Grouse & Grazing - 2016 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 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 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 scientific studies that have explicitly examined the effects of livestock grazing on sage-grouse. The objective of the Grouse & Grazing study is to document the effects of spring cattle grazing on sage-grouse demographic traits, nest-site selection, and habitat features. We focus 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 (2014-2016) 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*), and green rabbitbrush (*Chrysothamnus viscidiflorus*). The most common understory grasses (ordered based on their abundance in our 2016 surveys) include Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Elymus elymoides*), bluebunch wheatgrass (*Pseudoroegneria spicata*), western wheatgrass (*Pascopyrum smithii*), and Thurber's needlegrass (*Achnatherum thurberianum*).

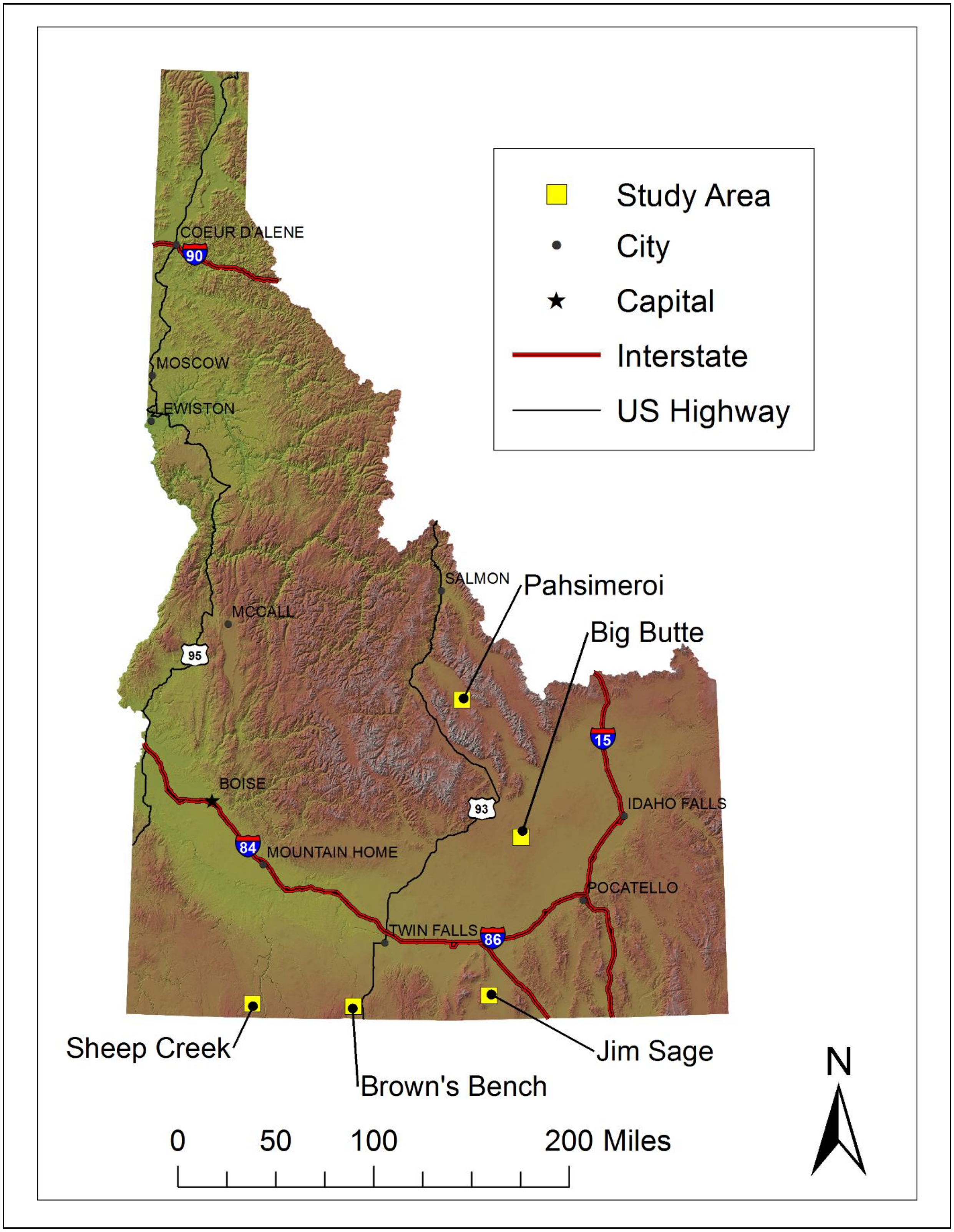

Figure 1. Five study sites in southern Idaho where field work was conducted for the Grouse & Grazing project in 2014, 2015, and 2016.

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 2016 we added a fifth study site (Pahsimeroi). We plan to eventually add 4 more study sites (9 total) in southern Idaho or adjacent states if sufficient funding/support becomes available. Additional study sites are needed to ensure sufficient sample sizes of grouse and grouse nests in each of the 4 experimental grazing treatments. Each study site was selected based on the following characteristics:

1. $\geq$15% sagebrush cover, including a *Artemisia tridentata wyomingensis* component in the overstory
2. Herbaceous understory that is dominated by native grasses and forbs
3. At least one sage-grouse lek of $\geq$ 25 males
4. Adequate road access in spring
5. Cooperative permittees
6. $\leq$38 cm of annual precipitation
7. $\geq$5,700 acres largely free of infrastructure development (i.e., few wind turbines, powerlines)
8. Spring cattle grazing occurs (or is at least allowed in 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 spring 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 ($\geq$2 years before experimental changes in grazing intensity and $\geq$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) for ≥2 years prior to experimental changes in grazing intensity (Fig. 2). These first two years of data allow us to identify the best grazing pastures 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 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	Grazing Treatments	Year 3	Year 4	Year 5	Year 6
Spring Odd Years	Current grazing	Current grazing		Spring Grazing	Rest	Spring Grazing	Rest
Spring Even Years	Current grazing	Current grazing		Rest	Spring Grazing	Rest	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 spring cattle grazing on sage-grouse demographic traits and habitat features.

Capture and Radio-collaring

We used a spotlighting technique (Wakkinen et al. 1992) to capture female sage-grouse at night in February and March of each year. In 2016, we also used rocket-nets (Giesen et al. 1982) to capture greater sage-grouse on a few leks. We recorded the location, 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 study. Once a female became localized (consistent location for 3 consecutive visits), we approached cautiously to confirm if she was nesting. We followed an explicit protocol for locating and monitoring nests. 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 nests). If the hen was found in the same location on subsequent visits, we assumed it was nesting within that cluster of shrubs. To monitor nests, we established a monitoring point approximately 200 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. If the hen was located at a consistent bearing from the monitoring point, we assumed she was incubating. If the bearing 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. 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 (those that were alive and whose signals were detected throughout the nesting season). We considered the nesting period to be 1 April – 15 May based on nest initiation dates and hatch dates from 2015.

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 is likely 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 estimated hatch date to the nearest half day. 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 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 0.5 days 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 flush count survey to document brood survival at 4 time intervals: 7, 14, 28, and 42 days after the estimated hatch date of her nest. We varied 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 flush counts 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. On each flush count survey, we approached the radio-collared sage-grouse hen by homing with telemetry equipment and attempted to flush the radio-collared hen and any chicks present. We counted the number of chicks that flushed and searched the surrounding 15 m from the approximate location the hen flushed to look for chicks that did not flush. We also estimated the distance that the hen flushed.

Brood Spotlight Surveys

We conducted brood spotlight surveys as an additional approach for estimating brood survival at 42 days (i.e., to ensure that flush count surveys were accurate). We conducted brood spotlight surveys >1 hour after sunset and >1 hour before sunrise to ensure complete darkness. 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 varied 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 conducted brood pellet counts at hen roost sites and we are testing the validity of this third method as an alternative approach for estimating brood survival. This third method (brood pellet counts at roost sites) is part of Ian Riley's graduate thesis, as is the comparison among these 3 methods.

