The Grouse & Grazing Project:
Effects of cattle grazing on sage-grouse demographic traits
2021 Annual Report

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EXECUTIVE SUMMARY

We completed the 8th year of field work on the Grouse & Grazing Project. In 2021, we conducted field work at 5 study sites: Big Butte, Brown's Bench, Jim Sage, Pahsimeroi Valley, and Sheep Creek. We had 40 technicians, crew leaders, and students that worked on the project in 2021, including 4 graduate students. We conducted field work in 19 BLM grazing pastures that are part of the grazing experiment, as well as dozens of BLM grazing pastures adjacent to the experimental pastures. We deployed and maintained 13 segments of temporary electric fences (~59.4 km total) on experimental pastures to implement experimental grazing treatments. We captured and marked an additional 160 female sage-grouse in 2021 and we followed 83 females that were captured in previous years and returned to our sites (243 radio-collared hens in 2021). We documented 67 mortalities of radio-marked hens in 2021. We located and monitored 138 sage-grouse nests and apparent nesting success across all 5 study sites was 43%. Nesting propensity was 96% and re-nesting propensity was 14% in 2021. We monitored 59 sage-grouse broods and apparent survival of broods was 59%.

We conducted vegetation measurements at 683 plots in 2021 (114 nest plots, 381 random plots, 42 lek plots, 65 brood plots, and 81 cattle use plots). We measured grass height, percent biomass removed, and other metrics on 31,104 grass plants within those 683 plots. We walked transects throughout the 19 experimental pastures to estimate utilization and measured grass metrics at 3,103 sampling points along those transects. We conducted invertebrate sampling at 119 plots on 4 of our study sites (Jim Sage, Brown's Bench, Big Butte, and Sheep Creek) and collected 1,779 pitfall samples and 838 sweep-net samples at those 119 plots. We also conducted ant mound transect surveys and measured the distance to (and size of) 159 ant mounds along 119 50-m transects located at the plots.

We collected the 6th year of post-treatment data at the Brown's Bench and Jim Sage study sites, the 5th year of post-treatment data at the Sheep Creek study site, the 4th year of post-treatment data at the Big Butte study site, and the 3rd year of post-treatment data at the Pahsimeroi Valley site. We did not collect any data at Idaho National Laboratory in 2021.

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). Livestock grazing is a common land use within sage-grouse habitat, and livestock grazing has been implicated as one of numerous factors contributing to sage-grouse population declines (Beck and Mitchell 2000, Schroeder et al. 2004). However, there are also numerous mechanisms by which livestock grazing might benefit sage-grouse (Beck and Michell 2000, Crawford et al. 2004). Livestock grazing on public lands is often restricted to try to minimize negative effects on populations of plants and animals (including sage-grouse), but we lack experimental studies that have explicitly examined the effects of livestock grazing on sage-grouse. The objective of the Grouse & Grazing Project is to implement randomized grazing treatments to better document the relationship between cattle grazing and sage-grouse demographic traits, nest-site selection, and habitat features. We focus particularly on spring cattle grazing because spring is thought to be the time when livestock grazing is most likely to adversely affect sage-grouse (Neel 1980, Pedersen et al. 2003, Boyd et al. 2014).

STUDY AREA

Our field work has occurred at 6 study sites in Idaho within Owyhee, Twin Falls, Cassia, Butte, Custer, Bingham, and Jefferson 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 6 study sites range from 1,400 m to 1,900 m. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) is common in the overstory at all study sites. 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*), and needlegrass (*Achnatherum spp.* and *Hesperostipa spp.*).

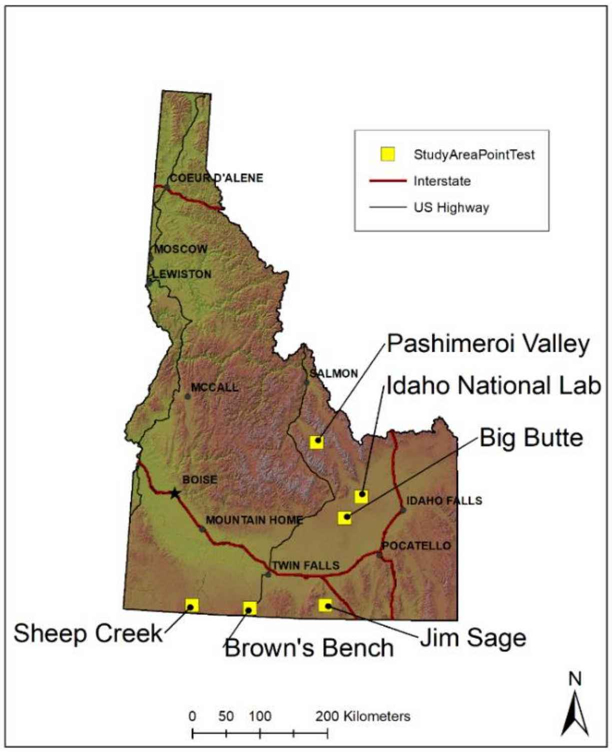

Figure 1. Location of 6 study sites where field work was conducted across southern Idaho (work was only conducted at Idaho National Lab in 2019).

METHODS

A detailed document containing all methods used in the Grouse & Grazing Project is available on the project website (https://idahograzing.wordpress.com/; Conway et al. 2021). In the sections below, we only mention changes to the methods that were implemented for the 2021 field season.

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), but we ceased field work at Idaho National Lab in March 2020 due to COVID-19 restrictions and the loss of sage-grouse habitat caused by the 2019 fire there. More details regarding the study design for the Grouse & Grazing Project is in the "Experimental Design" section of the methods document posted on the project website (Conway et al. 2021).

Capture and Radio-marking

We captured sage-grouse via nighttime spotlighting methods detailed in *section 1* of Conway et al. (2021). We did not attempt to capture any females with rocket-nets on leks in 2021; we only captured grouse via spotlighting.

Nest Searching and Monitoring

We monitored radio-marked sage-grouse using methods described in *section 2* of Conway et al. (2021). There were no major changes to our nest searching and hen monitoring protocol in 2021.

