The Grouse & Grazing Project:
Effects of cattle grazing on sage-grouse demographic traits
2017 Annual Report

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INTRODUCTION

The distribution of the greater sage-grouse (hereafter sage-grouse; *Centrocercus urophasianus*) has declined to 56% of its pre-settlement distribution (Schroeder et al. 2004) and abundance of males attending leks has decreased substantially over the past 50 years throughout the species' range (Garton et al. 2011, Garton et al. 2015, WAFWA 2015). Livestock grazing is a common land use within sage-grouse habitat, and livestock grazing has been implicated by some experts as one of the 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 Mitchell 2000, Crawford et al. 2004). Livestock grazing on public lands is often restricted to limit negative effects on populations of plants and animals, 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 effects of cattle grazing on 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 (2014-2017) has occurred 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 study sites range from 1400 m to 1900 m. Wyoming sagebrush (*Artemisia tridentata wyomingensis*) is common in the overstory at all sites. Other overstory shrub species include low sagebrush (*Artemisia arbuscula*), three-tip sagebrush (*Artemisia tripartita*), rubber rabbitbrush (*Ericameria nauseosa*), and green rabbitbrush (*Chrysothamnus viscidiflorus*). The most common understory grasses (ordered based on their abundance at study sites) include Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Elymus elymoides*), bluebunch wheatgrass (*Pseudoroegneria spicata*), western wheatgrass (*Pascopyrum smithii*), and needlegrass (*Achnatherum spp* and *Hesperostipa spp*).

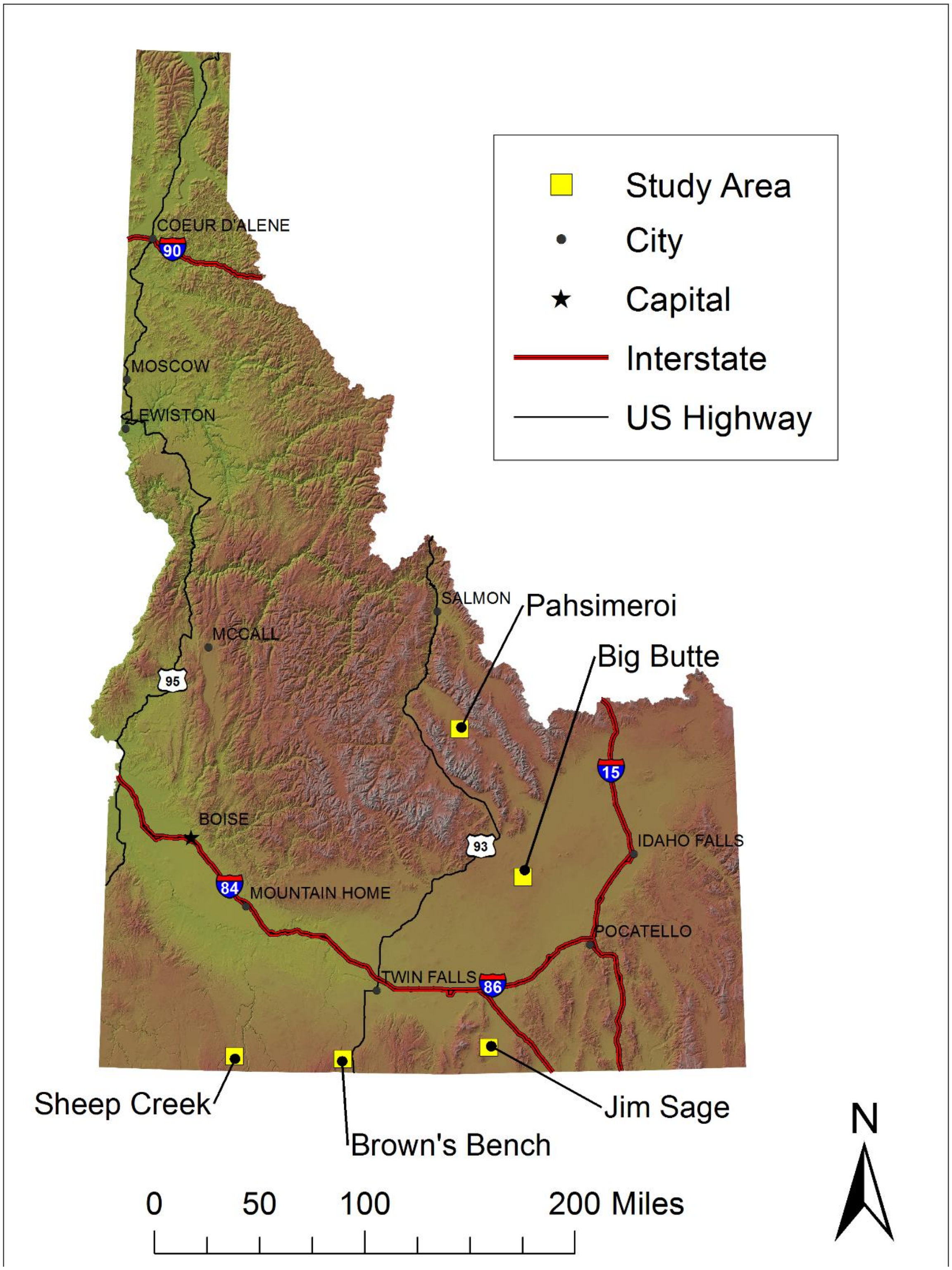


Figure 1. Five study sites in southern Idaho where field work has been conducted for the Grouse & Grazing project.

METHODS

Experimental Design

We began field work at two study sites in 2014 (Browns Bench, Jim Sage). In 2015, we added two more study sites (Big Butte, Sheep Creek), and in 2017 we added a fifth study site (Pahsimeroi). We hope to add more study sites or more treatments per study site but doing so requires additional funding/support. Additional replicates of the grazing treatments would help to ensure sufficient sample sizes in each of the 4 experimental grazing treatments. Each study site was selected based on the following characteristics:

1. ≥15% sagebrush cover, including *Artemisia tridentata wyomingensis* as a component of 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. ≤38 cm of annual precipitation
7. ≥5,700 acres largely free of infrastructure development (i.e., few wind turbines, powerlines)
8. Spring cattle grazing occurs (or is at least allowed under the current grazing permit)

For this project, we are applying a paired Before-After-Control-Impact (BACI) design with spatial and temporal replication and staggered entry 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 at least six 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 (Moynahan et al. 2006, Hovick et al. 2015, Skinner et al. 2002, La Pierre et al. 2011) and the staggered entry design will help us differentiate observed 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 first two years of data allow us to identify grazing pastures that are appropriate for inclusion in the experiment (based on discussions with permittees and BLM managers) and to provide the "Before" measures of demographic traits for the BACI design. In the spring of the third year of sampling at each study site, we alter the grazing regime in 4 pastures per study site and begin grazing according to one of four grazing treatments: 1) spring-only grazed in odd years, 2) spring-only grazed in even years, 3) no grazing, and 4) alternating years of spring-only grazed and fall-only grazed (Fig. 2). We define spring grazing as 1 March through 15 June and fall grazing as 1 September through 15 December.

Treatment	Year 1	Year 2		Year 3	Year 4	Year 5	Year 6
Spring Odd Years	Current grazing	Current grazing	Grazing Treatments	Spring Grazing	No Grazing	Spring Grazing	No Grazing
Spring Even Years	Current grazing	Current grazing		No Grazing	Spring Grazing	No Grazing	Spring Grazing
No Grazing	Current grazing	Current grazing		No Grazing	No Grazing	No Grazing	No Grazing
Spring and Fall	Current grazing	Current grazing		Spring Grazing	Fall Grazing	Spring Grazing	Fall Grazing

Figure 2. Experimental design to evaluate potential effects of cattle grazing on sage-grouse demographic traits and habitat features.

Capture and Radio-collaring

We traversed our 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. In 2016 and 2017, we also used rocket-nets (Giesen et al. 1982) to capture greater 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 outside the 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 cautiously to confirm if she was nesting. We followed an explicit protocol for locating and monitoring nests that ensured minimum disturbance to nesting hens. We used telemetry equipment to identify potential nest shrubs and confirmed a nest 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 bird, 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 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 of the hen on the nest. To monitor nests, we established two monitoring points, each $\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 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 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 who attempted a nest divided by the number of radio-collared hens tracked 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 nest within our experimental pastures more closely and 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) Any bird that we either found a nest or we did not find a nest but tracked at least 1 time per week between 1 April and 1 June, and 2) Any bird that we either found a nest or we did not find a nest but we tracked the hen for >50% of the weeks (i.e., located her at least once per week) between her capture date and 1 June. These dates (1 Apr and 1 Jun) were based on the earliest and latest nest initiation dates by hens in previous years of the study (2014-2016). We chose these two definitions for a tracked bird because they represent both a conservative definition (definition 1; should yield less tracked hens) and a liberal definition (method 2; should yield more tracked hens) of a tracked hen.

Critical Dates

Nest Initiation Date

Greater sage-grouse typically lay 1 egg every 1.5 days (Schroeder et al. 1999) and average clutch size is approximately 7 eggs in Idaho (Connelly et al. 2011, Schroeder et al. 1999, Wakkinen 1990). Therefore, we estimated the first egg laying date by subtracting 1.5 times 7 (the average clutch size) from the estimated incubation initiation date. If we observed greater than 7 eggs in the nest, we used the number of eggs observed in our calculation for that individual nest. We did not adjust our calculation if we observed fewer than 7 eggs in the nest 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 incubation period for sage-grouse averages 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. 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 onset of full incubation to be 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 to estimate the date of onset of full incubation.

Hatch Date

For hatched nests, we estimated the hatch date 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. 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 number of days we observed the nest. We used the midpoint of this range to estimate the projected hatch date (i.e., the estimated hatch date had the nest 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.

