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

Courtney J. Conway[1], Cody A. Tisdale[2], Karen L. Launchbaugh[2], Bryan S. Stevens[3], Grace E. Overlie[2], Sanford D. Eigenbrode[2], Paul D. Makela[4], and Shane B. Roberts[5]

[1]U.S. Geological Survey-Idaho Cooperative Fish and Wildlife Research Unit
[2]University of Idaho
[3]Pacific Northwest Research Station, U.S. Forest Service
[4]Bureau of Land Management (Retired)
[5]Idaho Department of Fish and Game

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For additional copies or information, contact:

Courtney Conway
U.S. Geological Survey
Idaho Cooperative Fish and Wildlife Research Unit
mail: cconway@usgs.gov

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[1]U.S. Geological Survey-Idaho Cooperative Fish & Wildlife Research Unit, Moscow, ID 83844
[2]University of Idaho, Moscow, ID 83844
[3]Pacific Northwest Research Station, U.S. Forest Service, La Grande, OR 97850
[4]Bureau of Land Management (Retired), Boise, ID 83709
[5]Idaho Department of Fish and Game, Boise, ID 83712

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EXECUTIVE SUMMARY

Greater sage-grouse (*Centrocercus urophasianus*) were once widespread within sagebrush-grassland ecosystems of western North America, but populations have declined since the mid-1960s. Though sage-grouse were not listed as threatened or endangered under the Endangered Species Act (ESA), when examined in 2015, they remain a species of interest and concern. Roughly half of the sage-grouse's remaining habitat is on federal land, most of it managed by the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS). Livestock grazing is the most extensive land use within sage-grouse habitat and the effects of livestock grazing on sage-grouse are often debated. The extensive decade-long research project summarized in this report was initiated to provide rigorous experimental research to inform the debate regarding the relationship between livestock grazing and sage-grouse. In 2012, the Idaho Grouse & Grazing Project was started with several partners including the University of Idaho, BLM, Idaho Department of Fish and Game (IDFG), and other partners to evaluate the effects of cattle grazing on sage-grouse vital rates. Many additional supporters have provided resources to this research effort including the Public Lands Council, Idaho Cattle Association, Idaho Governor's Office of Species Conservation, Western Association of Fish & Wildlife Agencies, U.S. Fish and Wildlife Service, USFS, and numerous grazing associations and ranchers in Idaho. This 10-year research project was a scientifically rigorous and replicated experiment, occurring across five study sites in Idaho. This document is intended to provide a summary of the findings of this unprecedented study. Annual reports are available on the project's website: https://idahogrousegrazing.org and scientific papers are being prepared and submitted to journals. The project focused on the influence of spring cattle grazing on sage-grouse vital rates across five study sites in Idaho including 21 BLM grazing pastures. From 2014-2023, we captured 1,343 grouse, documented the fate of 1,285 nests, and tracked 399 broods. Vegetation was characterized at 4,777 plots and grazing utilization levels were recorded at >30,000 locations. Because insects are an important food source for sage-grouse hens and their chicks, insect biomass and diversity were also examined in this study. We collected arthropods in 12,151 pitfall samples and 6,217 sweep-net samples across 786 plots within our five study sites. At each study site, three or four grazing treatments were implemented after two years of pre-treatment field investigations. These controlled cattle grazing treatments included spring-grazing in even years, spring-grazing in odd years, spring-and-fall grazing in alternating years, and a no grazing (or rested) control. Once grazing treatments were implemented at a study site, we measured sage-grouse demographic traits for 4-8 years post-treatment. Stocking rate (grazing intensity) was assessed across pastures each year and was influenced by vegetation communities, topography, and water sources. Grazed pastures exhibited lower grass cover and height compared to the no grazing pastures, and the extent of this difference varied based on annual precipitation levels. Rested pastures maintained higher grass cover and grass height, but the differences in habitat structure did not consistently translate to differences in sage-grouse

demographic traits. Apparent nesting success varied annually and by site, ranging from 24% to 44% over the study period. Like some other studies, results from this research show that successful (i.e., hatched) sage-grouse nests have taller grass heights than failed nests. The average grass height surrounding successful nests in grazed pastures was shorter than that surrounding successful nests in non-grazed (i.e., rested) pastures. It is well documented that grazing reduces grass height, and these observations have led to widely held assumptions that livestock grazing reduces grass height and therefore negatively affects sage-grouse nesting habitat. At the pasture scale, this study has found that sage-grouse nesting success is no greater in pastures that were rested for 4-8 years than those currently or recently grazed. This study gives no indication that removing cattle from pastures affected nesting success. We found some evidence that nest density varied among the grazing treatments, but we did not see compelling evidence of increases in density of nesting hens following cessation of grazing in the no grazing treatments. Brood survival varied by site and year but showed no strong effect of grazing treatment. Climatic conditions, particularly drought in 2021, had a greater effect on brood survival than grazing metrics. We also found no differences in hen survival among the grazing treatments. Results of this study suggest that hens nesting in spring and fall grazed pastures had similar or even slightly higher brood survival than hens in the rested pastures or the spring grazed pastures. Arthropod biomass and species diversity varied among our study sites and the differences between grazed and rested pastures also varied among study sites. Average biomass and diversity of arthropods was higher in the spring grazed pastures on two of three sites examined but higher in the rested pastures on the other site examined. Some taxa of arthropods were more abundant in grazed pastures while other taxa were more abundant in rested pastures. For example, Carabidae (Ground Beetles) and Formicidae (Ants) had higher biomass in grazed pastures, while Tenebrionidae (Darkling Beetles) and Acrididae (Grasshoppers) had higher biomass in non-grazed pastures. Results indicate that grazing effects on arthropod biomass and arthropod diversity are study site-dependent, suggesting a need to better quantify the most important prey taxa for sage-grouse chicks and to better control for other factors that influence arthropod abundance. Based on results of this research, livestock grazing, when properly managed, does not appear to negatively impact sage-grouse nest survival or brood success. This study provides critical insights for land managers balancing livestock production with sage-grouse conservation, supporting adaptive grazing strategies that maintain both economic and ecological objectives.

INTRODUCTION

The distribution of the greater sage-grouse (hereafter sage-grouse; *Centrocercus urophasianus*) has contracted (Schroeder et al. 2004) and abundance of males attending leks throughout the species' range has decreased substantially over the past 50 years (Garton et al. 2011, 2015; Western Association of Fish & Wildlife Agencies 2015; Coates et al. 2021; Coates et al. 2023). Many have attributed these declines to the loss, fragmentation, and degradation of sagebrush (*Artemisia* sp.)-steppe communities (Connelly et al. 2004; Knick and Connelly 2011; Doherty et al. 2016). Since 2001, the sage-steppe ecosystem has been contracting and is reduced by approximately 365,000 hectares each year due to anthropogenic development, invasion of non-native grasses, and conifer expansion (Connelly et al. 2011, Doherty et al. 2022). Anthropogenic threats to the sage-steppe include the expansion of cropland , as well as energy development, which can remove large expanses of sage-steppe vegetation (Naugle 2011; Knick 2011). Habitat loss is considered the primary reason for historical declines in sage-grouse populations, but even populations in relatively intact sage-steppe ecosystems have declined, suggesting other factors are contributing to range-wide declines (Nielson et al. 2015; Edmunds et al. 2018).

Livestock grazing is a common land use within sage-grouse habitat that has also been implicated as contributing to sage-grouse population declines (Beck and Mitchell 2000; Schroeder et al. 2004; Connelly et al. 2011; Monroe et al. 2017). A common assumption is that cattle grazing reduces forage availability and grass height, and thus reduces nest cover and increases the probability that sage-grouse nests are detected by nest predators. However, several recent studies failed to find a relationship between grass height and sage-grouse nesting success (Gibson et al. 2016; Smith et al. 2020) and failed to detect a negative effect of livestock grazing on sage-grouse nesting success (Smith et al. 2018a; Smith et al. 2018b). Moreover, livestock grazing may benefit sage-grouse via numerous mechanisms (Beck and Mitchell 2000, Crawford et al. 2004). Livestock grazing on public lands is often managed to try to minimize negative effects on populations and habitat of plants and animals, including sage-grouse, but we lack experimental studies that have explicitly examined the effects of livestock grazing on sage-grouse. The objective of the Idaho Grouse & Grazing Project was to implement randomized, experimental grazing treatments to more rigorously document the effect of cattle grazing on sage-grouse demographic traits, nest-site selection, and habitat features. The study focused primarily 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 SITES AND STUDY DESIGN

We conducted grazing experiments at five study sites in Idaho within Owyhee, Twin Falls, Cassia, Butte, Custer, and Bingham counties (Figure 1). All of these study sites are located in

Sage-Grouse Management Zone IV: The Snake River Plain (Knick 2011). Elevations at the five study sites range from 1,400 to 1,900 m.

We began field work at two study sites in 2014 (Brown's Bench, Jim Sage), two more sites in 2015 (Big Butte, Sheep Creek), and one site in 2017 (Pahsimeroi). We ceased field work at the Jim Sage study site after the 2021 field season, at the Sheep Creek site after the 2022 field season, and at the Big Butte, Brown's Bench and Pahsimeroi sites after the 2023 field season. We used two approaches to examine the relationship between livestock grazing and sage-grouse demographic traits: an experimental approach that compared randomly assigned grazing treatments (grazed versus non-grazed pastures) and an observational approach based on measurements of forage utilization at >1200 sage-grouse nests.

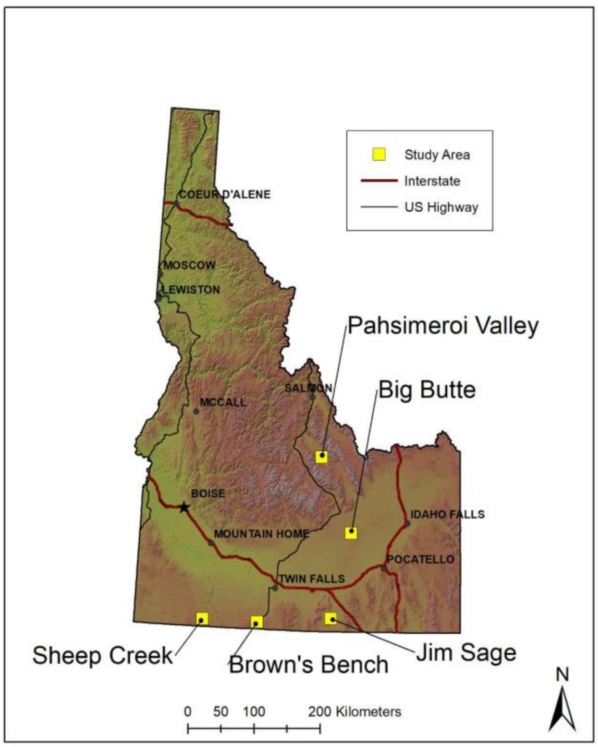

Figure 1. Location of study sites where field work was conducted across southern Idaho

Plant Communities

Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) was common in the overstory at all study sites. Criteria for selection of the research sites included >15% sagebrush cover. The pastures included in our study averaged 18.1% sagebrush cover whereas BLM pastures across southern Idaho averaged 9.4% sagebrush cover (estimates from RCMAP data from the Multi-Resolution Land Characteristics (MRLC) Consortium; https://www.mrlc.gov). Other overstory shrubs include low sagebrush (*Artemisia arbuscula*), three-tip sagebrush (*Artemisia tripartita*), rubber rabbitbrush (*Ericameria nauseosa*), and green rabbitbrush (*Chrysothamnus viscidiflorus*).

The most common understory grasses are Sandberg bluegrass (*Poa secunda*), bottlebrush squirreltail (*Elymus elymoides*), bluebunch wheatgrass (*Pseudoroegneria spicata*), western wheatgrass (*Pascopyrum smithii*), crested wheatgrass (*Agropyron cristatum*), and needlegrass (*Achnatherum spp.* and *Hesperostipa spp.*). Cover of perennial herbaceous plants averaged 26.7% on the pastures included in our study and averaged 30.6% on other BLM pastures in southern Idaho (https://www.mrlc.gov). Another selection criterion for research sites was low abundance of annual grasses; annual herbaceous cover averaged 7.7% on the pastures in our study and averaged 15.5% in other BLM pastures in southern Idaho (https://www.mrlc.gov).

Grazing Treatments

At each study site, we gathered baseline data on sage-grouse demographic traits for at least two years before grazing treatments were established (Figure 2). These first two years of data allowed the identification of appropriate grazing pastures for inclusion in the experiment based on discussions with permittees and BLM managers. During these first two years at each site, grazing occurred at times and intensities following ongoing grazing permits. These years also provide the "Before" measures of demographic traits for the BACI design (i.e., Before-After-Control-Impact). In the spring of the third year of sampling at each study site, we altered the grazing regime in 3-6 pastures per study site and began grazing according to one of four randomly assigned grazing treatments within each experimental pasture: 1) spring-only grazed in even years, 2) spring-only grazed in odd years, 3) no grazing, and 4) alternating years of spring-only grazed and fall-only grazed (Figure 2). We define spring grazing as 1 March through 15 June and fall grazing as 1 August through 15 December.

Treatment	Year 1	Year 2	Implement Grazing Treatments	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Spring Odd Years	Extant Grazing	Extant Grazing		Spring	Rest	Spring	Rest	Spring	Rest	Spring	Rest
Spring Even Years	Extant Grazing	Extant Grazing		Rest	Spring	Rest	Spring	Rest	Spring	Rest	Spring
No Grazing	Extant Grazing	Extant Grazing		Rest	Rest	Rest	Rest	Rest	Rest	Rest	Rest
Spring and Fall	Extant Grazing	Extant Grazing		Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall

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

At each site, field work was conducted for two years before grazing treatments were implemented. The number and size of experimental pastures varied among sites (Table 1). Once grazing treatments were implemented at a study site, we measured sage-grouse demographic traits for 4-8 years post-treatment; number of years varied among the five study sites.

Table 1. Pasture size and years that grazing treatments were implemented on the Idaho Grouse & Grazing project at each of the five study sites in southern Idaho.

Site	Pasture Name	Treatment	Area (ha)	Treatment Years
Big Butte	Butte South	Spring Even Years	1,711	2018-2023
	Serviceberry	Spring Odd Years	1,935	2018-2023
	Sunset North	Spring and Fall	1,774	2018-2023
	Frenchman South	No Grazing (Control)	367	2018-2023
Browns Bench	Browns Creek East	No Grazing (Control)	630	2016-2023
	Corral Creek East	Spring Even Years	618	2016-2023
	Indian Cave South	Spring Odd Years	503	2016-2023
	Indian Cave North	Spring and Fall	806	2016-2023
Jim Sage	Sheep Mountain South	No Grazing (Control)	1,071	2016-2021
	Sheep Mountain North	Spring Odd Years	883	2016-2021
	Kane Springs (Line Canyon)	Spring Even Years	368	2016-2021
Pahsimeroi Valley	River West	No Grazing (Control)	2,379	2019-2023
	River East	Spring Odd Years	2,723	2019-2023
	Goldburg SE - Summit	No Grazing (Control)	1,294	2019-2023
	Goldburg SW - Donkey Creek	Spring and Fall	549	2019-2023
	Goldburg NE - Big Gulch	Spring Even Years	1,614	2019-2023
	West River Flat North	Spring and Fall	2,194	2019-2023
Sheep Creek	(North) Tokum-Bambi West	Spring Even Years	1,721	2017-2022
	Slaughterhouse North	Spring and Fall	2,351	2017-2018*
	(North) Tokum-Bambi East	Spring Odd Years	2,385	2017-2018*
	East Blackleg (North)	No Grazing (Control)	1,491	2017-2022

*Pastures were burned in the Cat Fire just 1 year after the treatments began and were removed from the experimental treatments.

To accomplish grazing treatments, we deployed 81 electric fences (287 miles or 362 km of total fence line) across the five study sites. The temporary fences split a few large pastures into the smaller pastures above (Table 1) to more effectively manage grazing within experimental pastures and provide grazing opportunities outside experimental pastures. To effectively document the relationship between cattle grazing and sage-grouse demographic traits, we collected stocking rate data for cattle in each of our 19 experimental pastures and about 200 pastures surrounding our experimental pastures.

METHODS AND DATA SUMMARY

All methods employed in field studies are detailed in Appendix 1.

Weather and Climate Monitoring

We used Parameter-elevation Regressions on Independent Slopes Model (PRISM) to gather weather data for each of our study sites for all the years of the project (PRISM Climate Group). PRISM is a program that interpolates weather among weather stations to estimate weather conditions at a specific location. Weather impacts the reproductive success and survival of many avian species, especially sage-grouse and other ground-nesting birds (Dinkins et al. 2016; Gibson et al. 2017). The PRISM weather data allowed us to control for variation in weather experienced at our study sites across the 10 years and more rigorously address the project goals. Indeed, our study sites experienced substantial annual variation in weather, from the drought in 2021, to wetter than normal years in 2017 and 2023 (Figure 3).

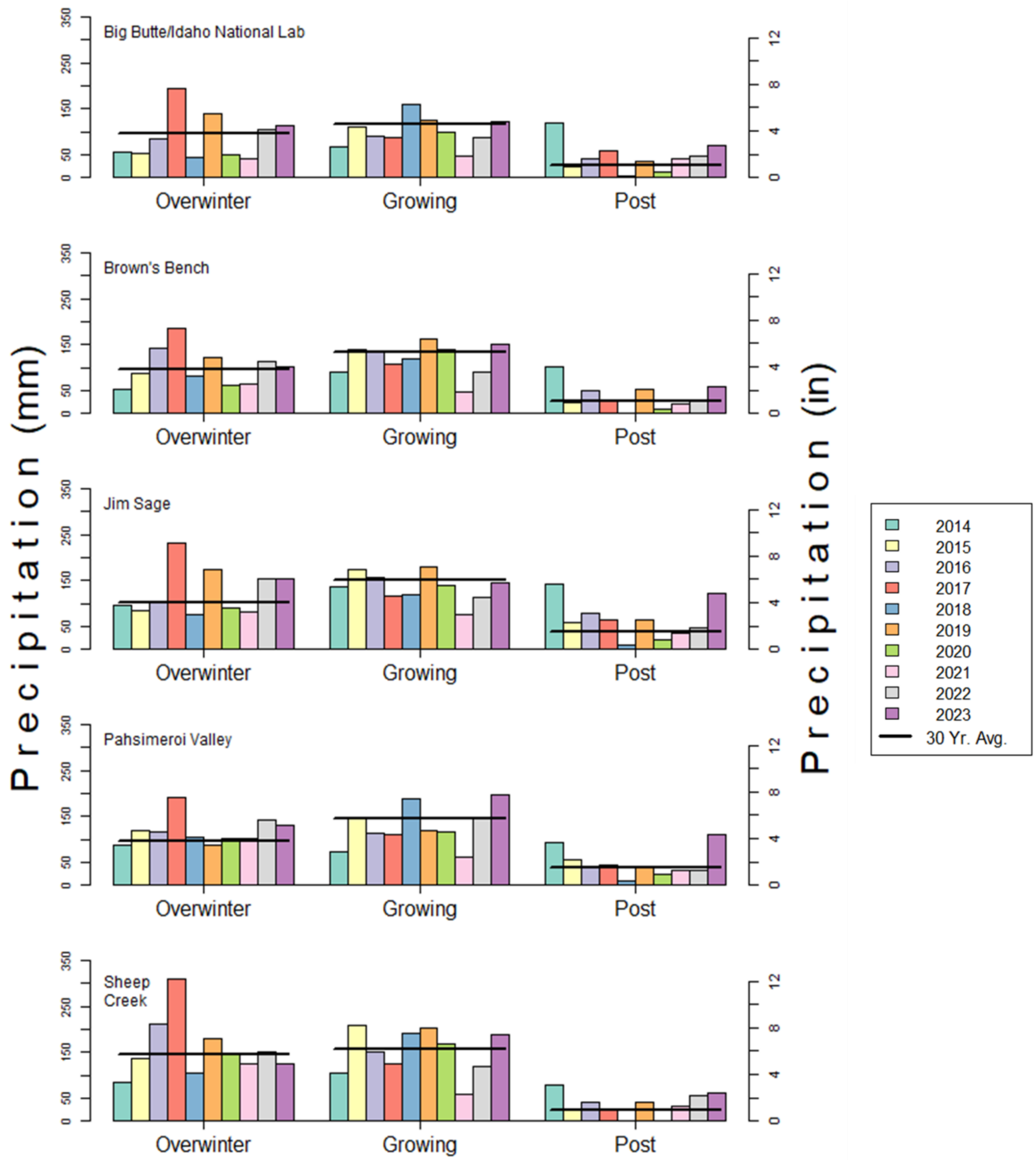

Figure 3. Precipitation (mm) by season (Overwinter 1 Oct – 29 Feb, Growing season 1 Mar – 31 Jul, Post-growing season 1 Aug – 30 Sep) for 5 study sites in southern Idaho from 2014 – 2023. Dark Lines in each plot represent a 30-year average for comparison. We used PRISM to record and model weather data at each of our five study sites.

Vegetation Measures

We conducted vegetation surveys consisting of two line-intercept transects to estimate percent shrub cover, estimates of grass height and utilization by species, Daubenmire plots to estimate percent vegetative cover, photographs to estimate percent nest concealment, dimensions of the nest or center shrub, and a count of herbivore fecal droppings. All these methods were used at “nest plots” which were centered on sage-grouse nests and “random plots” centered on sagebrush shrubs and randomly located in experimental grazing pastures. Our protocol was to conduct vegetation surveys at sage-grouse nests within 7 days of the estimated hatch date (regardless of fate) so that failed and successful nests were measured at the same times to avoid the phenological biases encountered in other studies and to prevent the need for any phenological corrections (Borgmann and Conway 2015, Gibson et al. 2016, Smith et al. 2017). Vegetation survey methods are detailed in Section 6 in our Vegetation Monitoring Protocol (Appendix 1).

In addition to nest and random plot surveys, we used various subsets of these methods to conduct surveys at other locations. From 2016-2023, we also conducted vegetation surveys at plots where hens with broods had been documented. From 2020-2021, we conducted vegetation surveys at the sage-grouse leks within and around our experimental pastures, and in 2021 we measured vegetation at 42 hen wintering locations in the Pahsimeroi Valley study site.

We conducted vegetation measurements during the sage-grouse breeding season (15 Apr – 18 Jul) at 4,777 plots across 10 years of the study (1,056 nest, 3,196 random, 331 brood, 72 lek, 80 cattle use areas, and 42 hen winter location plots; Table 2). We sampled grass height and grazing intensity metrics for 396,203 grass plants on the 4,777 vegetation sampling plots. We re-sampled 3,118 of the random plots again at the end of the growing season (18 July – 5 August). During the project, we walked transects through all 19 experimental pastures to provide estimates of percent utilization by the landscape appearance method at 32,203 sampling locations along the transects, and we used these data for pattern use mapping within these pastures. While conducting transects, we also recorded the most common grass, the dominant shrub, and the percent cover of cheatgrass and measured height, species, and evidence of grazing for 149,904 individual grass plants across 32,203 sampling locations. Summaries of these data are included in our site-specific grazing reports on the project website (https://idahogrousegrazing.org).

