SUMMARY OF FIELD METHODS
FOR THE
GROUSE & GRAZING PROJECT

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INTRODUCTION

The Idaho Grouse & Grazing Project is a 10-year study designed to assess the effects of cattle grazing on demographic traits and habitat features of greater sage-grouse (hereafter sage-grouse; *Centrocercus urophasianus*). The project began in 2014 and will to continue through 2023. Since the onset of this project, we have designed detailed protocols to collect the data needed to achieve the objectives of the project. This document summarizes the field methods used to collect data for the project.

EXPERIMENTAL DESIGN

We began field work at two study sites in 2014 (Brown's Bench, Jim Sage), two more in 2015 (Big Butte, Sheep Creek), one in 2017 (Pahsimeroi), and one in 2019 (Idaho National Lab; 2019 was the only year we conducted research at this site). Our initial study plan included a goal of nine study sites, but funding has precluded us from adding additional study sites. Additional replicates of the grazing treatments that would be afforded with additional study sites would help to ensure sufficient sample sizes in each of the 4 experimental grazing treatments (see below for descriptions of the 4 treatments). Each study site was selected based on the following characteristics:

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

For this project, we are applying a paired Before-After-Control-Impact (BACI) experimental design with spatial and temporal replication and a staggered-entry approach to evaluate the effects of cattle grazing on sage-grouse demographic traits and habitat characteristics. A paired BACI design that includes both spatial and temporal replication is considered the most rigorous experimental design 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 $\geq$6 years ($\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 (Skinner et al. 2002, Moynahan et al. 2007, La Pierre et al.

2011, Hovick et al. 2015) and the staggered-entry design will help us differentiate responses caused by the experimental changes in grazing intensity versus those caused by annual variation in weather. For example, this design ensures that all of the experimental changes in grazing intensity will not 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, grass height, shrub cover, etc.) for ≥2 years prior to experimental changes in grazing intensity where ranchers graze their allotments in consultation with BLM as they have done in prior years (Years 1-2 in Fig. 1). These initial years of field work and data collection allow us to identify grazing pastures that are appropriate for inclusion in the experiment (based on discussions with permittees and BLM managers and the presence of nesting sage-grouse) and they provide the 'Before' measures of demographic traits for the BACI design. In the spring of the 3rd year of sampling at each study site, we manipulate the grazing regime in 4 experimental pastures per study site and begin grazing those experimental pastures according to 1 of 4 grazing treatments: 1) spring-only grazing in odd years, 2) spring-only grazing in even years, 3) no grazing, and 4) alternating years of spring-only grazing and fall-only grazing (Fig. 1). We define spring grazing as 1 March through 15 June and fall grazing as 1 September through 15 December.

Treatment	Year 1	Year 2	Implement Grazing Treatments	Year 3	Year 4	Year 5	Year 6
Spring Odd Years	Current grazing	Current grazing		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 1. Experimental design to evaluate potential effects of cattle grazing on sage-grouse demographic traits and habitat features.

METHODS

1) CAPTURE AND RADIO-COLLARING

Each year of the study, we meandered through our experimental pastures at night with spotlights and used hand nets (Wakkinen et al. 1992) to capture female sage-grouse in February and March. In 2017-2018, we also used rocket-nets (Giesen et al. 1982) a few times to capture sage-grouse on leks during peak hen attendance (typically the first or second week in April). We recorded the capture location, body weight, and age of each hen captured. We used plumage characteristics to assign captured hens to one of two age classes: yearling and adult (Braun and Schroeder 2015). In 2018, we began recording the length of the innermost primary (P1) to help confirm the age class of the captured bird. In 2019, we expanded these measurements to include primaries 1-3 (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. At the Pahsimeroi Valley study site, we attached a small number (~15 individuals per year) of 22 g Platform Transmitter Terminals (PTTs; Microwave Telemetry, Columbia, MD) to a subset of captured female sage-grouse.