Brood Monitoring

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 was to confirm that the brood was either alive or dead (i.e., we didn't always flush the hen and brood). On the fourth and final brood flush count, we attempted to flush 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, we backed out of the area to avoid causing 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 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 could be used as less invasive method to document brood status and survival. Brood fecal surveys were part of Ian Riley's graduate thesis research (i.e., whether this method was a better approach for estimating brood survival).

Brood Spotlight Surveys

We conducted brood spotlight surveys as a third approach for estimating brood survival at 42 days (i.e., to ensure that flush count surveys were accurate). We conducted brood spotlight surveys at nighttime roost sites >1 hour after sunset and >1 hour before sunrise. We conducted 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 42-day brood surveys for the same hen (flush count survey and spotlight survey) were conducted >6 hours apart. We deviated from the 42-day timeframe 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 points at which we conducted independent random vegetation sampling; see below). We made 4 visits to each point which resulted in a total of 80 counts 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 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 5, one-minute intervals.

Vegetation Sampling

We 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 that was deemed suitable to contain a nest. Random plots were also centered on sagebrush shrubs and randomly located within experimental grazing pastures. We conducted vegetation surveys at these 3 types of plots from 4 May 2017 to 5 July 2017 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. The intensive vegetation sampling was used in Janessa Julson's graduate thesis (Julson 2017).

Plot Placement

Random plots were placed throughout each study pasture. We conducted vegetation sampling at a minimum of 20 random plots in each pasture (except at Pahsimeroi because we monitored 7 pastures and did not have the personnel to complete 20; we completed 10-15 per pasture instead). Dependent non-nest plots were paired with nest plots and were between 100 and 200 m from the paired nest location (in a random direction). Dependent and random plot locations were moved if the randomly generated location had 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 dependent non-nest plots and 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).

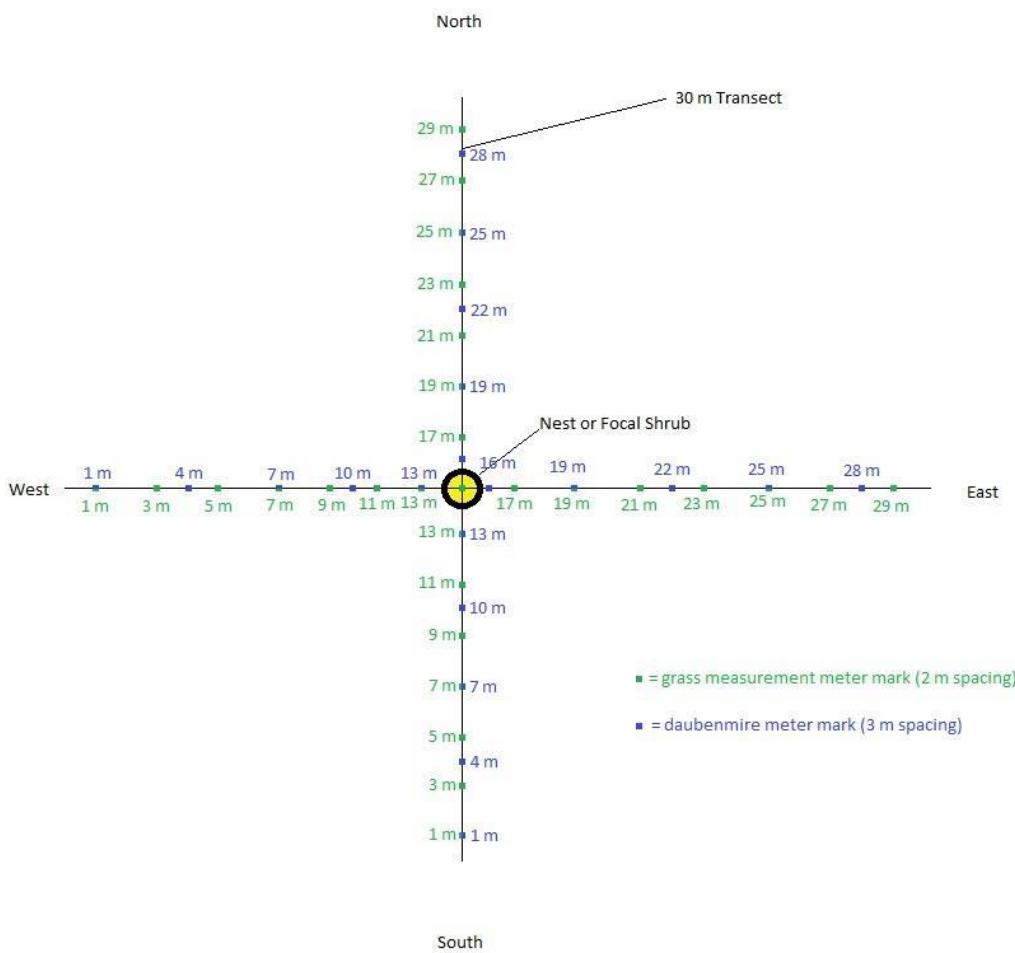


Figure 3. Visual depiction of the placement of two 30-m tapes stretched to conduct vegetation sampling at nest plots, random plots, and dependent (paired) non-nest plots for the Grouse & Grazing project in southern Idaho, 2014-2017.

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 and dependent plots). We took photographs of the pink ball from 3 m away in the four cardinal directions and from directly above the nest with the camera 1 m from the ground. We plan to use 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 nest/plot.

Focal Shrub Patch

The focal shrub was the shrub that contained the nest (at nest plots) or the shrub that was selected to be the center of the vegetation plot (for dependent non-nest and 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 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 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 x 20-cm Daubenmire frame along transects at every 3rd meter mark at each vegetation sampling plot (nest, dependent, or random plot). We estimated ground cover using 6 pin drops along the outer edges of each Daubenmire frame. These 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 vegetation), 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, and cover class at each vegetation plot (Table 1).

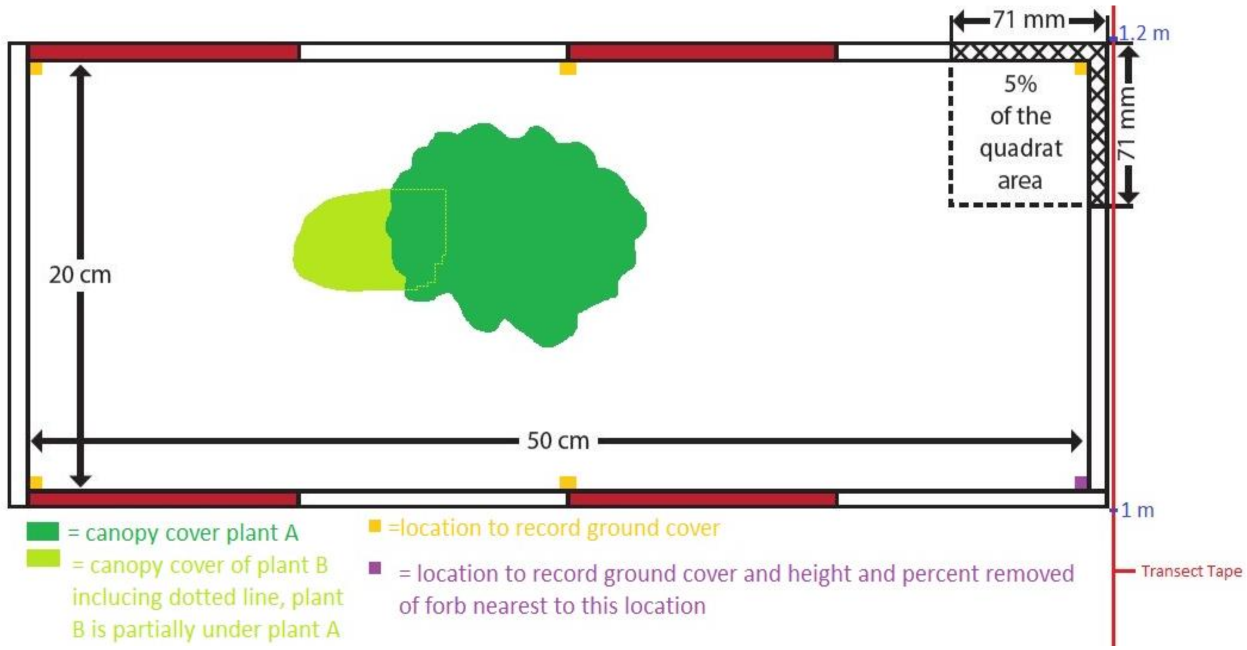


Figure 4. Example of Daubenmire frame cover measurements. Canopy cover of plant A would be an estimate of the percent of the frame the dark green colored area encompasses when looking from above the frame. Canopy cover of plant B would be an estimate of the percent of the frame the light green colored area encompasses including the area encompassed by the dotted line. The 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 difficulty distinguishing mule deer from pronghorn antelope fecal pellets).

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

Cover Class	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 Comp	*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 (% utilization).

Ocular Estimate

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 4 May to 5 July 2017 (described above under "Vegetation Sampling"), and 2) from 19 July to 15 August 2017 (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

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. If the pasture was grazed by livestock during spring/summer 2017, 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 2017, we instead placed transects 500 m apart and sampled at every 200 m (because we were expecting 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 perennial grass within the same 15-m radius half-circle in front of them at each sample point along the transect (i.e., every 200 m).

Percent Height Reduction

In 2017, we measured grass height for up to 16 grass plants at every 3rd point along 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. First, we took measurements for up to 4 grass plants of a different species (within 1 m of the point). If there were <4 different plant species, then we took measurements on the closest individual plant from each species present. For each plant measured, we recorded if 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 recorded precipitation and temperature data at each study site. We used Remote Automatic Weather Stations (RAWS) and National Weather Service (NWS) station to obtain these 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 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 4 of our 5 study sites (we did not collect insect samples at the Pahsimeroi study site in 2017). We established the center of our 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). In 2017, we only conducted pitfall traps and ant mound surveys. The insect sampling is part of Dave Gotsch's graduate thesis.