Table 2. Number of breeding-season and post-growing-season nest and random plots sampled each year and the earliest and latest date of completion of those plots at all 5 study sites, 2014-2023. The numbers below do not include plots sampled at brood locations or winter season plots.

	Breeding Season					Post-Growing Season		
Year	Random Plots	Nest Plots	Total Plots	Earliest Survey	Latest Survey	Random Plots	Earliest Survey	Latest Survey
2014	39	54	93	20-May	2-Jul	0	-	-
2015	280	89	369	7-May	9-Jul	279	20-Jul	4-Aug
2016	367	97	464	17-Apr	5-Jul	346	18-Jul	18-Aug
2017	351	93	444	4-May	5-Jul	379	19-Jul	15-Aug
2018	385	102	487	7-May	3-Jul	360	19-Jul	10-Aug
2019	397	120	517	30-Apr	27-Jun	398	19-Jul	7-Aug
2020	395	144	539	2-May	14-Jul	379	21-Jul	10-Aug
2021	382	117	499	3-May	2-Jul	377	19-Jul	4-Aug
2022	320	119	439	2-May	11-Jul	320	19-Jul	5-Aug
2023	280	121	401	22-May	14-Jul	280	18-Jul	2-Aug
Totals	3,196	1,056	4,252	25-Apr	14-Jul	3,118	18-Jul	18-Aug

Both grass cover and height varied by study site and year (Figures 4 & 5). The no grazing pastures tended to have higher grass cover and height than the grazed treatments, although this was more apparent in the grass height metrics (Figures 4 & 5). Overall, precipitation seems to have a much larger effect on these grass metrics than the grazing treatments, especially during the drought year of 2021.

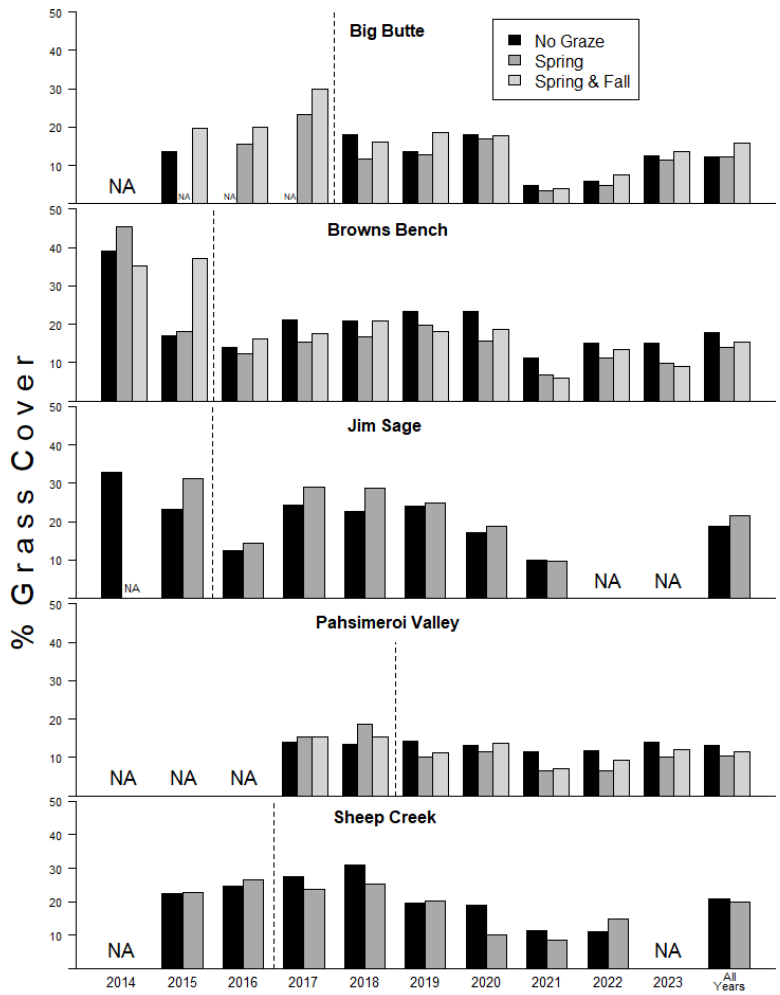

Figure 4. Grass cover (%) at each site over the 10 years of the project within each of the 3 grazing treatments. The dashed line indicates when treatments began at each site. Jim Sage did not have a Spring & Fall grazing treatment pasture. Sheep Creek was planned to have a Spring & Fall pasture, but a fire burned across it before the treatments could be implemented.

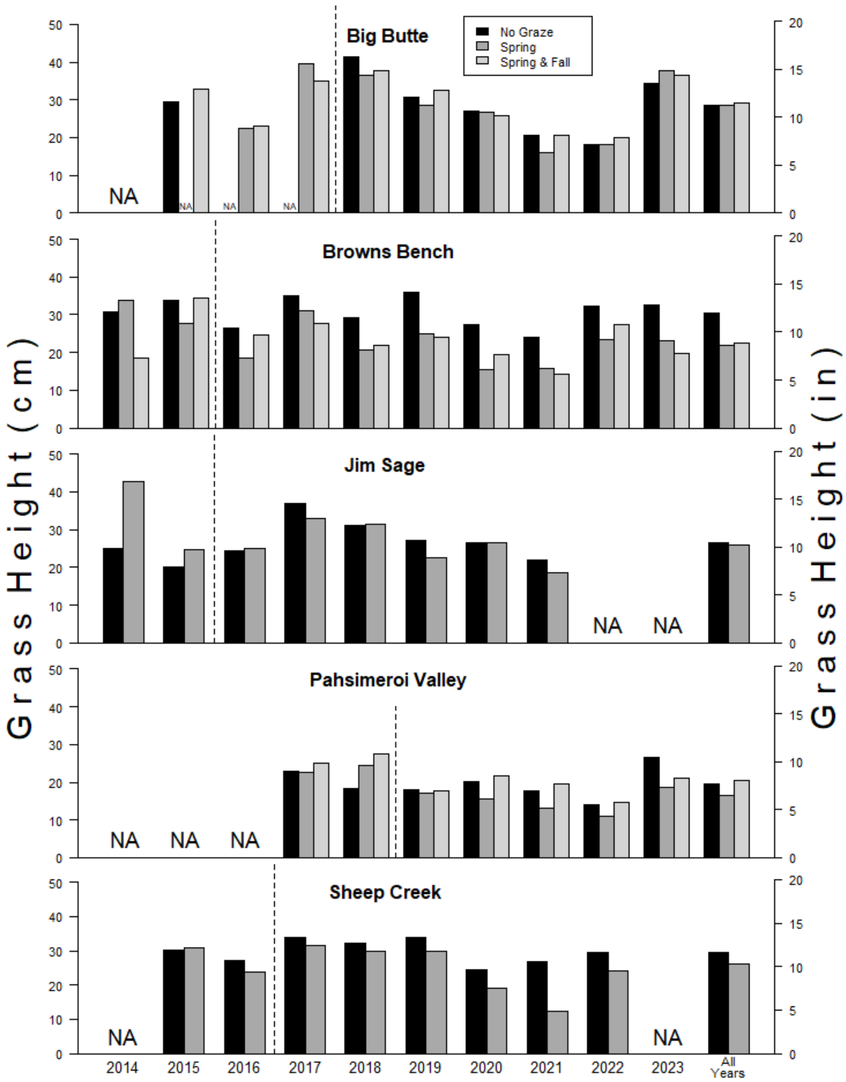

Figure 5. Grass height (cm) at each of the 5 study sites over the 10 years of the project (includes pre- and post-treatment years). Vertical dashed line indicates when experimental grazing treatments were implemented at each study site.

Utilization Sampling

Cattle use was not uniform within a pasture, reflecting differences in topography, proximity to water sources and other factors, so we therefore measured variation in utilization throughout each experimental pasture. To evaluate the proportion of above-ground perennial grass biomass removed by grazing animals (i.e., utilization), three different field methods were employed in experimental pastures: Ocular Estimates of Individual Grasses, Landscape Appearance, and Grass Height Along Transects. When and how these methods were applied are detailed in Section 7 of Appendix 1.

Utilization within pastures varied over the years depending on the number of cattle and grazing days in each pasture (Figure 6). These differences can also be seen across sites (Table 3). These surveys provide patterns of areas preferred or avoided by cattle and any variation in spatial distribution of cattle grazing across experimental pastures. Utilization in pastures not grazed by cattle also provides an estimate of grazing by wildlife. The remaining four study sites can be seen in Figures A2-1 thru A2-4 in Appendix 2.

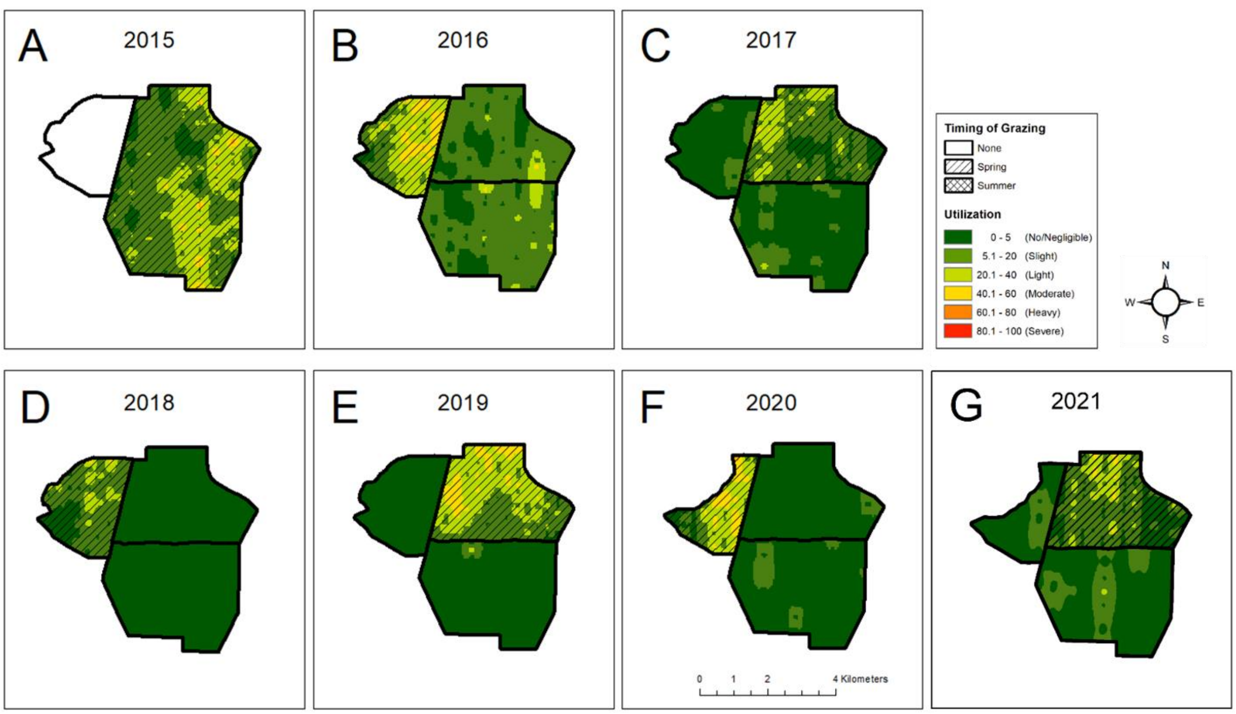

Figure 6. Pattern use mapping based on landscape appearance transects at Jim Sage, Idaho 2015-2023. We did not conduct utilization transects in 2014. These maps for Jim Sage are included here for an example. Similar maps, by year, were developed for each of the five study sites.

Table 3. Average utilization (%) measured in the field each year in each pasture via the landscape appearance method varied by site and treatment for all post-treatment years at five field sites across southern Idaho. Average utilization in Rested Years includes only the years when the pastures were not grazed by cattle, or rested, before we conducted utilization measurements, while Grazed Years includes utilization measured during years the pastures were grazed prior to utilization measurements.

		Average Utilization	
Treatment	Site	Rested Years (%)	Grazed Years (%)
No Grazing (Control)	Big Butte	4.8	NA
	Brown's Bench	4.7	NA
	Jim Sage	4.6	NA
	Pahsimeroi Valley	3.9	NA
	Sheep Creek	4.7	NA
Spring Only	Big Butte	7.6	24.3
	Brown's Bench	5.7	32.9
	Jim Sage	4.5	18.5
	Pahsimeroi Valley	4.0	17.3
	Sheep Creek	3.5	23.2
Spring and Fall	Big Butte	3.5	23.9
	Brown's Bench	4.4	16.7
	Pahsimeroi Valley	7.4	19.6

Arthropod Sampling

We used pitfall traps to conduct arthropod sampling annually from 2015-2021 at random vegetation sampling points within a subset of the experimental pastures. The intensity of arthropod sampling varied among project years because of variation in project funding. Pitfall traps have been used to measure arthropod abundance and biomass more than any other method (Hohbein and Conway 2018). We used methods for setting and deploying pitfall traps similar to standards recommended for estimating relative abundance of arthropods and similar to those used in many past studies (Hohbein and Conway 2018). A more detailed description of the methods we used for arthropod sampling is presented in Section 10 of Appendix 1.

Over the 7 years of arthropod sampling on the project, we collected 12,151 pitfall samples and 6,217 sweep-net samples across 786 plots in our experimental pastures at our five sites. We processed samples from four years (2018-2021) at three study sites (Brown’s Bench, Big Butte, and Jim Sage) within two treatments (Spring Grazing and No Grazing treatments). We combined the even years and odd years spring grazing treatments into a spring grazing treatment group for comparison with the no grazing treatment group. We identified adult insects captured in pitfall traps to taxonomic family and counted them, while non-insect arthropods were identified to taxonomic order. We recorded the length of each arthropod specimen into 11 size classes defined in 5 mm increments. We estimated biomass of each arthropod using its length and allometric regression equations derived from prior studies that established length-mass relationships in invertebrates (Rogers et al. 1977, Ganihar 1997, Wardhaugh 2013, Hódar 1997, Overlie 2024). For the samples processed, we identified and measured 99,832 arthropods representing 78 taxa from 1,040 pitfall samples. We separated our analyses and subsequent results into food arthropods and non-food arthropods. Food arthropods included taxa listed in Goosey et al. (2019): Acrididae, Carabidae, Chrysomelidae, Coccinellidae, Curculionidae, Formicidae, Gryllidae, Scarabaeidae, Tenebrionidae, and Tettigoniidae.

Capture and Radio-marking

We captured >99% of sage-grouse via nighttime spotlighting methods and <1% via rocket nets at leks. Details regarding explicit methods for both trapping approaches are included in Section 1 of field methods described in Appendix 1. We monitored radio-marked sage-grouse using methods described in Section 2 of Appendix 1. We used three methods to monitor the fate of sage-grouse broods (Riley and Conway 2020): daytime visual surveys, nighttime spotlight surveys, and nighttime fecal pellet surveys. We conducted daytime visual surveys at 7, 14, 28, and 42 days of age. More details of these methods are in Section 5 of Appendix 1.

We deployed radio transmitters on 1,343 female sage-grouse across 5 study sites from 2014-2023: 759 adults (57%), 538 yearlings (40%), and 46 of unknown ages (3%, Figure 7). Battery life of deployed transmitters was about 2.5 years, so we monitored hens for multiple seasons if they survived and were still within our study areas. We also recaptured hens opportunistically in years following their initial capture and deployed new transmitters, extending the period we could monitor some individuals.

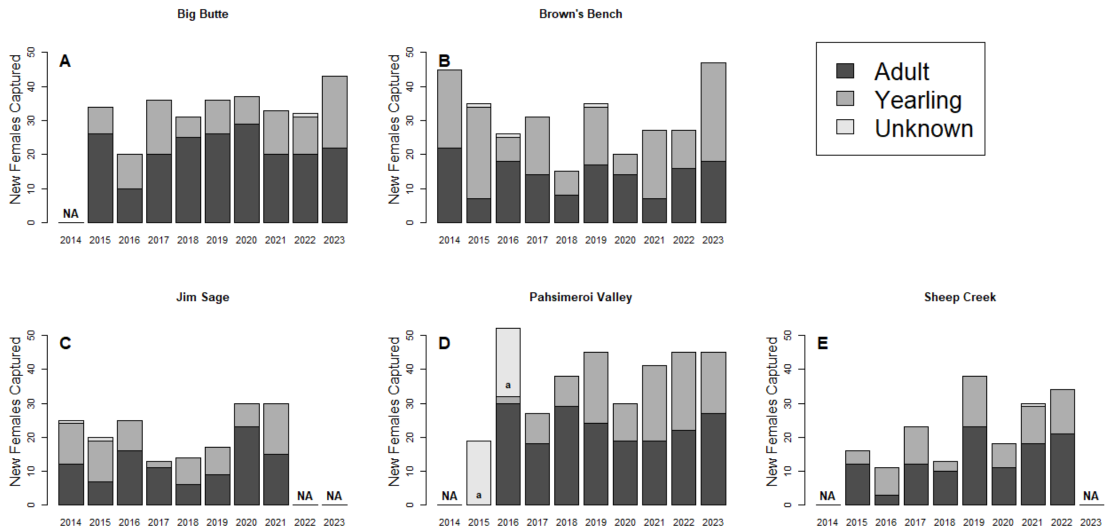

Figure 7. Number of new female sage-grouse captured (excluding recaptures) at five study sites in southern Idaho from 2014-2023. 'NA' denotes that no capture activities occurred in that year. An 'a' at Pahsimeroi in 2015 and 2016 indicates that trapping efforts in those years were conducted by entities other than the Grouse & Grazing Project field crews.

Age Ratios

We calculated the yearling-to-adult age ratio of female sage-grouse captured at all study sites: number yearling females/number adult females. This ratio provides an index of recruitment for the previous year. Higher numbers of yearling females in the population indicate high annual recruitment from the prior year and yield higher yearling-to-adult ratios. Yearling-to-adult ratio varied among sites (Table 4) and years (Table 5). The highest yearling-to-adult ratio was observed during the first year of the project (2014) while field work was only conducted at the Brown's Bench and Jim Sage sites. The lowest yearling-to-adult ratio was 0.36 during the spring of 2020 (Table 5). Overall (across all years), we observed the highest yearling-to-adult ratio at Brown's Bench (1.04) and the lowest at Big Butte (0.50) (Table 4).

Table 4. Number of yearling and adult female sage-grouse captured at 5 study sites across southern Idaho, 2014-2023. The numbers in this table include recaptures of females in subsequent years after they were first marked.

	Big Butte	Brown's Bench[a]	Jim Sage[b]	Pahsimeroi Valley	Sheep Creek	All Study Sites
#Yearling	103 (33%)	164 (51%)	73 (39%)	115 (37%)	72 (38%)	531[a] (40%)
#Adult	208 (67%)	157 (49%)	112 (61%)	198 (63%)	118 (62%)	799[a] (60%)
Yearling/ Adult Ratio	0.50	1.04	0.65	0.58	0.61	0.66

[a]Includes 4 yearlings and 6 adults captured at Idaho National Laboratory in 2019.

[b]23 female sage-grouse were captured at these sites in 2012 & 2013 by non-Grouse & Grazing personnel that are not included in this table. We did include these early captured grouse in our tracking efforts starting in 2014.

Table 5. Number of yearling and adult female sage-grouse captured by year across 5 study sites in southern Idaho from 2014-2023. This table includes recaptures and excludes hens whose age was not recorded at capture. Numbers in parentheses indicate the percentage of total captures that year.

	2014	2015	2016	2017	2018	2019[a]	2020	2021	2022	2023
#Yearling	35 (50%)	51 (47%)	36 (31%)	55 (42%)	33 (27%)	75 (40%)	39 (27%)	81 (49%)	58 (40%)	68 (48%)
#Adult	35 (50%)	57 (53%)	79 (69%)	75 (58%)	87 (73%)	112 (60%)	107 (73%)	86 (51%)	86 (60%)	75 (52%)
Yearling/Adult Ratio	1.00	0.89	0.46	0.73	0.38	0.67	0.36	0.94	0.67	0.91

[a]*Includes 4 yearlings and 6 adults that were captured at Idaho National Laboratory.*

Hen Mortality

We recovered 527 collars from apparent mortalities during the project. Of these mortalities, 120 (23%) occurred during the winter (1 Oct – 29 Feb), 368 (71%) occurred during the breeding season (1 Mar – 31 Jul), 30 (6%) occurred during the post-growing season (1 Aug – 30 Sep), and the remaining 9 have an unknown mortality date (hens that went missing over the winter and collars were not located until much later). Mortalities varied across years and study sites (Figure 8). Mortalities were most frequent during April and May (during nesting and the early stages of brood rearing). One major difference that began in 2019 was the number of overwinter mortalities recovered. From 2019-2023, flights were contracted to locate radio-marked hens early in the year (Feb-Mar) just prior to the arrival of field crews. This allowed us to recover mortalities of hens that died far from the experimental pastures (i.e., those that would not have otherwise been recovered in years without those flights). In 2023, this flight occurred in May due to the lack of availability of pilots to schedule flights (Table A2-1 in Appendix 2).

A few of our marked grouse were legally harvested by hunters each year in the September sage-grouse hunting season. In 2014-2018, there was a 7-day hunting season (~15 – 21 Sep) with a daily bag limit of 1 grouse. In 2019 and 2020, the season was reduced to a 2-day season (21 – 22 Sep) north of the Snake River and remained a 7-day season south of the Snake River (21 – 27 Sep). In 2021-2023, the length of the season was greatly expanded (18 Sept – 31 Oct, but tags were required, and hunters were limited to one or two grouse the entire season, depending on the area). Since 2017, 12 grouse banded by the Grouse & Grazing Project have been harvested (7 radio-collared females and 5 banded males). On the Brown's Bench Site, harvested females included two in 2018, two in 2019, one in 2020 and one in 2022. Two males were also harvested at Brown's Bench in 2020. No harvested animals were recorded on the Big Butte site. On the Jim Sage site, one male in 2017 and one male in 2019 were recorded as harvested. On the Pahsimeroi site, one banded male was harvested in 2021 and one female was harvested in 2018 on the Sheep Creek site.