Brood Monitoring

In 2021, we used 3 methods to monitor the fate of sage-grouse broods: daytime visual surveys, nighttime spotlight surveys, and nighttime fecal pellet surveys. In 2021, we conducted nighttime fecal surveys on sage-grouse hens at 4 intervals as the chicks aged: 2-4 days, 9-11 days, 20-22 days, and 34-36 days. We also conducted daytime visual surveys at 7, 14, 28, and 42 days of age. We also collected fecal pellets on daytime visual surveys. More details of these methods are in *section 5* of Conway et al. (2021).

Avian Point-Count Surveys (2016-2018)

We conducted avian point-count surveys at 5 of our study sites (Big Butte, Brown's Bench, Jim Sage, Pahsimeroi Valley, and Sheep Creek) from 2016-2018. Funding for these surveys expired in 2018. Methods for these surveys are detailed in our avian point-count protocol.

Short-Eared Owl Surveys (2018-2020)

We conducted surveys for short-eared owls (*Asio flammeus*) in 2018-2020 at 5 of our study sites (all except Idaho National Lab) during the months of March – May in collaboration with project WAfLS. The methods and results of the surveys are detailed in the 2018 and 2019 Short-Eared Owl Report (Meyers and Conway 2018, Meyers and Conway 2019), and the results were included as part of a west-wide report (Miller et al. 2020).

Vegetation Sampling

From 2014-2021, we measured vegetation at sage-grouse nest plots and random plots distributed throughout our experimental pastures (and at nests in adjacent pastures). More details regarding methods and results of our vegetation sampling are in our site-specific annual grazing reports. Methods for these surveys are in *section 8* of Conway et al. (2021) or in our Vegetation Monitoring Protocol. In 2021, we added two new vegetation sampling efforts: 1) we measured shrub cover and shrub height at 81 cattle use areas within 4 pastures where we had attached GPS collars to cattle at Jim Sage and Pahsimeroi Valley study sites, and 2) we measured vegetation plots at 46 hen wintering locations in the Pahsimeroi Valley study site.

Utilization & Offtake

We used 3 methods to estimate the percent of above-ground perennial grass biomass removed by herbivores (Ocular Estimate, Landscape Appearance, and Grass Height Along Transects). Details regarding these 3 methods are in *section 9* of Conway et al. (2021).

Stocking Rates

To effectively document the relationship between cattle grazing and sage-grouse demographic traits, we have been collecting stocking rate data of cattle in each of our experimental pastures and for many of the surrounding pastures. Detailed summaries of stocking rates are in the 2021 site-specific Grazing Reports (available at https://idahogrousegrazing.wordpress.com/).

Cattle Movements

During 2018-2020, we collaborated with Dr. Jason Karl, a professor in the Rangeland Sciences Department at the University of Idaho, to assess different measures of utilization. This has allowed us to bring 2 additional graduate students onto the project (A. Laurence-Traynor and T. Fletcher). Additionally, this has provided funding for 2 additional objectives that complement the Grouse & Grazing Project:

1. Create low-cost GPS collars and attach them to a subset of cattle within 5 of our experimental pastures (1 in 2018, 2 in 2019, and 2 in 2020). Deployment of GPS collars on cattle will allow us to link cattle usage with all of our vegetation-based

measurements of utilization. Additionally, we can compare grouse use (e.g., nest-site selection) to cattle use in the same pastures.

2. Develop a model to assess utilization via remotely sensed images and link those estimates to our on-the-ground estimates of utilization.

Weather and Climate Monitoring

Since the beginning of the study, we obtained precipitation and temperature data at each study site. In 2021, we began using PRISM to collect and model weather data at the study sites. Detailed descriptions of where these data were collected are in *section 12* of Conway et al. (2021).

Arthropod Sampling

We sampled arthropods at 10 of the random vegetation sampling points within each of 13 pastures at 4 of the 5 study sites in 2021 (Brown's Bench, Big Butte, Jim Sage, and Sheep Creek). Detailed field methods are in *section 13* of Meyers and Conway (2019). The arthropod sampling from 2014-2016 is part of Dave Gotsch's M.S. thesis research and samples from 2014-2021 will be part of Grace Overlie's M.S. thesis. The samples will also be used to create a reference collection for Ty Styhl's Ph.D. dissertation.

STATISTICAL ANALYSIS

Age Ratios

We calculated the yearling-to-adult age ratio of female sage-grouse captured at all study sites in 2021: number yearling females/number adult females. We included all 2021 captured female sage-grouse in this ratio, including those that had been radio-marked from a previous season. This ratio provides an index of recruitment for the previous year. Higher ratios indicate a higher number of yearling females in the population and thus an increase in recruitment.

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. 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 marked hens - we monitor the hens that stay within the experimental pastures closely whereas we largely ignore hens that completely leave the study area (and those whose signal disappears). 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 14^{th} and 23^{rd} 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 14^{th} and 23^{rd} 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.

Nest Success

We calculated apparent nest success by dividing the number of hatched nests by the total number of nests monitored (hatched nests/[hatched nests + failed nests]), excluding nests with unknown nest fate and those that were visited only once. We calculated apparent nest success for each study site across all 8 years of the study. We also calculated daily nest survival by using program RMark (White and Burnham 1999) to account for potential bias caused by low detection probability for nests that fail early in the nesting cycle (Mayfield 1975). We used the Julian day of the year for the start and end dates of each nesting attempt. We used daily nest survival estimates from RMark and raised that daily survival probability to the 37^{th} power to estimate the probability that a nest 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 detected some nests prior to the onset of incubation. We used the delta method (Powell 2007) to calculate standard errors for 37-day nest survival estimates.

Clutch Size & Average Hatch Date

We calculated average clutch size of hatched nests only because depredated nests have fewer eggshell fragments remaining than hatched nests (Schroeder 1997). Throughout the 8 years of our study, we detected eggshell fragments from 4.5 eggs at failed nests, compared to eggshells from 6.6 eggs at hatched nests. We also used only hatched nests when calculating average hatch date. Since we do not flush hens when we find a nest, we therefore cannot float eggs to determine if we found the nest at initiation or sometime during incubation. We excluded nesting attempts that we knew were re-nests (second nesting attempts) when calculating average hatch dates.