Pitfall Traps

We placed a pitfall trap array 20 m from the center of the associated random vegetation sampling plot to avoid disturbing vegetation during installation of pitfall traps (Fig. 6). 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 samples from pitfall traps once a week for 3 weeks during June 2017. We stored the collected samples in ethanol.

Sweep Net Samples

We did not collect sweep net samples in 2017, but we did in 2015-2016 (Conway et al. 2016).

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

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 pitfall trapping location (Fig. 5) for the ant mound surveys. We walked this transect recording 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 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). After the initial distance sampling occurred, we marked all ant mounds that were detected along the transect with a flag. At each subsequent visit, we returned to all marked ant mounds and recorded whether the mound still had ants present. We did this in order to document the reliability of single observations regarding whether an ant mound was active or not (i.e., the probability of incorrectly assigning an active mound as inactive).

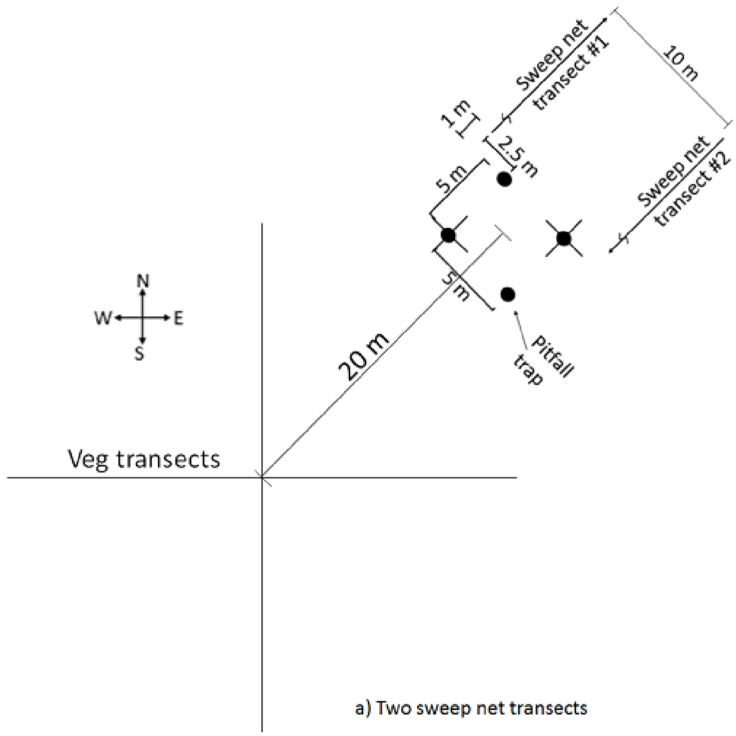


Figure 6. Visual depiction of all 3 insect sampling efforts (sweep net, pitfall, and ant mound) and their orientation in relation to the line transects on an accompanying random vegetation sampling plot.

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 years of the study. We also calculated daily nest survival by using program RMARK (White and Burnham 1999) to account for potential bias in detection of nests that failed early (Mayfield 1975). We used the day of the year to code start and end dates. This allowed us to compare nests across years on the same scale. We used daily survival estimates from RMARK and raised that number to the 27 power to estimate the probability that a nest would survive the entire incubation period. We did not include the egg-laying period in our estimate because we do not believe that we detected many nests prior to the onset of incubation.

Clutch Size

We calculated average clutch size for hatched nests because predated nests tend to have less eggshell fragments remaining than hatched nests (Schroeder 1997). We excluded definite re-nest attempts when calculating critical date averages and ranges.

Hen Survival

We estimated hen survival in 2014-2017 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 minimal 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, she had a separate encounter history for each year (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 with hatched nests. We also modeled daily brood survival to examine the effects of numerous explanatory variables on brood survival.

Grass Height and Shrub Cover

We first calculated the average grass height within each of the 707-m^2 (0.17 acre) plots. We then used the mean grass heights of plots to compare grass height among 3 plot types: failed nests, hatched nests, and random plots. We used the same approach to compare forb height and shrub cover among plot types.

Utilization

We used 3 approaches to quantify utilization:

1) We generated landscape appearance estimates by averaging percent utilization across all points in each pasture.
2) We subtracted the height of each grazed grass from the average height of the 5 nearest un-grazed grasses of the same species and then divided that value by the average height of the 5 nearest un-grazed grass of the same species. This provided one measure of the percent removal (in height) caused by grazing. For many grazed grasses measured, the approach outlined above yielded a negative value (i.e., the grazed grass was taller than the average of the 5 nearest un-grazed plants of the same species). In these cases, we substituted the negative value with a value of zero. We then averaged the percent height reduction of each grass in the pasture to get a pasture-wide estimate of percent height reduction.
3) We calculated the percent of plants that had been grazed upon by dividing the number of plants, by species, that showed evidence of grazing by the total number of plants (of that same species) measured in each pasture.

We created maps of pattern use by herbivores in each pasture based on our visual estimates of utilization from the landscape appearance transects. We used the Inverse Distance Weighted (IDW) tool in ArcGIS (version 10.4). IDW interpolation is based on the assumption that points closer together are more alike than those further apart. An advantage of using IDW interpolation is that it is an exact interpolator (i.e., the interpolated value at each point a measurement was taken will line up directly with what was actually measured at that point). We used the 12 nearest neighbors to interpolate each pixel of the resulting raster surface.

SUMMARY

Field Effort

We hired 5 crew leaders, 10 wildlife technicians, 8 vegetation technicians, and 2 point-count technicians across 5 field sites in 2017. One University of Idaho graduate student (Riley), a field coordinator (Meyers), and 2 IDFG biologists (Burman and Musil) also worked full-time on the project. From 6 February through 25 August 2017, field personnel worked about 22,000 person hours collecting field data on the project.

Electric Fencing

We temporarily deployed 2 cattle guards and 11 separate electric fences that totaled 43.5 km in length (shortest fence 1.9 km, longest fence 5.9 km) across 4 study sites in 2017. We only experienced a few minor incidents and received positive response from all permittees regarding the effectiveness of the temporary electric fences and temporary cattle guards.

Weather and Climate Monitoring

We obtained precipitation (Fig. 7) and temperature (Fig. 8) at 5 weather stations that were operated by RAWS and NOAA. In general, precipitation was at or above average during the winter leading up to the 2017 nesting season (April – June) and below average during the nesting season. Big Butte in particular had very high snow pack during the 2016 – 2017 winter. Continued collection of precipitation and temperature data will inform future analyses.

We experienced 4 fires on or near our study sites in 2017 (Table 3). One of these fires (at our Big Butte site) burned the entirety of one of our study pastures. At Sheep Creek, we may need to alter our fence in one pasture to exclude grazing of the burned area by the Black Fire in 2018 as per BLM policy. Burned areas are displayed in Figures 9 and 10.

Table 3. Name, ignition source, duration, and total acres burned for fires that burned on or near study pastures that are part of the Grouse & Grazing Project in 2017.

			Duration		Total
Site	Fire Name	Ignition Source	Start	End	Acres Burned[1]
Big Butte	Wildhorse	Lightning	30-Jul	2-Aug	27,184
Big Butte	Lava Flow	Lightning	2-Aug	6-Aug	22,641
Sheep Creek	Mustang	Lightning	13-Sep	13-Sep	1,247
Sheep Creek	Black	Lightning	13-Sep	13-Sep	847

[1]Not all of these acres were within experimental study pastures. Total area burned in our study pastures was: 6956 acres at Big Butte (6464 acres in Sunset South pasture and 492 acres in Serviceberry pasture) and 73 acres at Sheep Creek (all in Slaughterhouse North pasture).

