to the NE of the center of the vegetation sampling plot ensuring that the two plots remained in similar vegetation cover (e.g., if the vegetation plot was in sagebrush, we ensured that 20 m to the NE did not put our survey in juniper scrub). In prior years, insect sampling consisted of 3 different sampling methods: sweep net samples, pitfall traps, and ant mound surveys (Figs. 5-6). The insect sampling from 2014-2016 is part of Dave Gotsch's graduate thesis.

Pitfall Traps

We placed pitfall trap arrays within treatment and control pastures. Within each pasture, we placed pitfall trap arrays adjacent to random vegetation sampling plots (20 m from the center of the random plot to avoid disturbing vegetation during installation of pitfall traps; Fig. 6). We used pitfall trap methods similar to standards recommended for estimating relative abundance of arthropods and similar to those used in past studies (Hohbein and Conway 2018). A pitfall trap array consisted of four pitfall traps arranged in a 5-m by 5-m square, with pitfall traps located in the corners. We partially filled all pitfall traps with propylene glycol and we placed a piece of 1 x 1 inch mesh welded-wire (16-gauge) cage material below the rim of each pitfall trap to prevent vertebrates from falling into the propylene glycol. We collected pitfall trap samples once per week (for 3-6 weeks) at 178 sampling locations between mid-May and early July 2018 (>2500 pitfall trap samples). We stored the collected samples in ethanol.

Sweep Net Samples

We collected sweep net samples along insect sampling transects in 2015, 2016, and 2018. Sweep net surveys consisted of an observer using a sweep net along two ~50-m transects (100 sweeps) near the pitfall arrays (Fig. 6). Observers swept the net back and forth in a consistent pattern while walking the 2 transects. After each transect, all captured insect and plant material was transferred to a gallon Ziplock bag and frozen as soon as possible to preserve the sample. All samples were transported back to the University of Idaho at the end of the field season. We collected 2 sweep net transect samples once per week (for 3-6 weeks) at 178 sampling locations (1728 total samples) between mid-May and early July 2018.

Figure 5. Visual depiction of the layout of 2 transects used for sweep net samples to collect insects in 2015-16 and 2018.

Ant Mound Surveys

We conducted distance sampling along a 50-m transect to estimate ant mound density. We used a 50-m transect associated with each of the 178 insect sampling locations (Fig. 5) for the ant mound surveys. We walked this transect and recorded the perpendicular distance to each ant mound detected from the transect. We used a range finder (if the mound was >10 m away) or a measuring tape (if the mound was <10 m away) to measure perpendicular distance because the range finders could not estimate distances <10 m. We recorded dimensions of each ant mound (length, width, and height) and whether we detected ant activity on the mound (i.e., the presence of ≥1 ant on the mound).

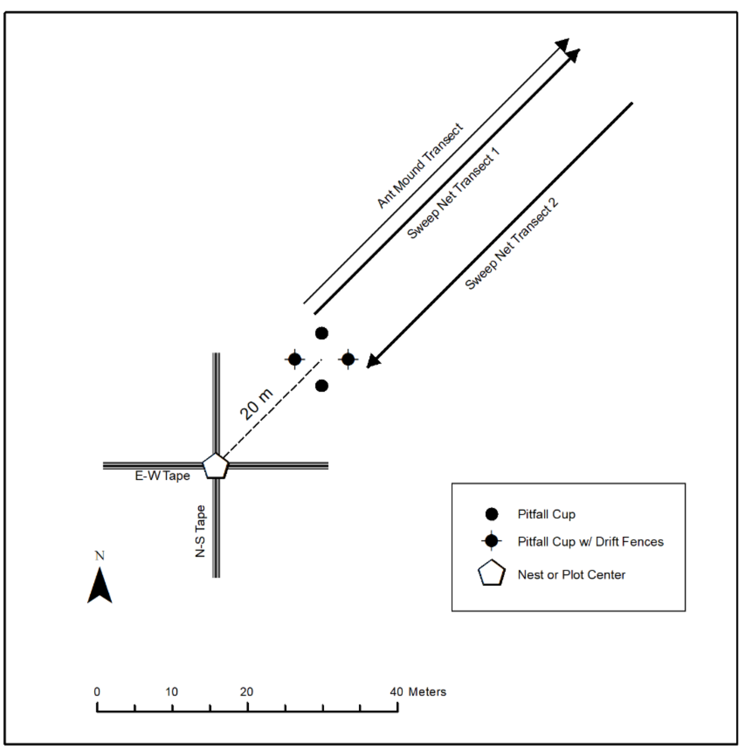

Figure 6. Visual depiction of all 3 insect sampling efforts (sweep net, pitfall, and ant mound) and their orientation in relation to the line transects on an accompanying random vegetation sampling plot.

Statistical Analysis

Nest Success

We calculated apparent nest success by dividing the number of hatched nests by the total number of nests monitored (hatched nests/[hatched nests + failed nests]), excluding nests with an unknown nest fate and those that were visited only once. We calculated apparent nest success for each study site across all 5 years of the study. We also calculated daily nest survival by using program RMARK (White and Burnham 1999) to account for potential bias caused by low detection probability for nests that fail early in the nesting cycle (Mayfield 1975). We used the day of the year to code start and end dates. We used daily nest survival estimates from RMARK and raised that number to the 37 power to estimate the probability that a nest would survive the entire ~10 day laying period and the 27-day incubation period. We included the egg-laying period in this estimate because we detected some nests prior to the onset of incubation.

Clutch Size

We calculated average clutch size for hatched nests because depredated nests tend to have fewer eggshell fragments remaining than hatched nests (Schroeder 1997). We excluded nesting attempts that we knew were re-nests (second nesting attempts) when calculating critical date averages and ranges.

Hen Survival

We estimated hen survival in 2014-2018 by using the known fate module in RMARK. We created weekly encounter histories based on telemetry, nest, and brood monitoring accounts. Radio-collared hens were coded as either alive, dead, or censored (not detected) for each week during the breeding season. We started our monitoring period on week 9 of each year (~1 March) and ended on week 29 (~15 July; a 20-week period). These reflected our typical earliest and latest monitoring efforts each year (excluding infrequent winter and fall monitoring efforts in 2014-2015). Instead of using a staggered entry design, we coded the 4 years of the study as 4 different groups. If a female was tracked for multiple seasons, we used a separate encounter history for each year for that hen (with corresponding covariates).

Brood Success

We calculated apparent brood success by dividing the number of females with ≥1 chick present through 42 days after hatch by the total number of females whose nests were successful (eggs hatched). We also modeled daily brood survival to examine the effects of numerous explanatory variables on brood survival.

SUMMARY

Field Effort

We hired 5 crew leaders, 13 wildlife technicians, 10 range technicians, and 1 point-count technician across 5 field sites in 2018. In addition to the seasonal field crews, one field coordinator (A. Meyers), and 2 IDFG employees (M. Courtney [technician] and D. Musil [biologist]) also worked full-time on the project. Two new University of Idaho graduate students (Alex and Ty; see Table below) began in fall of 2018 and they visited the field sites for several weeks in summer 2018 to obtain some experience and knowledge regarding our protocols and the data we are collecting. From 20 February through 15 August 2018, field personnel worked approximately 25,000 person-hours collecting field data related to the project. Karen Launchbaugh, Andrew Meyers, and botanists from district BLM offices provided field training on plant identification to all field personnel in 2018.

Grad Student	Years	Thesis Focus/Title	Completion Date
Dave Gotsch (MS)	2014-2017	Effects of cattle grazing on abundance of arthropod prey of the greater sage-grouse	Leave of absence
Janessa Julson (MS)	2015-2017	Variation in perennial grass height within greater sage-grouse nesting habitat	Dec 2017
Ian Riley (MS)	2015-2019	Sampling methods for lek and brood counts of greater sage-grouse: accounting for imperfect detection	May 2019
Alex Laurence-Traynor (MS)	2018-present	Determining appropriate utilization measurements for analysis of wildlife-livestock interactions	~2020
Ty Styhl (PhD)	2018-present	Relationship between cattle grazing and diet of greater sage-grouse	~2023

Electric Fencing

We deployed a temporary cattle guard at one site in 2018 (Big Butte) and deployed 12 separate electric fences (45.9 km of total fenceline) across 4 study sites in 2018 (Table 3). We deployed more electric fences and total length of fence than any previous year of the project. We experienced fewer fence problems than in 2017. Brown’s Bench was the only site at which we had any significant number of cows get through a fence and that was due to low voltage and old electric tape, and that issue was resolved quickly (within 1-2 days). All permittees again gave positive feedback regarding the effectiveness of the temporary electric fences and temporary cattle guard.

Table 3. Summary of electric fence deployment at 4 field sites for the Grouse & Grazing Project in southern Idaho from 2016 – 2018.

Year	# of Fences	Longest Fence (km)	Shortest Fence (km)	Total Length (km)
2016	5	5.3 (Brown's Creek East/West)	1.9 (Kane Springs - N/S Cottonwood)	17.2
2017	11	6.2 (Sunset North/South)	1.9 (Kane Springs - N/S Cottonwood)	43.5
2018	12	6.2 (Sunset North/South)	1.5 (Kane Springs North End)	45.9

Weather and Climate Monitoring

Fires

Four fires occurred on or near our study sites in 2018 (Table 4). The Cat and Bruneau Fires on the eastern edge of the Sheep Creek study site consumed more than 87,000 acres (352 km^2) of sagebrush steppe grassland. The Bruneau Fire did not burn any of the 4 experimental study pastures, but the Cat Fire burned the entire Slaughterhouse pasture and 76% of the Tokum-Bambi East pasture (Fig. 7). Due to rehabilitation efforts, these pastures will not be able to support grazing for at least 2 growing seasons. The permittee has agreed to continue treatments at the remaining 2 pastures at Sheep Creek so we will continue to have a field crew at that site for at least the 2019 and 2020 field seasons. The Jim Sage Fire and the Conner Fire affected the Jim Sage study site (Table 4). The Jim Sage Fire did not burn any of the 3 study pastures, but the Conner Fire burned 481 acres (1.9 km^2) (35%; Fig. 8) of the Kane Springs pasture.

Table 4. Name, ignition source, duration, size of fire, and portion of the study area burned for 4 fires on or near study pastures that are part of the Grouse & Grazing Project in 2018.