Hen Survival

We used the known-fate module in RMark to estimate hen survival in 2014-2021. We created weekly encounter histories based on telemetry, nest monitoring, and brood monitoring data. Radio-marked hens were coded as either alive, dead, or censored (not detected) for each week during the breeding season. To estimate survival, we focused on the period from week 9 of each year (~1 March) through week 29 (~15 July; a 20-week period) because that is the timeframe when we monitored hens consistently. These reflected our typical earliest and latest monitoring efforts each year (excluding infrequent winter and fall monitoring efforts in 2014-2015). Instead of using a staggered entry design, we coded the 8 years of the study as 8 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).

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 signals for hens with a brood and, hence, could not determine the fate of some broods with 100% 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 prior to their chicks reaching 42 days of age).

We also modeled daily brood survival to examine the effects of study site and year on brood survival by using a Cormack-Jolly-Seber model in RMark similar to methods described by Riley (2019).

2021 SUMMARY

Field Effort

In addition to the full-time project coordinator (C. Tisdale), we hired 1 assistant field coordinator (R. Wray), 5 crew leaders, 15 wildlife technicians, and 10 range technicians across 5 study sites in 2021. In addition to the 32 University of Idaho/Idaho Cattle Association employees above, 4 graduate students and 4 IDFG biologists (D. Musil, C. Henderson, Ian Riley, and S. Gennette) also worked on the project. Lynn Kinter and Jennifer Miller from IDFG provided field training on plant identification to all field personnel.

Electric Fencing

We deployed 13 separate electric fences (59.4 km of total fenceline) across 5 study sites in 2021 (Table 1). All permittees continued to give positive feedback regarding the effectiveness of the temporary electric fences and temporary cattle guard. In 2021, we had 2 instances of theft and vandalism of the electric fences that maintain the experimental treatments. The perpetrator was caught by IDFG Conservation Officers during the second occurrence, with most of our equipment being recovered. We hope it will put an end to the thefts we've experienced the previous two years of the study.

Table 1. Summary of electric fence deployment at 5 study sites for the Grouse & Grazing Project in southern Idaho from 2016 – 2021.

Year	# of Fences	Longest Fence (km)	Shortest Fence (km)	Total Length (km)
2016	5	5.3 (Brown's Creek East/West)	1.9 (Kane Springs - N/S Cottonwood)	17.2
2017	11	6.2 (Sunset North/South)	1.9 (Kane Springs - N/S Cottonwood)	43.5
2018	12	6.2 (Sunset North/South)	1.5 (Kane Springs North End)	45.9
2019	12	9.4 (River East/River West)	1.9 (Kane Springs/N & S Cottonwood)	54.6
2020	13	6.2 (Sunset North/South)	1.9 (Kane Springs/N & S Cottonwood)	52.4
2021	13	9.4 (River East/River West)	1.9 (Kane Springs/N & S Cottonwood)	59.4

Weather and Climate Monitoring

Precipitation and Temperature

Starting in 2021, we began to use PRISM to gather weather data from each site (PRISM Climate Group). PRISM is a program that interpolates weather for a precise area, which we believe will give us more accurate data than our previous method of selecting the closest weather station to the study pastures. Precipitation leading up to the 2021 breeding season (1 Oct – 1 Mar) decreased in comparison to 2020 at 3 study sites (13% at Sheep Creek, 26% at Jim Sage, and 59% at Big Butte). Meanwhile the Brown's Bench site experienced a 14% increase in overwinter precipitation and the Pahsimeroi Valley site experienced a 90% increase as compared to 2020. Idaho experienced a severe drought during 2021, which can also be seen in the precipitation data from all our field sites. All sites experienced rainfall well below the 30-year average during the 2021 growing season (1 Apr – 1 July) and a decrease in rainfall as compared to the 2020 growing season (82% at Big Butte, 51% at Brown's Bench, 71% at Jim Sage, 73% at Pahsimeroi Valley, 87% at Sheep Creek).

Temperatures at Big Butte and Brown's Bench were slightly lower leading up to and during the 2021 breeding season than in 2020, while the remaining 3 sites had lower temperatures during this period as compared to 2020 (Figure 3). Temperatures during the breeding season (1 Apr – 1 July) were similar in 2021 compared to 2020 at Pahsimeroi, while they were higher at the remaining 4 study sites. Overall, the temperature trend in 2021 was an average winter and spring leading up to the sage-grouse breeding season at most of our study sites and higher temperatures during the breeding season (Figures 2 & 3).