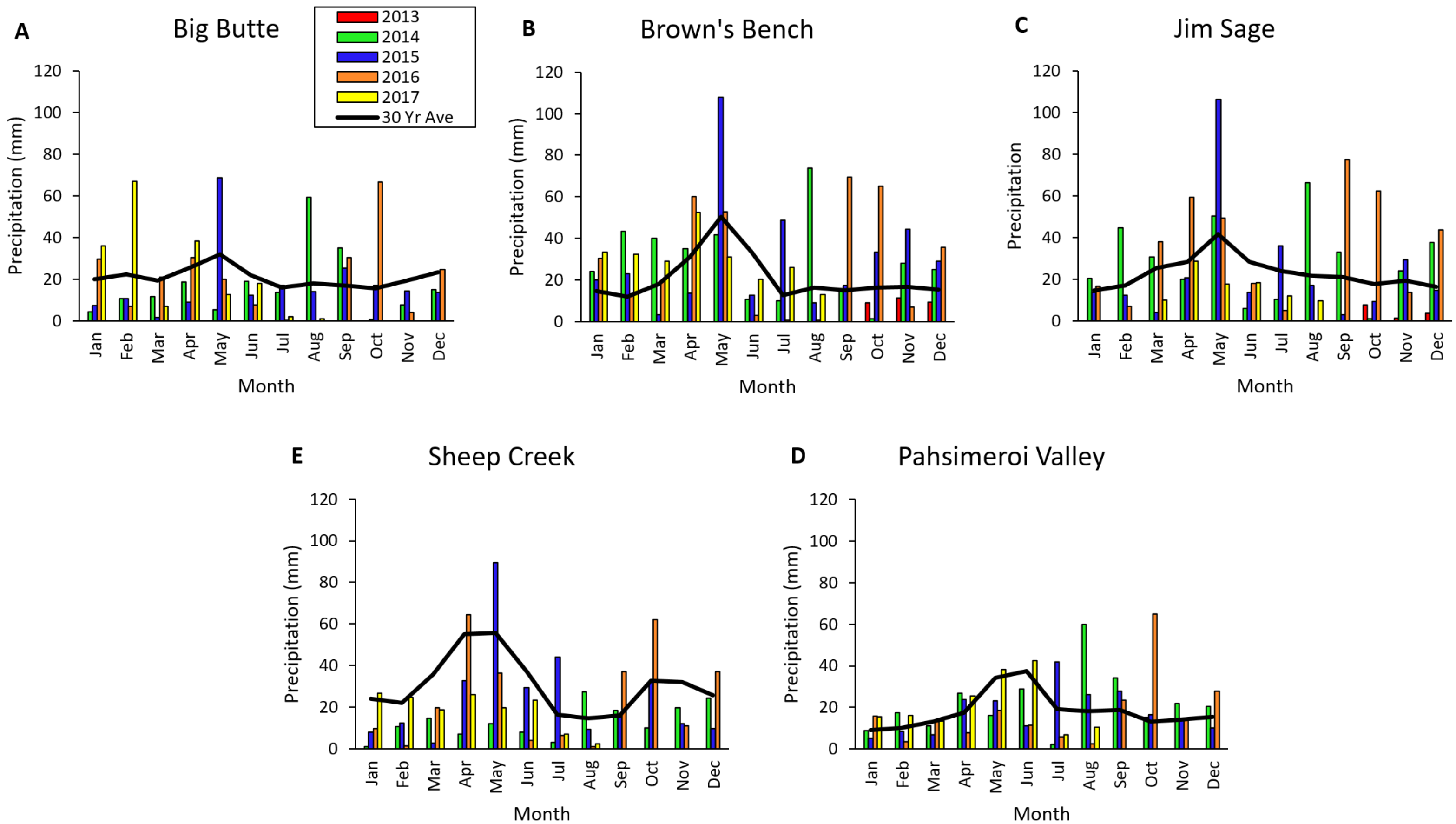


Figure 7. Precipitation (mm) by month for 5 study sites in southern Idaho from 2014-August 2017. Jim Sage and Brown's Bench also include data from October-December 2013. Dark Lines in each plot represent 30-year average for comparison. Weather data were recorded at RAWS stations: at Big Butte we used Arco station (43.623, -113.387); Sheep Creek, Pole Creek station (42.069, -115.786); Jim Sage, City of Rocks (42.091, -113.631); and Browns Bench, Bull Springs (42.080, -114.485). Pahsimeroi data were recorded at NOAA station May 2 SSE (44.5663, -113.895). The 30-year averages were recorded at alternate sites for Jim Sage at Malta 4 ESE (42.300, -113.300), Brown's Bench at Jackpot, NV (41.9867, -114.674), and Sheep Creek at Murphy Desert Hot Springs (42.0264, -115.362).

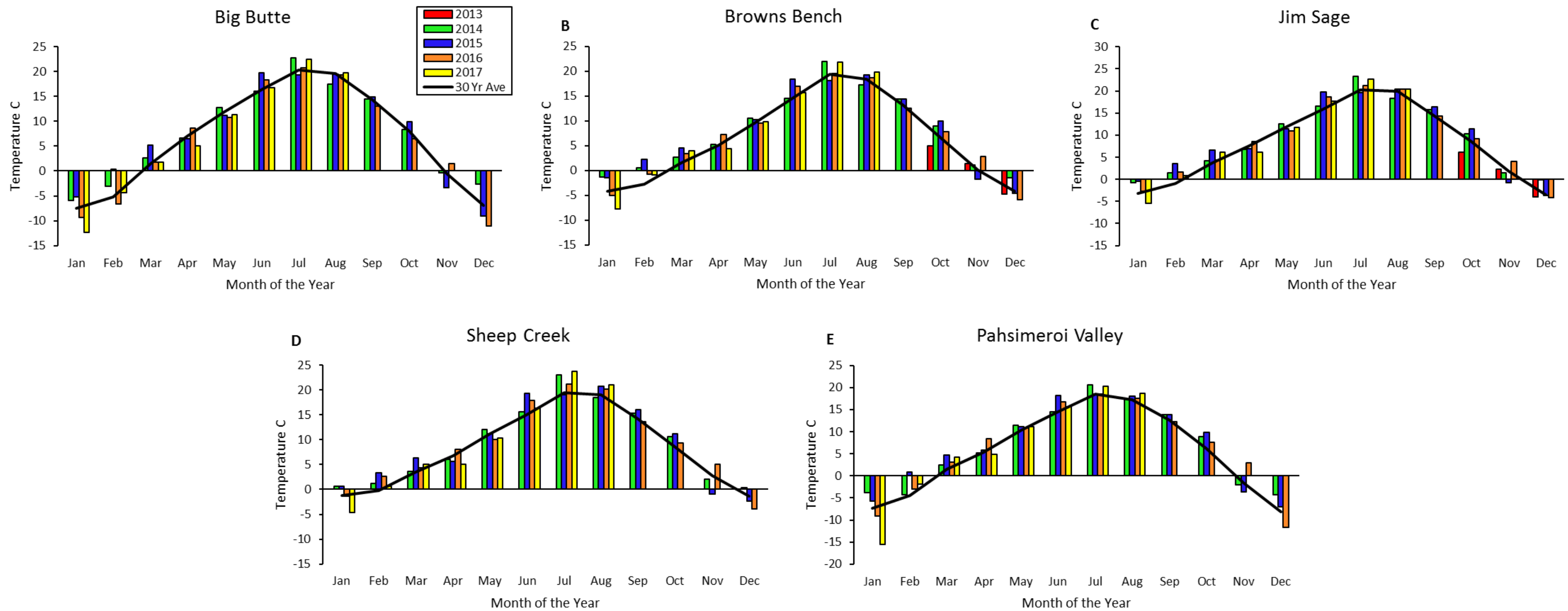


Figure 8. Temperature (C) average by month for 5 study sites in southern Idaho from 2014-August 2017. Jim Sage and Brown's Bench also include data from October-December 2013. Dark Lines in each plot represent 30-year average for comparison. Weather data were recorded at RAWS: at Big Butte we used Arco (43.623, -113.387); Sheep Creek, Pole Creek (42.069, -115.786); Jim Sage, City of Rocks (42.091, -113.631); and Browns Bench, Bull Springs (42.080, -114.485). Pahsimeroi data were recorded at NOAA station May 2 SSE (44.5663, -113.895). The 30-year averages were recorded at alternate sites for Jim Sage at Malta 4 ESE (42.300, -113.300), Brown's Bench at Jackpot, NV (41.9867, -114.674), and Sheep Creek at Murphy Desert Hot Springs (42.0264, -115.362).

Figure 9. Burned areas of the Black and Mustang fires near the Sheep Creek study site in 2017.