			Duration			Portion of Study Area Burned	
Site	Fire Name	Ignition Source	Start	End	Total Acres Burned	Acres	% of Site
Jim Sage	Jim Sage	Lightning	26-Jul	~31-Jul	1,936	0	0
Jim Sage	Conner	Human	22-Sep	25-Sep	13,626	481[1]	7.8
Sheep Creek	Cat	Lightning	24-Jul	~28-Jul	26,609	10,232[2]	52.1
Sheep Creek	Bruneau	Lightning	24-Jul	~31-Jul	60,896	0	0

[1]*The Conner Fire burned 35% of the spring-only even-years treatment pasture.*

[2]*The Cat Fire burned 100% of the spring-fall treatment pasture and 76% of the spring-only odd-years treatment pasture.*

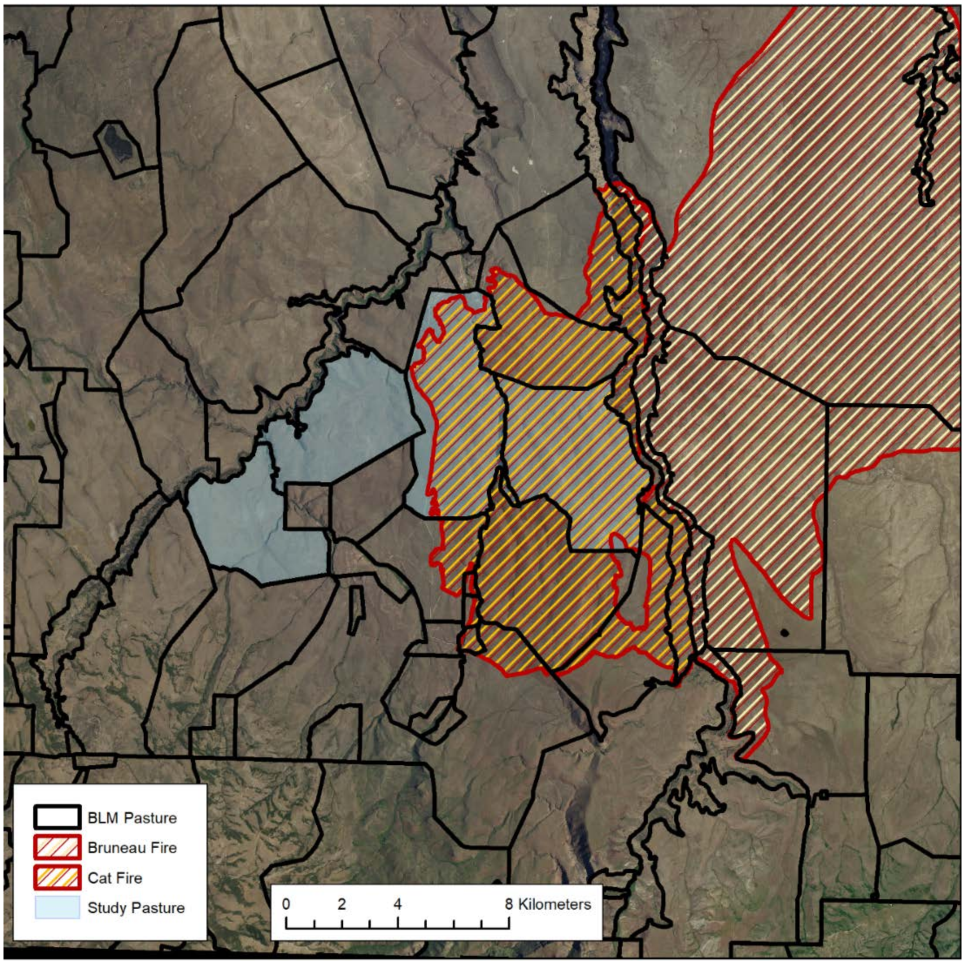

Figure 7. Burned areas of the Cat and Bruneau Fires near the Sheep Creek study site in 2018.

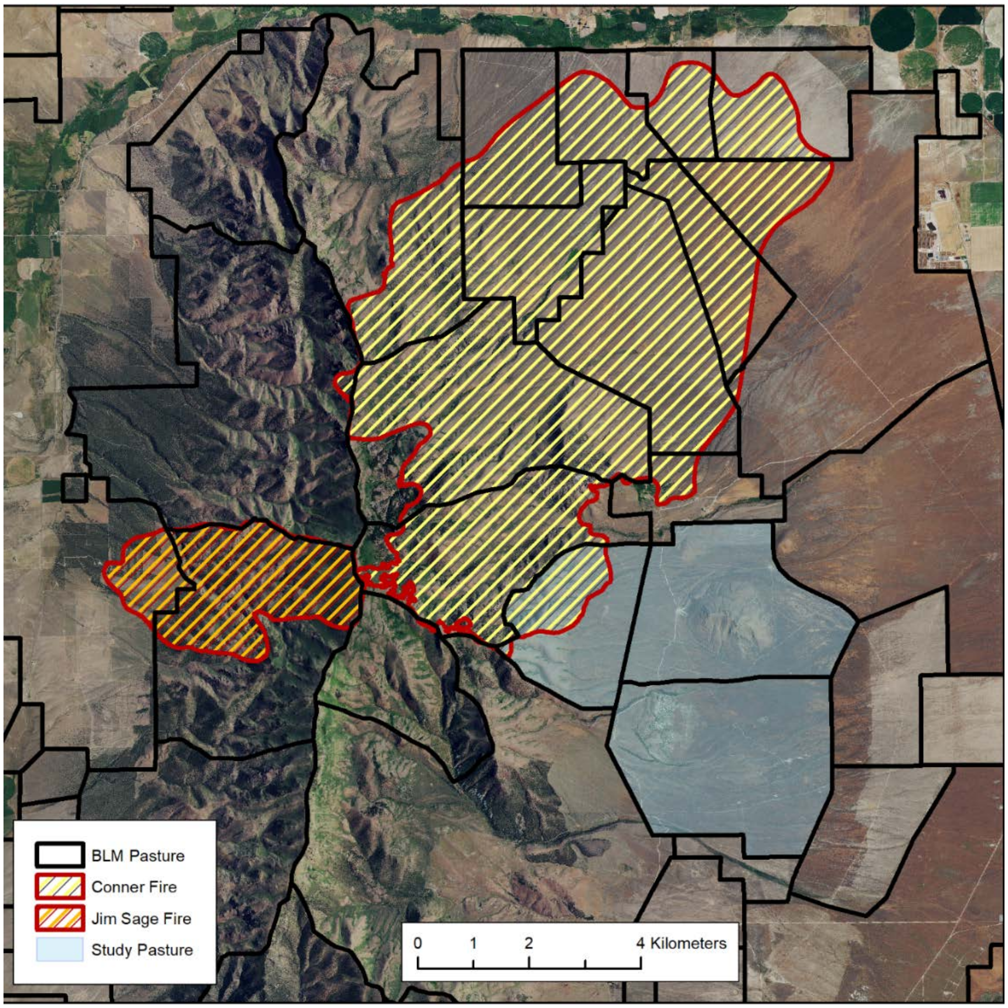

Figure 8. Burned areas of the Jim Sage Fire and the Conner Fire on and near the Jim Sage study site in 2018.

Precipitation and Temperature

We obtained precipitation and temperature data from weather stations operated by RAWS and NOAA. Precipitation was below average during the winter leading up to the 2018 nesting season at all 5 sites (Fig. 9). In 2018, Big Butte received precipitation at or above normal for March – June (Fig. 9a). Browns Bench and Jim Sage both had sporadic rainfall with above average totals in March and May (Fig. 9b,c). Pahsimeroi Valley had average precipitation leading up to and during the nesting season (Fig. 9e). Sheep Creek had precipitation well below average but received several heavy precipitation events in May (Fig. 9d). May 2018 had particularly high precipitation at Big Butte and Sheep Creek (orange bars in Fig. 10a,e). The snowfall at Big Butte in Jan and Feb 2017 was well above normal (blue bars in Fig. 10a). Maximum temperature has been consistent across the 5 years of the study (Fig. 11).

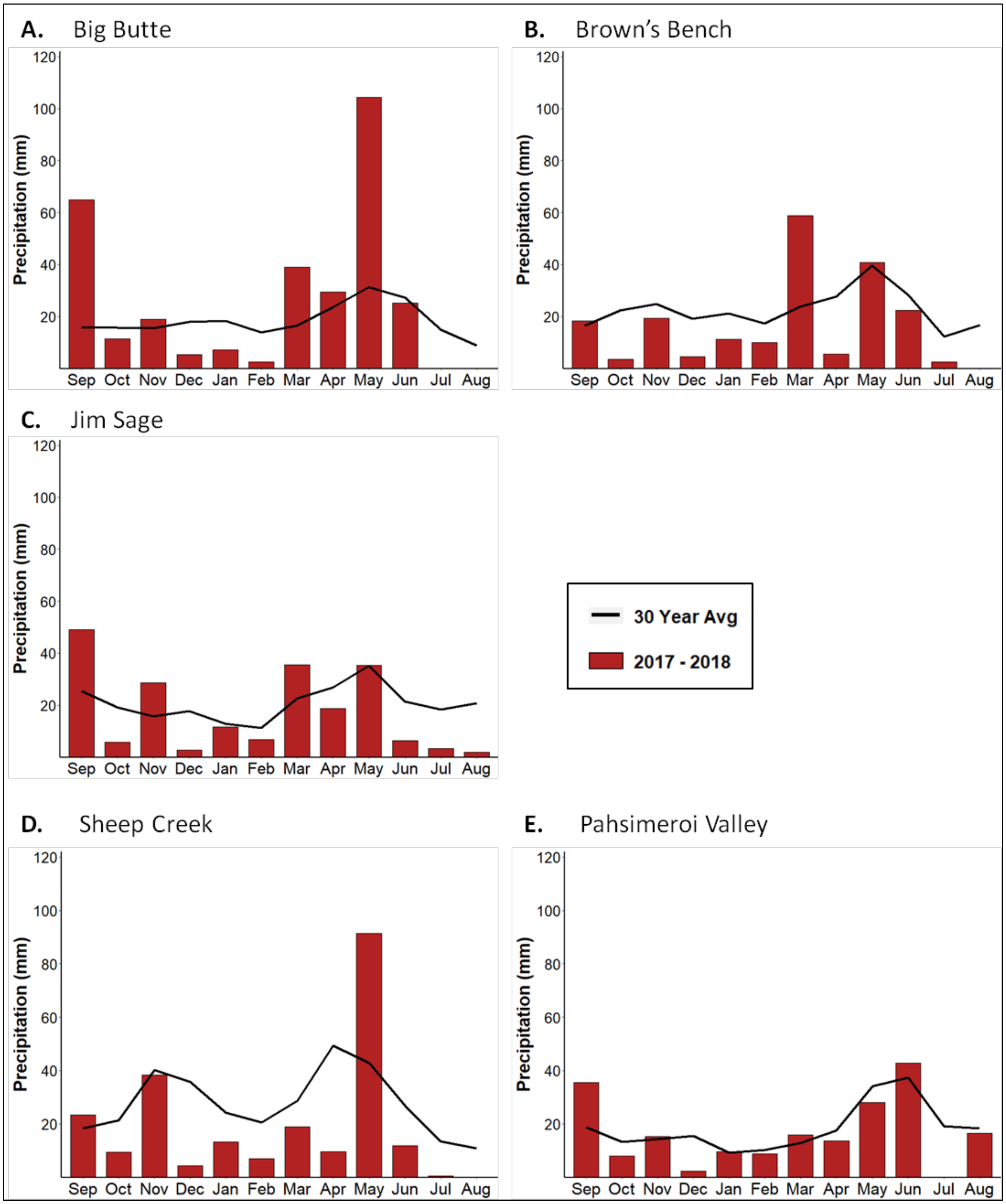

Figure 9. Precipitation (mm) during the breeding season (Mar-Aug) of 2018 and the 6 months prior (Sep 2017-Feb 2018) at each of the 5 study sites.