Vegetation Sampling

We measured vegetation at three types of plots: nest plots, dependent 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 17 April 2016 to 5 July 2016 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.

Plot Placement

Random plots were placed randomly throughout each study pasture. We conducted vegetation sampling at a minimum of 20 random plots in each pasture and more if time allowed. Dependent 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 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).

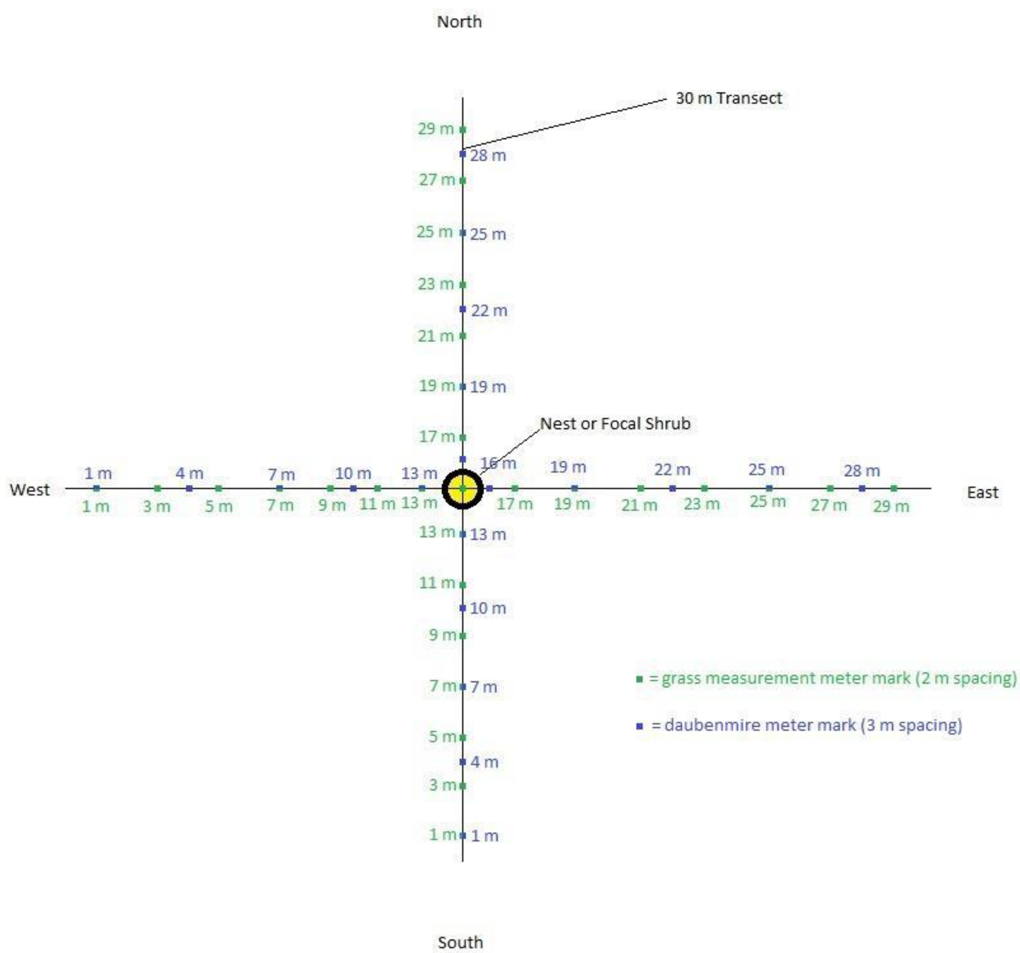

Figure 3. Visual depiction of the placement of two 30-m tapes stretched to conduct vegetation sampling at nest plots, random plots, and dependent (paired) plots for the Grouse & Grazing project in southern Idaho, 2014-2016.

Concealment

We placed a 4187-cm^3 (20-cm or 7.9-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 with the camera 1 m from the ground. We plan to use ENVI 5.3 (Exelis Visual Information Solutions 2015) to estimate the percent of the pink ball (and hence the nest area) concealed by vegetation. We will average the 4 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 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, measured the height, and measured the maximum length and width (measured perpendicularly to the maximum length).

Shrub Cover

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 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 on the edge 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 (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 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).

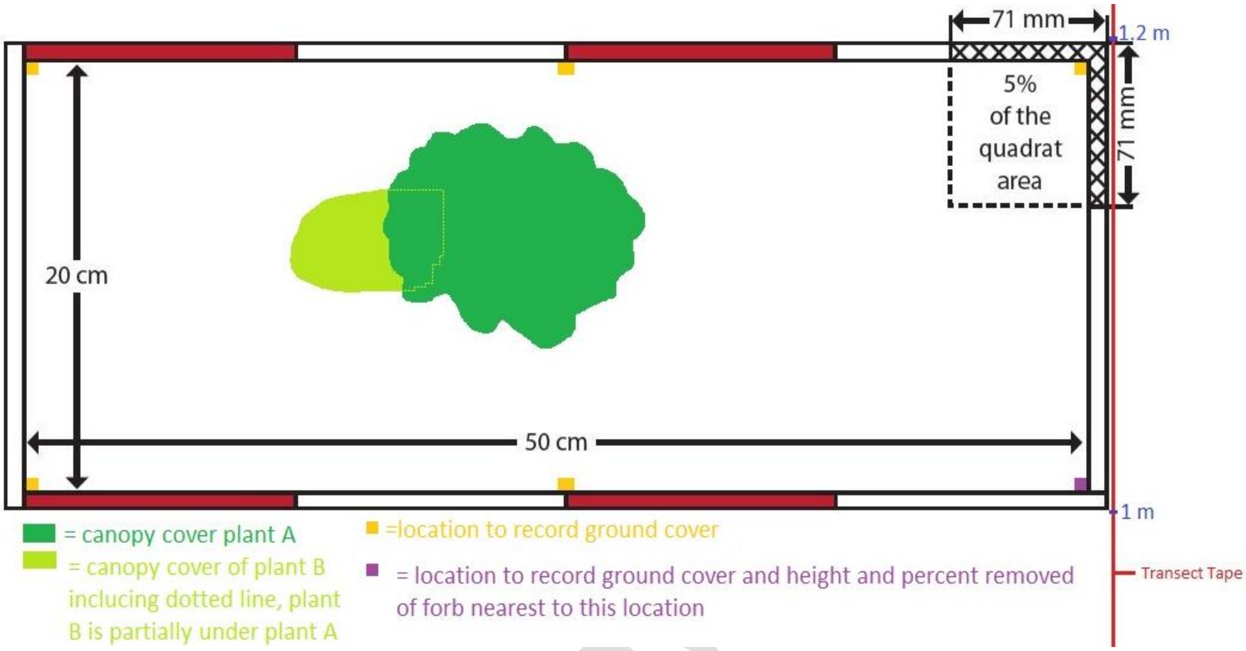

Figure 4. Example of Daubenmire frame cover measurements. Canopy cover of plant A would be an estimate of the percent of the frame the dark green colored area encompasses when looking from above the frame. Canopy cover of plant B would be an estimate of the percent of the frame the light green colored 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 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 Composit	*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 off-take by herbivores (% utilization).

Ocular Estimate Method

We sampled approximately 20 random vegetation sampling plots within each of our 20 experimental pastures twice: 1) from 17 April to 2 July 2016 (described above under "Vegetation Sampling"), and 2) from 18 July to 18 August 2016 (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).