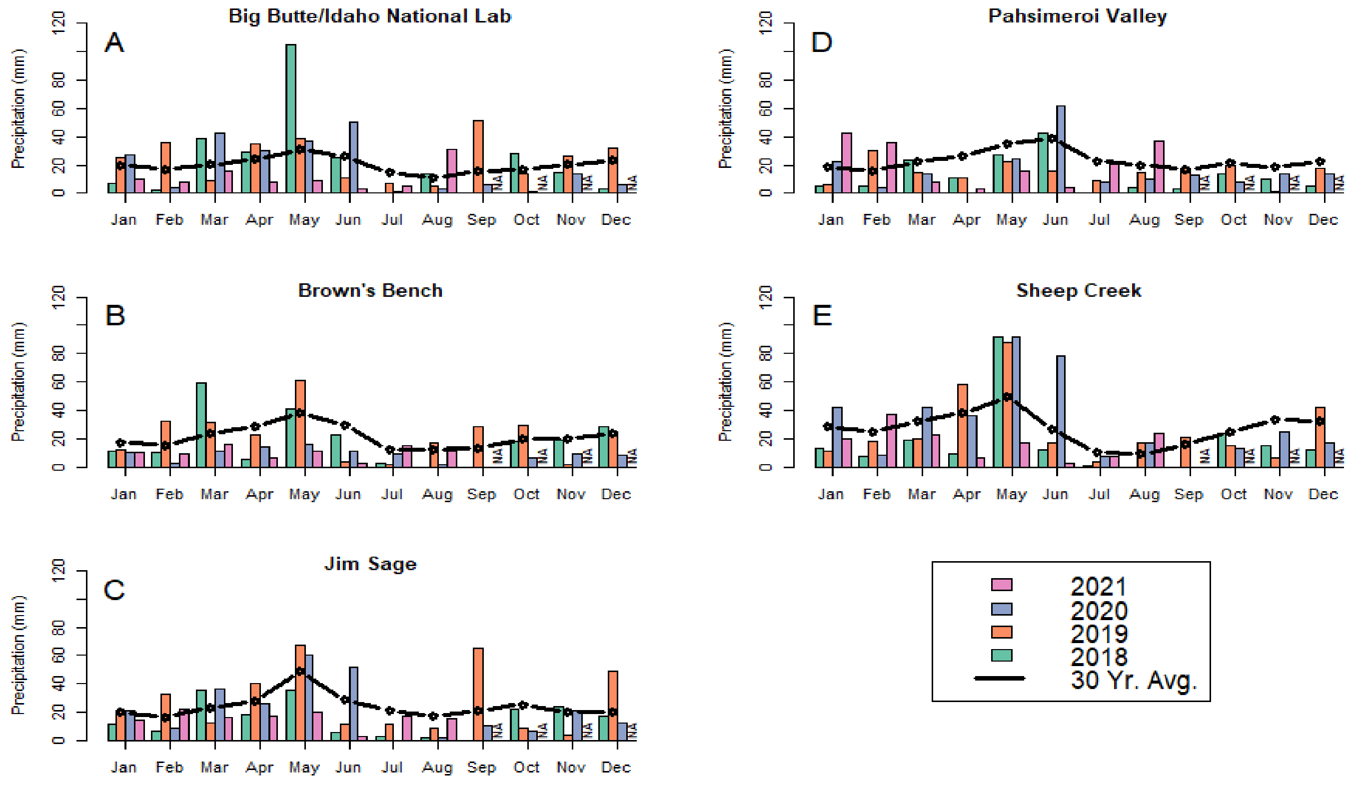

Figure 2. Precipitation (mm) by month for 5 study sites in southern Idaho from Jan 2018 – Sep 2021. Dark Lines in each plot represent 30-year average for comparison. NA denotes that weather data were not yet available for that particular month/year. From 2018-2020, precipitation data were recorded at the following weather stations: Big Butte/Idaho National Lab - Idaho Falls 46 W station (43.53160, -112.94220; NOAA), Brown's Bench - Jackpot, NV (41.9867, -114.674; NOAA), Jim Sage - City of Rocks (42.091, -113.631; RAWS) and Oakley (42.2341, -113.898; NOAA), Pahsimeroi Valley – Challis Airport (44.5228, -114.215; NOAA), and Sheep Creek - Pole Creek (42.069, -115.786; RAWS). In 2021, we started using PRISM to record and model weather data for more precise measurements.

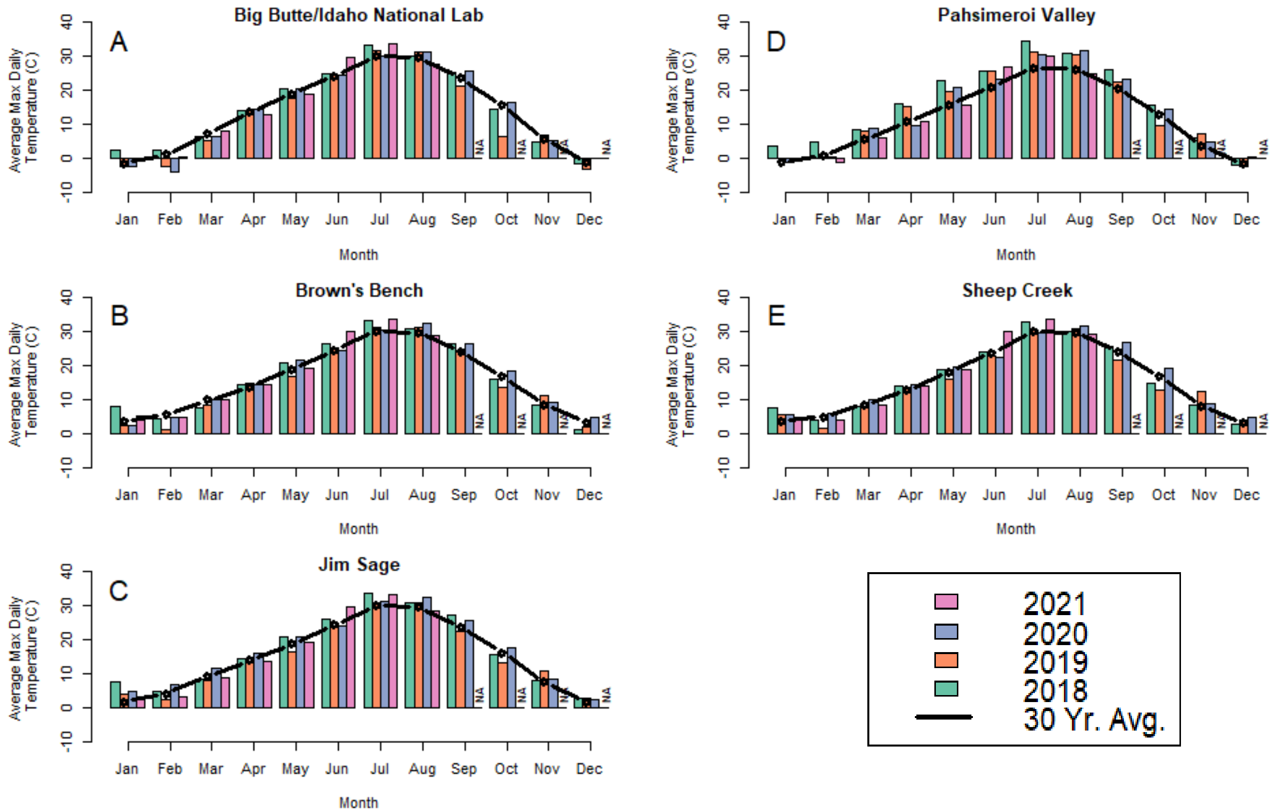

Figure 3. Average maximum daily temperature (°C) by month for 5 study sites in southern Idaho from Jan 2018 to Sep 2021. Dark Lines in each plot represent 30-year average for comparison. NA denotes that weather data were not yet available for that particular month/year. From 2018-2020, temperature data were recorded at the following weather stations: Big Butte/Idaho National Lab - Idaho Falls 46 W station (43.53160, -112.94220; NOAA), Brown's Bench - Jackpot, NV (41.9867, -114.674; NOAA), Jim Sage - City of Rocks (42.091, -113.631; RAWS) and Oakley (42.2341, -113.898; NOAA), Pahsimeroi Valley – Challis Airport (44.5228, -114.215; NOAA), and Sheep Creek - Pole Creek (42.069, -115.786; RAWS). In 2021, we started using PRISM to record and model weather data for more precise measurements.