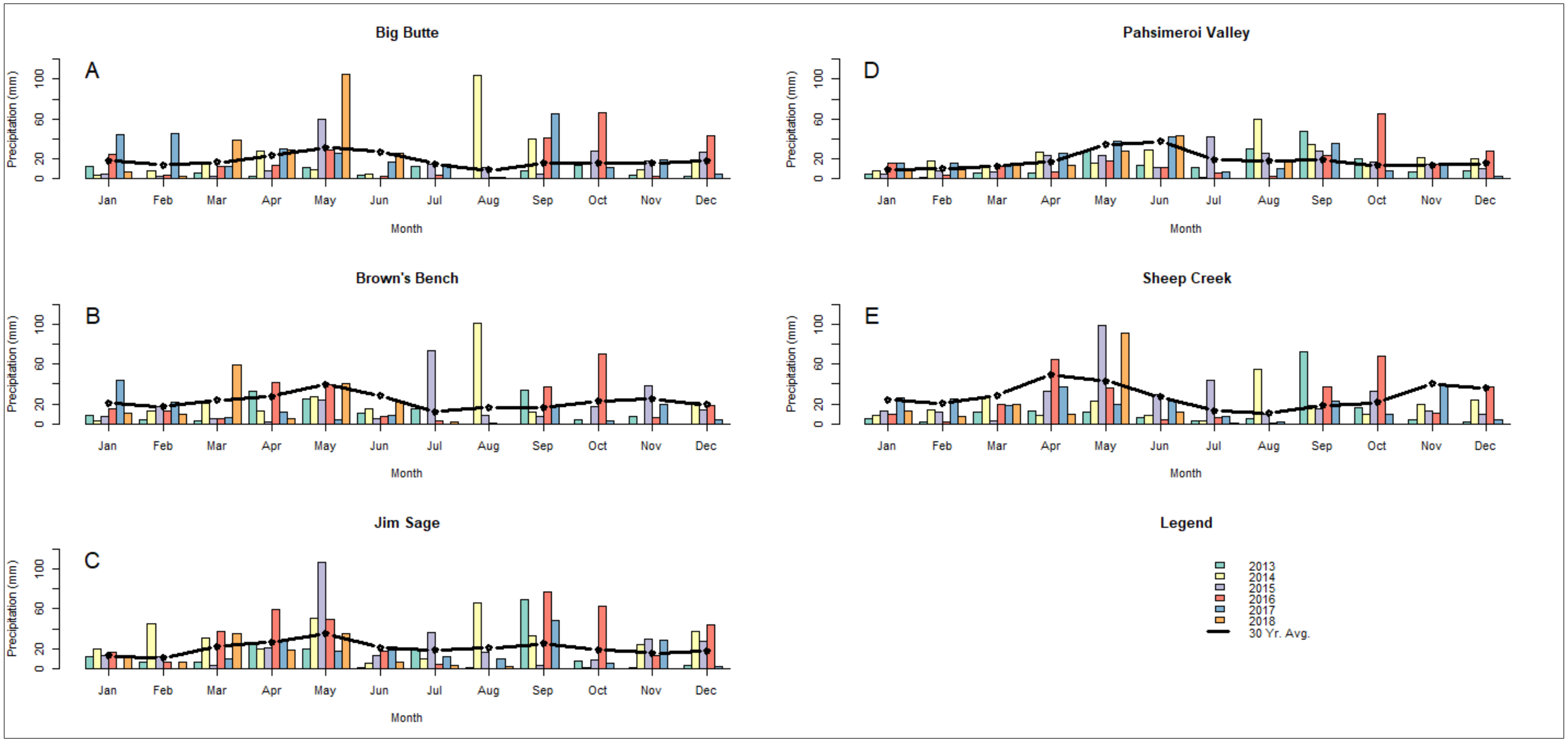

Figure 10. Precipitation (mm) by month for 5 study sites in southern Idaho from Jan 2013 – Aug 2018. Dark Lines in each plot represent 30-year average for comparison. Precipitation data were recorded at the following weather stations: Big Butte - Idaho Falls 46 W station (43.53160, -112.94220; NOAA), Brown's Bench - Jackpot, NV (41.9867, -114.674; NOAA), Jim Sage - City of Rocks (42.091, -113.631; RAWS), Pahsimeroi Valley - May 2 SSE (44.5663, -113.895; NOAA), and Sheep Creek - Pole Creek (42.069, -115.786; RAWS). The 30-year averages were recorded at nearby locations for 2 of the study sites due to lack of 30-year data set availability at Jim Sage - Malta 4 ESE (42.3061, -113.3688; NOAA) and Sheep Creek at Murphey Desert Hot Springs (42.0264, -115.362; NOAA).

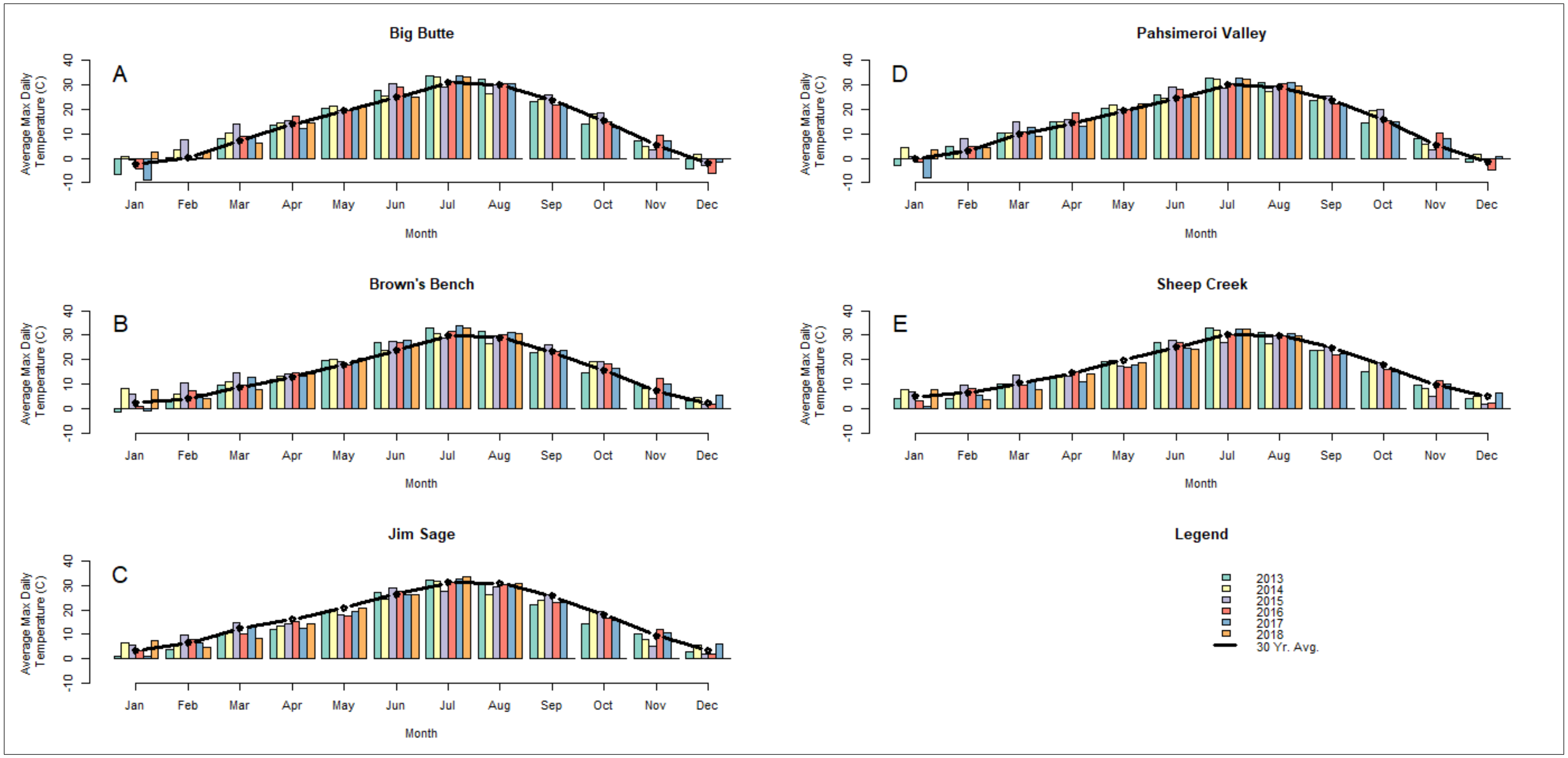

Figure 11. Average maximum daily temperature (°C) by month for 5 study sites in southern Idaho from Sep 2017 to Aug 2018. Dark Lines in each plot represent 30-year average for comparison. Temperature data were recorded at: Big Butte - Idaho Falls 46 W station (43.53160, -112.94220; NOAA), Brown's Bench - Jackpot, NV (41.9867, -114.674; NOAA), Jim Sage - City of Rocks (42.091, -113.631; RAWS), Pahsimeroi Valley - May 2 SSE (44.5663, -113.895; NOAA), and Sheep Creek - Pole Creek (42.069, -115.786; RAWS). The 30-year averages were recorded at nearby locations for 2 of the study sites due to lack of 30-year data set availability at Jim Sage - Malta 4 ESE (42.3061, -113.3688; NOAA) and Sheep Creek at Murphey Desert Hot Springs (42.0264, -115.362; NOAA).

Capture and Radio-collaring

We deployed new VHF radio transmitters on 111 female sage-grouse across 5 sites in spring 2018: 78 adults (70%) and 33 yearlings (30%; Tables 5-6). We recaptured 12 adult females that were already marked in previous years (total of 123 female captures). In addition to females captured in 2018, 66 radio-marked females whose VHF collars were deployed in past years were present at our sites in February 2018 and were monitored (≥5 detections; Table 7). Hence, we tracked 189 radio-collared hens in 2018.

Table 5. Number of adult and yearling female sage-grouse captured at 5 study sites across southern Idaho in 2018. This table includes recaptures.

	Big Butte	Brown's Bench	Jim Sage	Pahsimeroi Valley	Sheep Creek	All Sites
Adult	28 (82%)	11 (61%)	8 (50%)	30 (77%)	13 (81%)	90 (73%)
Yearling	6 (18%)	7 (39%)	8 (50%)	9 (23%)	3 (19%)	33 (27%)
Total	34	18	16	39	16	123

Table 6. Number of adult and yearling female sage-grouse captured by year across 5 study sites in southern Idaho. This table includes recaptures and excludes birds that had an unknown age at capture.

	2014	2015	2016	2017	2018
Adult	52 (57%)	57 (53%)	82 (68%)	76 (58%)	90 (73%)
Yearling	40 (43%)	51 (47%)	38 (32%)	55 (42%)	33 (27%)
Total	92	108	120	131	123

Table 7. Number of radio-marked female sage-grouse that were initially caught prior to 2018 and were alive and monitored (≥5 detections) at the start of the 2018 field season at 5 study sites in southern Idaho. Numbers below include 12 sage-grouse that were recaptured in 2018 (were initially collared in a prior year) and a new collar was attached.