2) NEST SEARCHING AND MONITORING

We used VHF telemetry to locate radio-collared sage-grouse hens every 2-3 days. We monitored hens that moved out of our experimental pastures less frequently (approximately once per week depending on accessibility) because information on hens that nest outside the 4 experimental pastures is not as useful for the BACI study. Once a radio-collared female became localized (consistent location for 2-3 consecutive visits), we approached the area cautiously to confirm if she was nesting and to find the location of the nest. We followed an explicit protocol for locating and monitoring nests that ensured minimum disturbance to nesting hens (i.e., we attempted to never flush a hen off her nest and to minimize the number of times we walked within 100 m of each nest). We used telemetry equipment to identify potential nest shrubs and we sometimes confirmed a nest was present if we obtained a visual confirmation with binoculars (Aldridge and Brigham 2002). If we could not obtain a visual confirmation but thought we were close to the nesting hen, we identified a cluster of shrubs from where the telemetry signal was emanating and assumed that cluster was the location of the nest (i.e., we avoided flushing a hen off her nest while trying to locate/confirm a nest). If the hen was found in the same location on subsequent visits, we assumed she was nesting within that cluster of shrubs, even if we did not obtain a visual confirmation of the hen on the nest. To monitor nests, we established two monitoring points where we created small rock cairns (Dahlgren et al. 2016) $\geq$100 m from the nest (Connelly et al. 1991) at which we listened for the telemetry signal of the radio-collared hen every 2-3 days. The 2 monitoring points were 90^{o} to 150^{o} apart from each other (relative to the nest) and allowed us to confirm whether the hen was still incubating the eggs without disturbing her. If the hen was located at consistent bearings from the 2 monitoring points, we assumed she was incubating a clutch of eggs. If the bearings indicated

the hen was not located on the nest during any of the monitoring visits, we walked into the area and searched the cluster of shrubs to locate the actual nest and documented its status and its precise location. If we located the nest bowl but no eggs were present, we determined the fate of the nest (hatched or failed) based on the condition of any eggshells we found (Connelly et al. 1991). We estimated minimum clutch size by searching the area surrounding the nest bowl for eggshells and estimated the minimum number of eggs based on the eggshell fragments (Schroeder 1997). If we located the nest bowl and eggs were present, we counted the eggs and quickly left the area. All hen and nest monitoring data were collected following an explicit hen monitoring protocol developed for the project.

3) NESTING PROPENSITY

We calculated nesting propensity as the number of radio-collared hens that initiated at least one nesting attempt divided by the number of radio-collared hens tracked (i.e., that we monitored closely) during the nesting period. Past studies that have reported estimates of nesting propensity have not clearly defined a "tracked bird" (i.e., the denominator used in calculating nesting propensity). Selecting an explicit definition of a 'tracked bird' is particularly important for this project because we do not put forth the same tracking effort on all collared hens (i.e., we monitor the hens that stay within the 4 experimental pastures closely whereas we largely ignore hens that completely leave the study area). Hence, we used 2 approaches to define a "tracked bird" and calculated 2 measures of nesting propensity based on these 2 approaches: 1) a tracked bird = any hen that we either found a nest or we did not find a nest but obtained a location on the hen at least 1 time per week between the 14th and 23rd week of the year; and 2) a tracked bird = any hen that we either found a nest or we did not find a nest but we obtained a location on the hen for >50% of the weeks (i.e., located her at least once during >50% of the weeks) between the 14th and 23rd week of the year. The range of dates that we used for both approaches were based on the earliest and latest nest initiation dates by hens in the first 4 years of the study (2014-2017). We chose these two definitions for a tracked bird because they represent a more conservative definition (approach #1; should yield fewer tracked hens) and a more liberal definition (approach #2; should yield more tracked hens) of a tracked hen.

4) CRITICAL DATES (NEST SUCCESS)

We used 2 approaches to quantify sage-grouse nest success: apparent nest success and daily nest survival. Apparent nest success is a simple ratio of the number of hatched nests divided by the number of total nests whereas daily nest survival is a model-based estimate that accounts for biases inherent in apparent nest success estimates (Mayfield 1975). To include a nest in our estimate of daily nest survival, we needed the date the nest was first found and the date that it attained its final fate (failed or hatched). Additionally, we wanted to estimate the date that each nest was initiated to determine if daily nest survival changes throughout the

nesting cycle (so that we could account for initiation date in other analyses). To do so, we used all information available to generate unbiased estimates of 3 critical dates for each nest: nest initiation date, date of onset of full incubation, and estimated hatch/fail date. Below is a summary of the information we used to estimate each of these 3 critical dates for each nest.

NEST INITIATION DATE

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

DATE OF ONSET OF FULL INCUBATION

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

FATE DATE (HATCHED AND FAILED NESTS)

For hatched and failed nests, we estimated the date of its fate by calculating the midpoint between the date the hen was first documented off the nest (i.e., no longer incubating eggs) and the last date the hen was detected on the nest. For hatched and failed nests, we further refined the estimated hatch date if we had additional information (e.g., eggshells were still wet when we inspected the nest, etc.) that suggested the hatch day was something other than the midpoint.