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. If the pasture was grazed during spring/summer 2016, we placed transects 300 m apart and sampled at every 200 m along each transect. If the pasture was not grazed during spring/summer 2016, 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 most dominant overstory shrub 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 2016, we measured grass height for approximately 16 grass plants at every 3^{rd} point along landscape appearance transects (i.e., every 600 m) to improve our utilization estimates. At every 3^{rd} point, we measured heights of grasses and recorded evidence of grazing. First we recorded the closest 4 grass species to the point (up to 1 m away). For each of the 4 closest grasses, 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 (~4 m) forward and repeated this procedure (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" in this case means that foraging ungulates have passed through the area

[b] "complete search" in this case 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) to obtain these data at each of our five field sites over the course of the entire year. Data were collected daily at RAWS 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 each pasture. 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). Insect sampling consisted of 3 different parts: sweep net samples, pitfall traps, and ant mound surveys (Figs. 5-6). 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- by 5-m square, with pitfall traps located in the corners. We placed four 60 x 3.7 x 1 cm drift fences made of wood approximately evenly spaced around two of the four pitfall traps. 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 during the first week of June (for the final 3 weeks of sampling). We collected samples from pitfall traps once every week and traps were deployed for 5-10 weeks. We stored the collected samples in ethanol and propylene glycol.

Sweep Net Samples

We used sweep nets along two 50-m transects that were parallel to one another and spaced 10-m apart. These transects originated one meter beyond the pitfall trap array to avoid disturbance of the pitfall traps (Fig. 5). We used standard sweep nets (38.1 cm diameter). While walking each 50-m transect, we moved the sweep net left and right 1-10 cm above the ground, maintaining momentum of the net to prevent insects from escaping. We walked 3-4 km/hr while sweeping 50 times (i.e., using a sweeping motion to move the net perpendicular to the transect, back and forth, while walking), attempting to perform one sweep per meter. We stored the insects collected from sweep nets in a plastic bag and put the bags in a freezer.

Figure 5. Visual depiction of the layout of transects used for sweep net samples to collect insects in 2016.

Ant Mound Surveys

We conducted distance sampling along a 50-m transect to estimate ant mound density. We used one of the 50-m sweep net transect 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 $\geq$1 ant on the mound).

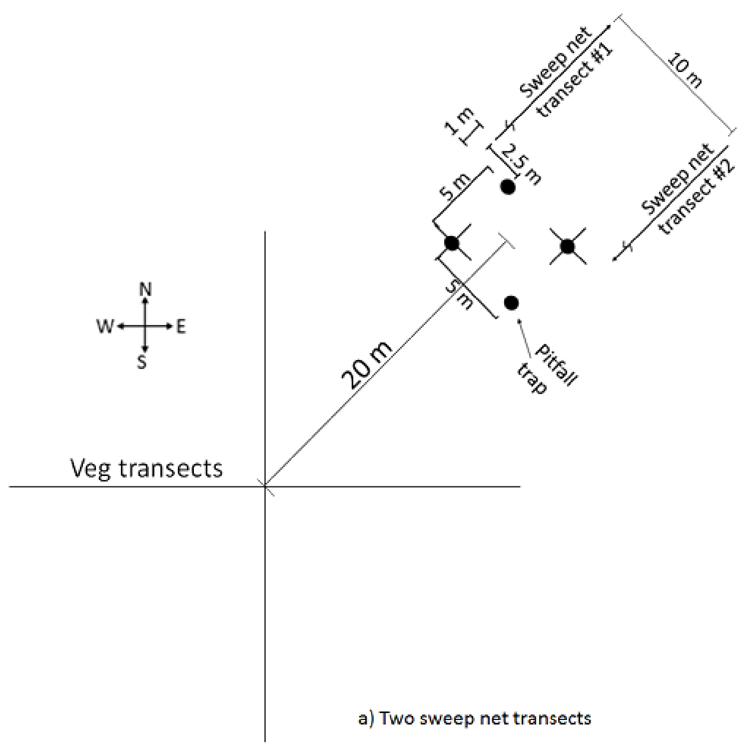

Figure 6. Visual depiction of all 3 insect sampling efforts (sweep net, pitfall, and ant mound) and their orientation in relation to the line transects on an accompanying random vegetation sampling plot.

Statistical Analysis

Nest Success

We calculated apparent nest success by dividing the number of hatched nests by the total number of nests monitored, excluding nests with an unknown nest fate and those that were monitored only once. We calculated apparent nest success for each study site across all years of the study. We also calculated Mayfield (1975) estimates of nest success to account for potential bias in detection of nests that failed early. We calculated average clutch size for hatched nests only 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.

Mayfield Nest Survival

We used methods described by Mayfield et al. (1975) to calculate daily nest survival for each site. We then raised this to the 37.5 power to account for the 37.5 day exposure period of a typical nest. The exposure period included 10.5 days for egg laying (7-egg average clutch size and 1.5 eggs laid per day) and 27 days for incubation. Sage-grouse chicks are precocial and typically leave the nest shortly after hatch (Schroeder et al. 1999) so we did not include any exposure time after hatch.

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. This was pooled across 2015 and 2016.

Grass Height and Shrub Cover

To compare grass heights between nest and random plots, we first calculated the average grass height within individual plots because the plot is our sampling unit. We then calculated the mean of these values for each point to come up with an overall sample mean. We calculated dispersion using standard errors. For comparison of shrub cover at nests and random locations we used the same method of calculating a mean at each point first then an overall sample mean to avoid pseudo-replication. To compare grass heights among study sites we considered the individual grass as the sampling unit and used standard errors as our measure of dispersion.

Utilization

We generated landscape appearance estimates by averaging percent utilization across all points in each pasture. We estimated percent height reduction for each grass in a pasture by subtracting the height of each grazed grass from an average of the 5 nearest un-grazed grasses of the same species and then dividing that difference by that average of the 5 nearest un-grazed grass of the same species. For 677 out of 2,219 grazed grasses measured (30%), 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. Our third approach for estimating utilization (percent of grazed plants) was calculated by dividing the number of plants 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 using 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 point.

SUMMARY AND PRELIMINARY ANALYSES

Field Effort

We hired 4 crew leaders, 8 wildlife technicians, and 7 range technicians across four field sites in 2016. Bart Zwetzig (BLM) and Nick Reith (USFS) conducted most of the field work at our 5th study site (Pahsimeroi) in 2016, except for the late-season vegetation sampling (vegetation plots at random sampling points and landscape appearance transects). Three University of Idaho graduate students (Gotsch, Julson, Riley), a field coordinator (Locatelli), and 2 IDFG biologists (Cross and Musil) also worked full-time on the project. From 29 February through 21 August 2016, field personnel worked approximately 18,000 person hours collecting field data on the project. R.Rosentreter and J.Connelly provided field training on plant identification to all field personnel.

Weather and Climate Monitoring

We obtained precipitation and temperature at five weather stations that were operated by RAWS. In general, precipitation was above average during the fall and below average during the spring and summer at most sites in 2016 (Fig. 7). Continued collection of precipitation data will inform future analyses.