	Year Initially Collared				
Site	2014	2015	2016	2017	Total Returning
Big Butte	-[a]	2	1	6	9
Brown's Bench	0	0	2	9	11
Jim Sage	0	0	4	9	13
Pahsimeroi	-[a]	0[b]	1[b]	15	16
Sheep Creek	-[a]	1	0	16	17
TOTAL	0	3	8	55	66

[a] Denotes that no trapping effort took place at this site during the specified year

[b]Birds were captured by BLM in these years as part of an earlier monitoring project (prior to the G&G project)

Our capture of new females (those that had not been marked before 2018) increased at Jim Sage and at Pahsimeroi Valley (relative to 2017), but decreased at the other 3 sites (relative to 2017). We marked >30 new females at Pahsimeroi Valley and Big Butte this year, but marked substantially fewer (range 13-15) at the other 3 sites (Fig. 12).

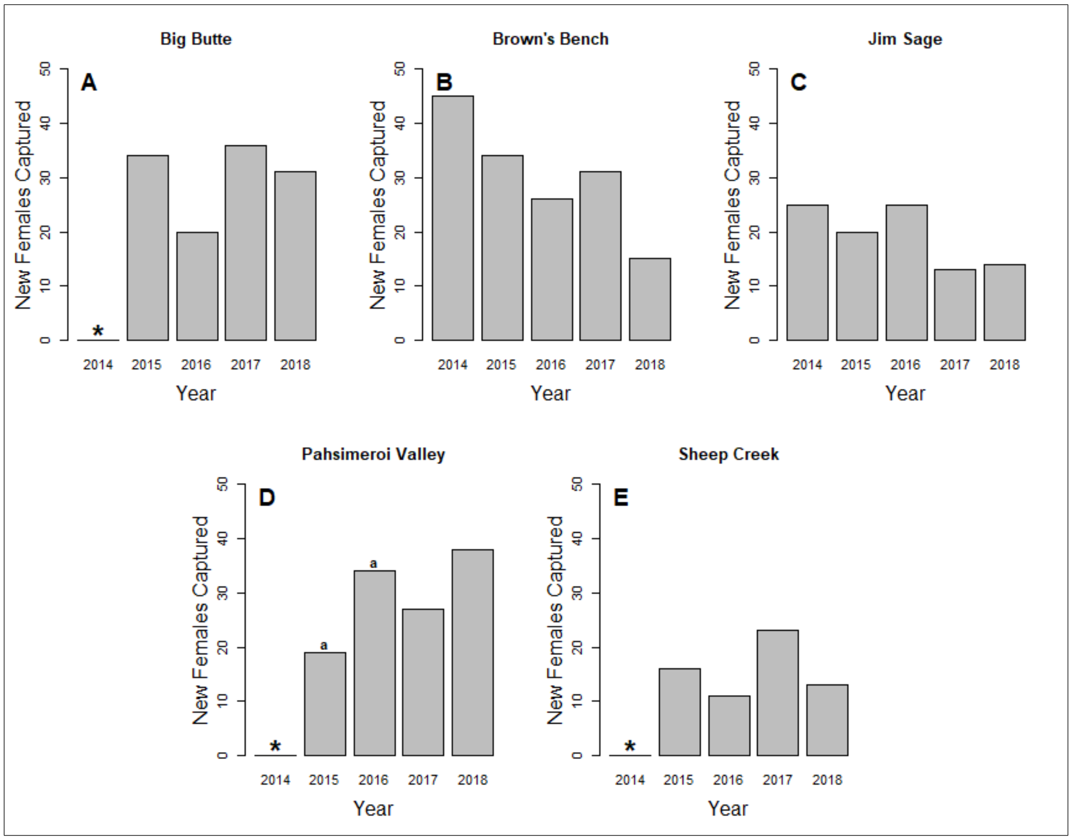

Figure 12. Number of new female sage-grouse captured (excludes any recaptures) at 5 study sites across southern Idaho 2014-2018. A '' denotes that no capture activities occurred in that year. An '[a]' indicates that trapping efforts were not conducted by the Grouse & Grazing Project field crews in that year.*

Adult-to-yearling age ratios varied greatly among study sites in 2018. We caught a higher proportion of adults at Big Butte, Pahsimeroi Valley, and Sheep Creek compared to Brown's Bench and Jim Sage (Table 5). The overall age ratio for 2018 represents the highest proportion of adults to yearlings we have seen in the 5 years of the study (Table 6).

Hen Survival and Mortality

Hen survival has varied among years and sites. Hen survival was lowest in 2017 (Fig. 13b), which had a very harsh winter preceding the grouse breeding season. Our sample size of hens has increased steadily every year as we continue to add new sites and become more efficient at capture and monitoring. Sheep Creek again had the highest survival in 2018 (Fig. 13a). Survival fluctuated among years. In 2018, Pahsimeroi Valley had the lowest point estimate for female survival among our 5 study sites (Fig. 13a).

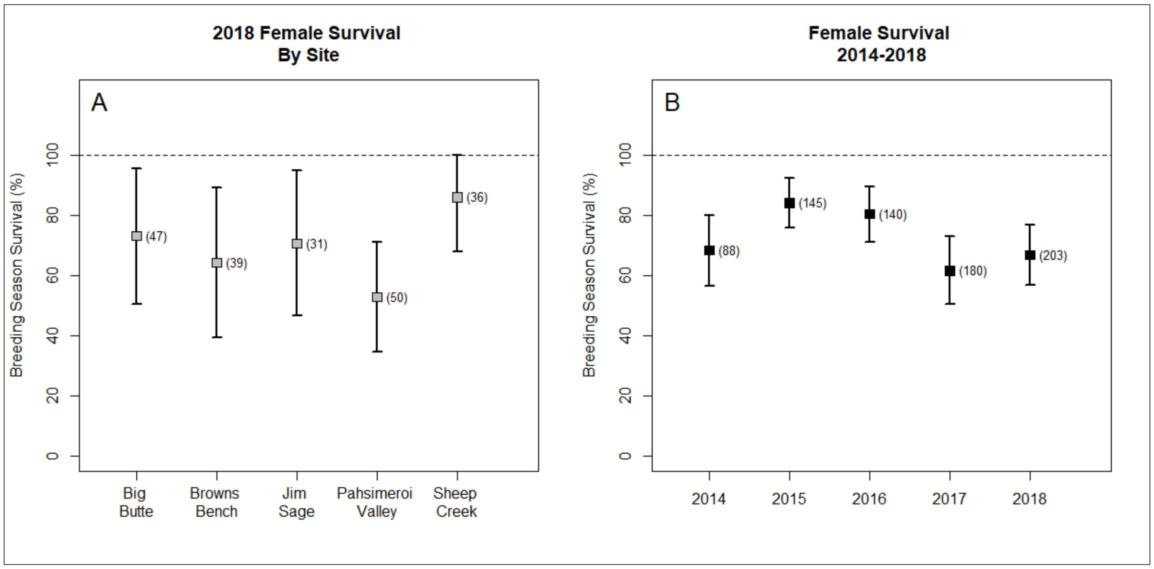

Figure 13. Survival estimates and 95% confidence intervals of female sage-grouse for 5 study sites in 2018 (A) and by year for all study sites pooled (B) during our monitoring period (Mar – Jul). Number to the right of each estimate represents the number of encounter histories (n) that contributed to the estimate.

We recovered 34 collars from apparent mortalities during the 2018 field season (March-July): 30 adult females and 4 yearling females. Timing and quantity of mortalities have varied across years and sites (Fig. 14). Mortalities are most frequent during April and May each year (during nesting and the early stages of brood rearing); this was again the case in 2018 (Fig. 14e). In 2018, we recorded the most mortalities at Pahsimeroi Valley (16 total, 13 during the breeding season; Fig. 14e) and the least at Sheep Creek (4 total, 2 during the breeding season; Fig. 14e).

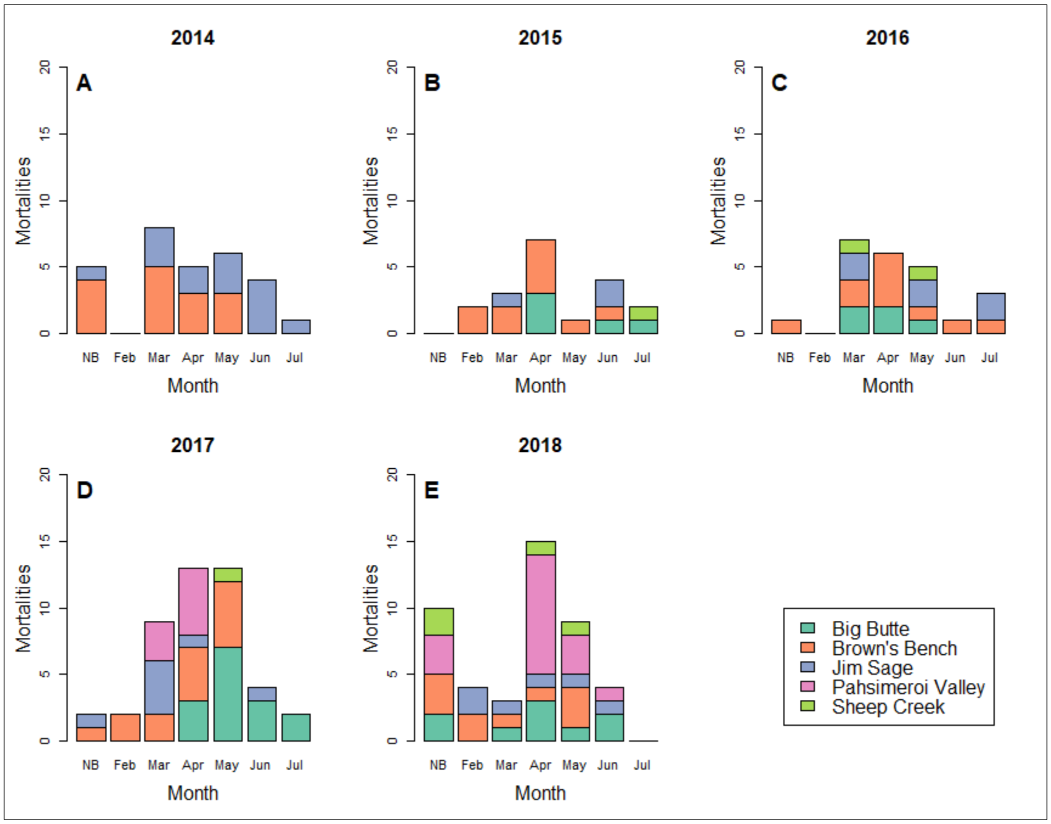

Figure 14. Mortalities of radio-marked female sage-grouse by month (and season) at 5 study sites across southern Idaho 2014-2018. The value 'NB' on the x-axis represents the cumulative non-breeding months (Aug – Jan; these are also months that we do not monitor sage-grouse and cannot accurately identify the exact month of mortality). We did not begin field work at Sheep Creek and Brown's Bench until 2015 and did not begin field work at Pahsimeroi Valley until 2017.