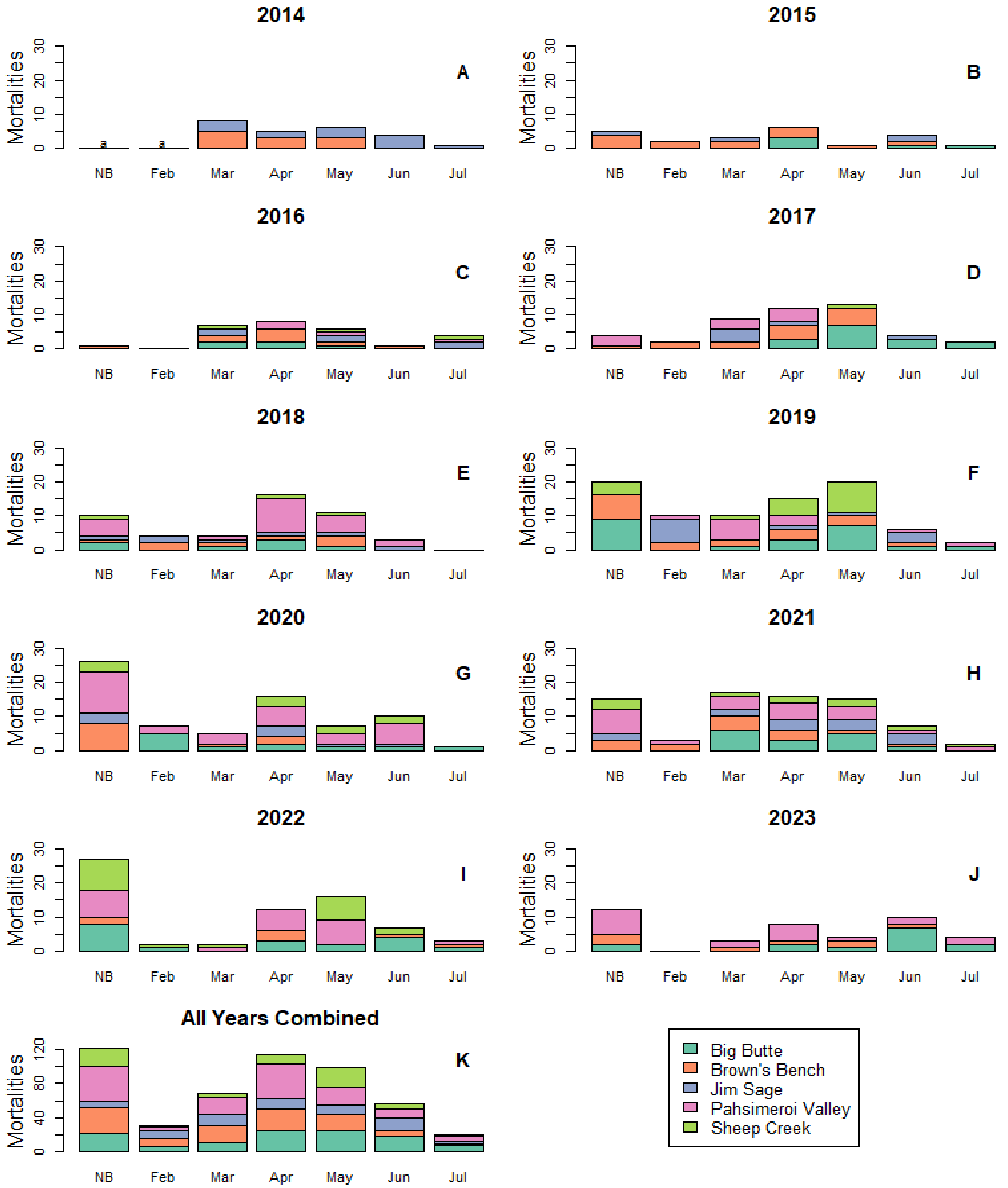

Figure 8. Mortalities of radio-marked female sage-grouse by month (and non-breeding season) at 5 study sites across southern Idaho from 2014-2023. The value 'NB' on the x-axis represents the cumulative non-breeding months (Aug – Jan; these are also months that we do not monitor sage-grouse and cannot accurately identify the exact month of mortality). Field work was not started at Sheep Creek and Big Butte until 2015 and was not started at Pahsimeroi Valley until 2017.

Nest Searching and Monitoring

We located 1,285 nests across five study sites from 2014-2023 including nests inside and outside of the 19 experimental pastures (Figure 9). We determined the fate for 1,278 nests including 68 incidental nests of hens that were not collared: 447 hatched at least 1 egg (35%) and 831 were unsuccessful (65%). Of the 1,217 nests monitored during the project, 1,070 were thought to be initial nesting attempts, 142 were second attempts, and 5 were documented third attempts. We found 68 nests of uncollared hens, and we could not determine whether those were 1st, 2nd, or 3rd nesting attempts. Of the 1,285 nests, 609 (47%) were within and 676 (53%) were outside of our experimental pastures (Figure 9). At some sites, such as Big Butte, most nest sites we assessed were outside the experimental pastures while at other sites, such as Jim Sage, most nest sites we examined were inside our experimental pastures.

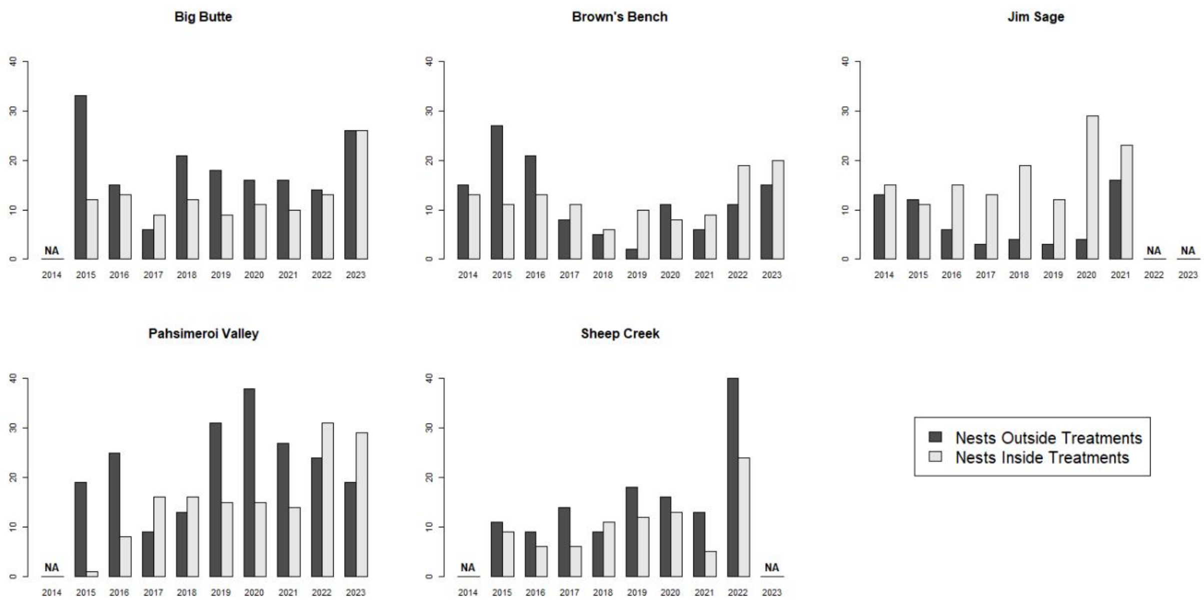

Figure 9. Number of sage-grouse nests inside and outside of the 19 experimental pastures at 5 study sites in southern Idaho, 2014-2023. Nests in 2015-2016 at Pahsimeroi Valley were collected by BLM and USFS personnel prior to inclusion in this study.

Nesting Propensity

We calculated nesting propensity as the number of radio-marked hens that initiated at least one nesting attempt divided by the number of radio-marked hens tracked (i.e., those that we monitored closely) during the nesting period. Not all studies that reported estimates of nesting propensity have clearly defined a "tracked bird" (i.e., the denominator used in calculating nesting propensity). Selecting an explicit definition of a tracked bird is important for this project because we did not put forth the same tracking effort on all marked hens. We monitored hens that stayed in the experimental pastures closely whereas we largely ignored hens that left the study area or whose signals disappeared. Hence, we used two approaches to define a “tracked bird” and calculated two measures of nesting propensity based on those two approaches: 1) a tracked bird was any hen that we either found or 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” was any hen that we either found or 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 of a tracked hen (approach #1; should yield fewer tracked hens) and a more liberal definition of a tracked hen (approach #2; should yield more tracked hens).

Overall nesting propensity was 95.1% (*n* = 1,136) for method 1 (liberal) and 81.6% (*n* = 1,323) for method 2 (conservative); the 2 methods differed in the number of hens included in the denominator that were effectively tracked (Tables 6 & 7). Nesting propensity was lower in the first few years of the study compared to the subsequent eight years, likely due to improved methods of tracking collared hens and more funding available that allowed more personnel to better track collared hens (Table 7).

Re-nesting propensity varied across years (Table 8), with the highest observed in 2022 (44.0%) and lowest in 2019 (11.9%). Re-nesting success ranged from 21.4% (2017) to 66.7% (2021). Sample sizes for re-nesting attempts are small for individual years, which is why the variation in these two parameters is high across years.

Table 6. Nesting propensity of radio-marked sage-grouse hens based on 2 different methods for calculating the number of hens effectively tracked at 5 study sites across southern Idaho 2014-2023.

Study Site	Hens that Initiated ≥1 Nest[c]	Method 1[a] Hens Tracked	Method 1[a] Nesting Propensity	Method 2[b] Hens Tracked	Method 2[b] Nesting Propensity
Big Butte	232	236	98.3	283	82.0
Brown's Bench	200	209	95.7	254	78.7
Jim Sage	175	200	87.5	227	77.1
Pahsimeroi Valley	289	305	94.8	348	83.0
Sheep Creek	170	172	98.8	196	86.7
Overall	1,066[d]	1,122	95.0	1,308	81.5

[a]Defined a tracked hen as “any hen that we either found a nest or we did not find a nest but obtained a location on the hen ≥1 time per week between the 14th and 23rd week of the year, and thus tracked at least 10 times within the nesting period”.
[b]Defined a tracked hen as “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 and thus tracked at least 5 times within the nesting period”.
[c]Number of hens that initiated at least one nest.
[d]68 incidental nests and 4 nests at Idaho National Laboratory are not included in this total.

Table 7. Nesting propensity (%) of radio-marked sage-grouse hens based on 2 different methods for calculating the number of hens effectively tracked for each of 10 years at 5 study sites (pooled) in southern Idaho, 2014-2023.

Year	Hens that Initiated ≥1 Nest[c]	Method 1[a]		Method 2[b]	
		Hens Tracked	Nesting Propensity	Hens Tracked	Nesting Propensity
2014	50	60	83.3	72	69.4
2015	117	136	86.0	170	68.8
2016	116	139	83.5	195	59.2
2017	81	86	94.2	110	73.6
2018	101	102	99.0	132	76.5
2019	123	128	96.1	149	82.6
2020	135	139	97.1	157	86.0
2021	124	130	95.4	157	79.0
2022	113	113	100	129	87.6
2023	114	115	99.1	125	91.2
Overall	1,074[d]	1,148	93.5	1,396	76.9

[a]Defined a tracked bird as "any hen that we either found a nest or we did not find a nest but obtained a location on the hen ≥1 time per week between the 14th and 23rd week of the year".
[b]Defined a tracked bird as "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".
[c]Number of hens that initiated at least one nest, does not include incidentally found nests of uncollared hens.
[d]69 incidental nests are not included in this total.

Table 8. Re-nesting propensity (%) for female sage-grouse at all 5 study sites combined in southern Idaho, 2014-2023.

Year	Failed 1st Attempt	Re-nested	Hatched	Re-nesting Propensity	Apparent Success of Re-nesting Attempts
2014	29	6	3	22.2	50.0
2015	64	12[a]	7	20.0	58.3
2016	82	15	8	16.9	53.3
2017	59	14	3	23.7	21.4
2018	68	11	5	16.2	45.5
2019	84	10	3	11.9	30.0
2020	81	18	7	22.2	38.9
2021	70	9	6	12.9	66.7
2022	84	37[a]	13	44.0	35.1
2023	64	16	6	25.0	37.5
Total	685	148	61	21.6	41.2

[a]includes 3rd nesting attempts (1 attempt in 2015 and 4 in 2022)

Nesting Success

We calculated apparent nesting success by dividing the number of hatched nests by the total number of nests monitored (hatched nests/[hatched nests + failed nests]), excluding nests with unknown nest fate (n=7). We calculated apparent nesting success for each study site across all 10 years of the study. We also calculated daily survival of nesting attempts by using the program RMark (White and Burnham 1999) to account for potential bias caused by low detection probability for nests that fail early in the nesting cycle (Mayfield 1975). We used the Julian day of the year for the start and end dates of each nesting attempt. We used daily survival estimates from RMark and raised that daily survival probability to the 37th power to estimate the probability that a nesting attempt would survive an entire 37-day nesting cycle (10-day laying period and 27-day incubation period). We included the egg-laying period in this estimate because we found and began monitoring some nests prior to the onset of incubation. We used the delta method (Powell 2007) to calculate standard errors for the 37-day nest survival estimates.

Apparent nesting success (percentage of nests tracked that hatched at least one egg) varied by pasture and year (Tables 9 & 10). We observed the lowest apparent nesting success in 2022 (24%) and highest in 2015 (44%). Apparent nesting success was highest at the Brown's Bench study site (44%) and lowest at the Sheep Creek study site (31%; Table 9).

Daily nest survival also varied by year. Modeling daily nest survival helps account for any nests that are initiated but fail before field crews can determine the hen has started nesting, which is one reason that nesting success probability is typically lower than apparent nesting success every year (Figure 10).

We also measured grass heights at nests with known fates, as well as random locations throughout our treatment pastures (Figure 11). Unsurprisingly, average grass heights in grazed pastures were lower than those that were not grazed by cattle before the vegetation survey or those in non-grazed pastures. However, grass heights were similar between hatched and failed nests, even in the grazed pastures.

Table 9. Apparent nesting success at 5 study sites across southern Idaho (2014-2023).

Study Site	Apparent Nesting Success (%)										
	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	All Years Pooled
Big Butte	-[a]	36	29	36	27	26	48	58	30	59	36
Brown's Bench	57	57	38	21	50	42	42	53	30	29	44
Jim Sage	28	43	33	23	32	20	45	34	-[a]	-[a]	34
Pahsimeroi	-[a]	-[a]	-[a]	28	26	33	32	38	20	33	31
Sheep Creek	-[a]	30	33	30	40	30	34	39	23	-[a]	31
Total	42	44	32	26	32	31	38	43	24	41	35

[a] We did not conduct field work at this study site during this year.

Table 10. Summary of sage-grouse nests by study site and pasture at 5 study sites in southern Idaho. Nests at the Pahsimeroi Valley site include nests tracked by USFS and BLM personnel before the Grouse & Grazing project started, numbers in parentheses indicate nests in 2017-2023 during the project.

Study Site	Pasture Name	Treatment	Failed	Hatched	Total	Apparent Nesting Success
Big Butte	Butte South	Spring	23	17	40	42.5
	Serviceberry	Spring	22	18	40	45.0
	Sunset North	Spring & Fall	12	7	19	36.8
	Frenchman South	No Grazing	13	3	16	18.8
	Other Pastures	Non-Treatment	99	66	165	40.0
	Total		169	111	280	39.6
Brown's Bench	Indian Cave South	Spring	24	17	41	41.5
	Corral Creek East	Spring	14	7	21	33.3
	Indian Cave North	Spring & Fall	14	13	27	48.1
	Browns Creek East	No Grazing	22	9	31	29.0
	Other Pastures	Non-Treatment	66	53	121	44.5
	Total		140	99	241	41.1
Jim Sage	Kane Springs	Spring	20	11	31	35.5
	Sheep Mountain North	Spring	25	16	41	39.0
	Sheep Mountain South	No Grazing	47	11	59[a]	18.6
	Other Pastures	Non-Treatment	40	25	67[a]	37.3
	Total		132	63	198[a]	31.8
Pahsimeroi Valley	Goldburg NE - Big Gulch	Spring	38(37)	13(12)	51(49)	25.5(24.5)
	River East	Spring	13(12)	7(6)	20(18)	35.0(33.3)
	Goldburg SW - Donkey Creek	Spring & Fall	12(12)	1(0)	13(12)	7.7(0.0)
	West River Flat North	Spring & Fall	12(11)	3(3)	15(14)	20.0(21.4)
	River West	No Grazing	18(16)	7(7)	25(23)	28.0(30.4)
	Goldburg SE – Summit	No Grazing	12(11)	9(9)	21(20)	42.9(45.0)
	Other Pastures	Non-Treatment	137(108)	68(51)	207(163)[a]	33.1(32.1)
	Total		242(207)	108(88)	352(299)[a]	30.7(29.4)
Sheep Creek	(North) Tokum-Bambi West	Spring	15	11	26	42.3
	(North) Tokum-Bambi East[a]	Spring	18	3	21	14.3
	Slaughterhouse North[b]	Spring & Fall	15	5	20	25.0
	East Blackleg (North)	No Grazing	43	17	60	28.3
	Other Pastures	Non-Treatment	59	30	89	33.7
	Total		150	66	216	30.6
	Overall Estimate		833(798)	447(427)	1,287(1,234)	34.9(34.8)

[a] *Contains nests with unknown fate, these nests were not included while calculating apparent nesting success.*

[b] *A fire burned most of these pastures in 2018 just a year after our treatments started and were not used as treatment pastures.*

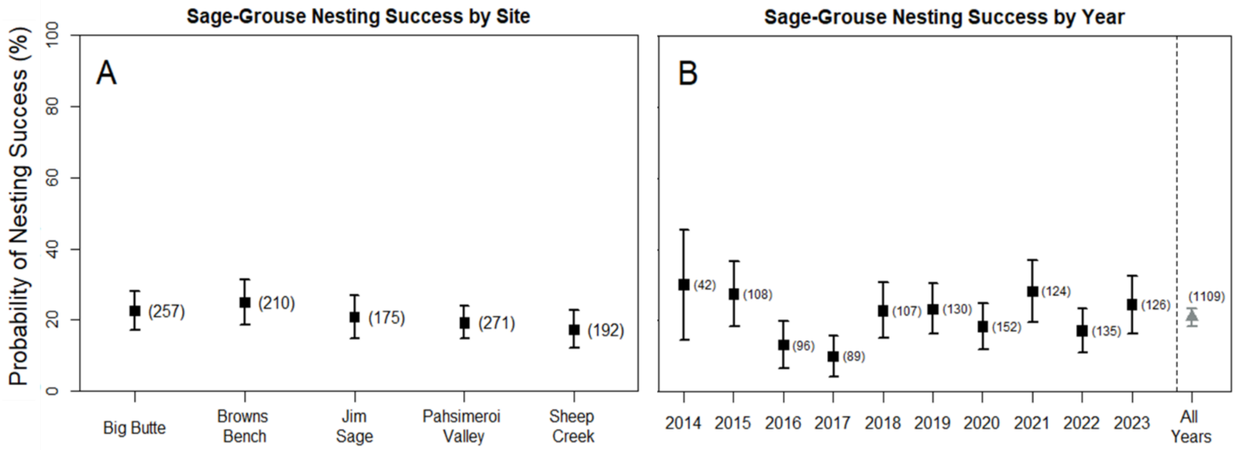

Figure 10. Probability of nesting success for each study site (A) and for each year (combined across all study sites) of the study as well as overall nesting success, 2014-2023 (B). All estimates were calculated using RMark. Estimates were calculated from daily survival to estimate the overall probability that a nesting attempt survives across the laying and incubation period (37 days). Bars represent 95% confidence intervals that were calculated using the delta method.

Figure 11. Average grass heights within pastures grazed the spring the nest was examined (Spring Grazed) and within pastures not grazed that spring (Rested) and how those grass heights differed among 3 types of plots (random plots, plots at failed nests, plots at hatched nests) across 5 study sites in southern Idaho, 2014-2023.

Clutch Size and Average Hatch Date

We calculated average number of hatched eggs (i.e., presumed clutch size) based only on hatched nests because depredated nests typically have fewer eggshell fragments remaining than hatched nests (Schroeder 1997). Indeed, throughout the 10 years of our study, we detected eggshell fragments from fewer eggs at failed nests (mean = 4.5 eggs) than at hatched nests (mean = 6.6 eggs). Mean clutch size at our 5 study sites ranged from 6.2 – 6.9 eggs per hatched nest (Table 11). These represent the minimum number of eggs at each hatched nest because they are based on the number of eggshells that we found at nest sites after hatch. The largest clutch we recorded was 11 eggs and the smallest was 1 egg. The lowest mean clutch size occurred in 2015 and 2017 (5.9 eggs) and highest in 2023 (7.6 eggs; Table 12).

We used only hatched nests (from all nest attempts including renests) when calculating average hatch date. To reduce the risk of damage to eggs or nest abandonment, we purposefully tried not to flush hens when we found a nest and hence, we could not float eggs to determine their developmental stage. Mean hatch date varied among the study sites from 20-May at the Jim Sage site to 1-June at the Pahsimeroi Valley site (Table 11). The earliest mean hatch date was 13-May in 2015 when field work was only conducted at Brown's Bench, Jim Sage, and Sheep Creek sites and latest mean hatch date was 8-Jun in 2023 when field work was only conducted at Brown's Bench, Big Butte, and Pahsimeroi sites (Table 12).

Table 11. Mean clutch size and hatch date of hatched nests at 5 study sites across southern Idaho from 2014-2023.

Study Site	Clutch Size			Hatch Date		
	Mean	SE	n	Mean	SE	n
Big Butte	6.9	0.18	108	31-May	1.5	108
Brown's Bench	6.7	0.20	97	21-May	1.4	99
Jim Sage	6.2	0.21	60	20-May	1.7	62
Pahsimeroi Valley	6.5	0.15	103	1-Jun	1.2	105
Sheep Creek	6.5	0.23	66	22-May	1.9	66
All Sites	6.6	0.09	434[a]	26-May	0.71	440

[a]Clutch sizes for 6 nests were not observed.

Table 12. Mean clutch size and hatch date of hatched nests from 2014-2023 with all study sites across southern Idaho combined.

Year	Clutch Size			Hatch Date		
	Mean	SE	*n*	Mean	SE	*n*
2014	7.0	0.33	21	22-May	2.7	23
2015	5.9	0.27	58	13-May	2.0	58
2016	6.4	0.27	42	23-May	2.3	42
2017	5.9	0.27	25	1-Jun	2.8	25
2018	6.4	0.24	35	27-May	1.9	35
2019	6.4	0.31	41[a]	26-May	1.4	41[a]
2020	6.6	0.24	59	24-May	1.6	61
2021	6.6	0.22	59	24-May	1.5	59
2022	6.9	0.28	42	3-Jun	2.7	42
2023	7.6	0.20	54	8-Jun	1.3	56
All Years	6.6	0.09	436	25-May	0.7	442

[a]Contains 2 nests at Idaho National Laboratory.

Brood Success and Brood Survival

We calculated apparent brood success by dividing the number of females with ≥1 chick present through 42 days post-hatch by the total number of females whose nests were successful (≥1 egg hatched). We sometimes were unable to detect the telemetry signals for hens with a brood and, hence, could not determine the fate of some broods with certainty. Therefore, we present our results using both a conservative estimate and a liberal estimate based on how we assigned brood fate to hens whose signals disappeared before their chicks reached 42 days of age. We also modeled daily brood survival to control for the effects of study site and year on brood survival by using a Cormack-Jolly-Seber model in RMark, similar to the methods described by Riley (2019) and Riley et al. (2021).