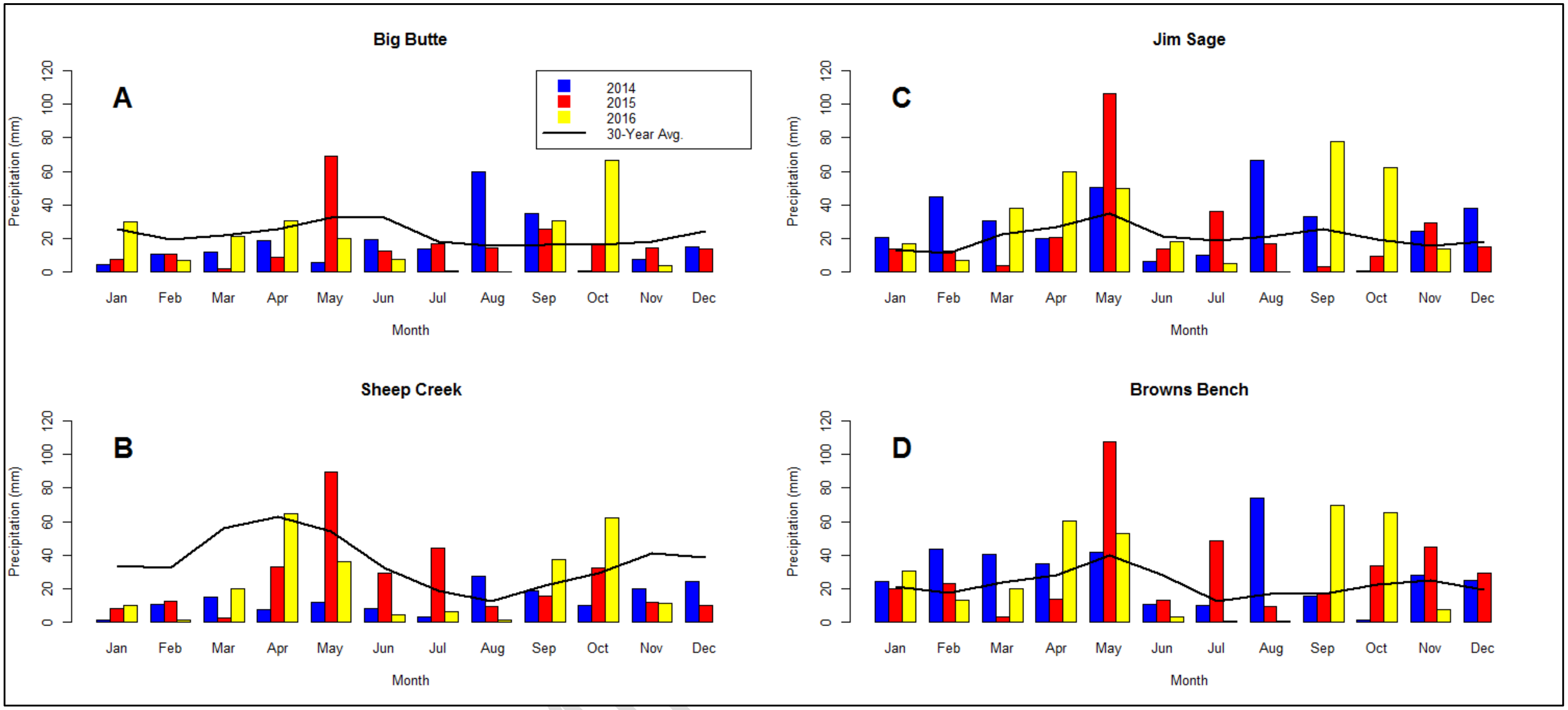

Figure 7. Precipitation (mm) by month for four study sites in southern Idaho in 2014-2016. Precipitation data for December 2016 were not available at the time of this report. Dark lines in each plot represent 30-year averages for comparison. Weather data were recorded at RAWS stations; at Big Butte we used the Bull Springs station (42.080, -114.485), at Sheep Creek we used the Pole Creek station (42.069, -115.786), at Jim Sage we used the City of Rocks station (42.091, -113.631), and at Browns Bench we used the Arco station (43.623, -113.387).

Capture and Radio-collaring

We deployed new VHF radio transmitters on 117 female sage-grouse across 5 sites in spring 2016: 58% adults, 41% yearlings, and 1% unknown age (Table 3). In the Fall of 2015, we re-captured 5 previously collared female sage-grouse and 1 new female sage-grouse. In addition, 78 radio-marked hens whose VHF collars were deployed in past years were present at our sites in February 2016 (this includes the 5 females re-captured in the fall of 2015). Hence, we tracked 195 radio-collared hens in 2016: 77% adults and 23% yearlings. We recovered/documented 20 mortalities during the 2016 field season (Feb-July): 16 adult females and 4 yearling females.

Table 3. Summary of female greater sage-grouse that were alive and had an active radio collar at the start of the 2016 field season (March) and the year in which they were initially collared. Also included are all confirmed mortalities of radio-collared hens at five study sites in southern Idaho in 2016.

Site	Year Initially Collared			
	2014	2015	2016	2016 Mortalities
Big Butte	-[a]	20	20	5
Browns Bench	10	10	25	8
Jim Sage	1	12	27	5
Pahsimeroi	-[a]	12	34	-[b]
Sheep Creek	-[a]	13	11	2
TOTAL	11	67	117	20

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

[b] Mortality data for the Pahsimeroi study site were not available at the time of this report

Nest Searching and Monitoring

We located a total 96 nests across four study sites in 2016 (including nests inside and outside of our focal/experimental study pastures; nest monitoring data for Pahsimeroi study site is yet available): 33 were successful (34%) and 63 were un-successful. Of the 96 nests monitored in 2016, 83 were initial nesting attempts and 13 were re-nest attempts.

Nesting Propensity

Overall nesting propensity in 2016 was 76% (n = 83), which was substantially lower than the 90% nesting propensity that we documented in 2015. Nesting propensity differed among study sites in 2016: 89% (n = 27) at Big Butte, 79% (n = 28) at Browns Bench, 57% (n = 23) at Jim Sage, and 80% (n = 5) at Sheep Creek.

Nest Success

Apparent nest success was slightly lower in 2016 at all sites compared to that in 2015, except for Sheep Creek where nest success was 33% in both years (Table 4). Mayfield estimates of nest success were substantially lower than apparent nest success at all sites individually and all sites combined (Table 5).

Table 4. Apparent nest success and clutch size (± standard error) of greater sage-grouse at five study sites in southern Idaho, 2014-2016.

Study Site	Apparent Nest Success (%)			Clutch Size at Hatched Nests ± SE		
	2014	2015	2016	2014	2015	2016
Browns Bench	54	67	38	7.3 ± 0.5	6.3 ± 0.6	7.2 ± 0.4
Jim Sage	29	44	33	7 ± 0.4	6.4 ± 0.7	5.8 ± 0.4
Big Butte	-[a]	30	29	-[a]	6.6 ± 0.8	5.5 ± 0.5
Sheep Creek	-[a]	33	33	-[a]	5.4 ± 0.7	8.0 ± 0.5
Pahsimeroi	-[a]	-[a]	-[b]	-[a]	-[a]	-[b]

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

[b] Data were not available at the time of this report

Table 5. Summary of greater sage-grouse nests by study site and pasture at four study sites in southern Idaho in 2016. Apparent nest success and nest success using the Mayfield method are presented for each study site (BIBU = Big Butte, BRBE = Browns Bench, JISA = Jim Sage, and SHCR = Sheep Creek).

Site	Pasture	Failed	Hatched	Total	Apparent Nest Success	Mayfield Nest Success
BIBU	Big Lake	3	3	6		
	Butte	7	2	9		
	Crossroads	2	0	2		
	Frenchman	3	0	3		
	Serviceberry	4	1	5		
	Sunset	1	2	3		
	Total	20	8	28	28.6	13.1
BRBE	Browns Creek	7	1	8		
	Canyon	0	1	1		
	China Creek	7	1	8		
	Corral Creek West	3	2	5		
	Deer Canyon	0	1	1		
	Indian Cave North	1	4	5		
	Indian Cave South	1	1	2		
	Meadow	1	0	1		
	Monument Springs	0	1	1		
	Three Mile	0	1	1		
	W/N Cow Tank	1	0	1		
	Total	21	13	34	38.2	16.4
JISA	Kane Springs	3	2	5		
	North Sheep Mountain	4	2	6		
	Parks Creek	0	1	1		
	Richard Ward Property	1	0	1		
	South Sheep Mountain	4	1	5		
	Unknown	2	1	3		
	Total	14	7	21	33.3	12.1
SHCR	Blackleg East	3	0	3		
	North JP Seeding	1	0	1		
	Slaughterhouse	3	2	5		
	South JP	1	0	1		
	Tokum-Bambi West	0	3	3		
	Total	8	5	13	33.3	16.1
	Grand Total	63	33	96	34.4	14.3

Critical Dates

Hatch Date

Mean hatch date ranged from 11-May (Sheep Creek) to 21-May (Big Butte) and was fairly similar among the 4 study sites (PAHS data was not available yet).