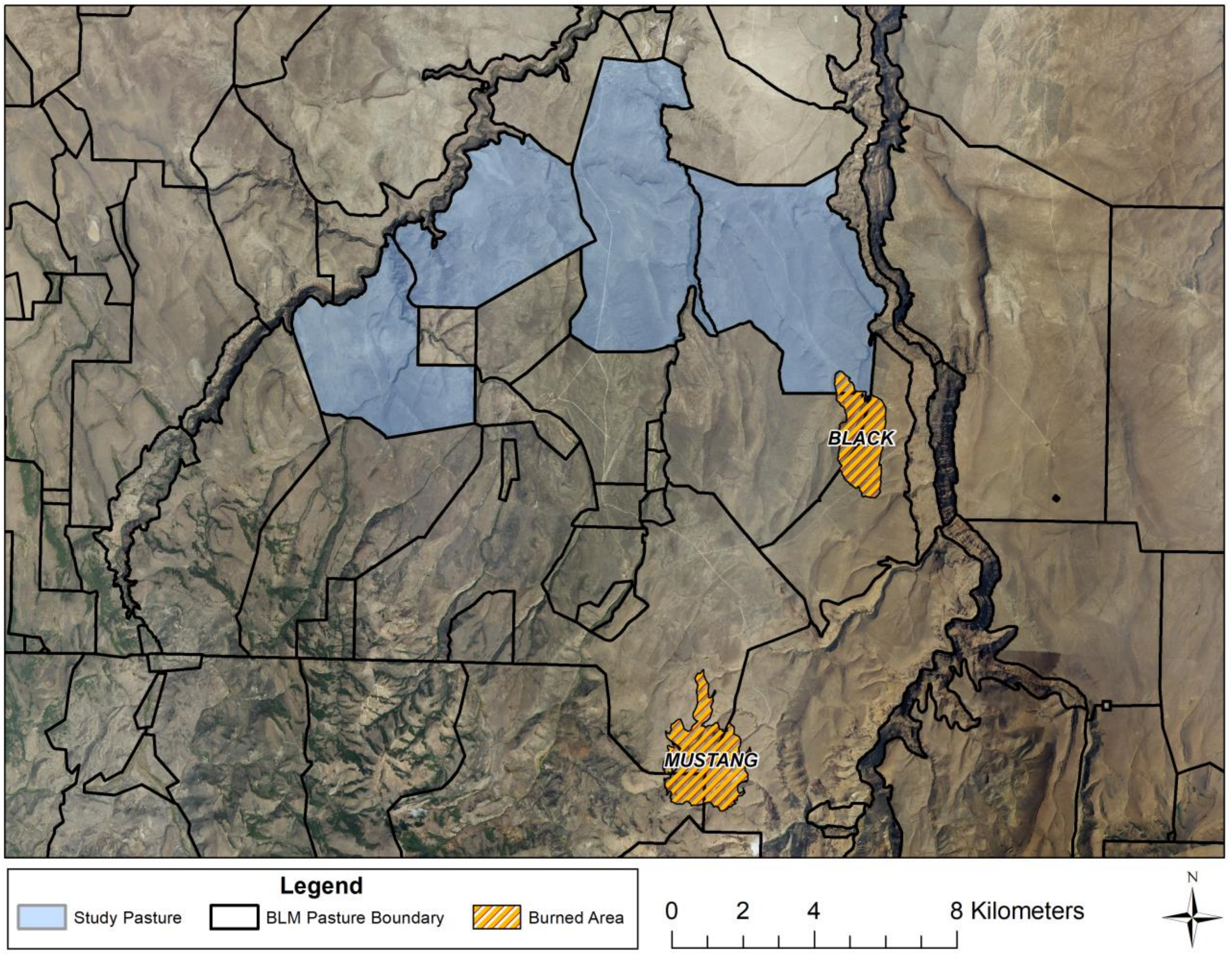
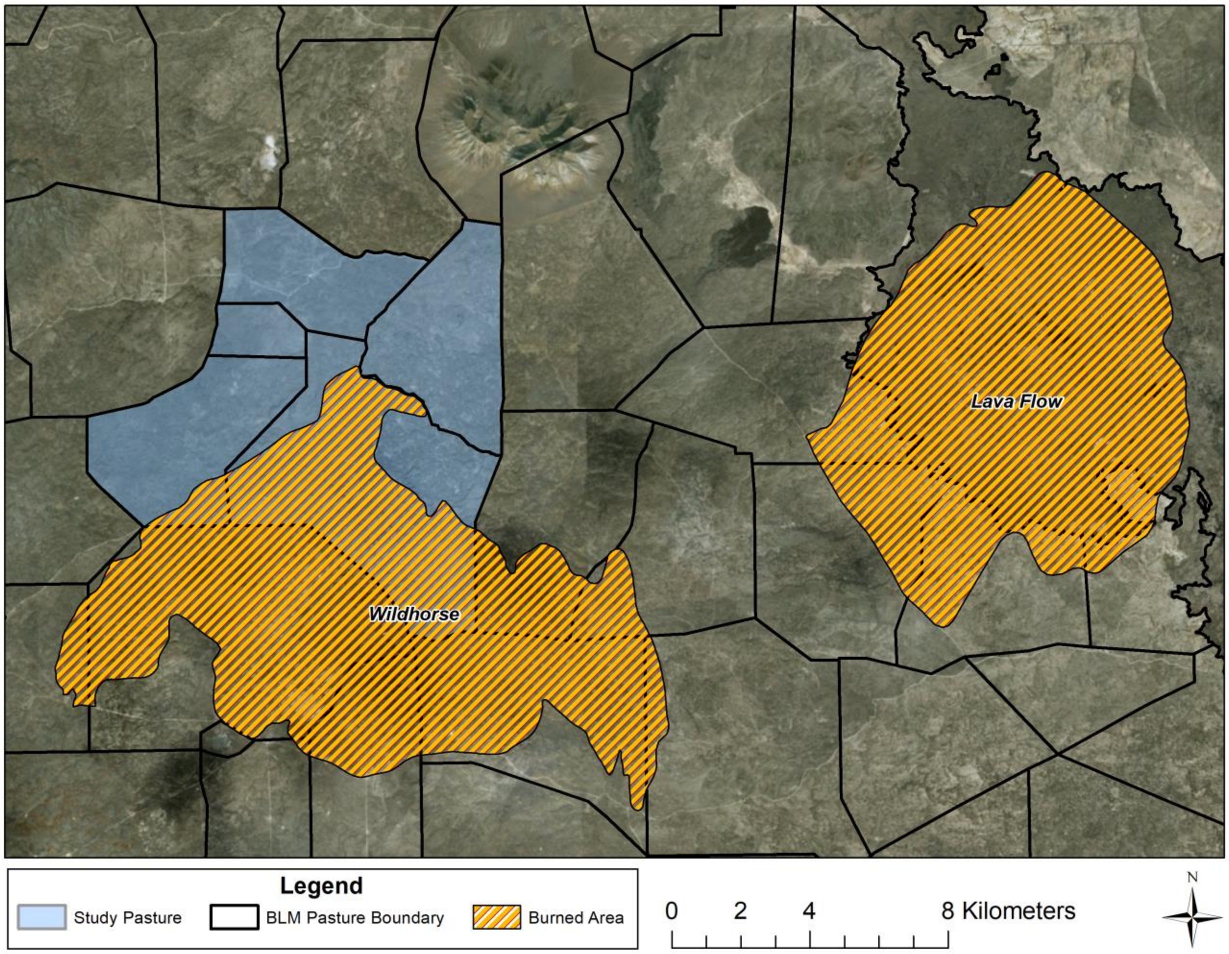


Figure 10. Burned areas of the Wildhorse and Lava Flow fires near the Big Butte study site in 2017.



Capture and Radio-collaring

We deployed new VHF radio transmitters on 130 female sage-grouse across 5 sites in spring 2017: 75 adults (58%) and 55 yearlings (42%; Table 4). In addition, 59 radio-marked hens whose VHF collars were deployed in past years were present at our sites in February 2017. Hence, we tracked 189 radio-collared hens in 2017: 71% adults and 29% yearlings. We recovered/documented 36 mortalities during the 2017 field season (March-July): 24 adult females and 10 yearling females.

Table 4. Summary of female greater sage-grouse that were alive (≥5 detections) and had an active radio collar at the start of the 2017 field season (March) and the year in which they were initially collared. Also included are all confirmed mortalities of radio-collared hens during the 2017 field season (March-August) at 5 study sites in southern Idaho in 2017.

Site	Year Initially Collared 2014	2015	2016	2017	2017 Mortalities
Big Butte	-a	4	7	36	14
Browns Bench	1	2	13	31	11
Jim Sage	0	1	9	13	2
Pahsimeroi	-a	0	16	27	7
Sheep Creek	-a	0	6	23	1
TOTAL	1	7	51	130	35

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

Nest Searching and Monitoring

We located a total of 94 nests across 5 study sites in 2017 (including nests inside and outside of our focal/experimental study pastures). Of these 94 nests we could not determine the fate of 3 for various reasons. Of the remaining 91 nests, 25 were successful (27.5%), 66 were un-successful (72.5%). Of the 94 nests monitored in 2017, 80 were thought to be initial nesting attempts and 14 were documented re-nest attempts.

Nesting Propensity

Nesting propensity in 2017 was 91% (n = 113) and 72% (n = 81) for the 2 methods we used; the 2 methods differed in the number of birds included in the denominator that were effectively tracked (see Methods section). Nesting propensity varied across sites from 61-100% for method 1 and varied from 45-86% for method 2 (Table 5). We used our 2 methods to calculate overall nesting propensity for earlier years in the study for comparison (Table 6).

Table 5. 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 2017.

Site	Initiated Nests[c]	Method 1[a]		Method 2[b]	
		Birds Tracked	Propensity	Birds Tracked	Propensity
Big Butte	14	14	100.0	25	56.0
Brown’s Bench	17	20	85.0	28	60.7
Jim Sage	15	17	88.2	18	83.3
Pahsimeroi	19	19	100.0	22	86.4
Sheep Creek	16	19	84.2	20	80.0
Overall	81	89	91.0	113	71.7

[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 1 June”

[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 (meaning located at least once per week) between capture date and last documented nest initiation date (~1 June)"
[c]Number of birds that initiated at least one nest

Table 6. 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, 2014-2017.

Year	Initiated Nests[c]	Method 1[a]		Method 2[b]	
		Birds Tracked	Propensity	Birds Tracked	Propensity
2014	50	56	89.3	63	79.4
2015	110	121	90.9	135	81.5
2016	115	133	86.5	138	83.3
2017	81	89	91.0	113	71.7
Total	356	399	89.2	449	79.3

[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 1 June"
[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 (meaning located at least once per week) between capture date and last documented nest initiation date (~1 June)"
[c]Number of birds who initiated at least one nest

Nest Success

Apparent nest success was slightly lower in 2017 compared to prior years at Brown's Bench and Jim Sage, but higher than past years at Big Butte (Table 7). RMARK estimates of nest success were lower than apparent nest success at all sites individually and all sites combined (Table 8).

Table 7. Apparent nest success and clutch size (± standard error) of greater sage-grouse at 5 study sites in southern Idaho, 2014-2017.

	Apparent Nest Success (%)				Clutch Size at Hatched Nests ± SE			
Study Site	2014	2015	2016	2017	2014	2015	2016	2017
Browns Bench	54	67	38	21	7.3 ± 0.5	6.3 ± 0.6	7.2 ± 0.4	6.0 ± 0.4
Jim Sage	29	44	33	23	7.0 ± 0.4	6.4 ± 0.7	5.8 ± 0.4	6.0 ± 0.6
Big Butte	-[a]	30	29	36	-[a]	6.6 ± 0.8	5.5 ± 0.5	5.4 ± 0.9
Sheep Creek	-[a]	33	33	30	-[a]	5.4 ± 0.7	8.0 ± 0.5	6.2 ± 0.5
Pahsimeroi	-[a]	-[a]	-	28	-[a]	-[a]	-[b]	5.9 ± 0.6

[a] We did not conduct field work during the specified year
[b] Data were not collected on clutch size

Table 8. Summary of greater sage-grouse nests by study site and pasture at 5 study sites in southern Idaho in 2017. Apparent nest success and nest success calculated using RMark for each study site (BIBU = Big Butte, BRBE = Browns Bench, JISA = Jim Sage, PAVA = Pahsimeroi Valley, and SHCR = Sheep Creek).