PROJECTED HATCH DATE FOR FAILED NESTS

For failed nests, we determined the range of possible projected hatch dates based on the estimated date that incubation began and the number of days we observed the nest, and then we used the midpoint of this range as our estimate of the projected hatch date (i.e., the estimated hatch date if the nest had not failed). If we observed a failed nest for more than 27 days, we estimated the projected hatch date by adding 1 day to the estimated fail date (i.e., we assumed that the nest would have hatched the next day had it not failed). This date was used to determine the timing that vegetation sampling was conducted for failed nests. This helps avoid confounding plant growth phenology (i.e., timing of measurement within the growing season) with differences in vegetation at hatched and failed nests (Gibson et al. 2016, Smith et al. 2017).

5) BROOD MONITORING

We used 3 methods to document the fate of each brood and, hence, to estimate brood survival: daytime flush count surveys, fecal pellet surveys at nighttime roost sites, and nighttime spotlight surveys. All brood survey data were collected following an explicit brood monitoring protocol developed for the project. Below are summaries of these 3 methods for monitoring brood fate.

BROOD VISUAL SURVEYS (USED 2015-2021)

For nests that hatched, we used a handheld telemetry antenna to walk out to the hen and then conducted a brood 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 brood visual survey in inclement weather to prevent additional stress to the chicks). We conducted these brood visual surveys >2 hours after sunrise and >2 hours before sunset (i.e., we avoided crepuscular hours) because we did not want to disturb broods while foraging during the critical early morning and late evening hours. On each brood visual 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. Our objective on the first three brood visual surveys (at 7, 14, and 28 days post-hatch) was to confirm that the brood was either alive or dead and, hence, we tried not to flush the hen and brood. If we saw $\geq$1 chick without flushing the hen on the first three surveys, we backed out of the area to prevent further disturbance. If we could not see any chicks on a brood visual survey, we flushed the hen and searched the 15 m radius area around where the hen flushed to look for chicks. On the fourth and final brood visual survey, we always attempted to flush the hen and searched the surrounding 15 m from the approximate location where the hen flushed to try to obtain a complete count of chicks that survived to 42 days. 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 (USED IN 2016-2017 & 2019-2021)

We conducted brood fecal surveys to test whether this is a less invasive but accurate method to document brood status and survival. For brood pellet count surveys, we first located the collared female sage-grouse with a suspected brood during nighttime hours (2000 – 0400). Once a hen's VHF signal was heard, we approached the bird by circling in. We made several tight circles around then hen to determine her exact location (usually within 10-20 m) without disturbing the roosting hen and brood. Next, we marked the area using a GPS unit and a small rock cairn or some other inconspicuous natural marker. We then left the area and returned 1-2 hours after sunrise to search the area for evidence of hen and chick fecal pellets. We recorded the brood as detected (i.e., alive) if we found ≥1 chick fecal pellets at the roost site. Brood pellet count surveys were part of Ian Riley's graduate thesis research. Ian explicitly compared brood fecal pellet surveys, spotlight surveys, and visual surveys and compared their utility for estimating brood survival. Ian defended his thesis and graduated in May 2019. His results showed that brood pellet count surveys have high detection probability that does not vary with brood age and this survey method provides an alternative to brood visual surveys that can potentially reduce disturbance to broods (Riley 2019).

BROOD SPOTLIGHT SURVEYS (USED IN 2015-2021)

We conducted brood spotlight surveys as a third approach for estimating brood survival at 42 days (i.e., to estimate detection probability of the 42-day flush count surveys). We conducted brood spotlight surveys at nighttime roost sites >1 hour after sunset and >1 hour before sunrise. We conducted brood spotlight surveys 42 days after hatch, randomly choosing which survey we conducted first: the 42-day brood spotlight survey or the 42-day brood visual survey. The two 42-day brood surveys for the same hen (visual survey and spotlight survey) were conducted >6 hours but <24 hours apart. We sometimes conducted the 42-day brood surveys slightly earlier or slightly later than 42 days when we were unable to locate a hen because of long-distance movement or because of logistical reasons (e.g., inclement weather). We used telemetry equipment to get approximately 10-20 m from the radio-collared hen and then cautiously circled the hen while scanning the surrounding area with a spotlight. We counted the number of chicks present within 15 m of the hen. We also revisited the roost site after sunrise to conduct brood pellet counts (see *Fecal Pellet Count Surveys* above). We only conducted brood spotlight surveys at 42 days because initial efforts in 2016 to use this method when broods were younger (e.g., 7, 14, and 28 days) proved to be ineffective because young chicks held tight under the brooding female at night and we would have had to flush the hen to see whether she was brooding chicks.