Clutch Size

Mean clutch size ranged from 5.5 – 8.0 eggs per hatched nest in 2016. Mean clutch size over the entire course of the study thus far (2014-2016) was 6.3 eggs per hatched nest (Table 6).

Table 6. Average hatch date and clutch size for greater sage-grouse nests (only nests that were successful) at four study sites in southern Idaho for 2014-2016.

Site	Hatch Date			Clutch Size		
	mean	SE	n	mean	SE	n
Big Butte	21-May	4.4	22	5.8	0.4	24
Browns Bench	16-May	1.8	48	6.7	0.3	48
Jim Sage	19-May	3.3	21	6.2	0.3	24
Sheep Creek	11-May	4.7	11	6.5	0.6	11
All 4 Sites	17-May	1.5	102	6.3	0.2	107

Brood Monitoring

In 2016, we conducted 125 brood flush surveys and 20 spotlight surveys on 30 different sage-grouse hens across four study sites (data from PAHS is not available yet). Brood survival ranged from a high of 73% (*n* = 11 broods) at Browns Bench to a low of 20% (*n* = 5) at Sheep Creek. This was consistent with overall brood success rates from the duration of the study (Table 7). In 2016, only 1 brood was detected with the spotlight technique, but not the flush technique across all broods that had both a spotlight survey and a flush survey conducted at 42 days of age.

Table 7. Number of broods, total broods survived to 42 days, and apparent brood success of greater sage-grouse at four study sites in southern Idaho, 2014-2016 (we did not track broods at Big Butte or Sheep Creek in 2014).

Site	Total Broods	Survived to 42 Days	%
Big Butte	8	4	50.0
Browns Bench	49	32	65.3
Jim Sage	15	2	13.3
Sheep Creek	10	3	30.0
All 4 Sites	82	41	50.0

Vegetation Sampling

In 2016, we conducted intensive vegetation sampling in April-June at 97 nest plots, 61 dependent plots, and 367 random plots for a total of 525 vegetation surveys across 4 study sites Big Butte, Brown's Bench, Jim Sage, 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. We sampled grass height and grazing intensity metrics for 32,718 grasses on the 525 vegetation surveys at the 4 sites in 2016. We re-sampled 387 random plots (20,796 grasses) at the end of the growing season (July-August). We estimated percent utilization at 4,409 sampling locations for the landscape appearance method, and we used these data for pattern use mapping at all 5 study sites. While conducting the landscape appearance transects, we also measured height and percent biomass removed for 11,247 individual grasses.

Nest Shrub Patch

In 2016, the majority of sage-grouse nests were located under Wyoming big sagebrush (Table 8). Low sagebrush and basin big sagebrush were the next most utilized species respectively, but only Wyoming big sagebrush and basin big sagebrush were used for nesting more frequently than expected based on its availability on random plots (Table 8).

Table 8. Plants used by greater sage-grouse for nest sites compared to focal shrubs at random plot locations across four study sites in southern Idaho in 2016. 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	
		%	SE	%	SE
Wyoming Big Sagebrush	*Artemisia tridentata wyomingensis*	40.2	5	30.8	2.4
Low Sagebrush	*Artemisia arbuscula*	21.6	4.2	33.5	2.5
Basin Big Sagebrush	*Artemisia tridentata tridentata*	12.4	3.3	8.7	1.5
Three-tip Sagebrush	*Artemisia tripartita*	7.2	2.6	9	1.5
Black Sagebrush	*Artemisia nova*	6.2	2.4	17.4	2
Rubber Rabbitbrush	*Chrysothamnus nauseosus*	6.2	2.4	--	--
Green Rabbitbrush	*Chrysothamnus viscidiflorus*	4.1	2	--	--
Western Juniper slash pile	*Juniperus occidentalis*	1	1	--	--
Spineless Horsebrush	*Tetradymia canescens*	1	1	--	--
Mountain Big Sagebrush	*Artemisia tridentata vaseyana*	0	0	0.5	0.4

Shrub Cover

Sagebrush cover at successful nests was greater than sagebrush cover at failed nests and both had more sagebrush cover than random plots (red triangles; Fig. 8). Total shrub cover (including non-sagebrush shrubs) at successful nests was greater than shrub cover at failed nests, but both successful nests and failed nests had less shrub cover than random plots (blue squares; Fig. 8).

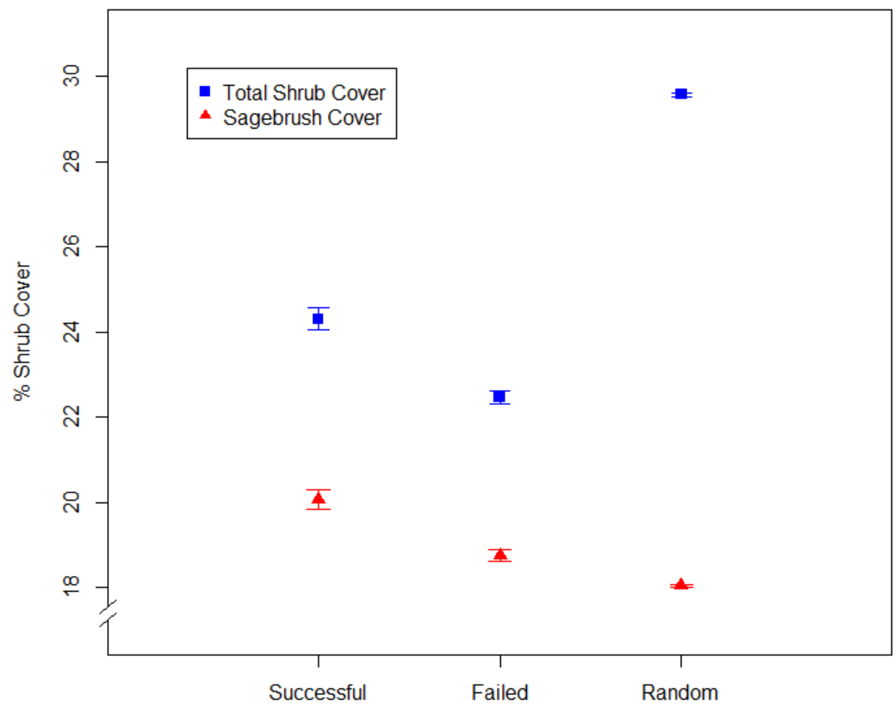

Figure 8. Percent total shrub cover (blue squares) and percent sagebrush cover (red triangles) at random plots, successful nests, and failed nests of greater sage-grouse at four study sites (Big Butte, Browns Bench, Jim Sage, and Sheep Creek) during 2015 and 2016 in southern Idaho (n = 72 successful nests, n = 114 failed nests, n = 465 random plots). Bars around symbols represent standard error around mean.

The height of nest shrub patches (the shrub or group of shrubs at a nest or potential nest site) was greater at successful and failed nests than at random locations (Fig. 9). Although failed nests had slightly greater shrub height than successful nests, the difference was not as substantial.