Nest Searching and Monitoring

We located a total 116 nests across 5 study sites in 2018 (including nests inside and outside of our experimental pastures; Fig. 15). We were able to determine the fate for 112 of the 116 nests: 36 were successful (32%) and 76 were unsuccessful (68%). Of the 116 nests monitored in 2018, 105 were thought to be initial nesting attempts and 11 were documented re-nesting attempts. Of the 116 nests, 73 were in our experimental pastures and 43 were outside of our experimental pastures (all nests within the 6 study pastures at the Pahsimeroi Valley site were included as outside because experimental pastures had not yet been identified; Fig. 15).

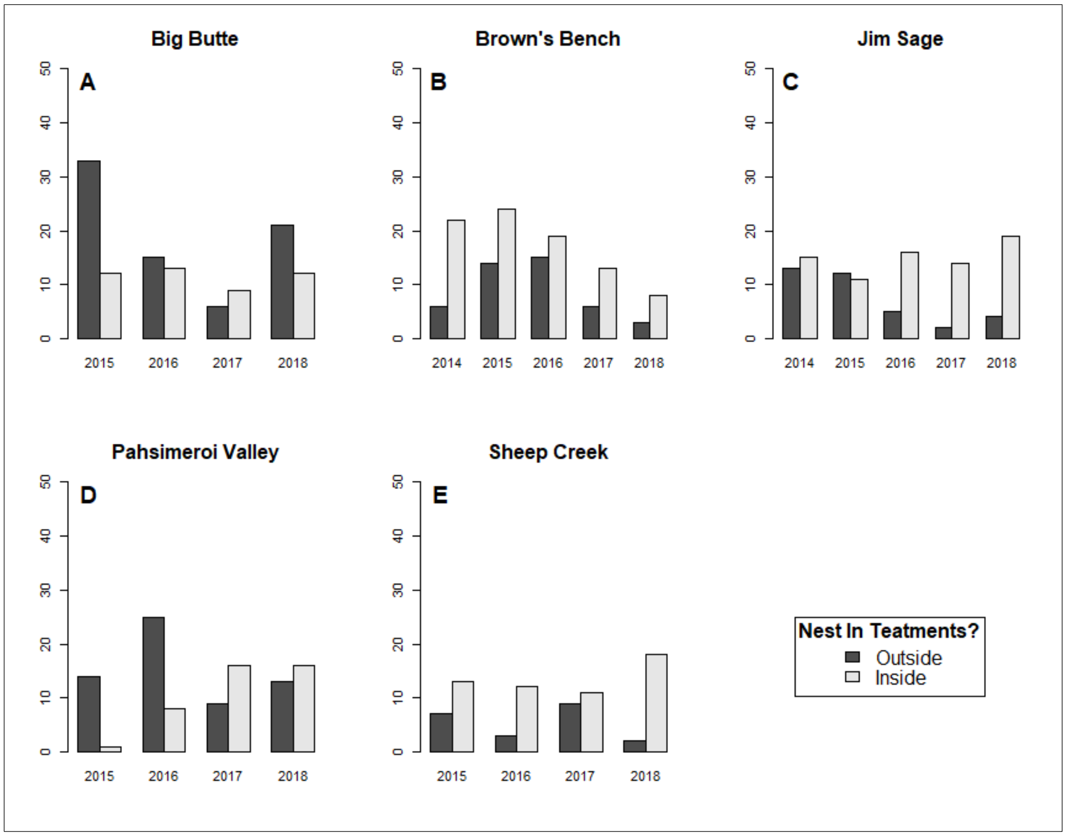

Figure 15. Number of sage-grouse nests inside and outside of treatment pastures by site and year at 5 study sites across southern Idaho, 2014-2018.

Nesting Propensity

Overall nesting propensity in 2018 was 100% (n = 102) and 90% (n = 114) respectively for method 1 (liberal) and method 2 (conservative); the 2 methods differed in the number of birds included in the denominator that were effectively tracked (Table 8). Nesting propensity ranged from 77-100% among the 5 study sites for method 2 (Table 8). We used our 2 methods to calculate overall nesting propensity for earlier years in the study for comparison. Our estimates of nesting propensity have generally increased since we started the study (Table 9).

Table 8. Nesting propensity of radio-collared sage-grouse hens based on 2 different methods for calculating the number of hens effectively tracked at 5 study sites across southern Idaho in 2018.

		Method 1[a]		Method 2[b]	
Site	Initiated Nests[c]	Birds Tracked	Nesting Propensity	Birds Tracked	Nesting Propensity
Big Butte	27	27	100.0	31	87.1
Brown's Bench	10	10	100.0	13	76.9
Jim Sage	21	21	100.0	21	100.0
Pahsimeroi Valley	25	25	100.0	25	100.0
Sheep Creek	19	19	100.0	24	79.2
Overall	102	102	100.0	114	89.5

[a]Defined a tracked bird as "Any bird that we either found a nest or we did not find a nest but tracked consistently (meaning at least 1 time per week) between 1 April and 3 June". (We used 1 April because it is the earliest date that we have recorded the onset of incubation for a sage-grouse nest and we used 3 June because it is the average, among years, for the latest onset of incubation for a nest).

[b]Defined a tracked bird as "Any bird that we either found a nest or we didn't find a nest but we tracked for >50% of the weeks (i.e., obtained $\geq$1 location on $\geq$50% of the weeks) between 1 April and 3 June".

[c]Number of birds that initiated at least one nest

Table 9. Nesting propensity of radio-collared sage-grouse hens based on 2 different methods for calculating the number of hens effectively tracked for each of 5 years (5 study sites pooled) across southern Idaho, 2014- 2018.

		Method 1[a]		Method 2[b]	
Year	Initiated Nests[c]	Hens Tracked	Nesting Propensity	Hens Tracked	Nesting Propensity
2014	50	59	84.7	72	69.4
2015	110	118	93.2	131	84.0
2016	116	121	95.9	136	85.3
2017	81	81	100.0	107	75.7
2018	102	102	100.0	114	89.5
Overall	459	481	95.4	560	82.0

[a]Defined a tracked bird as "Any bird that we either found a nest or we did not find a nest but tracked consistently between 1 April and 3 June". We used 1 April because it is the earliest date that we have recorded the onset of incubation for a sage-grouse nest and we used 3 June because it is the average, among years, for the latest onset of incubation for a nest.

[b]Defined a tracked bird as "Any bird that we either found a nest or we didn't find a nest but we tracked for >50% of the weeks (i.e., obtained $\geq$1 location on $\geq$50% of the weeks) between 1 April and 3 June".

[c]Number of birds that initiated at least one nest

Re-nesting propensity has varied across years. In 2018, we observed the lowest re-nesting propensity of any year since the study began. Apparent nest success of re-nesting attempts has been relatively high ranging from 21-67% (Table 10).

Table 10. Re-nesting propensity for female sage-grouse at all 5 study sites combined in southern Idaho, 2014-2018.

Year	Failed 1st Attempt	Re-Nested	Hatched	Re-nesting Propensity	Apparent Success
2014	24	6	3	25.0	50.0
2015	57	12	8	21.1	66.7
2016	81	14	8	17.3	57.1
2017	50	14	3	28.0	21.4
2018	61	10	4	16.4	40.0
Total	273	56	26	20.5	46.4

Nest Success

Apparent nest success at 3 sites (Brown's Bench, Jim Sage, and Sheep Creek) was higher in 2018 compared to 2017, but was slightly lower at the other 2 sites (Table 11). RMARK estimates of the probability of nest success were roughly equal to or lower than apparent nest success at all sites individually and all sites combined (Table 12). RMARK estimates for 2018 were similar among study sites (Fig. 16a) and 2016-18 estimates were slightly lower than 2014-15 (Fig. 16b).

Table 11. Apparent nest success of sage-grouse at 5 study sites in southern Idaho, 2014-2018.

Study Site	Apparent Nest Success (%)					
	2014	2015	2016	2017	2018	All Years
Big Butte	-[a]	36	29	36	27	32
Browns Bench	57	57	38	21	50	46
Jim Sage	28	43	33	23	32	33
Pahsimeroi Valley	-[a]	-[a]	-[a]	28	26	31
Sheep Creek	-[a]	30	33	30	40	33

[a] We did not conduct field work during the specified year

Table 12. Summary of sage-grouse nests by study site and pasture at 5 study sites in southern Idaho in 2018. Apparent nest success and nest success calculated using RMark for all study sites.

Site	Pasture Name	Failed	Hatched	Total	Apparent Nest Success	RMark Nest Success
Big Butte	Butte South	1	0	1		
	Serviceberry	6	2	8		
	Sunset North	0	1	1		
	Frenchman South	1	1	2		
	Other Pastures	16	5	21		
	Total	24	9	33	27.3	17.7
Browns Bench	Browns Creek East	0	1	1		
	China Creek BLM #1	1	0	1		
	Corral Creek East	1	1	2		
	Indian Cave North	2	0	2		
	Indian Cave South	0	1	1		
	Other Pastures	1	2	3		
	Total	5	5	10	50.0	30.8
Jim Sage	Kane Springs (Line Canyon)	4	1	5		
	Sheep Mountain North	2	2	4		
	Sheep Mountain South	8	2	10		
	Other Pastures	1	2	3		
	Total	15	7	22	31.8	21.6
Pahsimeroi Valley	Goldburg NE - Big Gulch	2	0	2		
	Goldburg NW - Bear Creek	0	0	0		
	Goldburg SE - Summit	0	2	2		
	Goldburg SW - Donkey Creek	2	0	2		
	River	5	1	6		
	West River Flat	5	0	5		
	Other Pastures	6	4	10		
	Total	20	7	27	25.9	12.5
Sheep Creek	East Blackleg North	4	4	8		
	Slaughterhouse North	4	2	6		
	Tokum-Bambi East	1	0	1		
	Tokum-Bambi West	2	1	3		
	Other Pastures	1	1	2		
	Total	12	8	20	40.0	17.4
	2018 Overall Estimate	76	36	112	32.1	17.9

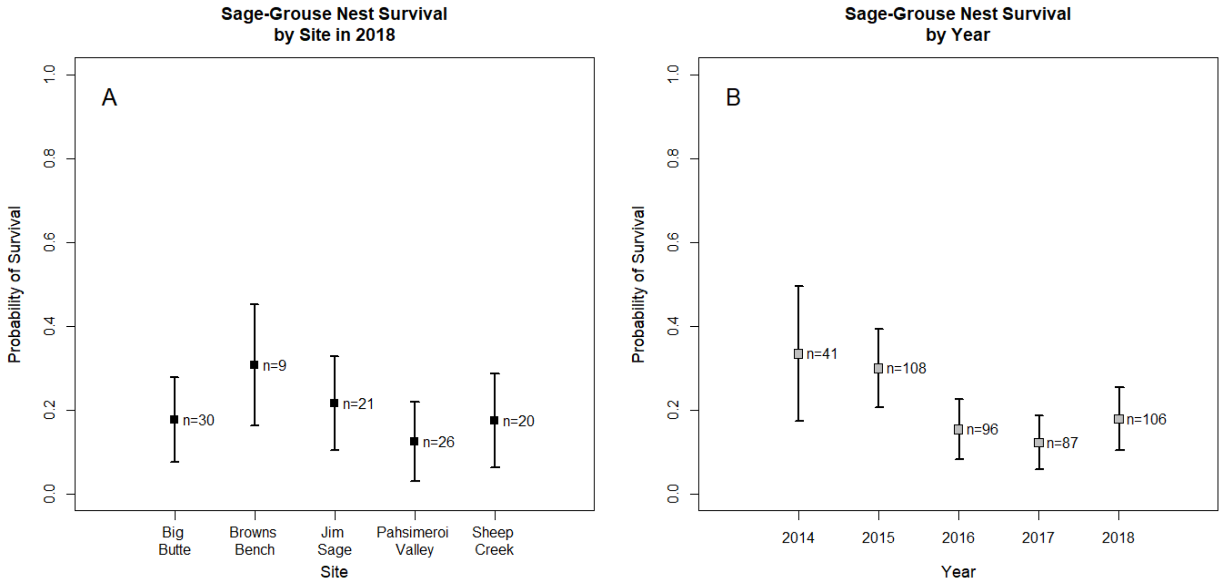

Figure 16. Probability of nest survival for each site in 2018 (A) and for each year of the study, 2014-2018 (B). All estimates were calculated using RMark. Estimates were extrapolated from daily nest survival to estimate the overall survival across the laying and incubation period (37 days). Bars represent 95% confidence intervals that were calculated using the delta method.