Of the 443 hatched nests that we monitored during the project, we tracked 399 broods in at least one survey. We conducted 2,143 surveys on these broods including 1,257 visual, 718 fecal, and 168 spotlight surveys. We flushed the hen on 97 of 524 fecal surveys (19%), 20 of 86 (23%) spotlight surveys, and 676 of the 774 daytime visual surveys (87%) between 2019-2023. Note that flush rate of hens was not recorded prior to 2019.

Of the 311 brooding hens that we were able to track through 42 days after hatch, 164 (53%) had at least one chick survive to 42 days of age (Table 13). We calculated a more conservative and a less conservative estimate of brood success to account for our lack of certainty regarding the fate of 90 broods. These 90 broods went missing before 42 days post-hatch due to sudden long-distance movements or signals that disappeared. Methods for estimating brood survival and the factors that affect brood survival were part of Ian Riley's graduate thesis (Riley 2019, Riley and Conway 2020, Riley et al. 2021) and we incorporated results from Riley's thesis into our brood survey methods and analysis.

Our model-based estimate of brood success was lowest at Jim Sage and similar for the other 4 study sites (Figure 12). Brood success ranged between 40% (2019) and 78% (2023). Brood sample size was typically low each year compared to our other demographic measurements. However, after 10 years of tracking broods, we obtained known fates for 311 broods.

Table 13. Fate of sage-grouse broods at 5 study sites across southern Idaho, 2015-2023. We only tracked broods intermittently in 2014 (first year of project) due to funding limitations, and very seldom out to 42 days post-hatch.

Study Site	Hatched Nests	Lost Hen's Signal[a]	Brood Failed[b]	Brood Survived to 42 days	Brood Success[c]	Brood Success[d]
Big Butte	108	37	31	40	37%	56%
Brown's Bench	83	19	27	37	45%	58%
Jim Sage	54	8	27	19	35%	41%
Pahsimeroi Valley	88[e]	10	40	38	43%	49%
Sheep Creek	66	16	22	28	42%	56%
Overall	401[f]	90	147	164[f]	41%	53%

[a]The signal of the focal hen was lost, and we were unable to accurately determine the fate of the brood at 42 days post-hatch.
[b]The hen did not have a live brood during the brood survey at 42 days post-hatch.
[c]Brood success assuming the broods had failed for hens' signals that were lost prior to 42 days post-hatch.
[d]Brood success censoring the broods for hens' signals that were lost prior to 42 days post-hatch (i.e., they were not included in the denominator).
[e]Does not include nests in 2015-2016 that were tracked by non-Grouse & Grazing personnel
[f]Includes 2 broods that survived to 42 days at Idaho National Laboratory.

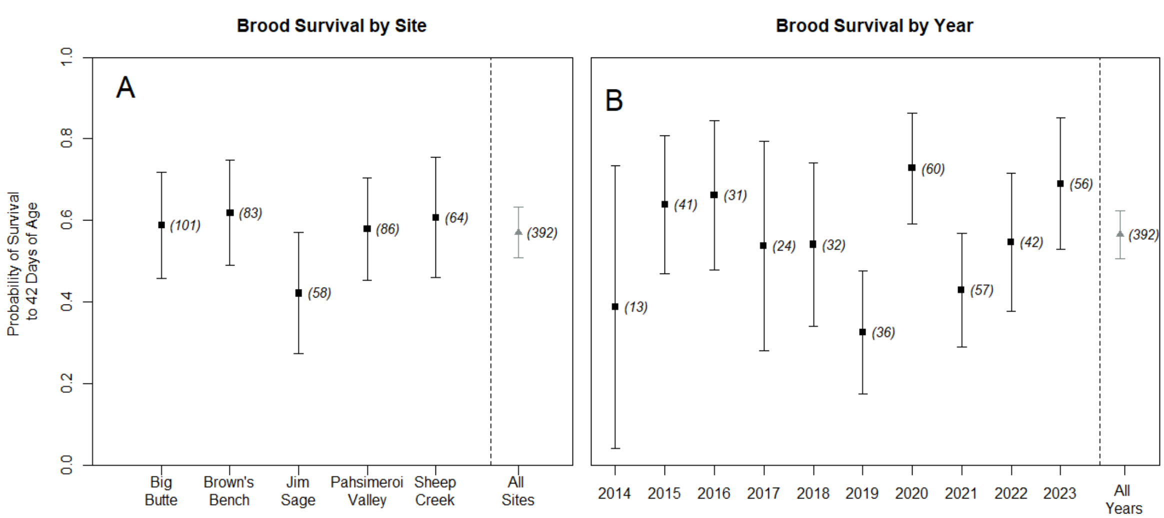

Figure 12. Probability of sage-grouse brood survival calculated using RMark from hatch to 42 days of age by site (A) and by year (B) for 5 study sites across southern Idaho 2014-2023. Detection probability was held constant for each set of estimates and was 0.64 (SE=0.05).

ANALYSIS AND RESULTS

Arthropods

Average abundance, species diversity, and species richness of food arthropods varied among the three study sites (Overlie 2024; Figures 13-15). Average biomass and species diversity were higher in the no grazing pasture at one of the three sites thus far summarized, but higher in the spring grazing pasture at the other two sites (Figures 14-15). Average abundance of food arthropods tended to be higher in no grazing at Big Butte and Jim Sage and higher in spring grazing at Brown's Bench (Overlie 2024). Average biomass was greater in no grazing pastures at Big Butte and Brown's Bench and was significantly greater in spring grazed pastures at Jim Sage (Overlie 2024). Species diversity was higher in spring grazing at Big Butte and Jim Sage and higher in no grazing at Brown's Bench (Overlie 2024). Taxa richness was higher in no grazing at Big Butte and Brown's Bench and was higher in spring grazing at Jim Sage (Overlie 2024). At all three sites, Carabidae (Coleoptera) had greater biomass in spring grazing pastures and Acrididae (Orthoptera) had greater biomass in no grazing pastures (Overlie 2024). Carabidae, Histeridae (Coleoptera), Cydnidae and Tingidae (Hemiptera), and Pseudoscorpiones all had higher abundance and biomass in the no grazing treatment at 3 sites. Stenopelmatidae and Tettigoniidae (Orthoptera), Geocorridae (Hemiptera), and Nitidulidae (Coleoptera) all had higher abundance and biomass in the spring grazing treatment at all three sites (Overlie 2024).

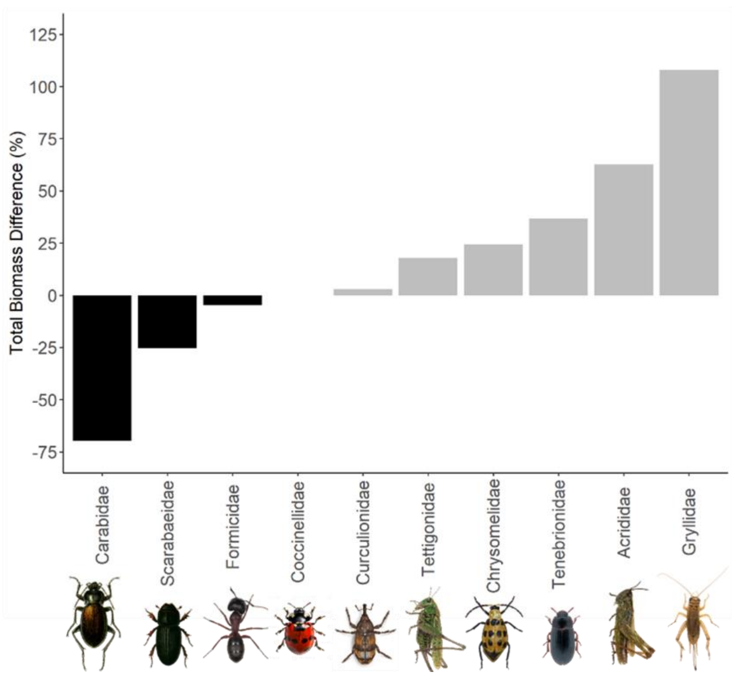

Figure 13. Differences in biomass of food arthropods between spring grazing and no grazing pastures, by taxonomic family (all sites combined). Biomass difference = Biomass in no grazing pasture – Biomass in spring grazing pastures. Black bars indicate taxa that had higher biomass in spring grazing pastures and grey bars indicate taxa that had higher biomass in no grazing pastures.

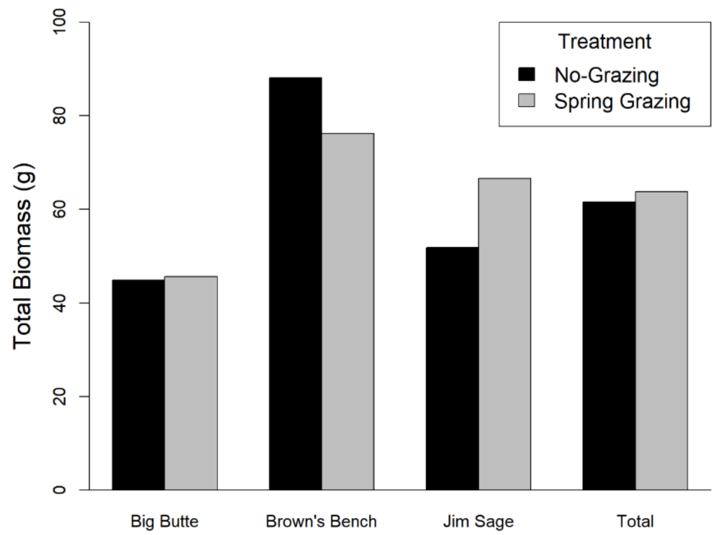

Figure 14. Total biomass of arthropods from pitfall traps in spring grazed and non-grazed pastures and each of 3 study sites, and total across all 3 sites combined.

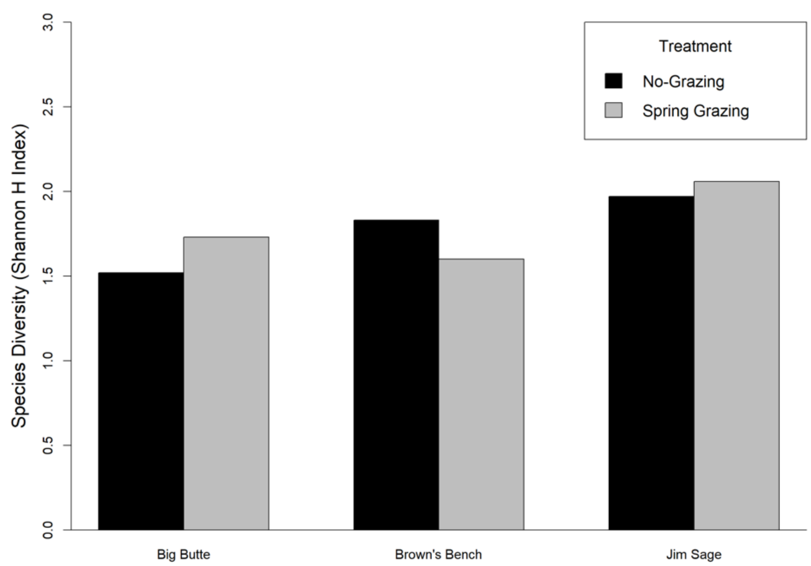

Figure 15. Comparison of species diversity index of arthropods captured in pitfall traps within spring grazed and non-grazed pastures at each of 3 study sites.

Hen Survival

We used the multistate module in Program MARK to examine whether grazing treatments affected daily mortality rate of hens (*Ψ)*. We created daily encounter histories for each field season (Mar 1 – Jul 19) based on telemetry, nest monitoring, and brood monitoring data. Radio-marked hens were coded in one of two states; alive (A) or dead (D) for each observation interval. Days where birds were searched for and not found (non-detections) and days where birds were not searched for were also included to help estimate detection probability (*p*). Hens marked with rump-mount transmitters have higher mortality rates than those with VHF collars (Severson et al. 2019, Stevens et al. 2023a), so we only included VHF-marked hens in this analysis. Instead of using a staggered-entry design, we coded the 10 years of the study as 10 different groups. If a female was tracked for multiple seasons, we used a separate encounter history for each year that a hen was monitored (with corresponding covariates). Hens that died within 10 days of capture were excluded from analysis to avoid potential capture myopathy in estimated mortality rates. Hens were assigned a grazing treatment based on the pasture they used during each observation interval. During days hens were not located, we assigned the grazing treatment from the closest day the hen had a known location.

We first modeled detection probability and included all combinations of site and year to determine which model fit the data best. We expected some variation among sites and years due to variation in monitoring effort caused by fluctuations in funding (year) and substantial variation in seasonal movements of hens at some sites and not others (site), which can make hens difficult to locate. The top model from the first step included both site and year and so these covariates were then used in the next step of model selection to test which environmental factors influenced daily mortality rate. Variables in the global model for step two included site, year, hen age, precipitation, temperature, and a time trend during the field season. For the time trend, we evaluated whether a linear, quadratic, or cubed effect best fit the data. Site and year were highly correlated with precipitation and temperature so were not included in any candidate models together (Table 14). Grazing treatment was then added to the top model from step two to test if the treatment pastures had an influence on daily mortality rates after accounting for the other covariates. The effect of grazing treatment improved the top model from step two, indicating treatment did influence daily mortality rates (Table 15). However, the effect of grazing treatments was driven by a difference between the non-treatment pastures and the three grazing treatments, indicating an increased mortality risk outside the treatment pastures (Figure 16). This difference in mortality rate is most likely a methodological artefact and reflects the different effort spent on tracking hens inside and outside of the treatment pastures. We spent less time trying to locate hens outside of treatment pastures due to time and logistical constraints, until their collar gave off a mortality signal, then they were located to recover the collar for redeployment. Most importantly, we did not detect noticeable differences in hen survival among the three grazing treatments (Figure 16).

Table 14. Model selection results in analyses to determine which environmental covariates influenced daily mortality rate of sage-grouse hens marked with VHF collars in Idaho 2014-2023.

Model	ΔAIC_c	w	K	-2LL
Ψ (Year + Trend^2) p(Site + Year)	0	0.312	26	13782.4
Ψ (Year + Trend^3) p(Site + Year)	1.87	0.123	27	13782.3
Ψ (Year + Age + Trend^2) p(Site + Year)	2.00	0.115	27	13782.4
Ψ (Site + Year + Trend^2) p(Site + Year)	2.56	0.087	30	13776.9
Ψ (Year + Age + Trend^3) p(Site + Year)	3.87	0.045	28	13782.3
Ψ (Site + Year + Trend^3) p(Site + Year)	4.43	0.034	31	13776.8
Ψ (Site + Year + Age + Trend^2) p(Site + Year)	4.56	0.032	31	13777.0
Ψ (Year) p(Site + Year)	4.74	0.029	24	13791.2

Table 15. Model selection results in analyses to determine if grazing treatment had an influence on daily mortality rate of sage grouse hens in Idaho 2014-2023.

Model	ΔAIC_c	w	K	-2LL
Ψ (Year + Trend^2 + Treatment) p(Site + Year)	0	0.781	29	13773.87
Ψ (Year + Trend^2) p(Site + Year)	2.54	0.219	26	13782.42

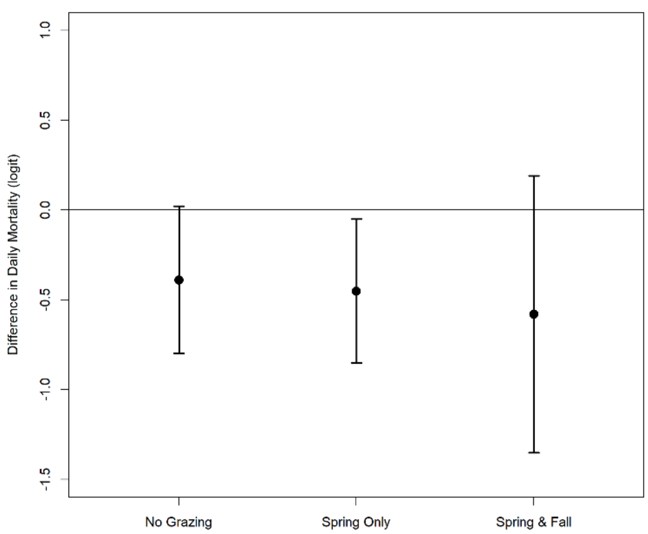

Figure 16. Difference in daily mortality probability on the logit scale of VHF-collared hens grouped by grazing treatment with 95% CIs. The line at 0 represents the mortality rate of hens within non-treatment pastures (i.e., outside of our experimental grazing treatment pastures).

Nest Propensity

We used logistic regression to examine factors that influenced nesting propensity. Hens that did not nest were assigned to one of our grazing treatments based on which treatment pasture they spent the most time within during the nesting period. Year was included in all the top models, as nest propensity steadily increased over the years, which is likely due to increased personnel over time and our improved methods as we became more efficient in tracking sage-grouse (Table 16). Other control variables (in addition to Year) included in many of the top models were temperature during the nesting season and site. Grazing treatment was included in 3 of the top 5 models, and hens showed an increased likelihood to nest in the no grazing pastures than the other two grazing treatments (Figure 17).

Table 16. Model selection results for analyses testing the effects of grazing treatment and control covariates on nesting propensity of sage-grouse across 5 field sites in southern Idaho during post treatment years. Of 256 candidate models, only models with ΔAIC_c <2 are shown. Parentheses indicate confidence interval overlapped 0.

Capture Date	Hen Age	Spring Precip.	Spring Temp	Site	Grazing Treatment	Winter Precip.	Year	ΔAIC_c	Model weight
			-		x		+	0	0.057
			-	(x)			+	0.06	0.056
			-	(x)	(x)		+	0.80	0.039
		(+)		(x)			+	0.97	0.039
		+		(x)	(x)		+	1.30	0.030
			-		x	(-)	(+)	1.51	0.027
(-)			-	(x)			+	1.67	0.025
			-	(x)		(-)	+	1.70	0.025
			-				+	1.79	0.024
(-)			-		x		+	1.95	0.022

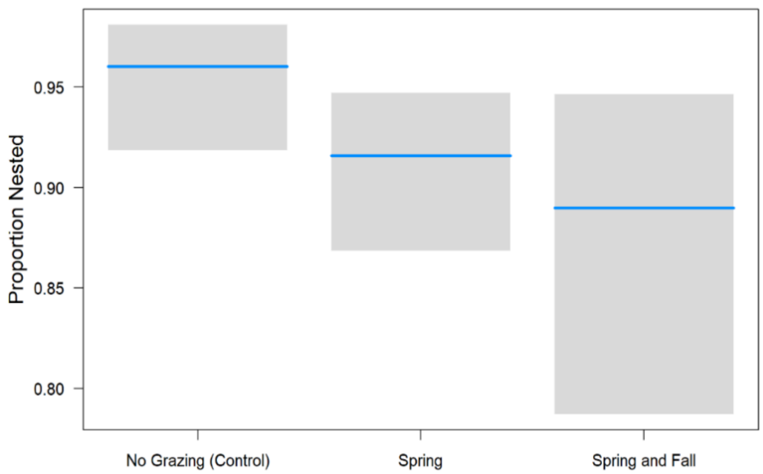

Figure 17. Nesting propensity of sage-grouse across 5 study sites in southern Idaho for each of our 3 grazing treatments. Blue bars represent model predictions with 95% CIs shaded in gray.

Re-nest Propensity

We also used logistic regression to examine factors that affected re-nesting propensity. We included several control variables that were included in all top models: fail date of first nesting attempt, spring temperature, and year (Table 17). Grazing treatment (of the initial nesting attempt) was also included in all top models, and hens that nested and failed in the spring grazing treatment were more likely to attempt a second nest in any pasture (Figure 18).

Table 17. Model selection results for analyses testing the effects of grazing treatments on sage-grouse re-nesting propensity across 5 study sites in southern Idaho during post-treatment years, parentheses indicate confidence interval overlaps 0. Of 256 candidate models, only models with ΔAIC_c <2 are shown.

Hen Age	Fail Date	Spring Precip	Spring Temp	Site	Grazing Treatment	Winter Precip	Year	ΔAIC_c	Model weight
	-		-		x		+	0	0.199
	-	(-)	-		x		+	0.77	0.135
(x)	-		-		x		+	1.27	0.105
(x)	-	(-)	-		x		+	1.65	0.087

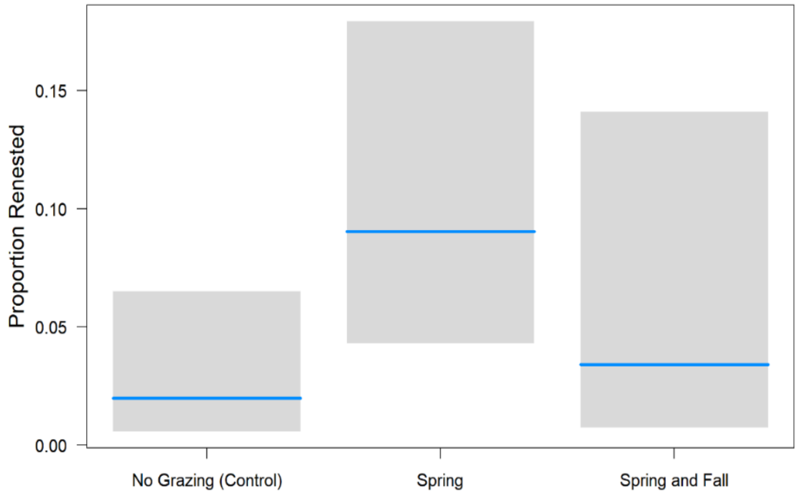

Figure 18. Re-nesting propensity of sage-grouse across 5 study sites in southern Idaho for each of 3 grazing treatments. Blue bars represent model predictions with 95% CIs shaded in gray.

Nest Density

We calculated nest density within each pasture each year to examine whether grazing treatment affected nest density. We divided number of nests located (excluding second attempts to avoid any effects of nest success) by pasture size to calculate nest density (nests/ha) for each pasture. To evaluate whether this metric was biased due to unequal search effort among pastures, we recorded the tracks of each trapping crew every night for the last 6 years of the study and calculated a distance traveled while spotlighting within each pasture. We included the distance travelled while trapping as a covariate in a generalized linear model (GLM) analysis on a 6-year subset of the data (from 2018-2023) but the variable was not included in any top models (those <2 AICc). We then used GLMs to examine what factors influenced nest density and the change in nest density between pre- and post-treatment years. For the analysis of nest density, grazing treatment was not in the top model (Table 18) and nest density was slightly higher (albeit not significantly so) in the no grazing and spring grazing treatments compared to the spring/fall grazing treatment (Figure 19). We detected a difference between the three grazing treatments for change in nest density (the difference in nest density before and after treatments were applied) where the change in nest density in the spring grazing treatment decreased, while the other two treatment pastures did not change (Table 19; Figure 20). Grazing treatment was in the top model but not the second-best, competing model (Table 19) and 95% confidence intervals overlapped zero (Figure 20) suggesting some uncertainty in the relationship between grazing treatment and change in nest density.