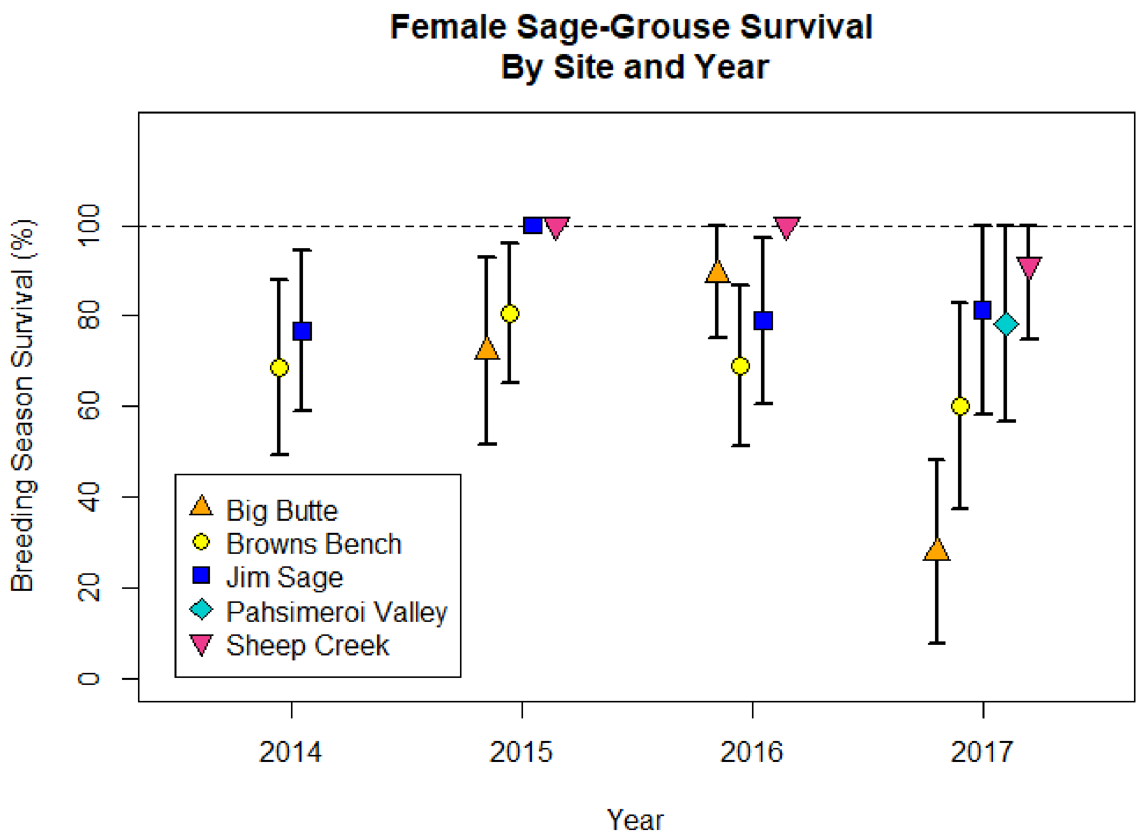
Site	Pasture Name	Failed	Hatched	Total	Apparent Nest Success	RMark Nest Success
BIBU	Butte South	3	0	3		
	Serviceberry	2	2	5[1]		
	Sunset North	1	0	1		
	Sunset South	2	0	2		
	Other Pastures	1	3	4		
	Total	9	5	15[1]	35.7	30.3
BRBE	Browns Creek East	5	1	6		
	China Creek BLM #1	0	2	2		
	Corral Creek East	2	0	2		
	Indian Cave North	1	1	2		
	Indian Cave South	1	0	1		
	Other Pastures	6	0	6		
	Total	15	4	19	21.1	12.1
JISA	Kane Springs	1	3	5[1]		
	Sheep Mountain North	6	0	6		
	Sheep Mountain South	2	0	2		
	Other Pastures	1	0	2[1]		
	Total	10	3	15[1]	23.1	21.1
PAVA	Donkey Hills	5	0	5		
	Goldburg NE - Big Gulch	4	2	6		
	Goldburg NW - Bear Creek	0	1	1		
	Goldburg SE - Summit	0	2	2		
	Goldburg SW - Donkey Creek	1	0	1		
	River	5	0	5		
	West River Flat	2	0	2		
	Other Pastures	1	2	3		
	Total	18	7	25	28.0	16.9
SHCR	East Blackleg North	2	0	2		
	Slaughterhouse North	2	1	3		
	Tokum-Bambi East	2	0	2		
	Tokum-Bambi West	2	2	4		
	Other Pastures	6	3	9		
	Total	14	6	20	30.0	21.3
	2017 Overall Estimate	66	25	94[1]	27.5	19.4

[1] *Includes 1 nest in each of these 3 pastures whose fate was not determined and so numerator for apparent nest success did not include these nests.*

Hen Survival

Hen survival has varied across years and sites. Sheep Creek has had the highest survival since we began work there in 2015. Survival at both Browns Bench (60.1 - 80.4) and Big Butte (27.9 - 89.2) have shown the greatest fluctuation in survival rates among years. In 2017, hen survival at Big Butte was significantly lower than all study sites except Browns Bench. We did not record any mortalities during the breeding season at Jim Sage in 2015 or Sheep Creek in 2015-2016 and therefore had survival estimates of 100% and could not estimate any confidence intervals.

Figure 11. Estimates of hen survival and 95% confidence intervals during our field season (1 March – 15 July) across 5 study sites from 2014-2017. The dotted line represents 100% survival. We did not record any breeding season mortalities at Sheep Creek in 2015-2016 or at Jim Sage in 2015.



Hatch Date

Mean hatch date ranged from 21-May (Browns Bench and Sheep Creek) to 12-June (Big Butte).

Clutch Size

Mean clutch size across sites ranged from 5.4 – 6.2 eggs per hatched nest in 2017 (Table 9). The largest clutch we recorded was 8 and the smallest was 4. Mean clutch size across all 5 study sites was 5.9 eggs per hatched nest.

Table 9. Average hatch date and clutch size for greater sage-grouse nests (only nests that were successful) at 5 study sites in southern Idaho for 2017.

Site	Hatch Date			Clutch Size		
	mean	SE	n	mean	SE	n
Big Butte	12-Jun	5.1	5	5.4	0.9	5
Browns Bench	21-May	5.1	4	6	0.6	4
Jim Sage	7-Jun	3.8	3	6	0.4	3
Pahsimeroi Valley	9-Jun	5.2	7	5.8	0.6	7
Sheep Creek	21-May	5.0	6	6.2	0.5	6
All 5 Sites	**2-Jun**	**2.9**	**25**	**5.9**	**0.3**	**25**

Brood Monitoring

In 2017, we conducted 77 brood flush surveys, 110 brood fecal pellet surveys, and 6 spotlight surveys on 20 sage-grouse hens across 5 study sites. Brood survival was 45.0% (*n* = 9 of 20 broods reached 42 days). This was similar to the 50% brood success from 2014-2015 (Conway et al. 2016). Brood survival is part of Ian Riley's graduate thesis and more detailed analyses will be available soon in his M.S. thesis (anticipated graduation in December 2018).

Table 10. Greater sage-grouse breeding productivity for 5 study sites in southern Idaho in 2016 and 2017. Hatch success is the percent of all nests located that were successful (eggs hatched), and brood survival is the percent of hatched nests (broods) where ≥1 chick survived to 42 days after hatch.

Site	2016			2017		
	Nest Attempts	**Hatch success**	**Brood survival**	**Nest Attempts**	**Hatch success**	**Brood survival**
Big Butte	28	28.6% (8)	50.0% (4)	15[a]	35.7% (5)	0.0% (0)
Brown's Bench	34	38.2% (13)	61.5% (8)	19	21.1% (4)	66.7% (2)
Jim Sage	21	33.0% (7)	28.6% (2)	15[a]	23.1% (3)	50.0% (1)
Sheep Creek	15	33.3% (5)	40.0% (2)	20	30.0% (6)	33.3% (2)
Pahsimeroi	-[c]	-[c]	-[c]	25	28.0% (7)	57.1% (4)
TOTAL	**98**	**33.7% (33)**	**45.0% (16)**	**94**[a]	**27.5% (25)**	**45.0% (9)**[b]

[a]*Fate was not determined for 1 nest at Big Butte and 2 nests at Jim Sage, so denominator for hatch success was reduced accordingly.*
[b]*Fate was not determined for 5 broods, so denominator for brood survival was reduced accordingly.*
[c]*Data for nests and broods were not collected in 2016*

Vegetation Sampling

In 2017, we conducted vegetation sampling in April-June at 92 nest plots, 50 dependent plots, and 351 random plots for a total of 493 vegetation plots across 5 study sites: Big Butte, Brown's Bench, Jim Sage, Pahsimeroi Valley, and Sheep Creek. We conducted vegetation surveys at fewer dependent plots than nest plots because we did not conduct dependent plots for some of the nests that were far from our experimental pastures (additionally we put lower priority on these plots when we were time- or personnel-limited at an individual site). We sampled grass height and grazing intensity metrics for 31,684 grasses on the 493 vegetation surveys at the 5 sites in 2017. We re-sampled 384 random plots (22,413 grasses) at the end of the growing season (July-August). In 2017, we estimated percent utilization (and the most common grass, the dominant shrub, and the percent cover of cheatgrass) at 4,359 sampling locations for the landscape appearance method, and we used these data for pattern use mapping at all 5 study sites. While conducting the 2017 landscape appearance transects at the 5 study sites, we also measured height, species, and evidence of grazing for 11,337 individual grasses.

Nest Shrub Patch

The majority of sage-grouse nests were located under Wyoming big sagebrush (Table 11). Low sagebrush and black sagebrush were the next most utilized species respectively.

Table 11. Percent of greater sage-grouse nest sites that were under different plant species compared to the percent of focal shrubs at random plot locations across 5 study sites in southern Idaho 2014-2017. During the first few years, all random plots were centered on a sagebrush shrub (as per our sampling protocols) so it was impossible for the focal shrub on a random plot to be anything other than a sagebrush shrub.