Critical Dates

Hatch Date

Mean hatch date in 2018 varied only slightly among the 5 study sites: from 23-May (Sheep Creek) to 31-May (Big Butte and Pahsimeroi Valley; Table 13). Across all 5 study sites, mean hatch date was approximately 5 days earlier than in 2017, but 2017 was the latest mean hatch date observed across all years (Table 14).

Clutch Size

Mean clutch size across sites ranged from 5.9 – 7.1 eggs per hatched nest in 2018 (Table 13). The largest clutch we recorded was 8 eggs and the smallest was 4 eggs. Mean clutch size across all 5 study sites was 5.9 eggs per hatched nest.

Table 13. Mean clutch size and hatch date of successful nests at 5 study sites across southern Idaho in 2018.

Site	Clutch			Hatch Date		
	mean	SE	*n*	mean	SE	*n*
Big Butte	6.3	0.577	9	31-May	4.1	9
Brown's Bench	6.4	0.400	5	25-May	5.0	5
Jim Sage	5.9	0.553	7	26-May	4.2	7
Pahsimeroi Valley	6.4	0.571	7	31-May	1.4	7
Sheep Creek	7.1	0.441	8	23-May	5.0	8

Table 14. Mean clutch size and hatch date of successful nests for each of the past 5 years (all study sites combined) across southern Idaho from 2014-2018.

Year	Clutch			Hatch Date		
	mean	SE	*n*	mean	SE	*n*
2014	6.4	0.330	23	22-May	2.7	20
2015	5.9	0.272	61	13-May	2.0	58
2016	6.4	0.273	42	22-May	2.3	41
2017	5.9	0.267	25	2-Jun	2.6	25
2018	6.4	0.237	36	27-May	1.9	36

Brood Monitoring

In 2018, we conducted 151 brood flush surveys (105 initial flushes and 46 re-flushes) and 20 spotlight surveys on 32 separate female sage-grouse broods. Of these broods, 11 (29% or 50%) had at least one chick survive to 42 days of age (Table 15). In 2018, we calculated a more conservative and a less conservative estimate of brood success to account for our lack of certainty regarding the fate of 16 (42%) broods. We have struggled to sufficiently track hens to 42 days after hatch in each season due to sudden long-distance movements by hens (or signals that disappear entirely). In future analyses we hope to use a daily brood survival method that will help us to obtain unbiased estimates of brood success. Brood survival is part of Ian Riley's graduate thesis and more detailed analyses will be available soon in his M.S. thesis (graduation in May 2019).

Vegetation Sampling

In 2018, we measured vegetation metrics at 487 vegetation sampling plots (102 nest plots and 385 random plots) from 7 May – 3 July across 5 study sites. We did not complete any dependent random plots during the 2018 season due to time constraints and insufficient personnel. We sampled grass height and grazing intensity metrics for 32,818 grass plants on the 487 vegetation sampling plots in 2018. We re-sampled 360 of the 385 random plots (including measurements for 22,681 grass plants) at the end of the growing season (19 July – 10 August). In 2018, we walked landscape appearance transects through 21 pastures to provide estimates of percent utilization (and the most common grass, the dominant shrub, and the percent cover of cheatgrass) at 3,934 sampling locations, and we used these data for pattern use mapping at all 5 study sites. While conducting the 2018 landscape appearance transects at the 5 study sites, we also measured height, species, and evidence of grazing for 11,249 individual grass plants at the 3,934 sampling locations. Summaries of these data are included in supplemental vegetation monitoring reports for each study site that will be sent to BLM field managers.

Table 15. Fate of sage-grouse broods at 5 study sites across southern Idaho in 2018.

Site	Hatched Nests	Lost[a]	Confirmed Failed[b]	Survived to 42 days	Brood Success[c]	Brood Success[d]
Big Butte	9	8	1	0	0	0
Brown's Bench	5	0	4	1	20	20
Jim Sage	7	3	1	3	43	75
Pahsimeroi Valley	9	4	3	2	22	40
Sheep Creek	8	1	2	5	63	71
Overall	38	16	11	11	29	50

[a]Indcates that the signal of the focal hen was lost and we were unable to accurately determine the fate of the brood at 42 days post hatch.
[b]Indicates that we were able to confirm that the hen in fact did not have a live brood at 42 days post hatch.
[c]Brood success assuming all lost broods (a) failed.
[d]Brood success censoring all lost broods (i.e., they were not included in the denominator)

Insect Sampling

We conducted insect sampling at 178 sampling locations across 5 study sites in 2018: 40 plots at Big Butte; 40 plots at Brown's Bench; 40 plots at Sheep Creek; 30 plots at Jim Sage; and 28 plots at Pahsimeroi Valley. We increased our sampling effort in 2018 (relative to 2017) because we had more funding in 2018 and because we wanted to make it more comparable to our efforts in 2015 and 2016 (Conway et al. 2016). Each of the 178 sampling locations had 4 pitfall traps and we emptied pitfall traps once per week for 3-6 weeks, yielding a total of 2,544 pitfall insect samples collected in 2018. For each visit, we also conducted 2 sweep-net transects per plot in 2018. These efforts yielded 1,730 sweep-net samples. Additionally, we conducted ant mound surveys at each insect sampling plot across all 5 study sites in 2018. We measured the distance to (and size of) 269 ant mounds on these 178 transects. Thus far, we have counted, identified, and measured 45,725 arthropods from 424 pitfall trap samples (108 arthropods per pitfall sample). The 45,725 arthropods include 15 taxonomic Orders, but 89% of the biomass in the samples is from 3 Orders: Orthoptera (grasshoppers and crickets; 47%), Hymenoptera (ants and bees; 24%), and Coleoptera (beetles; 17%). These are also the 3 Orders that are the most common arthropod Orders in the diet of sage-grouse chicks. We detected 40 ant mounds ($\geq$1 at 19 of 21 transects) at Big Butte, 27 ant mounds ($\geq$1 at 11 of 18 transects) at Brown's Bench, 8 ant mounds ($\geq$1 at 6 of 30 transects) at Jim Sage, and 58 ant mounds ($\geq$1 at 17 of 23 transects) at Sheep Creek.

DISCUSSION

In 2018, we hired a slightly larger crew (29 in 2018 compared to 25 in 2017) to collect data at 5 study sites. This was the 5th year of the Grouse & Grazing Project (a 10-year project) and we collected post-treatment data at 4 out of 5 study sites. Our sample sizes are still too small to report results of the experimental grazing treatments. However, we continue to build a robust dataset and will soon conduct some preliminary correlative analyses to document the relationship between grazing and sage-grouse metrics.

We deployed 46 kilometers of electric fence in 2018 and did not have any major issues or problems with any fences. The success of these temporary electric fences to keep cows in the treatment areas reflects our regular communication with permittees and BLM range specialists prior to and during the field season. Additionally, IDFG's technician took over as lead of the fencing logistics which helped this aspect run smoothly. Fires had a greater impact on the study in 2018 than in 2017. Portions of our treatment pastures burned at 2 study sites this year compared to only one in 2017. We shared vegetation data with the BLM to help with their decisions regarding species composition of fire rehab treatments. The winter of 2017-2018 had less snowfall than the previous winter (2016-2017), but April 2018 had above-average rain at both Sheep Creek and Big Butte (Figs. 9, 10a,e). This caused some road access issues at Big Butte but did not prevent work from being accomplished at the other 4 sites. However, 2018 was by-and-large a typical year regarding precipitation and temperature.

We captured fewer females in 2018 compared to prior years (111 in 2018, 130 in 2017). Pahsimeroi Valley was again our easiest site to catch hens. Sheep Creek and Jim Sage continued to be difficult areas to trap. At Jim Sage, we captured slightly more hens in 2018 than in 2017 (Fig. 12c). We captured fewer hens at Brown's Bench in 2018 compare to previous years (Fig. 12b). This could reflect trap-shyness – hens may be more likely to flush after multiple years of trapping activities at a site. Indeed, we catch surprisingly few of the radio-marked hens that return the subsequent year (even though we know they are alive and present). In 2019, we anticipate having more returning technicians to the project which should help increase the number of birds we are able to capture and mark because technicians with prior trapping experience are usually more effective.

Adult to yearling age ratios were higher in 2018 compared to the prior 4 years of the study (Table 6). Age ratios represent an index on the previous year's production provided that the sample of individuals is random and the probability of detection is independent and equal for all individuals (Hanson 1963). The high ratio of adults to yearlings in 2018 makes sense based on our other demographic parameter estimates. In 2017, we observed both the lowest estimates of nest success and the lowest estimates of hen survival of all the years of the study. This coincided with heavy snowfall in the winter leading up to 2017. Low nest success in 2017 would lead to a lower number of yearlings in the 2018 breeding season. This underscores the effect of weather on sage-grouse populations and how there can be cascading lag effects to these populations years into the future (Connelly et al. 2000, Gibson et al. 2017).

Some of the inter-annual variation in age ratios may also reflect variation in accuracy of field technicians to determine age of sage-grouse. Leading up to the 2018 field season, we documented the consistency of age estimates based on photographs of sage-grouse wings (which is how we estimate hen age). We asked 5 sage-grouse biologists to examine wing photos of 199 sage-grouse and then used those same photos to test our seasonal field technicians (after we had trained them on ageing methods). The 5 experts had clear consensus on 155 of the 199 grouse (the other 44 had too poor of pictures to make definitive categorization or feathers were intermediate). Accuracy among 14 technicians at the start of the field season (prior to any field work) ranged from 73% to 93%.