Table 18. Model selection results for analyses designed to examine the effects of grazing treatment on sage-grouse nest density during post-treatment years across 5 field sites in southern Idaho, parentheses indicate confidence intervals that overlap 0. Of 8 candidate models, only those ΔAIC_c <10 are shown.

Site	Grazing Treatment	Year	ΔAIC_c	Model weight
x			0	0.778
x	(x)		2.55	0.217

Table 19. Model selection results for analyses designed to examine the effects of grazing treatment on change in sage-grouse nest density between pre- and post-treatment years across 5 field sites in southern Idaho. Of 8 candidate models, only those ΔAIC_c <10 are shown.

Site	Grazing Treatment	Years of Treatment	ΔAIC_c	Model weight
x	x	+	0	0.718
x		+	2.04	0.259
x	x		7.67	0.016
x			9.26	0.007

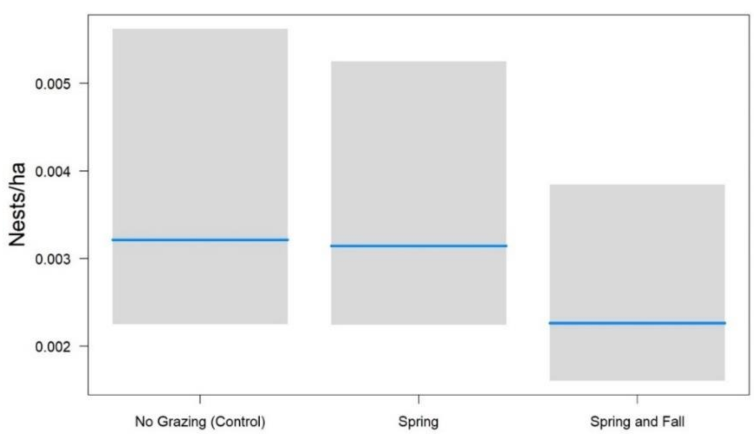

Figure 19. Nest density of sage-grouse by grazing treatments across 5 study sites in southern Idaho. Blue bars represent model predictions with 95% CIs shaded in gray.

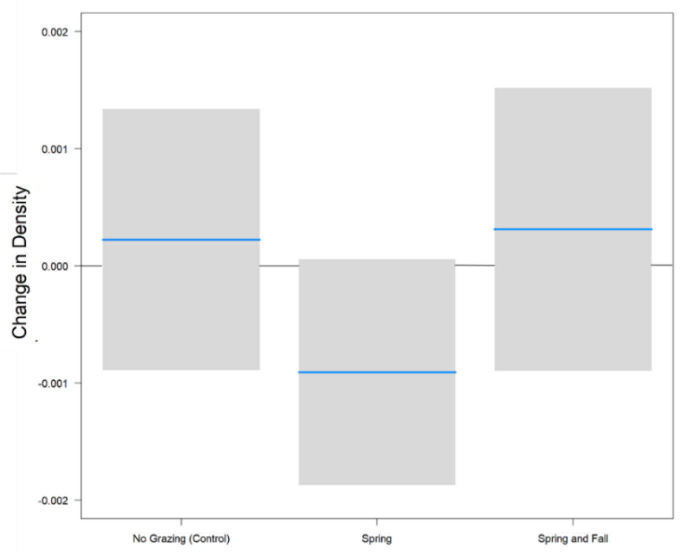

Figure 20. Change in sage-grouse nest density between pre- and post-treatment years across 5 study sites in southern Idaho. Blue bars represent model predictions with 95% CIs shaded in gray.

Nest Site Fidelity

We used GLMs to examine whether grazing treatment and other factors influenced nest site fidelity of hens nesting at our study sites. Model selection indicated that nest fate of the previous years' nest had the biggest impact on nest site fidelity (i.e., distance to the subsequent year's nest location); hens of failed nests chose locations farther for their next nest site than hens with successful nests (1,143m between years for hens with failed nests (n = 56) and 377m for hens with successful nests (n = 38); Figure 21). Incubation date was also included in 3 of the top 5 models and nest site fidelity did not differ among grazing treatments (Table 20).

Table 20. Model selection results for analyses testing the effects of grazing treatment and covariates on sage-grouse nest site fidelity across 5 study sites in southern Idaho. Parentheses indicate confidence interval overlaps 0. Of 64 candidate models, only those ΔAIC_c <3 are shown.

Hen Age	Incubation Day	Hen Flushed	Nest Fate	Site	Grazing Treatment	ΔAIC_c	Model weight
	(-)		x			0.00	0.241
			x			1.04	0.144
	(-)	(x)	x			1.12	0.138
		(x)	x			2.01	0.089
(x)	(-)		x			2.21	0.080

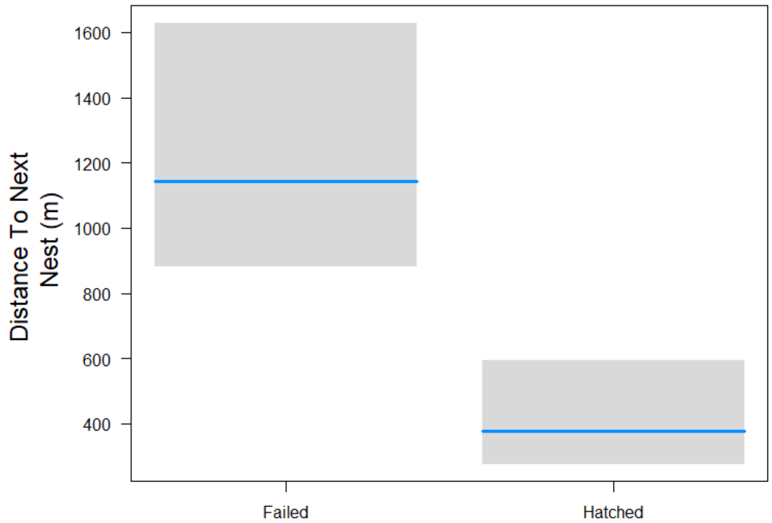

Figure 21. Distances between subsequent sage-grouse nests of the same female differed based on fate of previous years' nest across 5 study sites in southern Idaho. Blue bars represent model predictions with 95% CIs shaded in gray.

Clutch Size

We used GLMs to examine the effects of grazing treatment and other factors on clutch size for hens within our treatment pastures. We limited this analysis to just successful first nesting attempts because re-nesting attempts typically have much smaller clutch sizes and some failed nests are depredated with eggs potentially carried off by the predator, thus egg counts based on eggshells in failed nests are likely lower than the actual clutch size. Incubation initiation date, winter precipitation, and year were all included in the top models (those within 2 AIC_c of the top model) and winter temperature was included in 2 of the 3 top models. Treatment, however, was not included in any of the top models (Table 21). We ran model selection with a pre/post*treatment interaction, but the interaction was not included in any top models, indicating that clutch size did not differ among grazing treatments.

Table 21. Model selection results for analyses testing effects of grazing treatment and other covariates on clutch size of sage-grouse hens nesting within study pastures across 5 study sites in southern Idaho. Of 512 candidate models, only those ΔAIC_c <2 are shown.

Hen Age	Incubation Initiation	Spring Precip.	Spring Temp.	Site	Grazing Treatment	Winter Precip.	Winter Temp.	Year	ΔAIC_c	Model weight
	-					+	-	+	0.00	0.114
	-			x		+		+	0.35	0.095
	-	(-)				+	-	+	1.96	0.043

Nest Fate

We used 2 statistical approaches to examine whether grazing affected nesting success of sage-grouse: a logistic regression model and a daily nest survival model (Program MARK). We used 2 approaches for this analysis because it was the primary objective of the 10-year study and we wanted to be thorough. We first used logistic regression to examine whether the 3 grazing treatments or any other factors affected binary nest fate (success or failure) of sage-grouse hens. Grazing treatment was not included in any of the top models indicating that grazing treatments did not affect nest fate (Table 22), but weather metrics and incubation initiation date influenced nesting success during our study. We also used logistic regression to examine whether utilization affected nest fate. This analysis included 354 of 400 nests that were included in the previous analysis, as 46 nests did not have utilization recorded from the previous year (we identified experimental pastures after year 1 and randomly assigned treatments to pastures in year 2).). Again, incubation initiation date was included in all top models, as well as spring precipitation and temperature in many top models. However, study site was included in 5 of 15 of the top models <2 AIC_c. Grazing treatment and previous year utilization were included in a few of the top models, but their confidence intervals overlapped 0 indicating that grazing treatments and utilization levels in our study did not affect nest fate (Tables 22 & 23, Figure 22) and the non-significant pattern was positive rather than negative (Figure 23).

Table 22. Top models from a model selection analysis to examine whether grazing treatments and other factors affected nesting success of sage-grouse hens within treatment pastures across 5 study sites in southern Idaho. Of 512 candidate models, only those ΔAIC_c <2 are shown.

Hen Age	Nest Attempt	Incubation Initiation	Spring Precip.	Spring Temp.	Site	Grazing Treatment	Winter Precip.	Year	ΔAIC_c	Model weight
		+		+					0	0.038
		+	(-)						0.59	0.028
		+		+				(+)	0.60	0.028
	(x)	+		+					0.60	0.028
		+		(+)			(-)		0.78	0.026
		+					(-)		0.88	0.024
	(x)	+		(+)			(-)		1.08	0.022
	(x)	+					(-)		1.23	0.021
	(x)	+		+				(+)	1.28	0.020
	(x)	+	(-)						1.39	0.019
		+	(-)	(+)					1.46	0.018
		+							1.85	0.015
		+	(-)				(-)		1.97	0.014

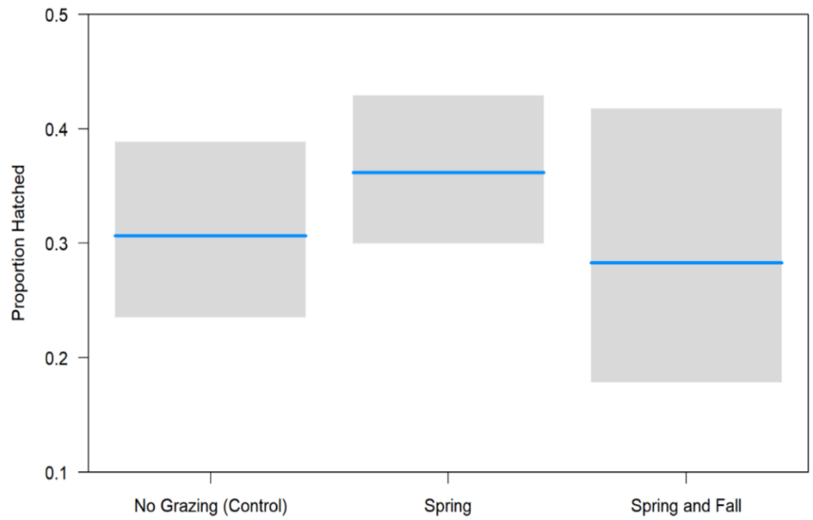

Figure 22. Proportion of sage-grouse nests that successfully hatched within treatment pastures across 5 study sites in southern Idaho. Blue bars represent model predictions with 95% CIs shaded in gray.

Table 23. Top models from a model selection analysis designed to examine whether utilization and other factors affected nesting success of sage-grouse hens within treatment pastures across 5 study sites in southern Idaho. Of 256 candidate models, only those ΔAIC_c <2 are shown.

Nest Attempt	Incubation Initiation	Spring Precip.	Spring Temp.	Nest Year Util.	Prev. Year Util	Site	Grazing Treatment	ΔAIC_c	Model weight
	+		+					0.00	0.035
	+		+			x		0.05	0.034
	+		+		(+)			0.07	0.034
	+	-						0.41	0.029
(x)	+		+					0.99	0.021
	+		+			x	(x)	1.17	0.020
	+		+		(+)	x		1.18	0.019
(x)	+		+		(+)			1.24	0.019
	+	(-)	(+)					1.29	0.018
	+	(-)			(+)			1.46	0.017
	+		+				(x)	1.46	0.017
(x)	+		+			x		1.54	0.016
(x)	+	-						1.68	0.015
	+		+	(+)				1.76	0.015
	+		+	(+)	(+)			1.79	0.014
	+	(-)	(+)		(+)			1.83	0.014

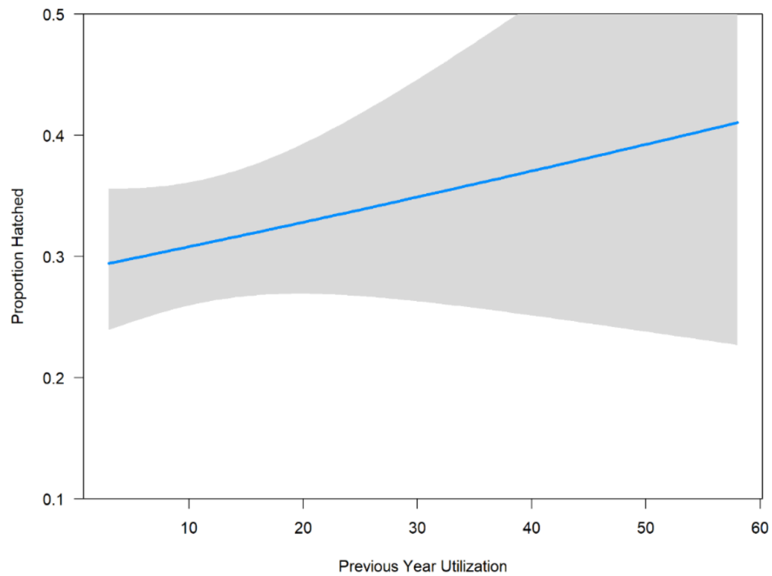

Figure 23. Proportion of sage-grouse nests that hatched within treatment pastures was positively associated with the previous year's utilization measured by Landscape Appearance Method across 5 study sites in southern Idaho. Blue bars represent model predictions with 95% CIs shaded in gray.

Daily Nest Survival

In addition to the logistic regression analyses of nest fate above (successful versus failed), we also used the nest survival model in program MARK to examine whether grazing treatments affected daily nest survival. We first used model selection to determine which large-scale environmental heterogeneity and animal-level variables influenced daily nest survival (site, year, age of nest, ordinal day of nest initiation, precipitation, and temperature) and then added the grazing variables to the top set of covariates from this initial step (site, year, age of nest, ordinal day of nest initiation, precipitation). We developed 23 *a priori* hypotheses reflecting different mechanisms by which grazing might influence nest survival and examined whether our data supported any of these 23 grazing-related hypotheses (Table 24). The 23 hypotheses included effects of current spring and fall grazing, presence of cattle, time elapsed since previous spring and fall grazing, experimental grazing treatments and their interactions with years since treatments were initiated, and combinations of these factors.

We found strong evidence for large-scale spatial and temporal variability in sage-grouse nesting success (high variation among the 10 years as well as variation among the 5 study sites where nest survival was highest at Brown's Bench; Figure 24) and effects of nest age (-) and timing of nest initiation, indicating variation in nest survival among sites and years, decreased daily nest survival throughout incubation , and benefits to initiating a nest in the middle of the nesting season (i.e., not too early or too late). However, we found little evidence for biologically meaningful effects of grazing on nest survival (Tables 25 & 26). Grazing hypotheses were included in top models, but effects of grazing metrics were either statistically insignificant or not biologically impactful (Table 26; Figure 25). For example, time since last fall grazing had a statistically significant negative effect on nest survival probability, suggesting more time since fall grazing resulted in reduced nest survival probability, but the effect was very small whereby daily probability of nest survival declined from 0.993 to 0.991 across the range of 0 to 12 years since last fall grazed (Figure 26).

Table 24. Grazing hypotheses considered in nest survival analyses.

Hypothesis
H1: Grazing effects on nesting success are a function of current (spring) and previous (fall) seasonal removal of herbaceous biomass
H2: Grazing effects on nesting success are a function of current (spring) seasonal removal of herbaceous biomass
H3: Grazing effects on nesting success are a function of seasonal removal of herbaceous biomass the previous fall
H4: Grazing effects on nesting success in a given spring season are dependent on whether or not pasture was grazed the previous fall
H5: Grazing effects on nesting success are a function of time since spring and fall grazing
H6: Grazing effect on nesting success are a function of time since last spring grazing
H7: Grazing effect on nesting success are a function of time since last fall grazing
H8: Time since grazing effects on nesting success in a given spring season are dependent on time since last fall grazing
H9: Cow presence in pasture affects daily nest survival
H10: There are systematic but consistent (over space and time) differences in effects of 4 treatments (no grazing, spring, spring + fall, external controls) on nesting success
H11: There are systematic differences in effects of 4 treatments (no grazing, spring, spring + fall, external controls) on nesting success that are consistent over space, but where the treatment effects change gradually over time
H12: Effects of 4 treatments (no grazing, spring, spring + fall, external controls) on nesting success are consistent over space but change continuously over time and in a consistent direction
H13: Grazing effects on nesting success are a function of current (spring) and previous (fall) seasonal removal of herbaceous biomass and presence of cows in pasture
H14: Grazing effect on nesting success are a function of cattle presence during nesting and presence of cows in pasture
H15: Grazing effect on nesting success are a function of seasonal removal of herbaceous biomass the previous fall and presence of cows
H16: Grazing effects on nesting success in a given spring season are dependent on whether or not pasture was grazed the previous fall and presence of cows
H17: Grazing effects on nesting success are a function of time since spring and fall grazing and presence of cows
H18: Grazing effect on nesting success are a function of time since last spring grazing and presence of cows
H19: Grazing effect on nesting success are a function of time since last fall grazing and presence of cows

H20: Time since grazing effects on nesting success in a given spring season are dependent on time since last fall grazing and presence of cows

H21: There are systematic but consistent (over space and time) differences in effects of 4 treatments (no grazing, spring, spring + fall, external controls) on nesting success and presence of cows

H22: There are systematic differences in effects of 4 treatments (no grazing, spring, spring + fall, external controls) on nesting success that are consistent over space, but where the treatment effects change gradually over time and presence of cows

H23: Effects of 4 treatments (no grazing, spring, spring + fall, external controls) on nesting success are consistent over space but change continuously over time and in a consistent direction and presence of cows

Table 25. Top models (ΔAIC_c<10) from sage-grouse nest survival analyses (n = 96 models compared).

Model	ΔAIC_c	w	K	-2LL
S(H12+Site+Year[a]+Nest age+Nest initiation+Precipitation)	0	0.22	25	3979.48
S(H7+Site+Year+Nest age+Nest initiation+Precipitation)	0.99	0.14	19	3992.51
S(H23+Site+Year+Nest age+Nest initiation+Precipitation)	2.01	0.08	26	3979.48
S(H19+Site+Year+Nest age+Nest initiation+Precipitation)	2.05	0.08	20	3991.56
S(H8+Site+Year+Nest age+Nest initiation+Precipitation)	2.09	0.08	21	3989.59
S(H20+Site+Year+Nest age+Nest initiation+Precipitation)	2.64	0.06	22	3988.14
S(Site+Year+Nest age+Nest initiation+Precipitation)	2.92	0.05	18	3996.44
S(H5+Site+Year+Nest age+Nest initiation+Precipitation)	2.95	0.05	20	3992.46
S(H10+Site+Year+Nest age+Nest initiation+Precipitation)	3.30	0.04	25	3982.78
S(H17+Site+Year+Nest age+Nest initiation+Precipitation)	3.55	0.04	21	3991.06
S(H9+Site+Year+Nest age+Nest initiation+Precipitation)	4.12	0.03	19	3995.64
S(H2+Site+Year+Nest age+Nest initiation+Precipitation)	4.71	0.02	19	3996.22
S(H3+Site+Year+Nest age+Nest initiation+Precipitation)	4.85	0.02	19	3996.37
S(H6+Site+Year+Nest age+Nest initiation+Precipitation)	4.91	0.02	19	3996.43
S(H21+Site+Year+Nest age+Nest initiation+Precipitation)	5.26	0.02	26	3982.74
S(H18+Site+Year+Nest age+Nest initiation+Precipitation)	6.05	0.01	20	3995.56
S(H14+Site+Year+Nest age+Nest initiation+Precipitation)	6.12	0.01	20	3995.63
S(H15+Site+Year+Nest age+Nest initiation+Precipitation)	6.12	0.01	20	3995.63
S(H1+Site+Year+Nest age+Nest initiation+Precipitation)	6.66	0.01	20	3996.17
S(H4+Site+Year+Nest age+Nest initiation+Precipitation)	7.10	0.01	21	3994.61
S(H13+Site+Year+Nest age+Nest initiation+Precipitation)	8.12	0.00	21	3995.63
S(H16+Site+Year+Nest age+Nest initiation+Precipitation)	8.93	0.00	22	3994.43

Table 26. Summary of covariates included and their effects from the five most competitive nest survival models (ΔAIC_c<2) for assessing impacts of grazing on sage-grouse nest survival in southern Idaho, 2014-2023.

	Model ranking				
Covariate	**1**	**2**	**3**	**4**	**5**
Large-scale environmental heterogeneity					
Year = 2015[a]	+	+	+	+	+
Year = 2016	NS[g]	NS	NS	NS	NS
Year = 2017	NS	NS	NS	NS	NS
Year = 2018	NS	NS	NS	NS	NS
Year = 2019	NS	NS	NS	NS	NS
Year = 2020	NS	NS	NS	NS	NS
Year = 2021	+	NS	+	NS	NS
Year = 2022	NS	NS	NS	NS	NS
Year = 2023	NS	NS	NS	NS	NS
Site = Jim Sage[b]	-	NS	-	NS	NS
Site = Big Butte	-	-	-	-	-
Site = Sheep Creek	-	-	-	-	-
Site = Pahsimeroi Valley	-	-	-	-	-
Control covariates					
Nest age	-	-	-	-	-
Ordinal day of nest initiation	+/-[h]	+/-	+/-	+/-	+/-
Daily precipitation	NS	NS	NS	NS	NS
Grazing covariates					
TimeF[c]	NA[i]	-	NA	-	NS
TimeS[d]	NA	NA	NA	NS	NS
TimeF*TimeS	NA	NA	NA	NA	NS
Group = spring grazing treatment[e]	NS	NA	NS	NA	NA
Group = spring and fall grazing treatment	NS	NA	NS	NA	NA
Group = non experimental pastures	NS	NA	NS	NA	NA
YrsPost[f]	-	NA	-	NA	NA
YrsPost*Group = spring grazing treatment	NS	NA	NS	NA	NA
YrsPost*Group = spring and fall grazing treatment	NS	NA	NS	NA	NA
YrsPost*Group = non-experimental pastures	NS	NA	NS	NA	NA
Daily presence of cows	NA	NA	NS	NS	NA

[a]Intercept was always 2014
[b]Intercept Site was always Brown's Bench
[c]Time since pasture was last grazed in fall
[d]Time since pastures was last grazed in spring
[e]Intercept treatment group was always no grazing
[f]Number of years elapsed since start of experimental treatments at site (equal to zero for pre-treatment years)
[g]NS = Not statistically significant
[h]+/- means dome shaped quadratic
[i]NA = not included in this model

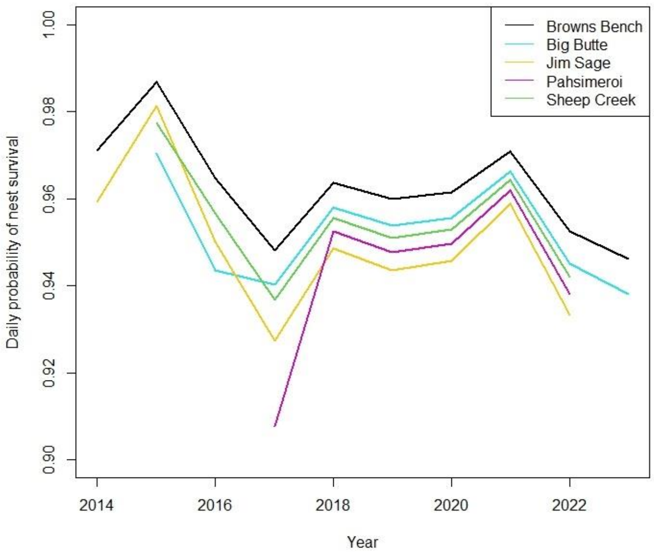

Figure 24. Marginal effects of spatial (study site) and temporal (year) variation in daily nest survival from the top nest survival model.