Common Name	*Scientific Name*	Nest Sites	Random Plots
Wyoming Big Sagebrush	*Artemisia tridentata wyomingensis*	42.6	39.2
Low Sagebrush	*Artemisia arbuscula*	13.5	23.1
Black Sagebrush	*Artemisia nova*	12.8	14.4
Three-tip Sagebrush	*Artemisia tripartita*	9.1	9.3
Basin Big Sagebrush	*Artemisia tridentata tridentata*	7.5	6.0
Mountain Big Sagebrush	*Artemisia tridentata vaseyana*	5.6	5.7
Rubber Rabbitbrush	*Ericameria nauseosa*	4.4	0.7
Green Rabbitbrush	*Chrysothamnus viscidiflorus*	2.8	1.2
Antelope Bitterbrush	*Purshia tridentata*	0.6	0
Shadscale Saltbush	*Atriplex conferifolia*	0.3	0
Western Juniper slash pile	*Juniperus occidentalis*	0.3	0
Spineless Horsebrush	*Tetradymia canescens*	0.3	0
Saskatoon Serviceberry	*Amelanchier alnifolia*	0	0.2
Mountain Mahogany	*Cercocarpus montanus*	0	0.1
Common Snowberry	*Symphoricarpus albus*	0	0.1

Shrub Cover

Shrub cover at successful nests was slightly greater than shrub cover at failed nests and both had more shrub cover than random plots (Fig. 12). Successful nests were more common than expected (based on availability on random plots) for all shrub cover categories above 20% and less common than expected in areas with <20% shrub cover (Fig. 13).

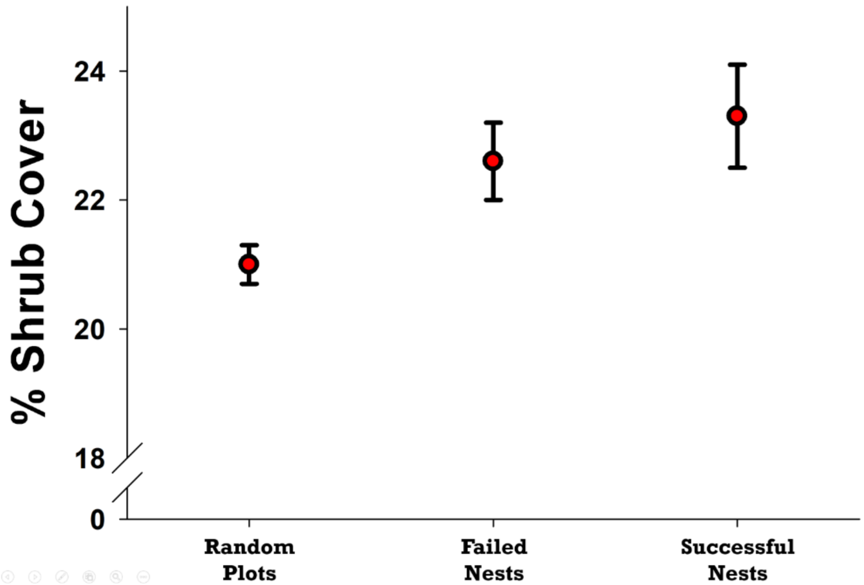


Figure 12. Percent total shrub cover at random plots, successful nests, and failed nests of greater sage-grouse at 5 study sites in southern Idaho during 2014-2017. Error bars represent standard error around mean.

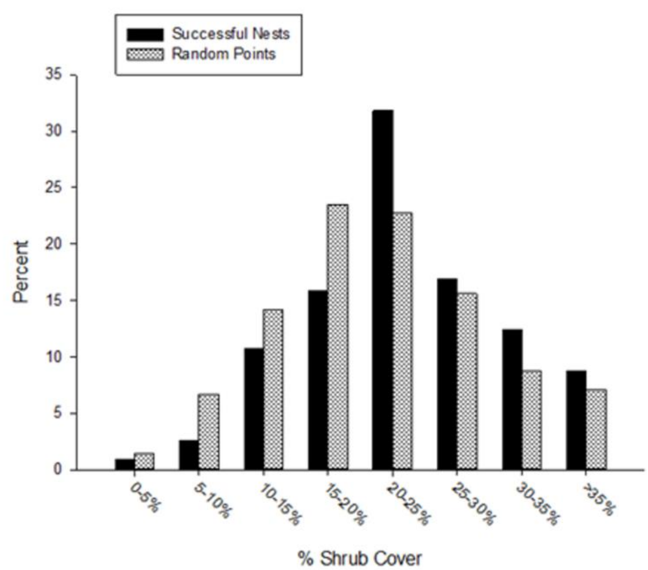


Figure 13. Percent random plots (hatched bars) and successful nest plots (solid black bars) where the average shrub cover was within each of 8 shrub cover categories. Data are for greater sage-grouse at 5 study sites in southern Idaho during 2014-2017.

Grass and Forb Height

Grass height at successful nests was taller than grass height at failed nests, and grass heights at failed nests were similar to grass heights at random plots (based on all grass species pooled) (Fig. 14). Similarly, forb height at successful nests was taller than forb height at failed nests and at random plots (Fig. 15). Height of ungrazed grasses varied among species and varied among our 5 study sites within species (Julson 2017).

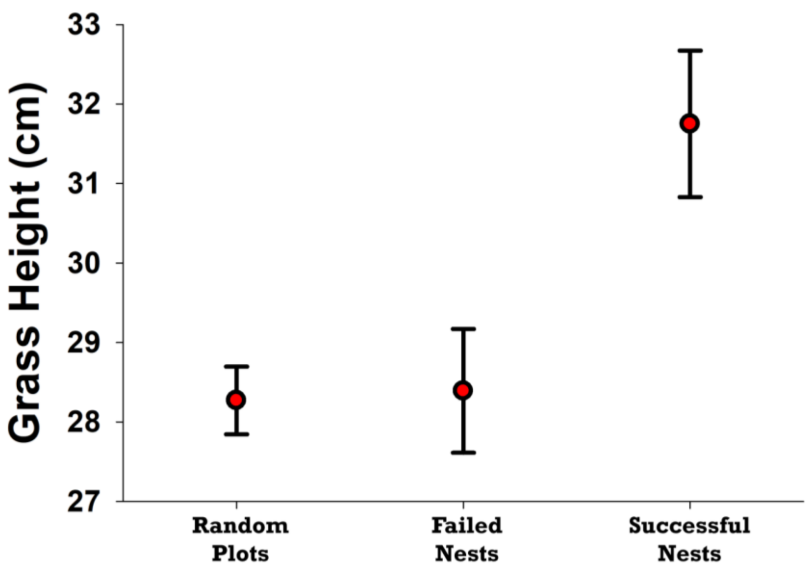


Figure 14. Mean droop height (cm) of grasses at successful and failed nests of greater sage-grouse at 5 study sites across southern Idaho in 2014-2017. The means are based on >60,000 grasses measured. Error bars are presented as means ± 1 standard error.

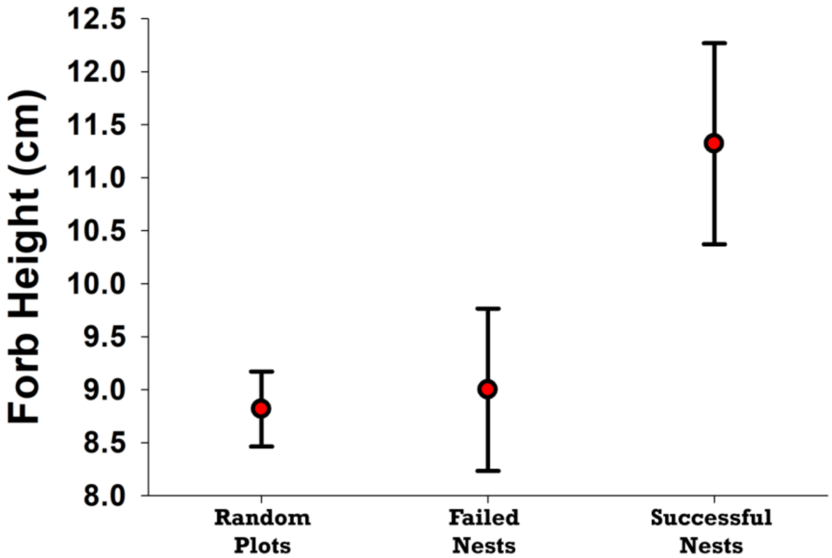


Figure 15. Mean height (cm) of forbs at successful and failed nests of greater sage-grouse at 5 study sites across southern Idaho in 2014-2017. Error bars are presented as means ± 1 standard error.

Utilization

Pattern use mapping indicated that grazing intensity varied spatially within and among the pastures included in our study (Fig. 16). Estimates of utilization vary greatly depending on the method used (Conway et al. 2016).