Female survival was slightly higher in 2018 compared to 2017, which is not surprising given that hen survival in 2017 was the lowest among the 5 years of the study. Winter conditions going into the 2018 season were much more favorable than in the 2017 season. Female survival is an important demographic parameter because it has a large influence on sage-grouse population growth (Taylor et al. 2012). Most of the mortalities of radio-collared hens occurred in April and May in 2018. This coincided with the nesting season when female birds must invest energy into reproductive effort and balance that investment with self-maintenance to ensure their own survival. Sage-grouse reproductive effort (e.g., nesting propensity) may greatly affect hen survival in both current and subsequent years (Blomberg et al. 2013). In 2018, we put additional effort into distinguishing overwinter mortalities from breeding season mortalities, and this additional effort likely explains why we documented more non-breeding season mortalities in 2018 compared to prior years (Fig. 14e). Correctly distinguishing between over-winter mortalities and breeding season mortalities will help us determine periods of highest risk to females during the breeding season and better understand the relationship between survival, reproductive effort, and cattle grazing.

Estimates of nesting propensity are very sensitive to how the metric is calculated (Tables 8 and 9), especially in studies like ours where hens are captured and radio-collared prior to the nesting season. We capture hens from Feb-Apr and we lose contact with some of the radio-collared hens prior to or during the first half of the nesting season (perhaps because they leave the study area to nest elsewhere) and others move so far from our study area that we are unable to monitor them regularly (and hence we don't document whether or not they initiate a nest). Hence, we used two methods to calculate nesting propensity – methods that vary due to constraints we imposed regarding which hens were monitored sufficiently such that we were likely to detect any nests that they initiated. Our estimates of nesting propensity based on these two approaches (100% and 90%) are higher than most previous studies (Table 16). Although other studies typically attempt to track all of their radio-collared birds equally (whereas we explicitly focused our monitoring efforts on hens that nested within our experimental study pastures), they have not explicitly defined what they deem to be a tracked bird (i.e., the denominator of the nesting propensity metric; Table 16). Future studies should explicitly address this so that future researchers can tease out if variations in this metric are truly due to environmental factors (annual weather patterns, latitude, habitat quality) or simply differences in how the metric was calculated. In future analyses, we plan to examine whether nesting propensity is influenced by habitat quality, annual weather patterns, and livestock grazing.

In 2018, all estimates of apparent nest success were within one standard error of each other indicating that nest success was similar among the 5 study sites. Our estimates of nest success were within the wide range that has been reported across other studies (15-70%; Connelly et al. 2011). When combined across years, our estimates show a declining pattern from 2014-2017 and a slight uptick in 2018. Sage-grouse demographic parameters often vary substantially from year to year due to weather and other environmental factors.

Our estimates of apparent nest success were higher than our estimates of nest success based on the Mayfield method (estimated using RMark). Apparent nest success in biased high (i.e., it always yields higher estimates than those from the Mayfield method) because most nests are not located on the day that the first egg is laid and, hence, successful nests have higher detection probability than failed nests. For estimates of nesting success based on daily nest survival in this report, we used an exposure period that was equal to the average incubation and laying period (37 days; Schroeder et al. 1997). This is in contrast to 2017 where we used an exposure period that only included the incubation period (27 days). The number of days used to extrapolate daily survival estimates greatly influences the overall nest survival estimates. Average hatch date in 2018 was 6 days earlier than in 2017. This was likely in response to lower snowpack that did not persist as long into the spring season. Average clutch size was also slightly higher (0.5 eggs/clutch higher compared to 2017; Table 14). Hatch date also varied among our study sites; the 2 northern sites (Pahsimeroi Valley and Big Butte) had later hatch dates by 5 days than the 3 southern sites (Brown's Bench, Jim Sage, and Sheep Creek) (Table 13).

Sage-grouse broods are notoriously difficult to track (Schroeder 1997, Aldridge and Brigham 2001) and unbiased estimates of brood survival are challenging due to differences in detection probabilities among brood survey methods (Dahlgren et al. 2010*a*), brood mixing (Dahlgren et al. 2010*b*), and hen movement behavior after hatching (Fischer et al. 1997). Moreover, the number of broods available for estimates of brood survival are typically quite small on an annual basis (Gregg 1991, Dahlgren et al. 2016). In 2018, we followed 38 hens with broods and we were able to positively determine fate on 22 of those 38 broods (58%). The primary reason we were unable to determine brood fate for 16 broods was the loss of signal of

Table 16. Estimates of nesting propensity from past sage-grouse studies. Only one previous study (Walker 2008) stated how a tracked bird was defined (i.e., included criteria regarding which birds were included in nesting propensity estimates).

Study	Category[a]	% nesting propensity	Location	Definition of tracked bird	Notes
Baxter et al. 2008	1st year after translocation	39	Utah	Not Stated	
	2nd year after translocation	73			Translocation study
Connelly et al. 1993	Yearling	55	Idaho	Not Stated	"Number of Sage-grouse followed through the nesting season"
	Adult	78			
Wallestad & Pyrah 1974	Ages combined	71	Montana	Not Stated	Estimated based on marked birds versus those that nested
Gregg 1991	Hart Mountain	46	Oregon	Not Stated	
	Jackass Creek	54			Split into 2 study sites
Holloran et al. 2005	Yearling	72	Wyoming	Not Stated	Stated not all birds were found immediately upon incubation and propensity estimate was a minimum
	Adult	86			
Schroeder 1997	Yearling	92	Washington	Not Stated	hens were localized in many cases where no nest was discovered. Some nest attempts were likely re-nest attempts (1st nest had not been detected).
	Adult	93			
Walker 2008	Yearling	97	Montana	Monitored at least once every 7 days during the breeding season	
	Adult	99			
Dahlgren et al. 2016	Yearling	60	Utah	Not Stated	
	Adult	80			
Sika 2006	Yearling	79	Montana	Not Stated	Eliminated observer induced abandonments, acknowledged that nest propensity was likely underestimated
	Adult	96			
Average across studies	Yearling	76			
	Adult	89			

[a]Group for which specific nesting propensity estimates were calculated

the radio-collared hen prior to the chicks reaching 42 days. Researchers in the past have often assumed that broods failed if the hen moved large distances (>1 km) prior to when her chicks would have reached 42 days of age. However, data from Idaho (Burkepile, unpubl. data) suggests that hens will sometimes move large distances (1.0-2.5 km) with live, intact broods (Fig. 17) and hens whose broods die do not move any further that hens whose broods are alive. In 2018, radio-collared hens with broods whose signals disappeared prior to the brood reaching 42 days of age was particularly common at our Big Butte study site where we lost signals for all broods prior to 42 days of age except one. Past studies have documented large movements by female sage-grouse in the Big Desert region (Connelly and Markham 1983, Connelly et al. 1988), especially later in the summer season (Fischer et al. 1997). In 2019, we hope to increase our tracking efforts at Big Butte to determine: 1) direction and distance females move during summer months (especially those with broods), and 2) if females are making these movements with their chicks (i.e., with intact, live broods).

Goals

In 2019, we have the following goals to improve our data and better address our objectives.

1. Capture more females than in 2018.
    a. We have 7 returning field crew members to the project in 2019, the highest number since its inception.
    b. We have purchased more high-quality spotlights and additional ATVs.
2. Improve technician's ability to distinguish between yearling and adult grouse.
    a. We will once again provide training, hands-on practice, and feedback using wing pictures from previous years, with testing and evaluation.
    b. We will measure primaries 1-3 for all captured females, which can help distinguish adults and yearlings (Braun and Schroeder 2015).
3. Improve monitoring efforts of hens with broods, especially at Big Butte and Idaho National Lab (our new site).
    a. We are altering our brood monitoring protocol to track hens almost daily and immediately search for lost hens from a high points throughout the study areas.
    b. Ty Styhl will be monitoring brood tracking efforts for his thesis and will provide more oversight than in previous years.
4. Secure stable funding for the project for the remaining 5 years of the study so that effort does not vary from year to year.

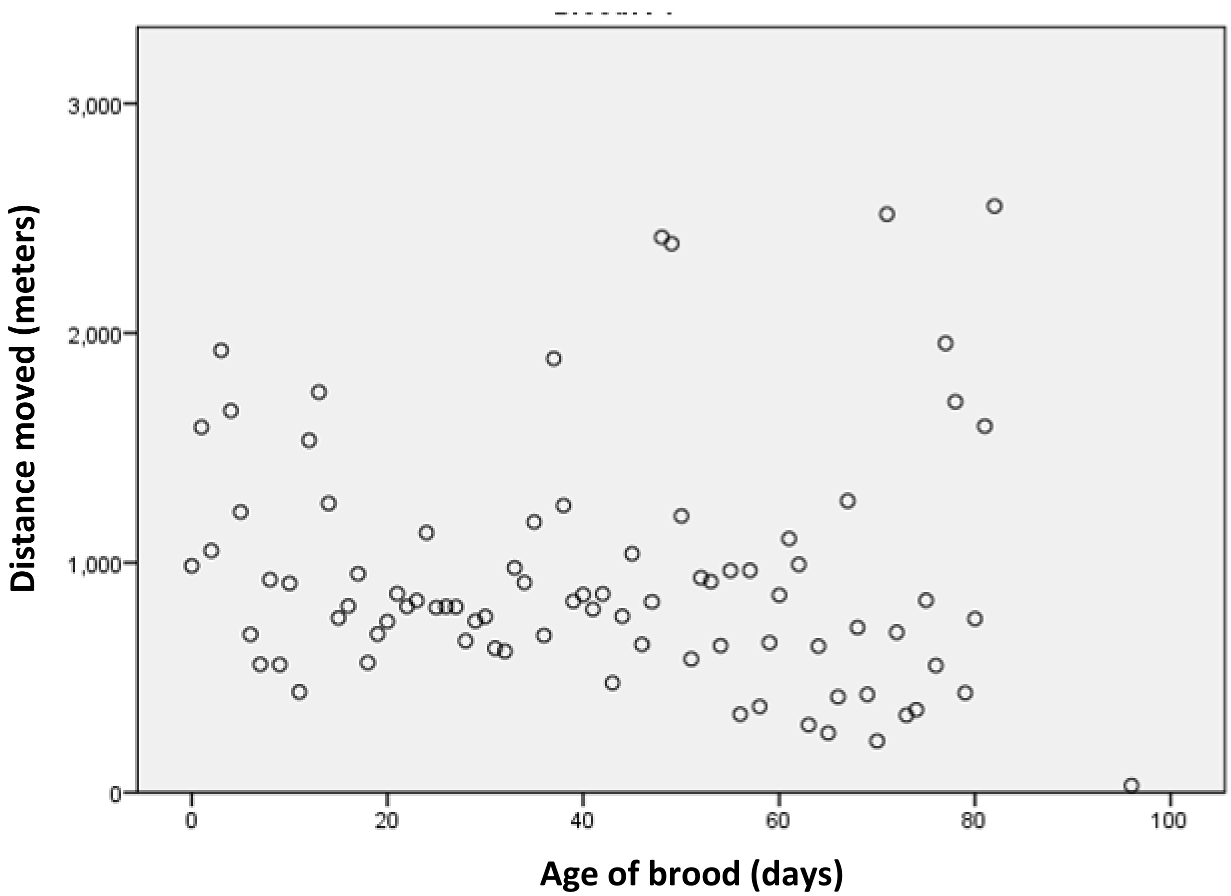

Figure 17. Distance that a hen with a live brood moved between sequential telemetry visits (most sequential visits were 1-2 days apart) for 39 radio-marked hens at 5 study areas in Idaho from 1998-2004 (N. Burkepile, unpubl. data).