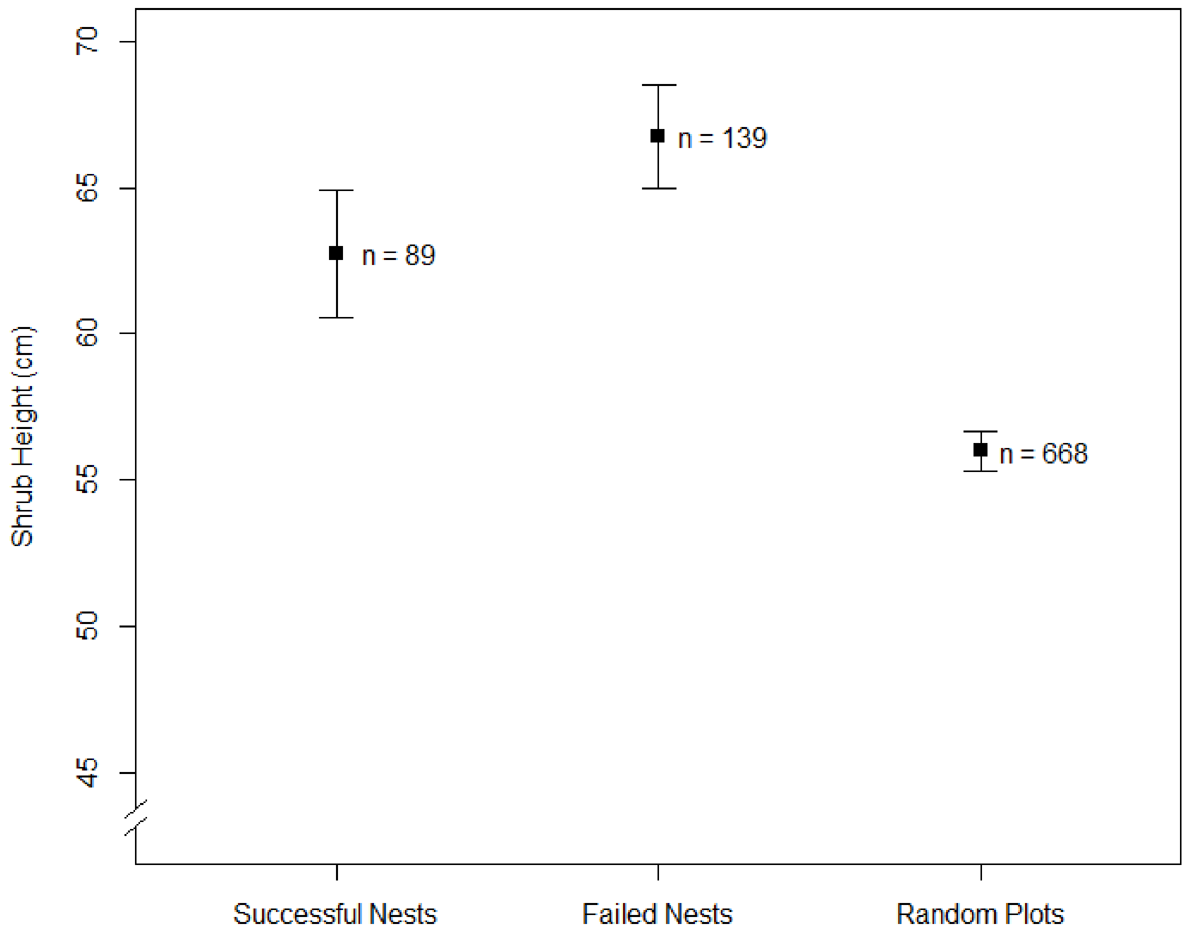

Figure 9. Height of the focal shrub at successful nests, failed nests, and random plots for sage-grouse in 4 study sites across southern Idaho, 2014-2016. The focal shrub for all plots was sagebrush (Artemisia spp.). Results are presented as means with ± one standard error.

Grass Height

Un-grazed grass heights of common species varied among study sites for western wheatgrass and needle grasses (Fig. 10). The height of un-grazed bluebunch wheatgrass, bottlebrush squirrel-tail, Sandburg bluegrass, and crested wheatgrass also varied among study sites but less so than the other two species. The site that grew the tallest grass was not the same for all grass species, though the Jim Sage study site had the tallest grass for three of the six most common grass species. Sheep Creek had very low occurrence of crested wheatgrass and western wheatgrass.

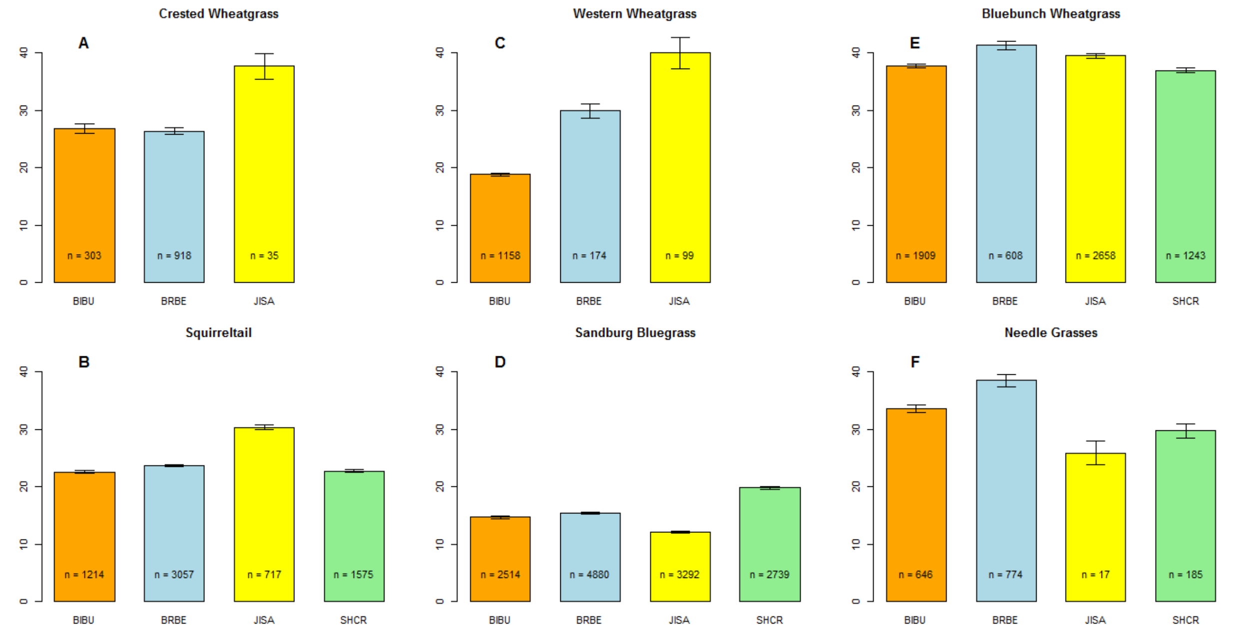

Figure 10. Mean droop height of un-grazed plants for six species of grasses across four study sites (BIBU = Big Butte, BRBE = Browns Bench, JISA = Jim Sage, and SHCR = Sheep Creek) in southern Idaho in 2016. Bars represent mean ± one standard error. Heights of un-grazed grasses differ among species and differ among the 4 study sites within species. We did not present heights of crested wheatgrass or western wheatgrass at Sheep Creek because these grasses were rare at that site (< 10 individuals).

Grass height at successful nests was similar to but slightly taller than grass height at failed nests, and grass heights at both successful and failed nests were greater than those at random plots (based on samples in 2015-2016 combined for all grass species pooled)(Fig. 11). Canopy cover of grasses at successful nests was slightly greater than that at both failed nests and random plots (Fig. 12). Failed nests and random plots had similar canopy cover of grasses.