Capture and Radio-marking

We deployed radio transmitters on 160 previously unmarked female sage-grouse across 5 study sites in spring 2021: 78 adults (49%), 81 yearlings (51%), and 1 unknown (Tables 3-4). In addition to the 160 new females captured in 2021, we also monitored 83 females whose transmitters were deployed in past years and had returned to the study sites in February 2021 (those with ≥5 detections; Table 2). Hence, we tracked 243 radio-marked hens in 2021.

Table 2. Number of radio-marked female sage-grouse that were initially caught prior to 2021 and were alive and monitored (≥5 detections) at the start of the 2021 field season at 5 study sites in southern Idaho.

	Year Initially Captured		
Study Site	2019	2020	Total Returning
Big Butte	2	14	16
Brown's Bench	2	11	13
Jim Sage	1	20	21
Pahsimeroi	7	15	22
Sheep Creek	2	9	11
TOTAL	14	69	83[a]

[a]No birds initially captured from 2014-2018 were present in 2021

Relative to 2020, the number of new females captured in 2021 (those that had not been marked before 2021) decreased slightly at 2 study sites (Big Butte, and Jim Sage), and increased at the remaining 3 study sites (Brown's Bench, Pahsimeroi Valley, and Sheep Creek). We did not capture any grouse at the Idaho National Laboratory Site in 2021; our access was rescinded soon after the 2020 season began due to COVID-19 restrictions.

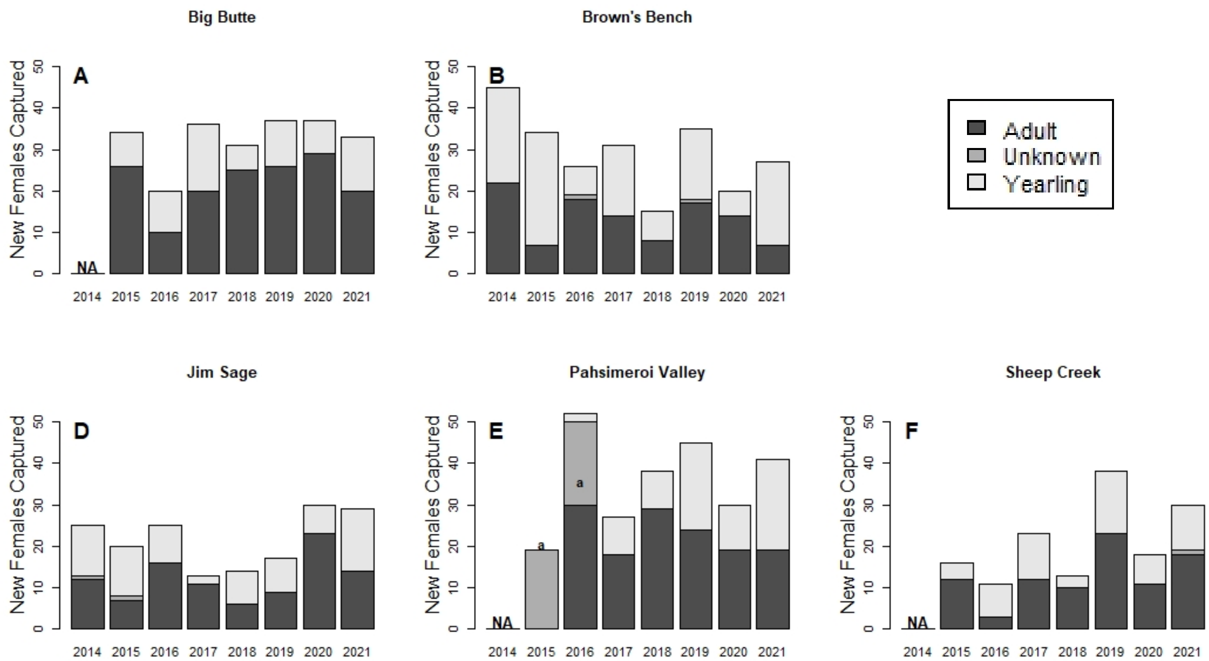

Figure 4. Number of new female sage-grouse captured (excludes any recaptures) at 5 study sites in southern Idaho from 2014-2021. 'NA' denotes that no capture activities occurred in that year. An 'a' indicates that trapping efforts were not conducted by the Grouse & Grazing Project field crews in that year.

Age Ratios

The Yearling-to-Adult ratios we observed this year were some of the highest that the project has encountered. Yearling-to-Adult age ratios at 4 of our 5 sites were higher in 2021 as compared to 2020 (Table 3). The proportion of yearlings was highest at Brown's Bench (3.00) and lowest at Sheep Creek (0.60). The high age ratios (i.e., many yearlings) in 2021 correspond with the high nesting and brooding success we observed in 2020 (Table 9 & Figure 9). Sheep Creek was our only site that had a lower yearling-to-adult ratio in 2021 relative to the overall ratio (across all years), and yearling ratios in 2021 were the highest among the 8 years of the study (Table 4).

Table 3. Number of yearling and adult female sage-grouse captured at 5 study sites across southern Idaho in 2021 and across all years of the study 2014-2021. The numbers in this table includes recaptures.