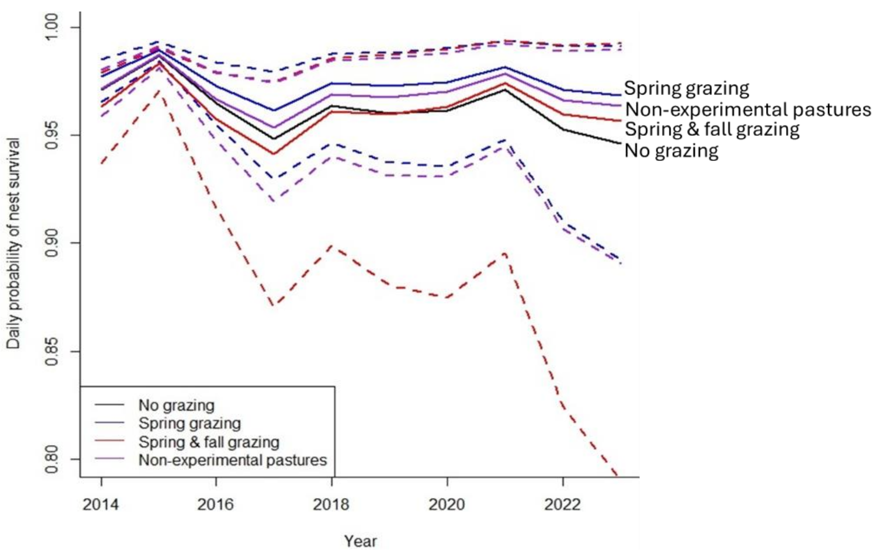

Figure 25. Marginal effects of experimental grazing treatments on daily probability of nest survival from the top nest survival model. Dashed lines indicate 95% confidence intervals.

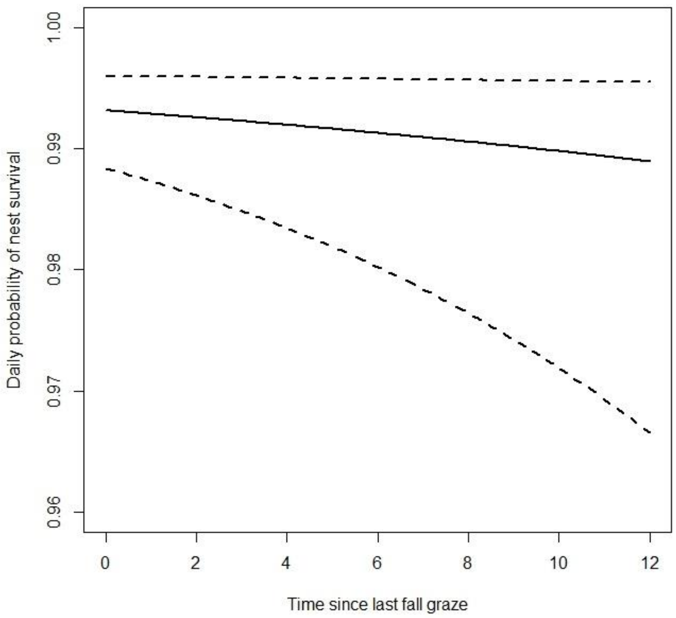

Figure 26. Marginal effect of time since last fall grazing (measured as the number fall seasons prior to current spring) on daily probability of sage-grouse nest survival, from the second-best nest survival model. Dashed lines indicate 95% confidence intervals.

Brood Fate

We continued to track hens post hatch and conducted brood surveys on hens until chicks reached 42 days of age. We used logistic regression and conducted model selection to determine whether grazing treatment in the nest pasture and other factors affected brood success (Table 27). Grazing treatment was included in the top model, and the partial effects plot from the top model suggested that hens that nested within Spring and Fall grazed pastures had higher brood survival than hens in the other 2 treatments (Figure 27). We also included an interaction between treatment and years since treatments were implemented, but it was not included in any of the top models suggesting grazing treatments did not become more influential as the years since they were implemented increased.

Table 27. Model selection results of analyses testing the effects of grazing treatment and other covariates on brood success of sage-grouse hens that nested within treatment pastures across 5 study sites in southern Idaho. Of 256 candidate models, only those ΔAIC_c <2 are shown.

Hen Age	Spring Precip.	Spring Temp	Summer Precip.	Summer Temp.	Site	Grazing Treatment	Year	ΔAIC_c	Model weight
	-	-				x		0	0.072
	-	-	(-)			x		0.44	0.037
	-	-				x	(-)	0.84	0.036
	-	(-)						1.31	0.035
	-	-		(+)		x	(-)	1.49	0.035
						x		1.49	0.034
	-	-		(+)		x		1.60	0.028
	-	-	(-)			x	(-)	1.96	0.027

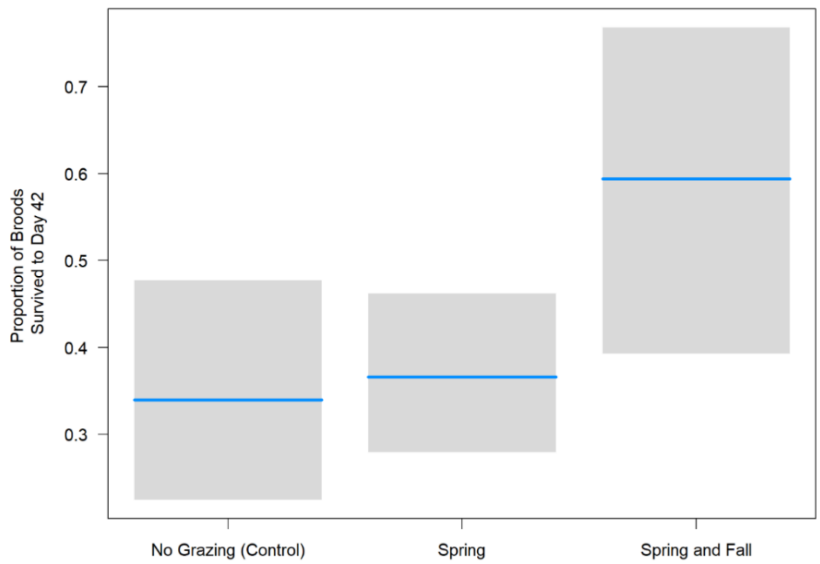

Figure 27. Partial effects plot from model designed to examine the factors that influence sage-grouse brood success; brood success was higher in the Spring and Fall Grazing treatment compared to that of the other 2 treatments based on data from 5 study sites in southern Idaho. Blue bars represent model predictions with 95% CIs shaded in gray.

Brood Survival

We used the Cormack-Jolly-Seber (CJS) model in program MARK to examine the effects of grazing treatments on daily brood survival (Phi). As we did not mark the chicks, we could not estimate the survival of individual chicks, and thus estimated the survival of the brood as a whole, and considered any hen detected with ≥ 1 chick a successful brood. Additionally, we did not count individual chicks during surveys, and could not determine whether brood mixing occurred (Street et al. 2022). Numerous methods have been used to document brood survival in sage-grouse and detection probability varies among brood survey methods (Riley and Conway 2020). Based on previous research conducted on the project (Riley et al. 2021) we first tested for differences in detection probability (*p)* based on survey method and brood age. Similar to that earlier study, brood age influenced *p* (Figure 28), but contrary to the earlier findings, survey type did not influence *p.* We next included animal-level variables (brood age, hatch date) and various transformations of these variables in model selection to determine which shape of both variables best fit daily brood survival. Next, we included large-scale environmental effects in model selection (site, year, ordinal day of nest hatch, precipitation, temperature). Our final model that we used to test grazing hypotheses included effects of Hatch Date, log(Brood Age), and Year on survival and Brood Age on *p*.

We examined 7 different grazing-related hypotheses (Table 28) that included effects of current spring and fall grazing, time elapsed since previous spring and fall grazing, experimental grazing treatments, and combinations of these factors. None of the grazing hypotheses were better than the informed null (a model without grazing metrics and only environmental variables), but many models with grazing metrics did remain within 2 ΔAIC_c. However, all grazing effects in these models had effects that were not statistically significant, indicating that the grazing treatments did not adversely affect brood survival.

Table 28. Model selection results of analyses testing the effects of grazing treatment and other covariates on daily brood survival of sage-grouse hens that nested within treatment pastures across 5 study sites in southern Idaho.

Model	ΔAIC_c	w	K	-2LL
S(Environmental Covariates)	0	0.24	14	2160.41
S(Environmental Covariates + YearsSinceFall)	0.05	0.23	15	2158.41
S(Environmental Covariates + YearsSinceSpring)	1.23	0.13	15	2159.59
S(Environmental Covariates + YearsSinceSpring + YearsSinceFall)	1.51	0.11	16	2157.82
S(Environmental Covariates + Treatment)	1.70	0.10	17	2155.97
S(Environmental Covariates + CurrentSpringGrazed)	1.97	0.09	15	2160.34
S(Environmental Covariates + MostRecentFallGrazed)	2.03	0.09	15	2160.39
S(Environmental Covariates + SpringGrazed + FallGrazed)	12.38	0.00	16	2168.70

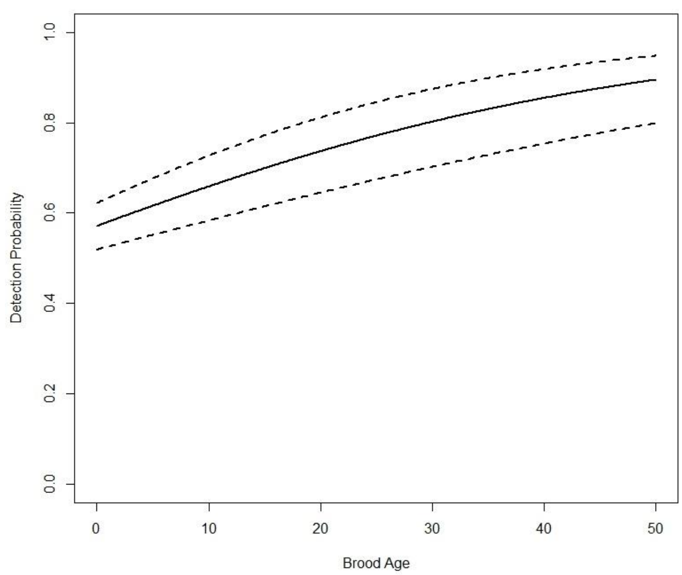

Figure 28. Model predicted detection probability (p) of sage-grouse broods in relation to brood age (in days). Dashed lines indicate 95% confidence interval.

DISCUSSION

Based on our 10-year experimental study where we manipulated cattle grazing at the scale of BLM grazing pastures using a BACI design, we found no indications that currently authorized cattle stocking rates applied in the BLM allotments we studied adversely affect nesting success, brood survival, or hen survival of greater sage-grouse (3 vital rates that most strongly affect population growth of sage-grouse; Taylor et al. 2012). The stocking rates in the experimental pastures in this study were similar to those in surrounding pastures that were not part of our study and, hence, are representative of current grazing on BLM pastures in these locations. We used two analytical approaches and explored many potential mechanisms by which cattle grazing might affect nesting success or brood survival but found none. These results corroborate some recent results from both Montana (Smith et al. 2018a; Smith et al. 2018b; Helm 2023) and Utah (Dettenmaier 2018) that also reported that nesting success of greater sage-grouse did not differ between different livestock grazing regimes. Moreover, our results corroborate results from the same Montana study that livestock grazing does not affect chick survival (Berkeley et al. 2023) and results from Utah that grazing regimes do not affect hen survival (Dettenmaier 2018). Our results build upon the results in Montana and Utah, and are novel in that our data were based on randomly assigned grazing treatments in an experimental context with one treatment at each of 5 study sites having cessation of livestock grazing for 4-8 years. We removed cattle grazing entirely from one pasture at each of the 5 study sites and compared sage-grouse vital rates in those pastures to those that were grazed by ranchers as per their BLM grazing permits. The actual grazing levels in our study pastures ranged from 8.5 to 11.1 acres/AUM and was similar to grazing levels in adjacent pastures; permitted grazing levels of other similar pastures in the BLM field offices where we conducted our research averaged from 9.0 to 14.4 acres/AUM (https://reports.blm.gov/reports/RAS/). The stocking rate in our allotments was similar or greater than the allotments administered by the 5 BLM field offices in southern Idaho where our research was conducted. This suggests that grazing levels in the pastures we studied were equivalent or slightly higher than grazing levels on other BLM lands in southern Idaho. The non-grazed pastures did not have higher nesting success or brood survival regardless of whether the grazing occurred during spring season in alternating years or in alternating spring and fall seasons. Our results suggested very slight patterns in the opposite direction for some metrics; the number of years since last fall grazed was very slightly negatively associated with nest survival (i.e., pastures with more years since last grazed in fall had lower, rather than higher, nest survival) and pastures that were grazed both spring and fall had higher, not lower, brood survival compared to the other two treatments.

We did find some evidence that cattle grazing affects nesting propensity (i.e., sage-grouse may select nest locations in areas that did not have cattle present). In contrast, a recent study on the Nevada/Oregon border found little evidence of an effect of livestock density on sage-grouse nesting propensity (Behnke et al. 2023). Moreover, lekking sage-grouse in areas with higher densities of cattle and feral horses had higher stress hormone levels, especially in drought years, but stress hormone levels were not associated with survival or reproductive success (Behnke et al. 2022). If cattle grazing in a pasture affects nesting propensity but not nesting success or brood success, as our results suggest, this bodes well for the compatibility of cattle grazing and sage-grouse population dynamics. These patterns imply that some sage-grouse may avoid areas with active cattle grazing but can find other nesting locations (i.e., those without cows present) and grouse that nest in areas with active grazing do not suffer reduced nesting success or brood survival.

Patterns in arthropod biomass between grazing treatments differed among three study sites that were sampled and also differed among arthropod taxa, but overall, we found more biomass in the spring grazing treatments at one study site, more biomass in the no grazing treatment at one study site and very similar biomass between treatments at the 3rd study site. We found evidence that biomass of darkling beetles, grasshoppers, and crickets was higher in non-grazed pastures but biomass of ground beetles, scarab beetles, and ants was higher in spring grazed pastures. We failed to detect any appreciable difference in arthropod species diversity between spring grazed and non-grazed treatments. These results corroborate those from a recent study in Montana where weekly catch rate of food arthropods (14 taxonomic families important in sage-grouse diets) was higher in grazed pastures compared to idle pastures whereas biomass of the other two arthropod categories (predators, detritivores) was higher in idle pastures (Goosey et al. 2019). Our results also corroborate another result in Goosey et al. (2019); that the effects of grazing treatments differed substantially among taxa. For example, both studies found that biomass of Carabidae and Formicidae were higher in grazed pastures whereas Acrididae were higher in non-grazed pastures, but the results for some other taxa were not consistent between the two studies. Other studies have also reported differences among arthropod taxa regarding the effects of grazing (Martínez et al. 2021, Mukwevho et al. 2023, Oyarzabal and Guimarães 2024).

In summary, we found no evidence that cattle grazing (at the levels in the allotments we studied) adversely affected most demographic traits of sage-grouse. How livestock grazing affects sage-grouse habitat has consistently focused on grazing during the nesting and early brood rearing seasons because nesting success is related to height and abundance of herbaceous plants, and livestock grazing can affect these traits (Beck and Mitchell 2000, Holloran et al. 2005). Prior management guidelines for maintaining sage-grouse nesting habitat were based primarily on plot-scale studies and suggested sagebrush cover >15%, perennial herbaceous plants ≥ 18 cm tall, and ≥ 15% canopy cover of grass (Connelly et al. 2000). More recently, studies have put less emphasis on plot-scale habitat features (outlined by Stiver et al. 2015) and put more emphasis on broader landscape-scale attributes (Naugle et al. 2024, Remmington et al. 2025). Our 10-year experimental study examined both plot-scale and pasture-scale relationships. Our results documented that livestock grazing reduced grass height and cover, but grazing did not reduce nesting success in pastures grazed by cattle compared to those not grazed by cattle. The apparent disconnect between plot-scale and pasture-scale results may reflect fine-scale behavioral decisions regarding where sage-grouse select nest locations which could buffer the impact of pasture-scale reduction in grass height and grass cover evident at the plot-scale. Indeed, prior studies have shown evidence of functional responses by sage-grouse whereby there is stronger selection for vegetation cover as the average availability of such cover declines at a pasture scale (Stevens et al. 2023b). An important caveat regarding all of our results is that they are only relevant to grazing at levels included in our study (our pastures were grazed ≤30% utilization in the allotments as measured by our field methods). The ranchers that participated in this study conducted grazing consistent with their BLM grazing permits as they had prior to the study. Hence, the level of grazing was not abnormally low in the grazed pastures during the 10 years of our study. Overall, our results suggest that cattle grazing at levels we examined is compatible with sage-grouse nesting and reproduction.

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Appendix 1. Detailed descriptions of field methods for the Grouse & Grazing Project.

INTRODUCTION

The Idaho Grouse & Grazing Project was 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 collected field data for 10 years, from 2014 through 2023. We 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 precluded us from adding additional study sites. Multiple replicates of the grazing treatments across the five study sites helped to provide 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 applied 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 gathered data at each of 5 study sites for $\geq$6 years ($\geq$2 years before experimental changes in grazing intensity and $\geq$4 years after experimental changes in grazing intensity). We used a 'staggered-entry' design so that experimental changes in grazing intensity were not initiated at all study sites in the same year (i.e., the switch from pre-treatment to post-treatment did not happen in the same year at all 5 study sites). 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 allowed us to 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 the experimental changes in grazing intensity did 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 gathered 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 and 2 in Fig. A1-1). These initial pre-treatment years of field work and data collection allowed us to identify grazing pastures that were appropriate for inclusion in the experiment (based on discussions with permittees and BLM managers and the presence of nesting sage-grouse) and they provided the 'Before' measures of demographic traits for the BACI design. In the spring of the 3rd year of sampling at each study site, we manipulated the grazing regime in 3-6 experimental pastures per study site and began 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. A1-1). We defined spring grazing as 1 March through 15 June and fall grazing as 10 August 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 A1-1. 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 searched 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 most female sage-grouse that we captured. At the Pahsimeroi Valley study site, we also attached some 22 g Platform Transmitter Terminals (PTTs; Microwave Telemetry, Columbia, MD) to a subset of captured female sage-grouse (91 hens across 7 years).

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 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 the explicit protocol below 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.

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., hens 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 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 (first egg laid) 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 for 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 given that some predators likely carry off some eggs).

DATE OF INCUBATION ONSET

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 on <1% of nest monitoring visits), 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 for 17 nests for which 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 during the first 6 years of the project (2014-2019), 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). After 2019, we added 27 to the estimated onset of incubation. 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 (Borgmann and Conway 2015, 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 visual surveys, fecal pellet surveys at nighttime roost sites, and nighttime spotlight surveys (Riley and Conway 2020). 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 2015-2023)

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). 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. On any of the first three surveys, if we saw $\geq$1 chick without flushing the hen (16.3% of those 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 (we detected chicks on 48.3% of those surveys). 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.

BROOD FECAL PELLET SURVEYS (USED IN 2016-2017 & 2019-2023)

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 (Riley 2019, Riley et al. 2021). 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, Riley et al. 2021).

BROOD SPOTLIGHT SURVEYS (USED IN 2015-2023)

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 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 females at night and we would have had to flush the hen to see whether she was brooding chicks.

6) VEGETATION SAMPLING

We measured vegetation at three types of plots: nest plots, dependent non-nest plots (100-200 m from each nest), and random plots. Nest plots were centered on sage-grouse nests. Each dependent 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. 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).

PLOT PLACEMENT

Random Plots

We placed random plots within each experimental pasture. We conducted vegetation sampling at a minimum of 20 random plots in each of our experimental pastures (we only completed 10-15 per pasture at Pahsimeroi in 2017-2018 because we monitored 7 pastures those years and did not have the personnel to complete 20 per pasture). Random plot locations were moved if the randomly generated location had $\geq$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 (i.e., a 15-m radius plot) in each cardinal direction (Fig. A1-2).

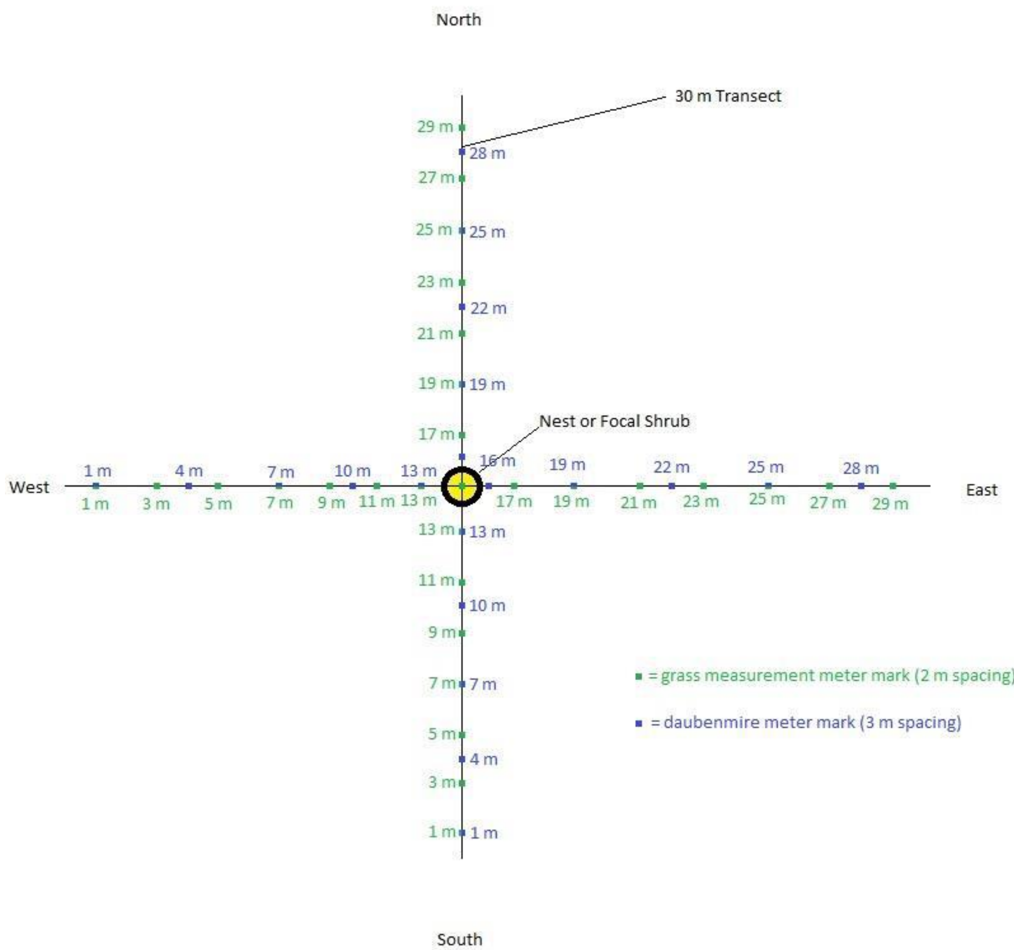

Figure A1-2. Visual depiction of the placement of two 30 m tapes stretched to conduct vegetation sampling at nest plots and random plots for the Grouse & Grazing Project in southern Idaho, 2014-2023.