6) AVIAN POINT-COUNT SURVEYS (conducted 2016-2018)

We conducted avian point-count surveys at 5 of our study sites (Big Butte, Brown's Bench, Jim Sage, Pahsimeroi Valley, and Sheep Creek) from 2016-2018. Funding for these surveys was from an explicit grant that provided funds for 2016-2018 and so we discontinued the surveys for the 2019 field season due to lack of funding. We developed a detailed protocol that we used to conduct these surveys.

7) SHORT-EARED OWL SURVEYS (conducted 2018-2019)

We conducted surveys for short-eared owls (*Asio flammeus*) in all of our study sites except Idaho National Lab in 2018-2019 during the months of March – May in collaboration with project WAfLS. Funding for these surveys were from an explicit grant from WAFWA that provided funds to them for 2018-2020. The results of these surveys in 2018 and 2019 are detailed in our short-eared owl annual reports (Meyers and Conway 2018, Meyers and Conway 2019).

8) VEGETATION SAMPLING

From 2014-2021, 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 non-nest 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. However, we discontinued dependent non-nest plots in 2018 due to funding limitations and other priorities. Random plots were centered on sagebrush shrubs and randomly located within experimental pastures. Each year, we conduct vegetation surveys at nest plots and random plots from ~20 April – 30 June. In 2020, we began conducting vegetation surveys centered on sage-grouse leks. And in 2021, we began conducting vegetation surveys at high-use cattle areas within our experimental pastures and at sage-grouse winter locations in and around our experimental pastures at a subset of sites. Vegetation surveys consisted of 6 components: a set of photographs to estimate percent nest concealment, measurements of the nest shrub (or the patch of shrubs), two line-intercept transects to estimate percent shrub cover, estimates of grass height and grazing intensity (by species) along the line transects, Daubenmire plots to estimate percent cover, and a count of herbivore fecal droppings along the line transects. Some of the 2015-2016 data from the intensive vegetation sampling were used in Janessa Julson's graduate thesis (Julson 2017). All aspects of the vegetation sampling (summarized below) are explained in greater detail in our vegetation and utilization sampling protocols.

PLOT PLACEMENT

Random Plots

Random plots were placed throughout each experimental pasture. We conducted vegetation sampling at a minimum of 20 random plots in each of our experimental pastures

(except at Pahsimeroi in 2017-2018 because we monitored 7 pastures and did not have the personnel to complete 20 per pasture; we completed 10-15 per pasture instead). Random plot locations were moved if the randomly generated location had ≥1 of the following criteria:

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

We centered all random plots on a focal shrub (because all nest plots were also centered on a shrub) and spread two 30 m tapes that intersected at the 15 m mark in each cardinal direction (Fig. 2).