	Big Butte	Brown's Bench	Jim Sage	Pahsimeroi Valley	Sheep Creek	All Study Sites
2021						
#Yearling	20 (40%)	21 (75%)	17 (49%)	22 (51%)	12 (38%)	92 (49%)
#Adult	30 (60%)	7 (25%)	18 (51%)	21 (49%)	20 (63%)	96 (51%)
Yearling/ Adult Ratio	0.67	3.00	0.94	1.05	0.60	0.96
Entire Study (2014-2021)[a]						
#Yearling	80 (32%)	129 (49%)	85 (39%)	76 (33%)	60 (38%)	434 (38%)
#Adult	173 (68%)	135 (51%)	133 (61%)	151 (67%)	97 (62%)	696 (62%)
Yearling/ Adult Ratio	0.46	0.95	0.64	0.5	0.62	0.62

[a]*This total includes 4 yearlings and 7 adults that were captured at INL in 2019*

Table 4. Number of yearling and adult female sage-grouse captured by year across 5 study sites in southern Idaho 2014-2021. This table includes recaptures and excludes birds whose age was uncertain at capture.

	2014	2015	2016	2017	2018	2019[a]	2020	2021
#Yearling	40 (43%)	51 (47%)	38 (32%)	55 (42%)	33 (27%)	79 (41%)	39 (26%)	92 (49%)
#Adult	52 (57%)	57 (53%)	82 (68%)	76 (58%)	90 (73%)	116 (59%)	110 (74%)	96 (51%)
Yearling/Adult Ratio	0.77	0.89	0.46	0.72	0.37	0.68	0.35	0.96

[a]*This total includes 4 yearlings and 7 adults that were captured at INL*

Hen Survival and Mortality

Hen survival has varied among years and study sites. Hen survival was lowest in 2017 (Figure 5B), which had a very harsh winter preceding the grouse breeding season. Our sample size for this analysis was higher than in Table 2 (and the text above it) because we included all hens rather than just those hens that were tracked ≥5 times. Our sample size of hens increased slightly in 2021 and sage-grouse survival was similar across all sites (Figure 5A). Survival in 2021 was similar to sage-grouse survival observed the last few years of the study, but was lower compared to 2015 and 2016 (Figure 5B).

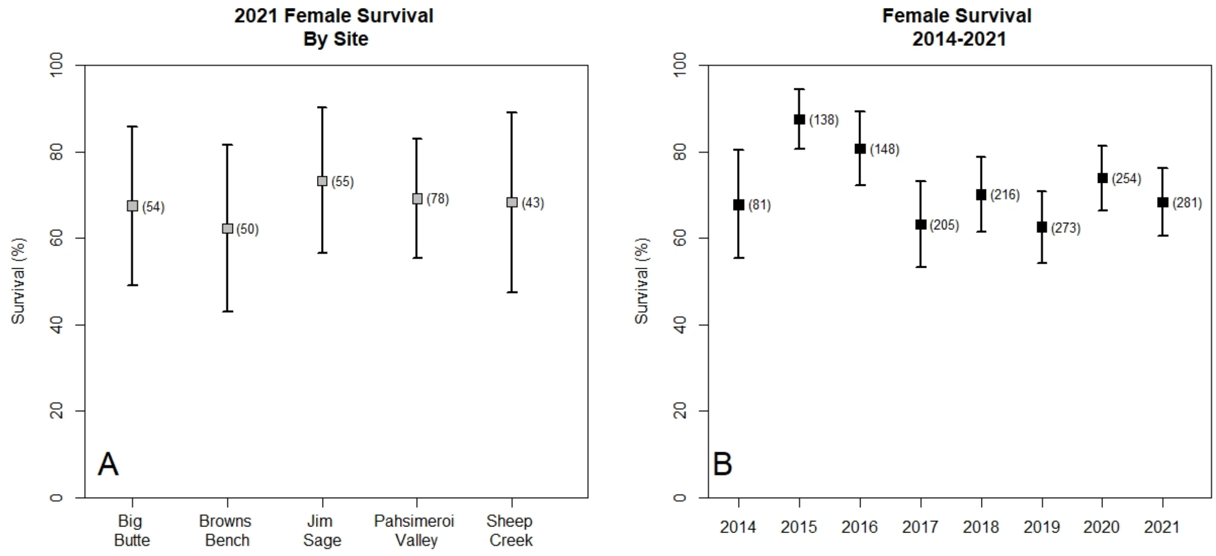

Figure 5. Survival estimates and 95% confidence intervals of female sage-grouse at 5 study sites in 2021 (A) and by year for all study sites pooled (B) during our field season (1 Mar – 15 Aug). Number to the right of each estimate represents the number of hens whose encounter histories contributed to the estimate (i.e., the sample size of hens).

We recovered 70 collars from apparent mortalities during the 2021 field season. Of these 70 mortalities, 14 (20%) occurred during the winter leading up to the 2021 breeding season (1 Oct 2020 – 29 Feb 2021), 55 (79%) occurred during the breeding season (1 Mar – 31 Jul), and 1 (1%) occurred as a result of the sage-grouse hunting season (18 Sept – 31 Oct). Timing and quantity of mortalities varied across years and study sites (Figure 6). Mortalities were most frequent during April and May each year (during nesting and the early stages of brood rearing); this was again the case in 2021, although we observed a high number of mortalities in March of 2021 as well (Figure 6G). In 2021, we recorded the most mortalities at Pahsimeroi (21; Figure 6G) and the least at Jim Sage (9; Figure 6G). One major difference that began in 2019 was the number of overwinter mortalities recovered. Since 2019, we've contracted flights to locate radio-marked hens in early Feb just prior to the arrival of field crews. This allowed us to recover mortalities of birds that had died far from the experimental pastures and would not have otherwise been recovered.