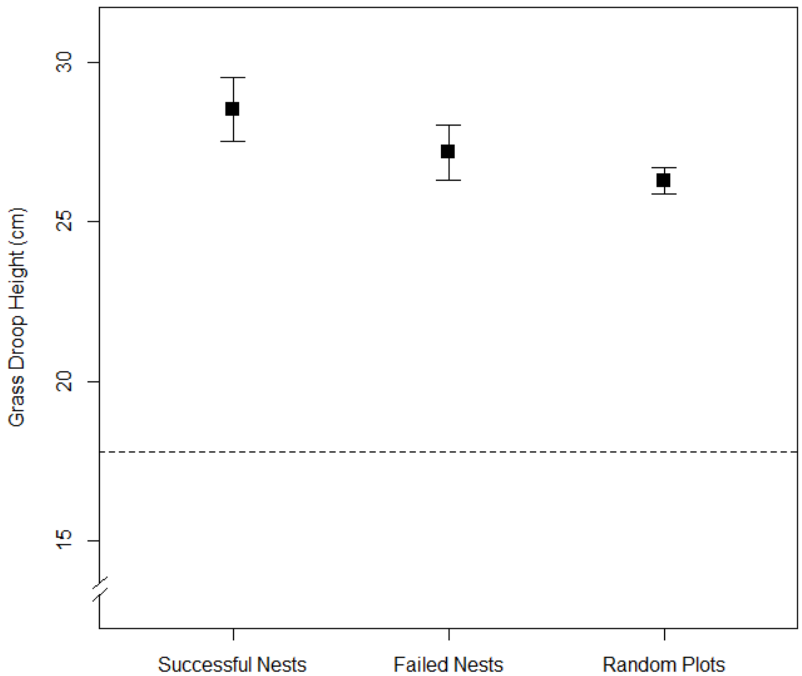

Figure 11. Mean droop height (cm) of grasses at successful and failed nests of greater sage-grouse at four study sites (Big Butte, Browns Bench, Jim Sage, and Sheep Creek) across southern Idaho in 2015-2016. The means are based on 72 plots (4,548 grasses measured) for hatched nests, 144 plots (7,330 grasses measured) for failed nests, and 465 plots (38,187 grasses measured) at random locations (all species of grasses combined). Bars are presented as means ± 1 standard error. The dashed horizontal indicates 7 inches (~18cm) which is commonly used as a guideline for residual stubble height in sage-grouse habitat (Connelly et al. 2000, Crawford et al. 2004).

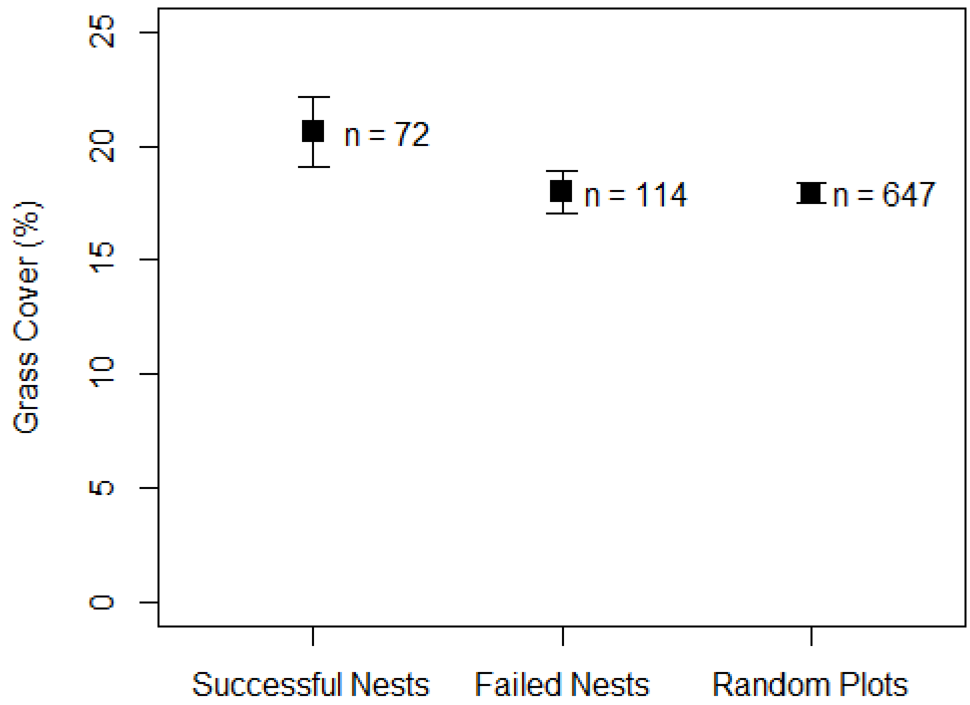

Figure 12. Percent grass cover at successful nests, failed nests, and random plots for sage-grouse at 4 study sites in southern Idaho, 2015-2016. Results are presented as mean ± one standard error.

Utilization

Pattern use mapping indicated that grazing intensity varied spatially within grazed pastures (Fig. 13). Estimates of utilization varied greatly depending on the method used (Table 9).

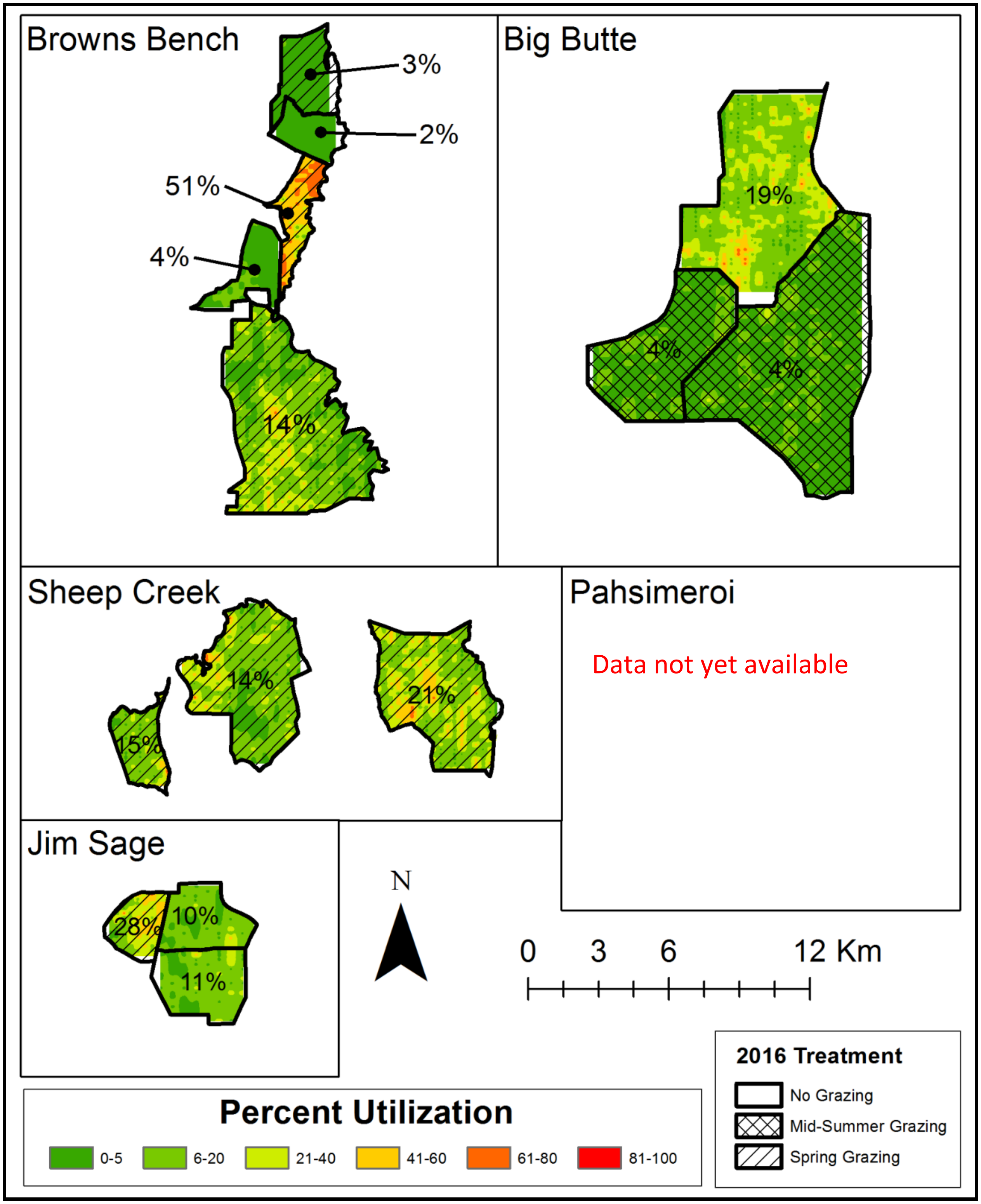

Figure 13. Pattern use mapping based on the landscape appearance method in July-August 2016 for study pastures at five study sites in southern Idaho in 2016. We used an Inverse Distance Weighted (IDW) algorithm to interpolate use across each pasture to create the maps.