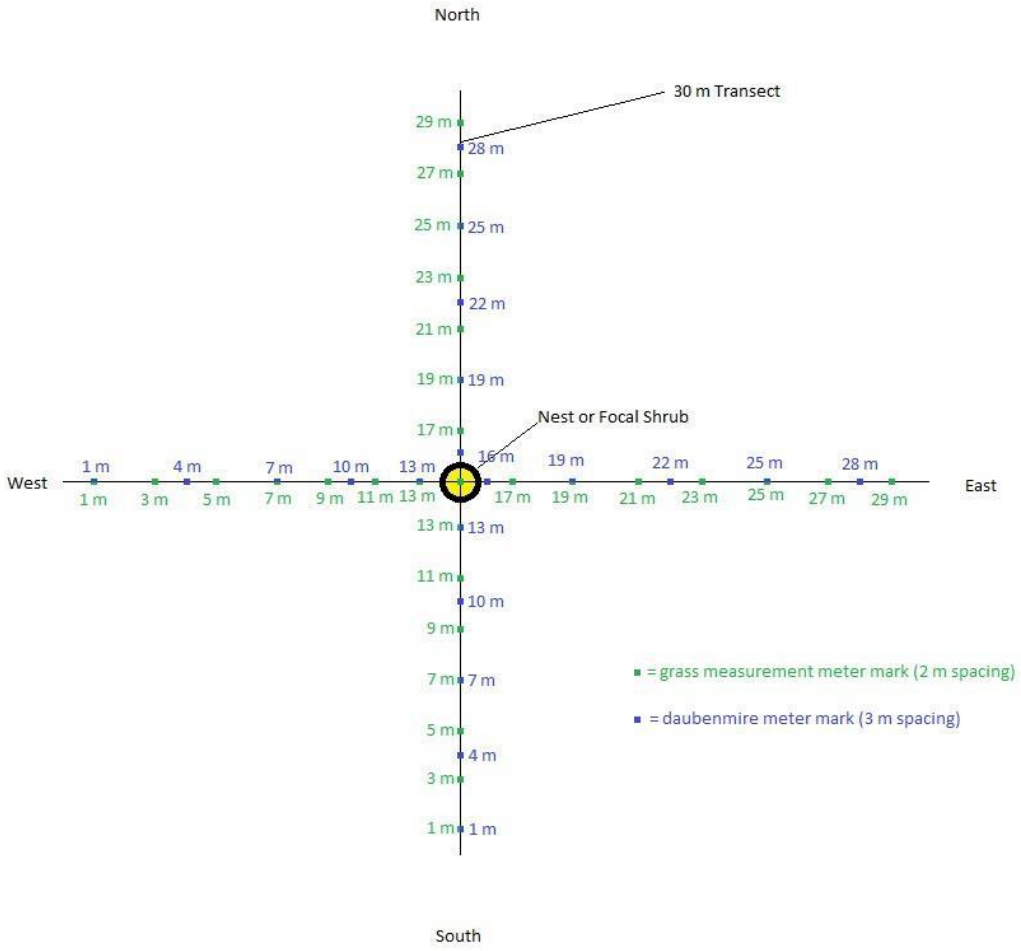

Figure 2. Visual depiction of the placement of two 30 m tapes stretched to conduct vegetation sampling at nest plots and random plots for the Grouse & Grazing Project in southern Idaho, 2014-2021.

Lek Plots

We selected leks that were in or near our experimental pastures to conduct lek vegetation surveys. We placed these surveys at the center of the lekking activity based on visual confirmation during lekking season, or sage-grouse sign (i.e. fecal, feathers) present on lekking grounds.

Wintering Plots

These vegetation surveys were located at coordinates taken by GPS units deployed on grouse during a previous field season. These locations were taken between 1 Dec – 15 Feb and were surveyed the following field season between 15 Jun – 10 Jul. Locations were randomly selected from winter-season GPS coordinates provided by satellite GPS transmitters deployed on hens at our Pahsimeroi study site. All wintering locations sampled were >500 meters of all other selected winter sampling locations. We repeated this process until we had selected 5 locations for each hen.

Cattle Use Plots

We conducted only the shrub cover portion of our vegetation surveys at high-use cattle locations within grazed pastures. GPS collars were deployed on cattle in 1 of our experimental pastures at Jim Sage in 2018, and 3 of our experimental pastures at Pahsimeroi Valley 2019-2020. We selected the locations in each pasture that had the highest cattle use and removed any locations that were within 100 m of a previously selected high-use cattle point. We continued this process until we selected 10 high-use cattle points in each of the 4 pastures. We then centered our shrub survey at this location.

CONCEALMENT

We placed a 4187-cm^3 (20-cm or ~8-inch diameter) pink ball on top of each sage-grouse nest bowl and in the most-concealed location of the focal shrub for random plots (i.e., where a sage-grouse would mostly likely build a nest in that shrub). We took photographs of the pink ball from 3 m away in each of the four cardinal directions and from directly above the nest. For the 4 pictures in the 4 cardinal directions, we took the picture with the camera 1 m from the ground. We took a 5^{th} photo directly above the pink ball with the camera 1 m above the ground to estimate overhead concealment. We used ImageJ software and followed an explicit protocol to process those images to estimate the percent of the pink ball (and hence the nest area) concealed by vegetation.

FOCAL SHRUB PATCH

The focal shrub was the center of the vegetation sampling plot and was the shrub that contained the nest (at nest plots) or the shrub that was closest to the randomly selected point that was large enough to support a sage-grouse nest (at random plots). The focal shrub

consisted of a single shrub or multiple shrubs with an intertwined and continuous canopy. We identified the shrub species, and 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 (Fig. 2). 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 (Fig. 2). Every 2 m along transects and within 1 m of each respective meter mark, we selected the nearest individual perennial grass plant for each of 3 grass species. For each of the 3 individual perennial grasses at each 2 m interval, we measured 5 traits: droop height, droop height sans flower stalk, effective height (i.e., vertical cover; based on Musil 2011), whether the grass was under a shrub canopy, and an ocular estimate of percent biomass removed by herbivores (Coulloudon et al. 1999). Some key differences in effective height measurement that we implemented as compared to Musil 2011 were 1) we measured effective height using a cover pole with 1 inch alternating red and white segments and 2) we estimated cover by selecting the first 1 inch segment that was <50 covered (>50 visible). Using this method, the lowest estimate of cover is 1.