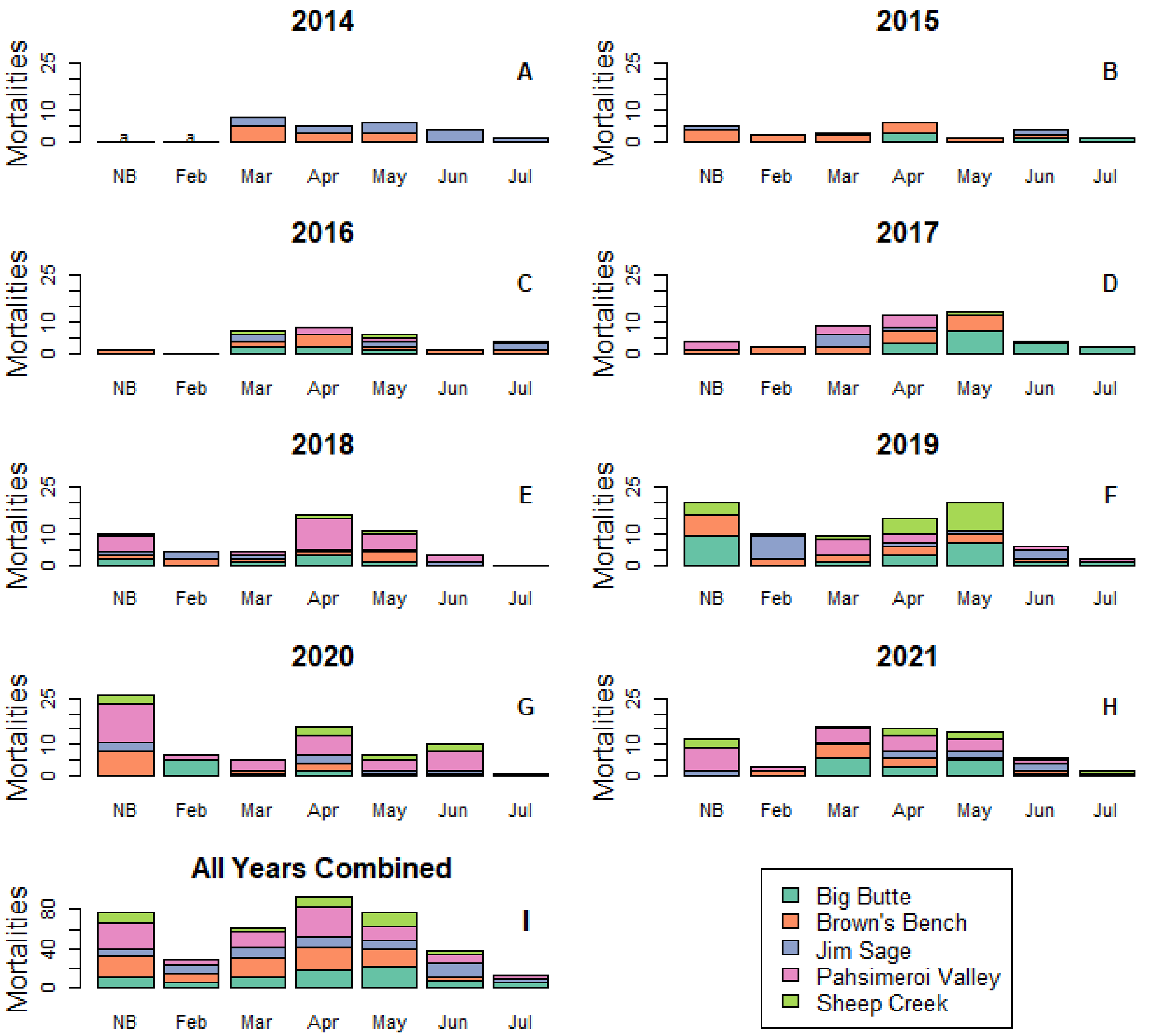

Figure 6. Mortalities of radio-marked female sage-grouse by month (and season) at 5 study sites across southern Idaho from 2014-2021. The value 'NB' on the x-axis represents the cumulative non-breeding months (Aug – Jan; these are also months that we do not monitor sage-grouse and cannot accurately identify the exact month of mortality). "a" denotes that no mortalities occurred in this period because capture work did not begin until Mar 2014. Field work was not started at Sheep Creek and Big Butte until 2015, at Pahsimeroi Valley until 2017.

A few of our marked grouse are legally harvested by hunters each year in the September sage-grouse hunting season. In 2018, there was a 7-day hunting season (15 – 21 Sep.) with a daily bag limit of 1 grouse. In 2019, the season was reduced to a 2-day season (21 – 22 Sep) north of the Snake River and a 7-day season south of the Snake River (21 – 27 Sep). This season structure continued in 2020, with the 2-day season occurring 15-17 Sep and the 7-day season occurring 15-22 Sep. In 2021 the length of the season was greatly expanded (18 Sept – 31 Oct0, but tags were required, and hunters were limited to one or two grouse the entire season-depending on the area. Since 2017, 11 grouse banded by the Grouse & Grazing Project have been harvested (6 radio-collared females and 5 banded males; Table 5).

Table 5. Number of marked sage-grouse from the Grouse & Grazing Project that were harvested by hunters in southern Idaho from 2017-2021. No hunter harvests were reported for 2014-2016.

	2017		2018		2019		2020		2021	
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
Brown's Bench	-	-	-	2	-	2	2	1	-	-
Big Butte	-	-	-	-	-	-	-	-	-	-
Jim Sage	1	-	-	-	1	-	-	-	-	-
Pahsimeroi Valley	-	-	-	-	-	-	-	-	1	-
Sheep Creek	-	-	-	1	-	-	-	-	-	-
All Sites (total)	**1**	**0**	**0**	**3**	**1**	**2**	**2**	**1**	**1**	**0**

Nest Searching and Monitoring

We located a total of 138 nests across 5 study sites in 2021 (including nests inside and outside of our experimental pastures; Figure 7). We were able to determine the fate for 137 nests: 59 hatched at least 1 egg (43%) and 78 were un-successful (57%). Of the 138 nests monitored in 2021, 129 were thought to be initial nesting attempts while only 9 were documented re-nesting attempts. Of the 138 nests, 62 (45%) were in our experimental pastures and 76 (55%) were outside of our experimental pastures (Figure 7).