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 5th photo directly above the pink ball with the camera 1 m above the ground to estimate overhead concealment. We used ImageJ software 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. A1-2). 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. A1-2). 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).

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. A1-2). 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. A1-3). 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 A1-1).

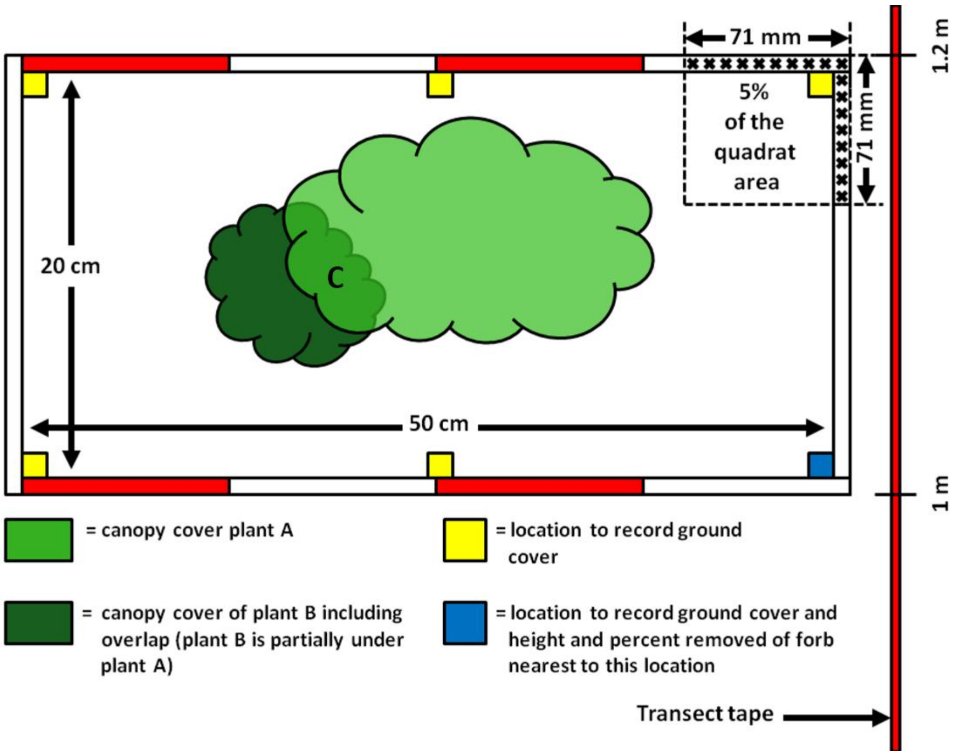

Figure A1-3. Example of Daubenmire frame cover measurements. Canopy cover of plant A would be an estimate of the percent of the frame the dark green colored area encompasses when looking from above the frame. Canopy cover of plant B would be an estimate of the percent of the frame the light green colored 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. A1-2). 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 A1-1. 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	

7) 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 the explicit utilization sampling protocol described here 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. A1-2). 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 each July.

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 in pre-treatment years when 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 A1-2) 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 2016-2023, 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 grass 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 A1-2. 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.

8) STOCKING RATES

To comprehensively monitor the effects of cattle grazing on sage-grouse demographic traits, we collected and recorded a suite of details regarding the grazing regime of cattle in each of our experimental pastures and for many of the surrounding pastures. We contacted range management specialists at each of the local BLM field offices in which we conducted field work to collect this information. We recorded 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 for use in analyses of sage-grouse demographic traits.

9) WEATHER MONITORING

We obtained precipitation and temperature data at each study site via PRISM to collect and model climate data for each of our study sites (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. Given that the nearest weather station to some of our study sites is many miles away, we believe PRISM data provide a more precise measurement of precipitation and temperature at our experimental pastures. 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.

10) ARTHROPOD SAMPLING

We sampled arthropods at random vegetation sampling points in a subset of pastures starting in 2015. 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. A1-4 and A1-5) but the intensity of arthropod sampling varied annually based on funding. The arthropod samples were the focus of Grace Overlie's thesis (Overlie 2024).

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. A1-5). 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. A1-5). 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 A1-4. 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. A1-5) 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).

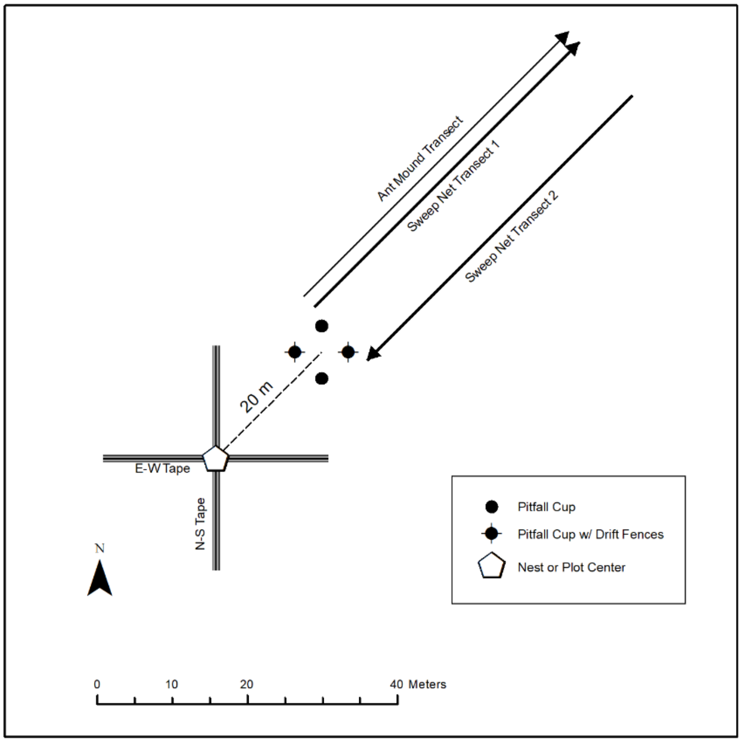

Figure A1-5. Visual depiction of all 3 arthropod sampling efforts (sweep net, pitfall, and ant mound) and their orientation in relation to the line transects on an accompanying random vegetation sampling plot.

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Appendix 2. Supplemental Tables and Figures.

Table A2-1. Telemetry flights conducted to search for collared sage-grouse hens in 2014-2023, Idaho. Field sites searched during the project were Brown's Bench (BRBE), Big Butte (BIBU), Idaho National Laboratory (IDNL), Jim Sage (JISA), Pahsimeroi Valley (PAVA), and Sheep Creek (SHCR).

Year	Dates	Sites Searched
2014	3-Mar, 30-May, 2-Jul, 2-Aug	JISA
	4-Sep, 31-Oct, 9-Dec	BRBE
2015	5-Apr	BRBE, JISA, SHCR
	30-Apr	BRBE, SHCR
	1-4 Jun	BIBU, BRBE, JISA
	1-2 Jul	BIBU, BRBE, JISA, SHCR
2016	5-11 Jan	BIBU, BRBE, JISA, SHCR
	4-7 Apr	BIBU, BRBE, JISA, SHCR
	29 Nov & 12 Dec	BIBU, SHCR
2017[a]	27-Apr	
	28-Jun	
2019	7-8 Feb	BIBU, BRBE, JISA, PAVA, SHCR
	12-Jun	BIBU, IDNL
	25-26 Jun	BIBU, BRBE, IDNL, SHCR
	8-Jul	BIBU, IDNL, PAVA
2020	27-28 Feb	BIBU, BRBE, IDNL, JISA, PAVA, SHCR
	21-May	BIBU, IDNL, PAVA
	15-Jul	PAVA
2021	1-2 Mar	BRBE, JISA, PAVA
	19-21 Jun	BIBU, BRBE
	20-23 Dec	BIBU, BRBE, JISA, PAVA, SHCR
2022	8-Jan	BRBE, SHCR
	20-Jul	BIBU, BRBE
2023	3-May	BIBU, PAVA
	1-Jul	BRBE

[a]*Records of which sites these flights searched were not available.*

<u>Table A2-2. Products from the Grouse & Grazing Project.</u>

<u>CONFERENCE CALLS</u>

- Monthly conference calls with Planning Team, with agendas and minutes written and distributed
- Weekly conference calls during the field season (Feb-Aug) with the Technical Team and all field crew leaders

ANNUAL MEETINGS

2-day meetings every fall with Planning Team members

PROJECT WEBSITE

https://idahograusegrazing.wordpress.com/

ANNUAL REPORTS

Detailed annual reports each year sent to all partners and stakeholders, and posted on project website

Conway, C.J., C.A. Tisdale, K.L. Launchbaugh, B.S. Stevens, G.E. Overlie, S.D. Eigenbrode, P.D. Makela, and S.B. Roberts. 2025. The Grouse & Grazing Project: Effects of cattle grazing on demographic traits of greater sage-grouse – Final Report (this report).

Conway, C. J., C.A. Tisdale, K. L. Launchbaugh, P. Makela, S. Roberts, and C. Henderson. 2022. The Grouse & Grazing Project: Effects of cattle grazing on sage-grouse demographic traits – 2022 Annual Report. College of Natural Resources, University of Idaho.

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Locatelli, A., C. J. Conway, K. L. Launchbaugh, and D. Musil. 2015. Grouse & Grazing: 2015 Annual Report. Idaho Cooperative Fish & Wildlife Research Unit, Moscow, ID.

FIELD TOURS

1. October 2017 – Idaho Grouse & Grazing Project. A stop on the Rangeland Fall Forum Field Tour. A joint activity of the Idaho Rangeland Center and the Idaho McClure Center for Public Policy. About 80 participants

2. August 2017 – Grouse & Grazing Project in the Pahsimeroi. A stop on the Idaho Society for Range Management Field tour. About 80 participants.

3. June 2017 – Idaho Grouse & Grazing Project Update. A stop on the field tour of the Idaho Cattle Association Summer meeting. About 65 participants.

4. April 2017 – Idaho Grouse & Grazing Study Update. A stop on the field tour of the field tour for the Idaho University of Idaho President, College of Natural Resources Advisory Council, and Idaho Natural Resource Policy Leaders About 82 participants

5. August 2016 – Targeted grazing and influence on sage-grouse. A stop on the field tour of the 100-Year celebration of the U.S. Sheep Experiment Station. About 60 participants.

6. June 2016 – Grouse & Grazing on Jim Sage Allotment. About 25 participants.

7. June 2014 – Grouse & Grazing on Jim Sage Allotment About 38 participants.

GRAD STUDENTS ON PROJECT

1. David Gotsch, M.N.R. Student, Wildlife Sciences, University of Idaho, Non-thesis. Jan 2014-Dec 2024.

2. Janessa Julson, M.S. Student, Range Management, University of Idaho, Thesis Title: *Variation in perennial grass height within greater sage-grouse nesting habitat*. Jan 2015-2017.

3. Ian Riley, M.S. Student, Wildlife Sciences, University of Idaho, Thesis Title: *Sampling methods for lek and brood counts of greater sage-grouse: accounting for imperfect detection*. Aug 2015-2019.

4. Alex Laurence-Traynor, M.S. Student, Range Management, University of Idaho, Thesis Title: *Determining appropriate utilization measurements for multi-scale rangeland management*. Jan 2018-2019.

5. Ty Styhl, M.S. Student (non-thesis), Wildlife Sciences, University of Idaho. May 2018- May 2024.

6. Taylor Fletcher, M.S. Student, Range Management, University of Idaho, Thesis Title: *Using global positioning system collars to assess the impact of livestock grazing on the greater sage-grouse*. Aug 2019-May 2021.

7. Nolan Helmstetter, M.S. Student, Wildlife Sciences, University of Idaho, Thesis Title: *Effects of livestock grazing and habitat on predator-specific nest mortality and spatiotemporal activity patterns of sage-grouse nest predators*. Aug 2019-Aug 2023.

8. Grace Overlie, M.S. Student, Entomology, University of Idaho, Thesis Title: *Effects of Spring Cattle Grazing on Arthropod Communities in Idaho Sagebrush Ecosystems: Impacts for Greater Sage-grouse Conservation*. Aug 2021-May 2024.

PUBLICATIONS (To Date)

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

2. Karl, J.W., and J.E. Sprinkle. 2019. Low-cost livestock global positioning system collar from commercial off-the-shelf parts. *Rangeland Ecology and Management* 72:954-958.

3. Riley, I. P., and C. J. Conway. 2020. Methods for estimating vital rates of greater sage-grouse broods: A review. *Wildlife Biology* 2020:wlb00700.

4. Riley, I. P., C. J. Conway, B. S. Stevens, and S. Roberts. 2021. Aural and visual detection of greater sage-grouse leks: Implications for population trend estimates. *Journal of Wildlife Management* 85:508-519.

5. Riley, I. P., C. J. Conway, B. S. Stevens, and S. Roberts. 2021. Survival of greater sage-grouse broods: survey method affects disturbance and age-specific detection probability. *Journal of Field Ornithology* 92:88-102.

6. Stevens, B. S., C. J. Conway, C. Tisdale, K. Denny, A. Meyers, and P. Makela. 2023. Backpack satellite transmitters reduce survival but not nesting propensity or success of greater sage-grouse. *Ecology and Evolution* 13:e10820.

7. Helmstetter, N. A., C. J. Conway, S. Roberts, J. R. Adams, P. D. Makela, and L. P. Waits. 2024. Predator-specific mortality of sage-grouse nests based on predator DNA on eggshells. *Ecology and Evolution* 14:e70213.

8. Helmstetter, N.A., C. J. Conway, S. Roberts, P. Makela, and L.P. Waits. 2025. The influence of grazing on the spatiotemporal activity patterns of a primary sage-grouse nest predator. *Rangeland Ecology & Management* 98:316-323.

COMPLETED THESES

Overlie, G. 2024. Effects of Spring Cattle Grazing on Arthropod Communities in Idaho Sagebrush Ecosystems: Impacts for Greater Sage-grouse Conservation. M.S. Thesis, University of Idaho, Moscow, ID.

Helmstetter, N.A. 2023. Effects of livestock grazing and habitat on predator-specific nest mortality and spatiotemporal activity patterns of sage-grouse nest predators. M.S. Thesis, University of Idaho.

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Riley, I. 2019. Sampling methods for lek and brood counts of greater sage-grouse: accounting for imperfect detection. M.S. Thesis, University of Idaho.

Laurence-Traynor, A.C.E. 2020. Evaluating field-based grazing intensity measurements for adaptive rangeland monitoring. M.S. Thesis, University of Idaho.

Fletcher, T. 2021. Evaluating GPS-derived estimates of livestock use and their value in assessing impacts of spring cattle grazing on greater sage-grouse demographics. M.S. Thesis, University of Idaho.

PRESENTATIONS

1. Conway, C.J., C. Tisdale, K.L. Launchbaugh, B.S. Stevens, S. Eigenbrode, P. Makela and S.B. Roberts. 2025. Grouse & Grazing Project: Summary of cattle grazing effects on demographic traits of greater sage-grouse. BLM Idaho Leadership Team meeting. Virtual. 19 May 2025.

2. Denny, K., C.J. Conway, K.L. Launchbaugh, P.D. Makela, and S. Roberts. 2025. Measuring vegetation characteristics at greater sage-grouse nest sites one year after nest fate: is it as effective as traditional methods? Idaho Chapter of The Wildlife Society Annual Conference. Moscow, ID. 20 Mar 2025.

3. Denny, K., C.J. Conway, K.L. Launchbaugh, P.D. Makela, and S. Roberts. 2025. Measuring vegetation characteristics at greater sage-grouse nest sites one year after nest fate: is it as effective as traditional methods? Montana Chapter of The Wildlife Society Annual Conference. Billings, MT. 7 Mar 2025.

4. Conway, C.J., C. Tisdale, K.L. Launchbaugh, S.B. Roberts, P. Makela and B. Stevens. 2024. Relationship between cattle grazing and demographic traits of greater sage-grouse: The Grouse &

Grazing Project. WAFWA 34th Biennial Sage & Sharp-tailed Grouse Workshop. Wenatchee, WA. 6 Aug 2024.

5. Conway, C.J., K.L. Launchbaugh, P. Makela, S. Roberts, C. Tisdale, and N. Helmstetter. 2024. Effects of cattle grazing on greater sage-grouse: Idaho Grouse & Grazing Project. USGS Land Management Research Program Sagebrush & Fire Science Webinar Series. Virtual. 22 Feb 2024.

6. Launchbaugh, K., C.J. Conway, C. Tisdale, N. Helmstetter, G. Overlie, P. Makela, and S. Roberts. 2024. Effects of cattle grazing on greater sage-grouse: Idaho Grouse & Grazing Project. Idaho Section of the Society for Range Management. Virtual. 3 Jan 2024.

7. Conway, C.J., C. Tisdale, K. Launchbaugh, P. Makela, and S. Roberts. 2023. Effects of cattle grazing on greater sage-grouse. USGS-BLM Sage and Fire Research Workshop. 2 Feb 2023.

8. Tisdale, C. A., W. Field, A. Means, D. Brewster, J. Hamaker, C. J. Conway, P. Makela, S. Roberts, and K.L. Launchbaugh. 2023. Relationship between livestock grazing and sage-grouse populations. Idaho Cattle Association meeting. Rogerson, ID. 26 Jun 2023.

9. Conway, C.J., C. Tisdale, K. Launchbaugh, P. Makela, and S. Roberts. 2023. Effects of cattle grazing on greater sage-grouse. USGS-BLM Sage and Fire Research Workshop. 2 Feb 2023.

10. Helmstetter, N. A., C. J. Conway, S. Roberts, P. D. Makela, J. A. Adams, S. A. Nerkowski, and L. P. Waits. 2022. eDNA Applications for improving sage-grouse management: Detecting nest predators from eggshells after depredation events. Annual Conference of The Wildlife Society. Spokane, WA. 9 Nov 2022.

11. Overlie, G. 2022. Effects of grazing on pitfall-detectable arthropods in Idaho sagebrush systems. Department of Entomology, Plant Pathology and Nematology Seminar Series. 2 May 2022.

12. Conway, C. J., K. L. Launchbaugh, C. Tisdale, P. Makela, and S. Roberts. 2022. Effects of cattle grazing on demographic and behavioral traits of greater sage-grouse: a 10-year experimental study. 5th Gunnison Sage-grouse Summit. Gunnison, CO. 5 Apr 2022.

13. Helmstetter, N. A., C. J. Conway, S. Roberts, P. D. Makela, J. R. Adams, S. A. Nerkowski, and L. P. Waits 2022. Who Dunnit? A non-invasive method for identifying sage-grouse nest predators. Idaho Chapter of The Wildlife Society. Boise, ID. 24 Feb 2022.

14. Conway, C. J., C. Tisdale, K. L. Launchbaugh, P. Makela, and S. Roberts. 2021. Effects of cattle grazing on greater sage-grouse. USGS-BLM Sage and Fire Research Workshop. 9 Nov 2021.

15. Launchbaugh, K. L., and C. J. Conway. 2021. Relationships between Livestock Grazing & Greater Sage-grouse: the Grouse & Grazing Project. Public Lands Council Executive Committee Annual Meeting. Virtual. 27 Sep 2021.

16. Fletcher, T., J. Karl, C. J. Conway, V. Jansen, and E. Strand. 2021. Assessing the impacts of scale on estimates of grazing intensity derived from livestock global positioning system collars. Society of Range Management, annual conference. Virtual. 17 Feb 2021.

17. Conway, C. J., K. L. Launchbaugh, D. Musil, P. Makela, S. Roberts, A. Meyers, and C. Tisdale. 2020. Effects of cattle grazing on sage-grouse: The Grouse & Grazing Project. USGS Sagebrush and Fire Research - Info Transfer Workshop. Online Webinar. 10 Dec 2020.

18. Fletcher, T., J. Karl, C. Conway, V. Jansen E. Strand, S. Roberts, and P. Makela. 2020. Using global positioning system collars to assess the impact of livestock grazing on the greater sage-grouse. The Wildlife Society, virtual conference. 28 Sep 2020.

19. Launchbaugh, K. L., and C. J. Conway. 2020. Effects of livestock grazing on greater sage-grouse: the Grouse & Grazing Project. Public Lands Council Executive Committee Annual Meeting. Virtual. 22 Sep 2020.

20. Fletcher, T., J. Karl, C. J. Conway, V. Jansen, E. Strand, S. Roberts, and P. Makela. 2020. Use of global positioning system collars to assess the impact of livestock grazing on the Greater Sage-Grouse. Idaho Chapter of The Wildlife Society. Moscow, ID. 11 March 2020.

21. Laurence-Traynor, A., J. W. Karl, and V. S. Jansen. 2020. Determining appropriate utilization measurements for multiscale spatial analysis of Greater Sage-grouse habitat in southern Idaho. Annual Meeting of the Society for Range Management Annual Meeting. Denver, CO. 17 Feb 2020.

22. Launchbaugh, K. L., D. Musil, C. J. Conway, A. Meyers, P. Makela, and S. Roberts. 2019. Effects of cattle grazing on sage-grouse: an update on the Grouse & Grazing project. Jim Sage Grazing Association. Malta, ID. 20 Dec 2019.

23. Karl, J. W., C. J. Conway, and K. L. Launchbaugh. 2019. Effects of cattle grazing on sage-grouse: an update on the Grouse & Grazing project. Annual meeting of the Idaho Rangeland Resource Commission. Sun Valley, ID. 13 Nov 2019.