DAUBENMIRE CANOPY COVER

At each vegetation sampling plot, we also collected canopy cover data within 20 Daubenmire (1959) frames along the two 30 m transects that intersected at the nest or focal shrub (Fig. 2). We placed a 50 x 20 cm Daubenmire frame at 3 m intervals along each of the 2 line transects at each vegetation sampling plot (nest or random plot). We estimated ground cover by using 6 pin drops along the outer edges of each of the 20 Daubenmire frames. These 6 measurements were taken in each of the 4 corners of the frame and at the midpoints on the long edges of each frame (yellow squares in Fig. 3). 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).

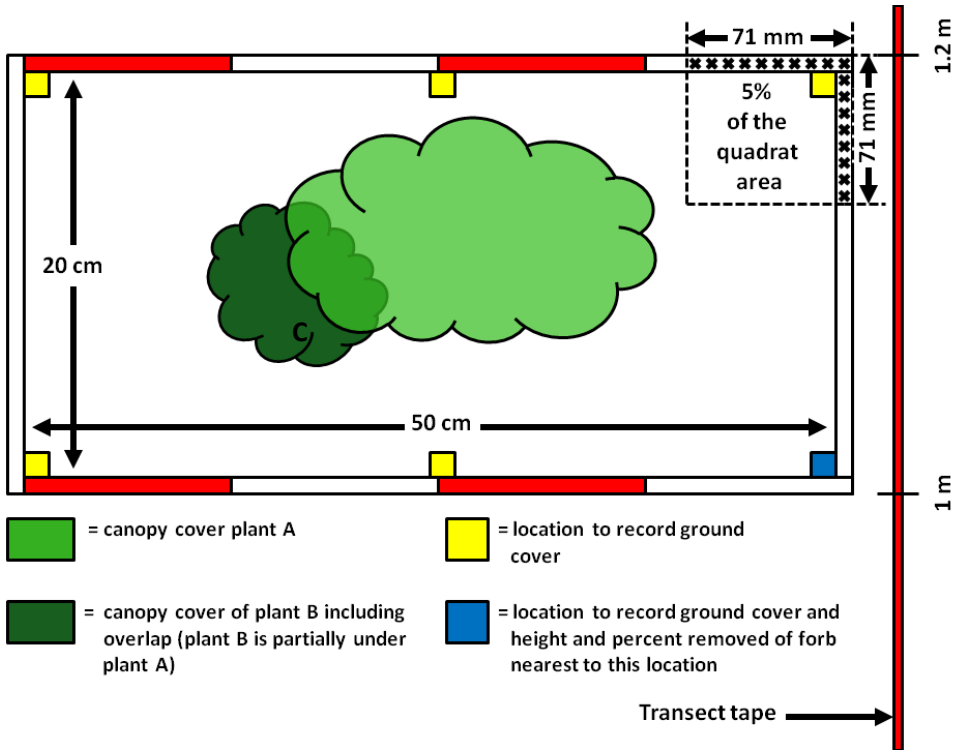

Figure 3. Example of Daubenmire frame cover measurements. Canopy cover of plant A would be an estimate of the percent of the frame the dark green colored area encompasses when looking from above the frame. Canopy cover of plant B would be an estimate of the percent of the frame the light green colored area encompasses, including the area encompassed where plant A and Plant B overlap. The region with a 'C' in the middle represents a portion of plant B protruding underneath plant A. The six small squares (5 yellow and 1 blue) 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 (Fig. 2). We counted the number of current-year cattle fecal piles and the number of past-year cattle fecal piles. We also recorded the presence or absence of elk, rabbit, and mule deer/pronghorn antelope fecal pellets (we pooled deer and antelope because of the similarities between mule deer and pronghorn antelope fecal pellets).

Table 1. We estimated percent cover for each of the 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	

9) BIOMASS FUELS SAMPLING

In 2022, we began measuring biomass at our random plots throughout our experimental pastures. We clipped and collected all forbs, grass, and litter at 4, 50x50 cm quadrats at each random plot between 1 July - 1 Aug. These squares were placed 20 m from the center point of the plot in each cardinal direction. We sorted collected biomass into 6 functional groups:

1. CPG – current year's growth of perennial grasses
2. DPG – standing dead perennial grasses
3. AG – annual grass (cheatgrass, bulbous bluegrass, and six weeks fescue)
4. F – forbs
5. HL – herbaceous litter
6. WL – woody litter

We weighed and recorded each functional group separately and collected a portion from each functional group at each quadrat and placed into a composite bag. We collected a separate composite bag for each functional group for each ~4-hour sampling period to account for changes in moisture content throughout the day. We then placed composite bags in a drying oven to calculate moisture content in each functional group to be used across the random plots that were collected during the sampling period. We aim to use these data to calculate fuels levels across our study pastures to determine any differences between treatment.