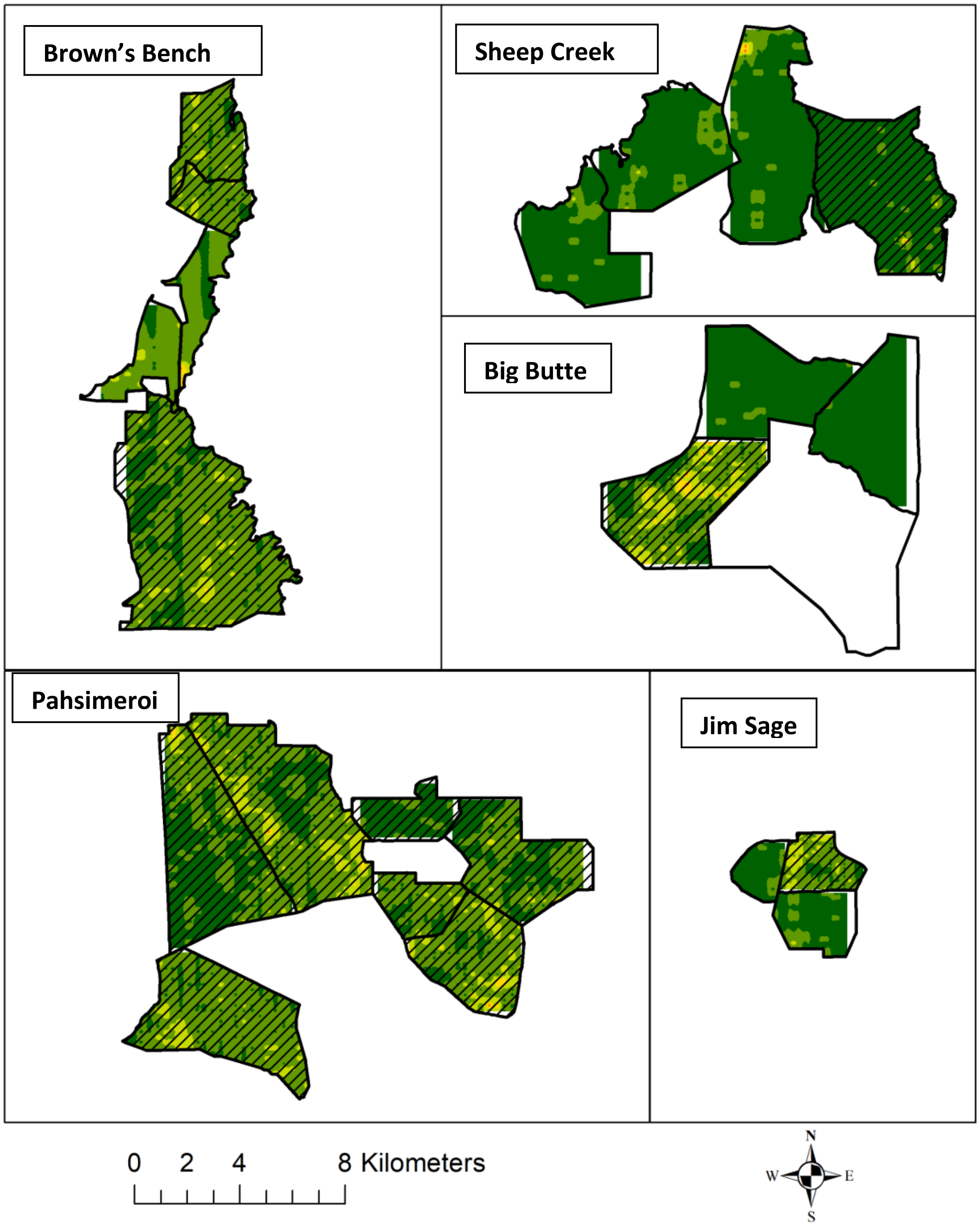


Figure 16. Pattern use mapping based on the landscape appearance method (measured on 19 July - 15 August 2017) for study pastures at 5 study sites in southern Idaho in 2017. Slashed lines through a pasture indicate that it was grazed by cattle prior to or during our data collection. We used an Inverse Distance Weighted (IDW) algorithm to interpolate use across each pasture to create the maps Cooler colors (green) indicate little or no grazing and warmer colors (orange, red) indicate more grazing..

Insect Sampling

We used pitfall traps to sample arthropods at 92 sampling locations across four study sites in 2017 (we did not sample arthropods at Pahsimeroi in 2017): Big Butte, 21 plots; Browns Bench, 18 plots; Sheep Creek, 23 plots; and Jim Sage, 30 plots. We placed pitfall traps at fewer sampling locations in 2017 compared to 2015 and 2016 (Conway et al. 2016) due insufficient funding. Each sampling location had four pitfall traps and we emptied those pitfall traps once per week for 3 weeks, yielding a total of 1,106 pitfall samples collected in 2017. We conducted ant mound surveys along 92 transects (one at each pitfall sampling location) across the 4 study sites in 2017, and measured the distance to (and size of) 133 ant mounds on those 92 transects. Thus far, we have counted, identified, and measured 45,725 arthropods from 424 pitfall trap samples (average of 108 arthropods per pitfall sample). The 45,725 arthropods that we have processed from pitfall traps thus far 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 most common in arthropod orders in diet of sage-grouse chicks. We detected 40 ant mounds ($\geq$1 at 19 of 21 transects) at Big Butte, 27 ant mounds ($\geq$1 at 11 of 18 transects) at Browns Bench, 8 ant mounds ($\geq$1 at 6 of 30 transects) at Jim Sage, and 58 ant mounds ($\geq$1 at 17 of 23 transects) at Sheep Creek. Hence, ant mounds were most common at Sheep Creek and least common at Jim Sage.

DISCUSSION

In 2017, we hired 20 seasonal technicians and 5 crew leaders to collect data at 5 study sites. This was the 4th year of the Grouse & Grazing project (a 10-year project) and we collected post-treatment data at 2 study sites in 2017. Our sample sizes are too small to report results of the experimental grazing treatments; the study is not yet complete and 6 more years are planned, after which sufficient data should be able to compare the grazing treatments rigorously.
The winter of 2016-2017 was particularly long with snowfall and spring snow pack that were much higher than average. The late snowpack and with so much snow melting, we had difficulty accessing several study sites to trap grouse (especially at Big Butte). We began field work at Pahsimeroi in 2017 and anticipated that grouse nesting would be delayed by several weeks there (compared to our other 4 study sites), but that was not the case.

Nest success was lower in 2017 compared to past years at 2 study sites (Brown's Bench and Jim Sage), but was higher at Big Butte (and similar at Sheep Creek). However, our estimates of nesting success were still within the range that has been reported by other studies (15-70%; Connelly et al. 2011) albeit on the lower end of this range.

Our estimates of apparent nest success were higher than our estimates of nesting success based on the Mayfield method. Apparent nest success is biased high (i.e., it always yields higher estimates than those from the Mayfield method) unless all nests are located and monitored on or prior to the first laid egg. If we do not locate successful nests early in their exposure period then we should expect a larger discrepancy between the two methods. We attempt to confirm a nest after a hen remains in the same area on repeated monitoring visits, but we are extremely cautious and minimize our disturbance to laying/nesting hens. Confirming a nest is difficult during the egg laying period because the hen usually only visits the nest for a few hours to lay her egg then leaves. This difficulty is compounded by the overlap of trapping activities during the early portion of the laying and nesting period.

Estimates of nesting propensity are very sensitive to how the metric is calculated. We capture hens during winter and some of the signals disappear (perhaps because they leave the study area to breed or to nest) and others move so far from our study area that we choose not to monitor them regularly. 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 most likely to detect their nest had they indeed nested. Our estimates of nesting propensity based on these two approaches (91% and 72%) are similar to those reported by others (78% in Connelly et al. 1993 and 81% in Holloran et al. 2005). Other grouse species may forego nesting in years with less than optimal conditions (i.e., drought, high temperatures; Grisham et al. 2014).

Sage-grouse nest sites had higher shrub cover than random sites and this pattern is consistent with other sage-grouse studies (Wakkinen 1990, Connelly et al. 1991, Holloran et al. 2005). Our results suggest that the average shrub cover within the allotments where we work is within the 15-25% recommended by Connelly et al. (2000), but that grouse are actively seeking out the patches with 20-40% shrub cover to place their nests (and nest in areas with <20% total shrub cover less often than would be expected based on its availability). Other studies have reported that shrub height also is often greater at nest sites than at random plots (Klebenow 1969, Sveum et al. 1998, Holloran et al. 2005); greater shrub height likely provides greater concealment from ground and aerial nest predators. Many areas had 40-80 cm tall shrubs – the range recommended by Crawford et al. (2004).

Mean droop height of grass (averaged across all species) was taller at successful nests compared to failed nests and random plots. Average grass height at all 3 plot types was greater than the recommended 18 cm (7 inches) for sage-grouse nesting habitat (Connelly et al. 2000, Crawford et al. 2004).

Previous sage-grouse studies have also reported higher grass cover at nest sites compared to random plots (Gregg et al. 1994, Sveum et al. 1998). Greater coverage of taller grasses can provide visual obstruction at ground level to help supplement overhead cover provided by sagebrush and other shrubs (Sveum et al. 1998). The relationships presented here provide an initial indication of the data that this project will generate regarding the multifaceted relationship between grazing, shrub and sagebrush cover, and grass density (Hendrick et al. 1996, Bork et al. 1998, Strand et al. 2014, Sowell et al. 2016). Estimates of utilization (percent of the annual grass biomass removed by herbivores) vary depending on the method used (Conway et al. 2016). Various methods of measuring utilization may be more beneficial for answering certain questions and further investigation into the most appropriate method is warranted.

Grass heights for the same species vary greatly among our study sites (Conway et al. 2016). Grass heights likely vary at even more localized scales (e.g., within pastures or drainages). One problem we have encountered in our utilization by height reduction approach was that we encountered negative utilization values on 30% of the grazed grasses measured (i.e., the grazed grass plants were taller than the 5 nearest non-grazed plants of the same species despite having been grazed) (Conway et al. 2016). This result could reflect one of several things: 1) perhaps cattle are more likely to remove the upper portions of the tallest grass plants while they graze (leaving smaller grass plants of the same species un-grazed), 2) perhaps grazed grasses experienced heightened regrowth after grazing, 3) ungrazed grasses may be more likely to be knocked over or drooped over and so the droop height might be lower than a grazed grass despite more biomass, or 4) a combination of the above mechanisms. Estimates of utilization from utilization cages may be the most appropriate solution to this problem.

Utilization varied spatially within individual pastures (as well as among pastures) which highlights the need for spatially explicit methods of mapping utilization. By accounting for and mapping this spatial variation, we will be able to rigorously investigate how utilization patterns may affect nest-site selection by sage-grouse within a given pasture.

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