24. Karl, J. W., C. J. Conway, and K. L. Launchbaugh. 2019. Effects of cattle grazing on sage-grouse: an update on the Grouse & Grazing project. Annual meeting of the Idaho Rangeland Committee annual meeting. Sun Valley, ID. 11 Nov 2019.

25. Conway, C. J., K. L. Launchbaugh, A. Meyers, D. Musil, P. Makela, and S. Roberts. 2019. Summary of project goals and accomplishments. Briefing session for Idaho Agency Directors. Boise, ID. 31 Oct 2019.

26. Conway, C. J. A. Meyers, D. Musil, P. Makela, S. Roberts, and K. L. Launchbaugh. 2019. Relationship between grass height and nesting success of greater sage-grouse. Joint Meeting of The Wildlife Society and the American Fisheries Society, Reno, NV. 2 Oct 2019.

27. Launchbaugh, K. L., and C. J. Conway. 2019. Public Lands Endowment Board of Directors Annual Meeting. Great Falls, MT. 27 Sep 2019.

28. Musil, D., C. J. Conway, A. Meyers, P. Makela, S. Roberts, and K. L. Launchbaugh. 2019. Response of sage-grouse to spring grazing - Update: Year 6 of 10-year research project. Owyhee County Sage-Grouse Local Working Group. 17 Sep 2019.

29. Zuniga, Z., E. Cook, J. T. Styhl, K. T. Vierling, and C. J. Conway. 2019. Ant mound density estimation in greater sage-grouse habitat. Moscow Outdoor Science School, McCall, ID. 26 Jul 2019.

30. Cook, E., Z. Zuniga, J. T. Styhl, K. T. Vierling, and C. J. Conway. 2019. Modeling changes in grass height over time; implications for grazing effects studies. Moscow Outdoor Science School, McCall, ID. 26 Jul 2019.

31. Riley, I., and C. J. Conway. 2019. Estimating detection and survival probabilities of sage-grouse broods: a comparison of field methods. Idaho Chapter of The Wildlife Society, Boise, ID. 21 Mar 2019.

32. Laurence-Traynor, A., J. W. Karl, C. J. Conway, K. L. Launchbaugh, and A. R. Meyers. 2019. Determining appropriate utilization measurements for multiscale spatial analysis of wildlife-livestock interactions in southern Idaho. Society for Range Management, Minneapolis, MN. 11 Feb 2019.

33. Launchbaugh, K. L, and C. J. Conway. 2018. Grouse & Grazing: Effects of livestock grazing influence on sage-grouse populations. Public Lands Council Annual Meeting. Park City, UT. 27 Sep 2018.

34. Launchbaugh, K. L., and C. J. Conway. 2018. Grouse & Grazing Study: Effects of Spring Grazing on Sage-grouse Populations. Idaho Range Livestock Symposium. Rexburg, ID. 12 Jan 2018.

35. Launchbaugh, K. L., and C. J. Conway. 2018. Grouse & Grazing Study: Effects of Spring Grazing on Sage-grouse Populations. Idaho Range Livestock Symposium. Pocatello, ID. 11 Jan 2018.

36. Launchbaugh, K. L., and C. J. Conway. 2018. Grouse & Grazing Study: Effects of Spring Grazing on Sage-grouse Populations. Idaho Range Livestock Symposium. Twin Falls, ID. 10 Jan 2018.

37. Launchbaugh, K. L., and C. J. Conway. 2018. Grouse & Grazing Study: Effects of Spring Grazing on Sage-grouse Populations. Idaho Range Livestock Symposium. Marsing, ID. 9 Jan 2018.

38. Conway, C. J., K. L. Launchbaugh, A. R. Meyers, D. Musil, P. Makela, and S. Roberts. 2017. The Grouse & Grazing Project. Public Forum. Burley, ID. 27 Oct 2017.

39. Gotsch, D., C. J. Conway, D. D. Musil, and S. Roberts. 2017. Prey for sage-grouse: Impacts of livestock grazing. Annual Meeting of The Wildlife Society. Albuquerque, NM. 27 Sep 2017.

40. Meyers, A. R., C. J. Conway, D. D. Musil, K. L. Launchbaugh, and S. Roberts. 2017. Effects of spring cattle grazing on nest survival of greater sage-grouse in southern Idaho. Annual Meeting of The Wildlife Society. Albuquerque, NM. 27 Sep 2017.

41. Launchbaugh, K. L, and C. J. Conway. 2017. Grouse & Grazing: How does spring livestock grazing influence sage-grouse populations? Public Lands Endowment Board of Directors Annual Meeting. Flagstaff, AZ. 21 Sep 2017.

42. Musil, D., C. J. Conway, K. L. Launchbaugh, A. R. Meyers, P. Makela, and S. Roberts. 2017. Response of sage-grouse to spring grazing – project update. Shoshone Basin Sage-Grouse Local Working Group, Twin Falls, ID. 19 Sep 2017.

43. Conway, C. J., K. L. Launchbaugh, A. Meyers, D. Musil, P. Makela, and S. Roberts. 2017. Effects of grazing on sage-grouse and other shrub-steppe birds: a collaborative project to inform management of sage-steppe rangelands. Great Basin Landscape Conservation Cooperative Webinar Series. 13 Sep 2017.

44. Conway, C. J., K. L. Launchbaugh, A. Meyers, D. Musil, P. Makela, and S. Roberts. 2017. Effects of cattle grazing on greater sage-grouse and other sagebrush-steppe birds. Special Symposium at the Annual Meeting of the American Ornithological Society. East Lansing, MI. 5 Aug 2017.

45. Conway, C. J., K. L. Launchbaugh, D. Musil, P. Makela, and S. Roberts. 2017. Effects of livestock grazing intensity on greater sage-grouse. BLM Idaho Leadership Team meeting, Boise, ID. 11 Apr 2017.

46. Conway, C. J., K. L. Launchbaugh, D. Musil, P. Makela, and S. Roberts. 2017. Effects of livestock grazing intensity on nesting success and brood movements in greater sage-grouse. Annual Meeting of the Idaho Chapter of The Wildlife Society, Boise, ID. 2 Mar 2017.

47. Gotsch, D., C. J. Conway, and D. Musil. 2017. Prey availability for sage-grouse chicks: effects of cattle grazing and vegetative structure. Annual Meeting of the Idaho Chapter of The Wildlife Society, Boise, ID. 2 Mar 2017.

48. Conway, C. J., K. L. Launchbaugh, D. Musil, P. Makela, and S. Roberts. 2017. The Idaho Grouse & Grazing Project: a collaborative, landscape-scale experiment to assess the effects of cattle grazing. Annual Meeting of the Idaho Bird Conservation Partnership, Boise, ID. 27 Feb 2017.

49. Julson, J., K. L. Launchbaugh, E. Strand, C. J. Conway, and A. Locatelli. 2017. Relationships among spring livestock grazing, sage-grouse nest fate, and climate in sagebrush-steppe communities. Society for Range Management Conference. St. George, UT. 29 Jan 2017.

50. Julson, J., K. L. Launchbaugh, and C. J. Conway. 2017. How to estimate utilization of grasses: ocular estimation or height-weight method? Society for Range Management Annual Conference. St. George, UT. 29 Jan 2017.

51. Launchbaugh, K. L., and C. J. Conway. 2015. Livestock grazing and sage-grouse. Meeting of the Environment and Natural Resources Section of the Idaho Bar Association. Boise, ID. 2 Dec 2016.

52. Conway, C. J., and K. L. Launchbaugh. 2016. Grouse & Grazing: How does spring livestock grazing influence sage-grouse populations? Public Lands Endowment Board of Directors Annual Meeting. Boise, ID. 7 Sep 2016.

53. Conway, C. J., K. L. Launchbaugh, A. Locatelli, D. Musil, P. Makela, and S. Roberts. 2016. Effects of spring-season cattle grazing on greater sage-grouse. USGS/BLM Grazing Research Webinar. 13 Jul 2016.

54. Conway, C. J., K. L. Launchbaugh, A. Locatelli, D. Musil, P. Makela, and S. Roberts. 2016. Effects of spring-season cattle grazing on greater sage-grouse. Western Agencies Sage and Columbian Sharp-Tailed Grouse Workshop. Lander, WY. 14 Jun 2016.

55. Conway, C. J. 2016. Effects of cattle grazing on Greater Sage-Grouse: a 10-year experimental study. Invited Departmental Seminar. School of Natural Resources, University of Arizona. Tucson, AZ. 6 April 2016.

56. Conway, C. J., A. Locatelli, D. Musil, S. Roberts, K. L. Launchbaugh, and P. Makela. 2016. Effects of spring cattle grazing on greater sage-grouse: a 10-year experimental study to manipulate grazing regimes in Idaho. Sagebrush Ecosystem Conservation Conference: All Lands, All Hands. Salt Lake City, UT. 25 Feb 2016.

57. Conway, C. J., K. L. Launchbaugh, A. Locatelli, D. Musil, P. Makela, and S. Roberts. 2016. Large-scale field experiments to assess the effects of cattle grazing on greater sage-grouse. Idaho Chapter of The Wildlife Society conference, Coeur d' Alene, ID. 23 Feb 2016.

58. Locatelli, A., C. J. Conway, D. Musil, K. L. Launchbaugh, S. Roberts, and D. Gotsch. 2016. Factors influencing nest survival of greater sage-grouse (*Centrocercus urophasianus*) in southern Idaho. Annual Meeting of the Idaho Chapter of The Wildlife Society, Coeur d' Alene, ID. 23 Feb 2016.

59. Conway, C. J., K. L. Launchbaugh, A. Locatelli, D. Musil, P. Makela, and S. Roberts. 2015. Large-scale field experiments to assess the effects of cattle grazing on greater sage-grouse. Tri-state coordination meeting for sage-grouse grazing research. Helena, MT. 4 Nov 2015.

60. Conway, C. J., K. L. Launchbaugh, A. Locatelli, W. Pratt, P. Makela, D. Kemner, D. Musil, and S. Roberts. 2015. Experimental study to assess effects of spring cattle grazing on sage-grouse. Association of Fish and Wildlife Agencies conference, Tucson, AZ. 15 Sep 2015.

61. Launchbaugh, K. L., and C. J. Conway. 2015. Sage-grouse and livestock grazing. Public Lands Endowment Board of Directors Annual Meeting. Cody, WY. 9 Sept 2015.

62. Conway, C. J., J. W. Connelly, K. L. Launchbaugh, D. Gotsch, W. Pratt, P. Makela, D. Kemner, D. Musil, E. Strand, J. Robison, and J. Whiting. 2015. Effects of spring cattle grazing on sage-grouse: a project update. Annual Meeting of the Idaho Chapter of The Wildlife Society, Pocatello, ID. 11 Mar 2015.

63. Conway, C. J., and K. L. Launchbaugh. 2014. Cattle grazing effects on sage-grouse populations. Grouse & Grazing Planning Team Meeting. Twin Falls, ID. 18 Sep 2014.

64. Launchbaugh, K. L., and C. J. Conway. 2014. Sage-grouse and livestock grazing. Public Lands Endowment Board of Directors Annual Meeting. Ignacio, CO. 4 Sep 2014.

65. Conway, C. J., and K. L. Launchbaugh. 2014. How does spring livestock grazing influence sage-grouse populations? Idaho Sage-grouse Advisory Committee Meeting, Boise, ID. 28 May 2014.

66. Connelly, J. W., C. J. Conway, D. Kemner, K. L. Launchbaugh, W. Pratt, K. P. Reese, E. T. Rinkes, J. Robison, E. Strand, and J. Whiting. 2013. Grouse & Grazing in Idaho: a collaborative approach to answering difficult questions. Idaho Chapter of The Wildlife Society. Coeur d'Alene, Idaho. 13 Mar 2013.

Updates at Regular Meetings of Research Partners:

- Idaho Rangeland Center
- Idaho Cattle Association
- Idaho Rangeland Resource Commission
- Idaho Rangeland Committee

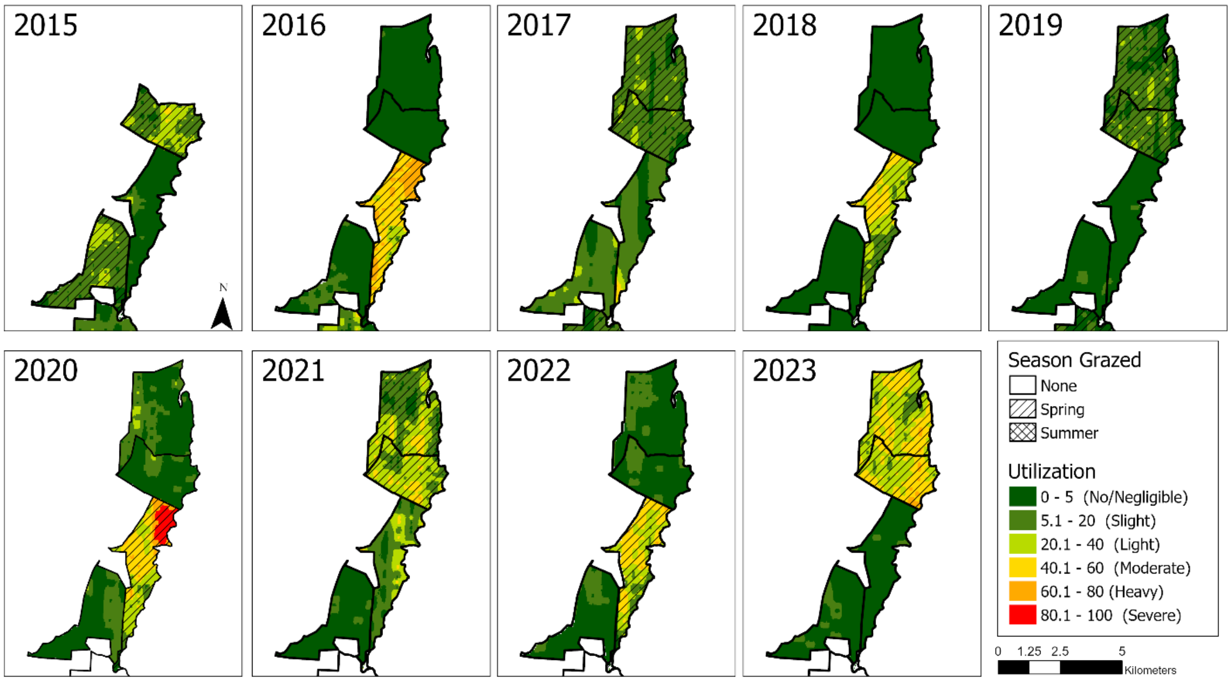

Figure A2-1. Pattern use mapping based on landscape appearance transects at Browns Bench, Idaho 2015-2023. We did not conduct utilization transects in 2014.

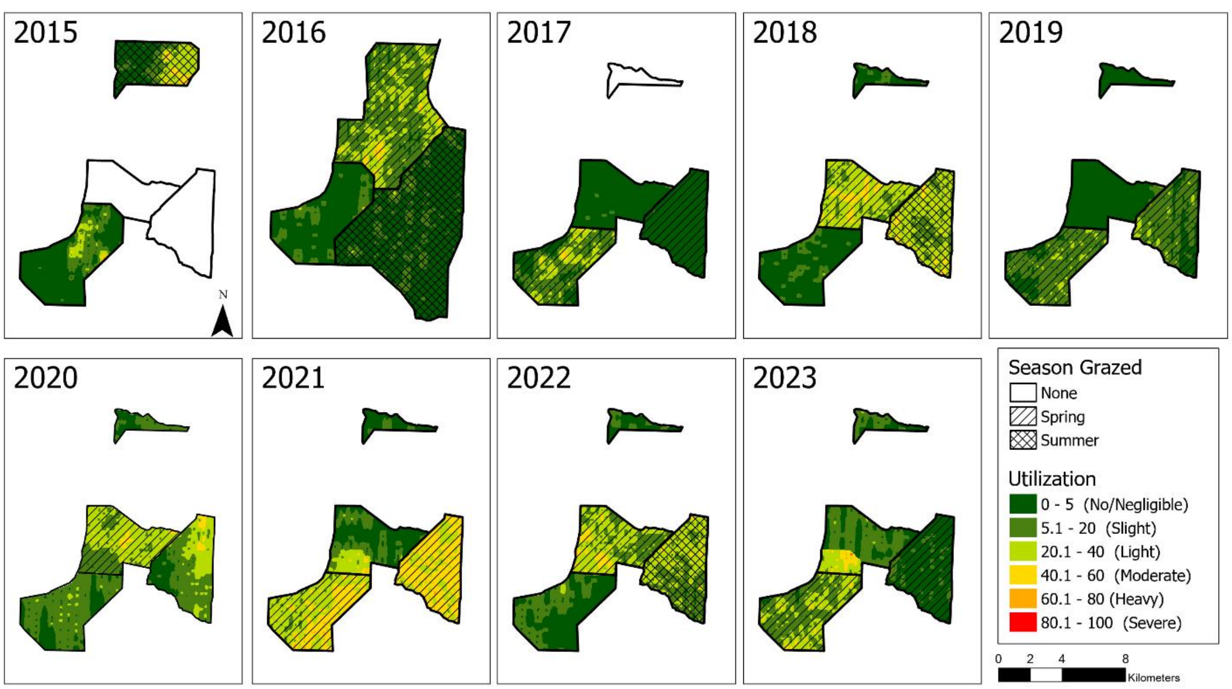

Figure A2-2. Pattern use mapping based on landscape appearance transects at Big Butte, Idaho 2015-2023.

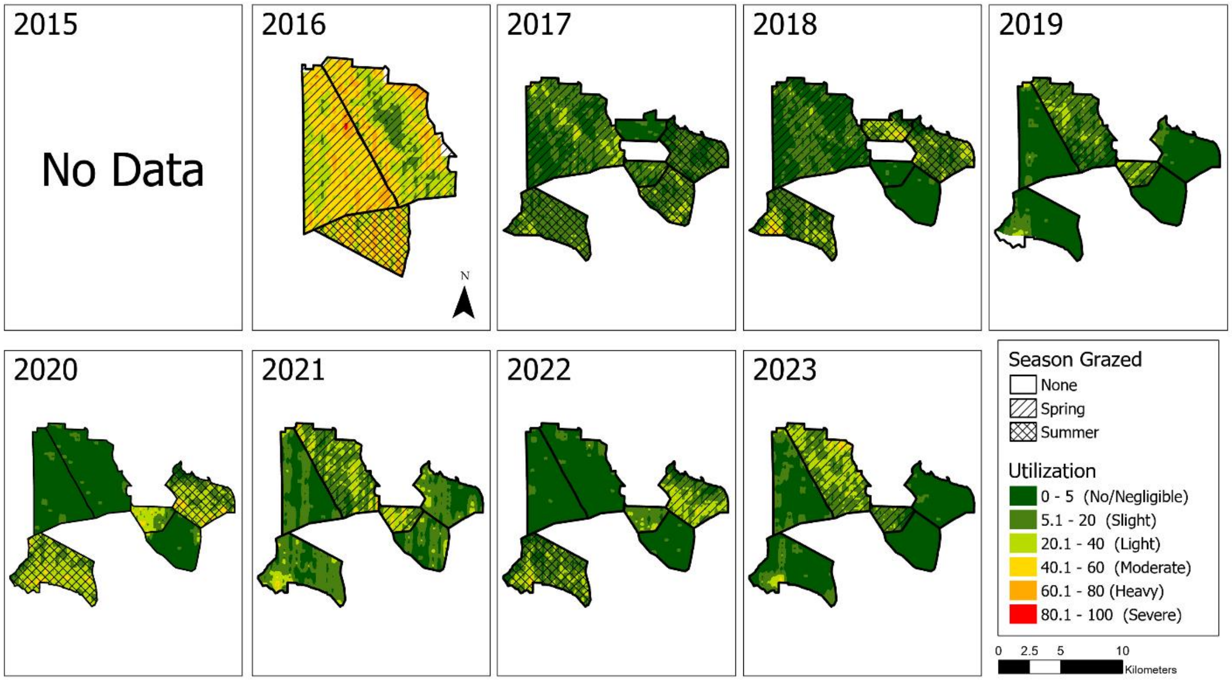

Figure A2-3. Pattern use mapping based on landscape appearance transects at Pahsimeroi Valley, Idaho 2016-2023. We did not conduct utilization transects in 2015.

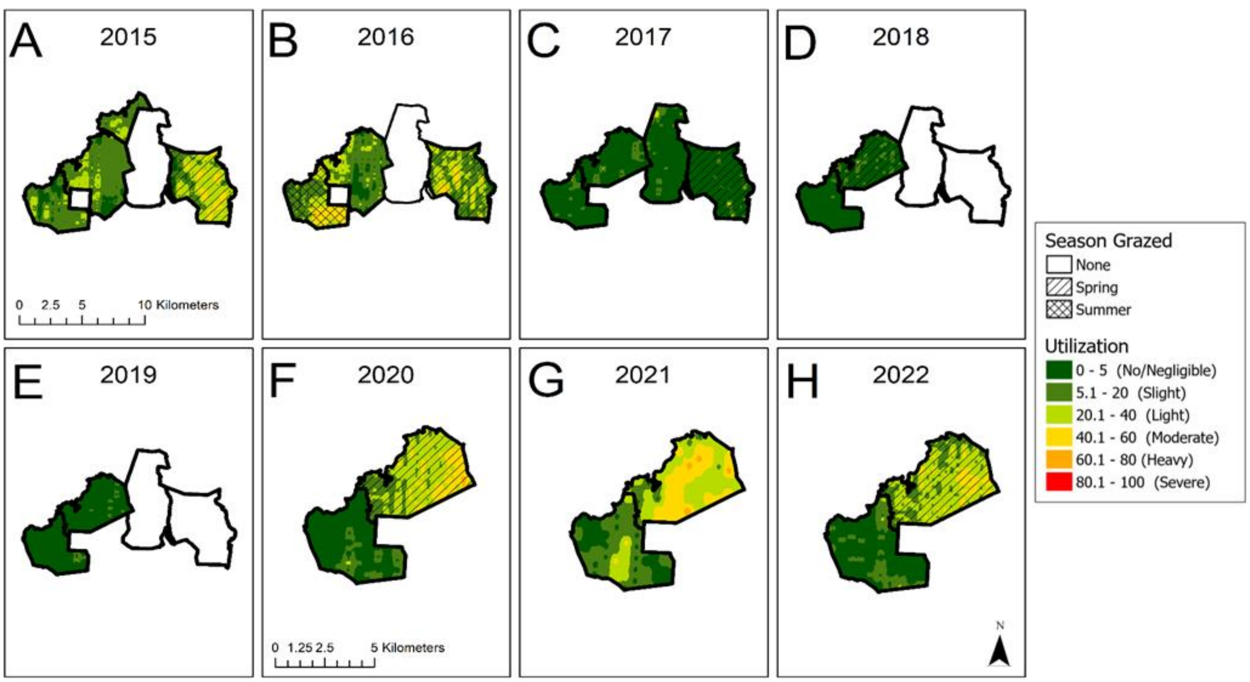

Figure A2-4. Pattern use mapping based on landscape appearance transects at Sheep Creek, Idaho 2015-2022.