10) UTILIZATION

We used 3 methods to estimate the percent of above-ground perennial grass biomass removed by herbivores (i.e., % utilization). Utilization and grass height sampling data were collected according to an explicit utilization sampling protocol developed for the project.

OCULAR ESTIMATE METHOD

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

LANDSCAPE APPEARANCE METHOD

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

GRASS HEIGHT ALONG TRANSECTS

In 2016-2021, we measured grass height for up to 16 grass plants at every 3rd point along the landscape appearance transects (i.e., every 600 m) to improve our utilization estimates. At every 3rd point, we measured heights of grasses and recorded evidence of grazing. We measured height for each of 4 grass species within 1 m of the point (1 plant for each of 4 species). If there were <4 different plant species present at a point, then we took measurements on the closest individual plant from each species present. For each grass plant measured, we recorded 3 measurements: whether the grass plant had been grazed, the droop height, and the average height of all grazed stems (if there was evidence of grazing). After measuring height metrics of 4 grass plants at this initial location, we moved 2 paces (~3 m) forward and repeated this procedure (i.e., we measured the 3 traits above for 4 more grasses). We repeated this procedure 4 times at each 600 m interval (i.e., at 4 sampling points every 600m with a total of 16 grass plants measured every 600m along transects).

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.

11) STOCKING RATES

To comprehensively monitor the effects of cattle grazing on sage-grouse demographic traits, we collect and record a suite of details regarding the grazing regime of cattle in each of our experimental pastures and for many of the surrounding pastures. We contact range management specialist at each of the local BLM field offices in which we conduct field work to collect this information. We record the following grazing details each time cattle are put in and taken out of each of the pastures in our study sites: date cattle were turned into the pasture, the date they were taken out, the exact number of cows, and the type of cows (cow calf pairs, steers, etc.). In addition to these data, we have been updating pasture boundaries in a spatial database so that we can accurately generate random survey locations and calculate the area over which grazing has occurred. This allows us to calculate variables such as Animal Units Months (AUMs), and AUMs per hectare which give us an index of the grazing pressure in that pasture and can be used in future analyses of sage-grouse demographic traits.

12) VALIDITY OF MEASURES OF UTILIZATION (Conservation Innovation Grant)

In 2018, we began collaboration with Dr. Jason Karl, a new professor in the Rangeland Center at the University of Idaho, on a project to compare the utility of different measures of utilization. This grant from Natural Resources Conservation Service supported two additional graduate students that have been engaged in the project (A. Traynor and T. Fletcher). Additionally, this has provided funding for two additional objectives that complement the Grouse & Grazing Project:

1. Create low-cost GPS collars to fit onto a subset of cattle being turned out in the springtime in 4 of our experimental pastures. Deployment of GPS collars on cattle will allow us to link cattle usage with all of our vegetation-based measurements of utilization. Additionally, we can compare grouse use (e.g., nest-site selection) to cattle use in the same pasture.
2. Develop a model to assess utilization via remotely sensed images and link those estimates to our on-the-ground estimates of utilization.

13) WEATHER AND CLIMATE MONITORING

From 2014-2020, we obtained precipitation and temperature data at each study site via Remote Automatic Weather Stations (RAWS) and National Weather Service (NWS) stations over the course of the entire year. The weather station for the Big Butte study site is located on the southern edge of the Idaho National Lab site. Since these sites are so close together, we used the same weather station to represent climate and weather data for those 2 sites. 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 the purposes of our annual summaries, we report monthly rainfall by year and average monthly maximum temperature by year. We also include 30-year local averages of rainfall and temperature for comparison. We began using PRISM to collect and model climate data for each of our study sites in 2021 (PRISM Climate Group). PRISM incorporates data from weather stations as well as various modelling techniques to interpolate weather data across the gaps between weather stations. Since some weather stations we previously used are miles away from our study sites, we believe PRISM will give us a more precise measurement of precipitation and temperature at our experimental pastures.