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LITERATURE CITED

Aldridge, C. L., and R. M. Brigham. 2001. Nesting and reproductive activities of Greater Sage-Grouse in a declining northern fringe population. Condor 103:537–543.

Aldridge, C. L., and R. M. Brigham. 2002. Sage-Grouse nesting and brood habitat use in southern Canada. Journal of Wildlife Management 66:433–444.

Baxter, R. J., J.T. Flinders, and D. L. Mitchell. 2008. Survival, movements, and reproduction of translocated greater sage grouse in Strawberry Valley, UT. Journal of Wildlife Management 72: 179-186.

Beck, J. L., and D. L. Mitchell. 2000. Influence of livestock grazing on sage-grouse habitat. Wildlife Society Bulletin 28:993–1002.

Bernstein, B. B., and J. Zalinski. 1983. An optimum sampling design and power tests for environmental biologists. Journal of Environmental Management 16:35–43.

Blomberg, E.J., D. Gibson, J.S. Sedinger, M.L. Casazza, and P.S. Coates. 2013. Intraseasonal variation in survival and probable causes of mortality in greater sage-grouse Centrocercus urophasianus. Wildlife Biology 19:347-357.

Boyd, C. S., J. L. Beck, and J. A. Tanaka. 2014. Livestock grazing and sage-grouse habitat: Impacts and opportunities. Journal of Rangeland Applications 1:58–77.

Braun, C. E., and M. A. Schroeder. 2015. Age and sex identification from wings of sage-grouse. Wildlife Society Bulletin 39:182–187.

Connelly, J. W., H. W. Browers, and R. J. Gates. 1988. Seasonal movements of sage-grouse in southeastern Idaho. Journal of Wildlife Management 52:116–122.

Connelly, J. W., C. A. Hagen, and M. A. Schroeder. 2011. Characteristics and dynamics of greater sage-grouse populations. Studies in Avian Biology 38:53-67.

Connelly, J. W., and O. D. Markham. 1983. Movements and radionuclide concentrations of sage-grouse in southeastern Idaho. Journal of Wildlife Management 47:169–177.

Connelly, J. W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage-grouse populations and their habitats. Wildlife Society Bulletin 28:967–985.

Connelly, J. W., W. L. Wakkinen, A. D. Apa, and K. P. Reese. 1991. Sage-grouse use of nest sites in southeastern Idaho. Journal of Wildlife Management 55:521–524.

Connelly, J. W, W L. Wakkinen, A. D. Apa, K. P. Reese, and J. W. Fischer. 1993. Re-nesting by sage grouse in southeastern Idaho. Condor 94:1041-1043.

Conway, C. J., K. Launchbaugh, D. Musil, S. Roberts, P. Makela, A. Locatelli, and A. Meyers. 2016. The Grouse & Grazing – 2016 Annual Report. College of Natural Resources, University of Idaho.

Conway, C. J., A. Meyers, K. Launchbaugh, D. Musil, P. Makela, and S. Roberts. 2017. The Grouse & Grazing Project: Effects of cattle grazing on sage-grouse demographic traits – 2017 Annual Report. College of Natural Resources, University of Idaho.

Coulloudon, B., K. Eshelman, J. Gianola, N. Habich, L. Hughes, C. Johnson, M. Pellant, P. Podburny, A. Rasmussen, B. Robles, P. Shaver, J. Spehar, and J. Willoughby. 1999. Utilization studies and residual measurements. Interagency Technical Reference 1734-3. U.S. Department of Agriculture (NRCS) and U.S. Department of Interior (Bureau of Land Management). Denver, CO.

Crawford, J. A., R. F. Miller, T. D. Whitson, C. S. Boyd, M. A. Gregg, N. E. West, R. A. Olson, M. A. Schroeder, and J. C. Mosley. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2–19.

Dahlgren, D. K., M. R. Guttery, T. A. Messmer, D. Caudill, R. D. Elmore, R. Chi, and D. N. Koons. 2016. Evaluating vital rate contributions to greater sage-grouse population dynamics to inform conservation. Ecosphere 7:1–15.

Dahlgren, D. K., J. Merzenich, E. T. Thacker, and M. R. Guttery. 2010*a*. Evaluation of brood detection techniques: Recommendations for estimating greater sage-grouse productivity. Western North American Naturalist 70:233–237.

Dahlgren, D. K., T. A. Messmer, and D. N. Koons. 2010*b*. Achieving better estimates of greater sage-grouse chick survival in Utah. Journal of Wildlife Management 74:1286–1294.

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

Fischer, R. A., W. L. Wakkinen, K. P. Reese, and J. W. Connelly. 1997. Effects of prescribed fire on movements of female sage-grouse from breeding to summer ranges. Wilson Bulletin 109:82–91.

Garton, E.O., J.W. Connelly, J.S. Horne, C.A. Hagen, A. Moser, and M.A. Schroeder. 2011. Greater sage-grouse population dynamics and probability of persistence. Studies in Avian Biology 38: 293-382.

Garton, E. O., A. G. Wells, J. A. Baumgardt, and J. W. Connelly. 2015. Greater sage-grouse population dynamics and probability of persistence. Final Report to Pew Charitable Trusts.

Gibson, D., E.J. Blomberg, M.T. Atamian, and J.S. Sedinger. 2017. Weather, habitat composition, and female behavior interact to modify offspring survival in greater sage-grouse. Ecological Applications 27:168-181.

Giesen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage-grouse in Colorado. Wildlife Society Bulletin 10:224–231.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. Wiley Interscience, Chichester, England.

Gregg, M. A. 1991. Use and selection of nesting habitat by sage grouse in Oregon. M.S. Thesis, Oregon State University, Corvallis, OR.

Hohbein, R., and C. J. Conway. 2018. Pitfall traps: a review of methods for estimating arthropod abundance. Wildlife Society Bulletin 42:597-606.

Holloran, M.J., B.J. Heath, A.G. Lyon, S.J. Slater, J.L. Kuipers, and S.H. Anderson. 2005. Greater sage-grouse nesting habitat selection and success in Wyoming. Journal of Wildlife Management 69:638-649.

Hovick, T.J., R.D. Elmore, S.D. Fuhlendorf, & D. Dahlgren. 2015. Weather constrains the influence of fire and grazing on nesting greater prairie-chickens. Rangeland Ecology & Management 68:186–193.

Julson, J.C. 2017. Variation in perennial grass height within greater sage-grouse nesting habitat. Thesis, University of Idaho, Moscow, ID.

Knick, S. T. 2011. Historical development, principal federal legislation, and current management of sagebrush habitats: Implications for conservation. Studies in Avian Biology 38:13–31.

Kruse, R. E. 2002. Beef cattle management decisions relating to drought in the Northern Great Plains. M.S. Thesis. Montana State University, Bozeman, MT.

La Pierre, K. J., S. Yuan, C. C. Chang, M. L. Avolio, L. M. Hallett, T. Schreck, and M. D. Smith. 2011. Explaining temporal variation in above-ground productivity in a mesic grassland: The role of climate and flowering. Journal of Ecology 99:1250–1262.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456–466.

Moynahan, B. J., M. S. Lindberg, J. J. Rotella, and J. W. Thomas. 2007. Factors affecting nest survival of greater sage-grouse in northcentral Montana. Journal of Wildlife Management 71:1773–1783.

Musil, D. D. 2011. Use of dwarf sagebrush by nesting greater sage-grouse. Ecology, conservation, and management of grouse. Studies in Avian Biology 39:119–136.

Neel, L. A. 1980. Sage-grouse response to grazing management in Nevada. M.S. Thesis. University of Nevada, Reno, NV.

Pedersen, E. K., J. W. Connelly, J. R. Hendrickson, and W. E. Grant. 2003. Effect of sheep grazing and fire on sage-grouse populations in southeastern Idaho. Ecological Modelling 165:23–47.

Schroeder, M. A. 1997. Unusually high reproductive effort by sage-grouse in a fragmented habitat in north-central Washington. Condor 99:933–941.

Schroeder, M. A., C. L. Aldridge, A. D. Apa, J. R. Bohne, C. E. Braun, S. D. Bunnell, J. W. Connelly, P. A. Deibert, S. C. Gardner, M. A. Hilliard, G. D. Kobriger, S. M. McAdam, C. W. McCarthy, J. J. McCarthy, D. L. Mitchell, E. V. Rickerson, and S. J. Stiver. 2004. Distribution of sage-grouse in North America. The Condor 106:363-376.

Schroeder, M. A., J. R. Young, and C. E. Braun. 1999. Greater sage-grouse (*Centrocercus urophasianus*). The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology.

Sika, J. L. 2006. Breeding ecology, survival rates, and causes of mortality of hunted and nonhunted greater sage-grouse in central Montana. M.S. Thesis. Montana State University, Bozeman, MT.

Skinner, R. H., J. D. Hanson, G. L. Hutchinson, and G. E. Schuman. 2002. Response of C3 and C4 grasses to supplemental summer precipitation. Journal of Range Management 55:517–522.

Stewart-Oaten, A., W. W. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: “pseudoreplication” in time? Ecology 67:929–940.

Stiver, S.J., E.T. Rinkes, D.E. Naugle, P.D. Makela, D.A. Nance, and J.W. Karl, eds. 2015. Sage-grouse habitat assessment framework: a multiscale assessment tool. Technical Reference 6710-1. Bureau of Land Management and Western Association of Fish and Wildlife Agencies, Denver, Colorado.

Taylor, R.L., B.L. Walker, D.E. Naugle, and L.S. Mills. 2012. Managing multiple vital rates to maximize greater sage-grouse population growth. Journal of Wildlife Management 76:336–347.

Wakkinen, W. L. 1990. Nest site characteristics and spring-summer movements of migratory sage-grouse in southeastern Idaho. M.S. Thesis. University of Idaho, Moscow, ID.

Wakkinen, W. L., K. P. Reese, J. W. Connelly, and R. A. Fischer. 1992. An improved spotlighting technique for capturing sage-grouse. Wildlife Society Bulletin 20:425–426.

Walker, B.L. 2008. Greater Sage-Grouse Response to Coal-Bed Natural Gas Development and West Nile Virus in the Powder River Basin, Montana and Wyoming, USA. PhD Dissertation, University of Montana, Missoula, MT.

Wallestad, R., and D. Pyrah. 1974. Movement and nesting of sage grouse hens in central Montana. Journal of Wildlife Management 38:630–633.

Western Association of Fish and Wildlife Agencies. 2015. Greater sage-grouse population trends: An analysis of lek count databases 1965-2015. Technical Report. Western Association of Fish and Wildlife Agencies, Cheyenne, WY.

White, G. C., and K. P. Burnham. 1999. Program mark: Survival estimation from populations of marked animals. Bird Study 46:S120–S139.