Table 9. Utilization (percent off-take) of grasses based on three different methods (landscape appearance, % height reduction, % of grazed grasses) within 17 study pastures at five study sites in southern Idaho. All sampling was conducted at the end of the growing season (July-August) 2016. BIBU = Big Butte, BRBE = Browns Bench, JISA = Jim Sage, PAHS = Pahsimeroi, and SHCR = Sheep Creek.

Site	Pasture	Landscape Appearance Method	% Height Reduction	% Grazed Plants	# Grasses Measured	2016 Grazing Treatment
BIBU	Butte	19	22	22	1835	No Grazing
	Serviceberry	4	24	2	654	Summer Grazing
	Sunset	4	21	8	1625	Summer & Fall Grazing
BRBE	Browns Creek East	4	26	5	184	Spring & Fall Grazing
	China Creek	14	32	18	1408	Spring Grazing
	Corral Creek East	51	50	50	218	Spring Grazing
	Indian Cave North	3	0	0	186	Spring & Fall Grazing
	Indian Cave South	2	0	0	145	No Grazing
JISA	Kane Springs	28	15	33	216	Spring Grazing
	Sheep Mountain North	10	18	21	156	No Grazing
	Sheep Mountain South	11	19	20	194	No Grazing
PAHS	3-Corner		35	24	493	Unknown
	River East		31	30	1098	Unknown
	River West		32	35	928	Unknown
SHCR	East Blackleg	15	19	14	301	Spring Grazing
	Slaughterhouse	21	22	24	1005	Spring Grazing
	Tokum-Bambi West	14	24	19	551	Spring Grazing

Insect Sampling

We sampled arthropods at 140 sampling locations across our four study sites in 2016. Each sampling location had four pitfall traps and we emptied those pitfall traps once per week for ~7 weeks (range of 5-9 weeks), yielding a total of 4,056 pitfall samples collected in 2016. We also collected 2,171 sweep net samples and 37 D-vac samples at those 140 sampling locations. We conducted ant mound surveys along 120 transects across the 4 study sites in 2016, and measured the distance to (and size of) 331 ant mounds on those 120 transects. Most (73%) of the 331 ant mounds were 'active' (had ants present). Of the 4,791 pitfall trap samples we have collected on this project (735 in 2015 and 4056 in 2016), we have processed 424 of those samples thus far. From the 424 pitfall samples that we've processed, we have counted, identified, and measured 45,725 arthropods (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 included ramps on half of the pitfall traps in 2015, but we didn't use ramps in 2016 because we caught 123% less arthropod biomass in pitfall traps with ramps compared to those without ramps.

DISCUSSION

Effort

We hired about the same number of technicians in 2016 as in 2015. We collared slightly fewer birds (83 vs. 90) in 2016 versus 2015 but we monitored more collared birds (because we had 67 hens radio-collared in 2015 that returned and whose collars were still active in 2016). Birds at Pahsimeroi were captured and monitored by BLM and USFS biologists in 2016. In 2017, we plan to hire 20 seasonal technicians and 5 crew leaders to collect data at 5 study sites.

Since the beginning of our study, we have conducted vegetation sampling at 1,756 plots (breeding and post-breeding season surveys combined). Our pattern use mapping efforts have produced measurements at 8,601 unique locations. From a statistical standpoint this provided high statistical power and very small error bars (Figs. 8-12). With this continued effort we will be able to make extremely meaningful inference regarding the specific effects of spring cattle grazing on sage-grouse populations and habitat in Idaho (and these results will be relevant throughout the species range).

Nest Success

Nest success was lower at all sites in 2016 than in 2015 except Sheep Creek where it was the same as last year. Nest success rates that we reported for 2016 are still within the range that has been reported by other studies (15-70%; Connelly et al. 2011). However, they are on the lower end of this range.

Our estimates of apparent nest success were much higher than our estimates using the Mayfield method. If we do not locate successful nests early in their exposure period then we should expect a larger discrepancy between the two methods. The mean number of exposure days for successful nests that we monitored was 23.3 days. The longest number of exposure days for a nest that we monitored was 33 days. We attempt to confirm a nest after a hen has become localized. 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. In 2016, we monitored hens on nests once every 2 days on average.

Nest Propensity

Our estimates of nesting propensity in 2016 were slightly lower than in 2015. They were however, more consistent with those reported by Connelly et al. (1993; 78%) and Holloran et al. (2005; 81%). Other grouse species may forego nesting in years with less than optimal conditions (i.e., drought, high temperatures; Grisham et al. 2014).

Hatch Date

Hatch dates observed in our study are inside the expected values for sage-grouse across their range (Schroeder et al. 1999). Our mean hatch date of 17 May was earlier than other recent studies (5 June; Aldridge and Brigham 2002, 4 June; Holloran et al. 2005). In Idaho this may be due to earlier snow melt, which would allow breeding and hence nesting to occur at earlier dates.

Shrub Cover and Height

Sage-grouse nest sites had higher sagebrush cover than random sites and this pattern is consistent with other sage-grouse literature (Wakkinen 1990, Connelly et al. 1991, Holloran et al. 2005). The amount of sagebrush cover available to sage-grouse at random locations fell within the 15-25% recommended by Connelly et al. (2000). Small error bars reflect our large sample sizes and allowed us to detect relatively small, but statistically significant, differences in sagebrush cover between random plots and nest plots.

In contrast to sagebrush cover, overall shrub cover at random plots was greater than at both successful and failed nests. Sage-grouse appear to be selecting areas within pastures where sagebrush is more prevalent.

Shrub height was greater at nest sites than at random plots. This result is consistent with many other sage-grouse studies (Klebenow 1969, Sevum et al. 1998, Holloran et al. 2005) and suggests that greater shrub height likely provides greater concealment from ground and aerial nest predators. The height of both nest shrubs and focal shrubs at random plots were within the 40-80 cm recommended by Crawford et al. (2004; Fig. 9).

Grass Height and Grass Cover

Mean grass height differed among the 3 plot types (successful nests, 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).

Higher grass cover at nest sites compared to random plots is consistent with other sage-grouse studies (Gregg et al. 1994, Sevum et al. 1998) and the values reported here are within the recommended guidelines for sage-grouse habitat (Connelly et al. 2000, Crawford et al. 2004). Greater coverage of taller grasses can provide visual obstruction at ground level to help supplement overhead cover provided by sagebrush and other shrubs (Sevum et al. 1998). The relationships presented here provide an initial indication of the data that this project will eventually generate regarding the multifaceted relationship between grazing, sagebrush cover, and grass density (Hendrick et al. 1996, Bork et al. 1998, Strand et al. 2014, Sowell et al. 2016). As we add data to our already large dataset of grass and shrub metrics, we will produce thorough documentation of these relationships and their effect on sage-grouse.

Utilization

Estimates of utilization vary depending on method used. We did not see any specific pattern suggesting that one method consistently produced higher or lower estimates of utilization. Various methods of measuring utilization maybe more beneficial for answering certain questions and further investigation into the most appropriate method is warranted. We are also planning to estimate utilization via height-weight regressions and these metrics are part of Janessa Julson's graduate thesis.

Grass heights for the same species varied greatly among our study sites (Fig. 10). Grass heights likely vary at even more localized scales (e.g., within pastures or drainages). One problem we 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). 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), or 2) perhaps grazed grasses experienced heightened regrowth after grazing. Estimates of utilization from utilization cages may be the most appropriate solution to this problem. We deployed utilization cages at our study sites in 2016, and we will take steps to create more robust utilization cages in 2017.

Utilization varied spatially within individual 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 investigate how utilization patterns may affect nest site selection by sage-grouse within a given pasture.

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