14) ARTHROPOD SAMPLING

We sampled arthropods at random vegetation sampling points in a subset of pastures starting in the 2015 field season. We established the center of arthropod 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. Insect sampling consisted of 3 different sampling methods: sweep net samples, pitfall traps, and ant mound surveys (Figs. 4-5) but the intensity of arthropod sampling

varied annually based on funding. The arthropod sampling from 2014-2016 is part of Dave Gotsch's graduate thesis and will be part of Grace Overlie's thesis (starting fall 2021). The samples will also be used to create a reference collection for Ty Styhl's dissertation (2019-2024). Arthropod sampling data were collected following an explicit arthropod sampling protocol developed for the project.

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. 5). We used pitfall trap methods similar to standards recommended for estimating relative abundance of arthropods and similar to those used in past studies (Hohbein and Conway 2018). A pitfall trap array consisted of 4 pitfall traps arranged in a 5 m by 5 m square, with pitfall traps located in the corners. We partially filled all pitfall traps with propylene glycol and we placed a piece of 1 x 1 inch mesh welded-wire (16-gauge) cage material below the rim of each pitfall trap to prevent vertebrates from falling into the propylene glycol. We collected pitfall trap samples once per week for ≥4 weeks at all sampling locations between mid-May and early July 2015-2021. We stored the collected samples in ethanol.

SWEEP NET SAMPLES

We collected sweep net samples along arthropod sampling transects in 2015-2016, and 2018-2021. Sweep net surveys consisted of an observer using a sweep net along two ~50 m transects (100 sweeps) near the pitfall arrays (Fig. 5). Observers swept the net back and forth in a consistent pattern while walking the 2 transects. After each transect, all captured arthropod and plant material was transferred to a gallon Ziplock bag and frozen as soon as possible to preserve the sample. All samples were transported back to the University of Idaho at the end of the field season. We collected 2 sweep net transect samples per week for ≥4 weeks at all sampling locations between mid-May and early July of each year.

Figure 4. Visual depiction of the layout of 2 transects used for sweep net samples to collect arthropods in 2015-16 and 2018-2021.

ANT MOUND SURVEYS

We conducted distance sampling along one of the two 50 m transects to estimate ant mound density. We used a 50 m transect associated with each arthropod sampling location (Fig. 5) for ant mound surveys. We walked this transect and recorded the perpendicular distance to each ant mound detected from the transect. We used a range finder (if the mound was >10 m away) or a measuring tape (if the mound was <10 m away) to measure perpendicular distance between each mound and the transect. We recorded dimensions of each ant mound (length, width, and height) and whether we detected ant activity on the mound (i.e., the presence of ≥1 ant on the mound).

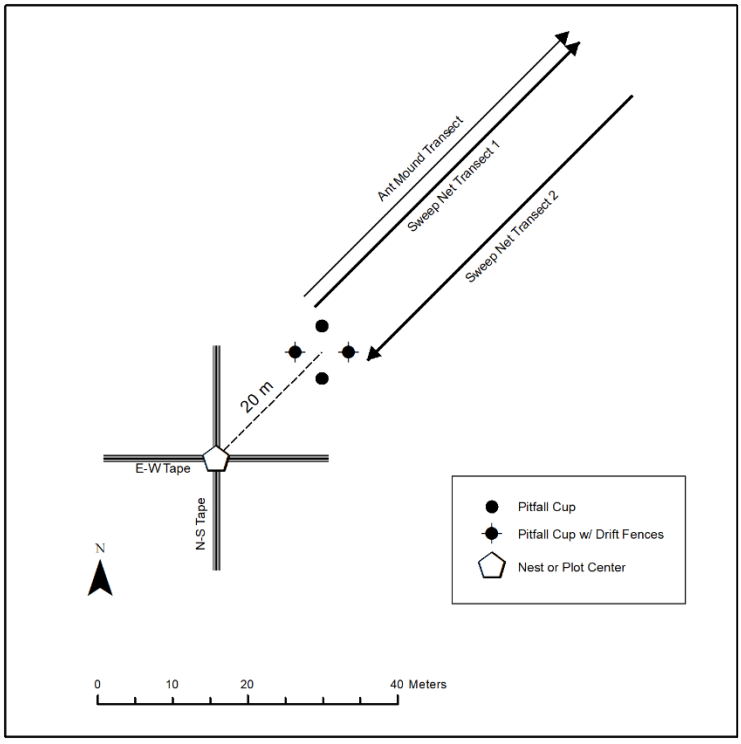

Figure 5. Visual depiction of all 3 arthropod sampling efforts (sweep net, pitfall, and ant mound) and their orientation in relation to the line transects on an accompanying random vegetation sampling plot.

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