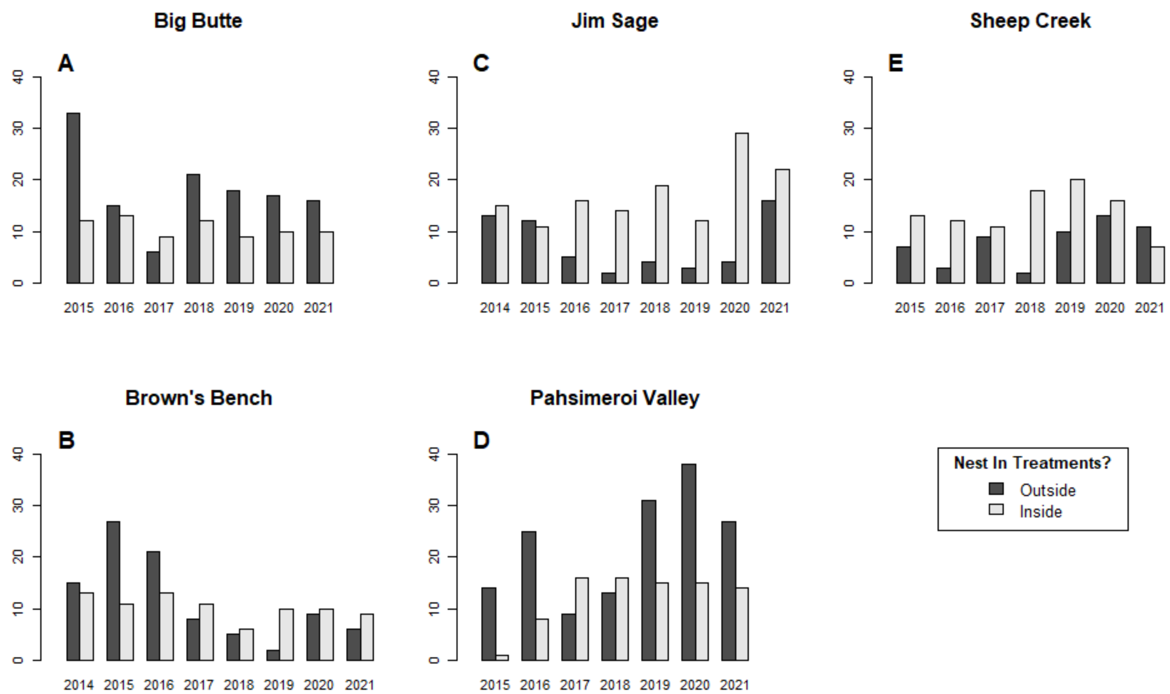

Figure 7. Number of sage-grouse nests inside and outside of experimental pastures at 5 study sites in southern Idaho, 2014-2021. Nests in 2015-2016 at Pahsimeroi Valley were collected by BLM personnel prior to the study.

Nesting Propensity

Overall nesting propensity in 2021 was 96.1% (*n* = 129) for method 1 (liberal) and 79.0% (*n* = 157) for method 2 (conservative); the 2 methods differed in the number of birds included in the denominator that were effectively tracked (Tables 6-7). Nesting propensity was lower during the first few years of the study relative to the subsequent 6 years (Table 7).

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 in 2021.

		Method 1[a]		Method 2[b]	
Study Site	Initiated Nests[c]	Birds Tracked	Nesting Propensity	Birds Tracked	Nesting Propensity
Big Butte	24	24	100.0	36	67.7
Brown's Bench	15	17	88.2	22	68.2
Jim Sage	35	35	100.0	37	94.6
Pahsimeroi Valley	33	36	91.6	41	80.5
Sheep Creek	17	17	96.4	21	81.0
Overall	124[d]	129	96.1	157	79.0

[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 $\geq$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 birds that initiated at least one nest
[d]5 incidental nests were found in 2021 and 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 8 years at 5 study sites (pooled) in southern Idaho, 2014- 2021.

		Method 1[a]		Method 2[b]	
Year	Initiated Nests[c]	Hens Tracked	Nesting Propensity	Hens Tracked	Nesting Propensity
2014	50	60	83.3	72	69.4
2015	110	119	92.4	134	82.1
2016	117	133	88.0	157	74.5
2017	81	87	93.1	111	73.0
2018	101	102	99.0	134	75.4
2019	123	128	96.1	149	82.6
2020	143	149	96.0	167	85.6
2021	124[d]	129	96.1	157	79.0
Overall	849	907	93.6	1,081	78.5

[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 $\geq$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 birds that initiated at least one nest.
[d]5 incidental nests were found in 2021 and are not included in this total

Re-nesting propensity has varied across years. In 2021, we observed very few re-nesting attempts as compared to previous years. Apparent nest success of re-nesting attempts has varied across years, from as low as 11.8% to this year's high of 66.7% (Table 8).

Table 8. Re-nesting propensity for female sage-grouse at all 5 study sites combined in southern Idaho, 2014-2021.

Year	Failed 1st Attempt	Re-Nested	Hatched	Re-nesting Propensity	Apparent Success of Re-nesting Attempts
2014	27	6	3	22.2	50.0
2015	67	12	7	17.9	58.3
2016	59	13	7	22.0	53.8
2017	55	14	3	25.5	21.4
2018	70	11	5	15.7	45.5
2019	85	10	3	11.8	30.0
2020	85	18	7	21.2	38.9
2021	70	9	6	12.8	66.7
Total	518	93	41	18.0	44.1

Nest Success

Apparent nest success was relatively high in 2021 at all study sites (except for Jim Sage) compared to previous years, with Big Butte experiencing the highest apparent nest success since the study began (Table 9). We also observed the highest total nest success across all sites since 2014. RMark estimates of the probability of nest success were lower than apparent nest success at all study sites (Table 10). RMark estimates for 2021 ranged from 17% (Sheep Creek) to 28% (Brown's Bench; Figure 8A). These estimates of nest success were the highest since 2015 (Figure 8B).

Table 9. Apparent nest success at 5 study sites across southern Idaho (2014-2021).

Study Site	Apparent Nest Success (%)								
	2014	2015	2016	2017	2018	2019	2020	2021	All Years
Big Butte	-[a]	36	29	36	27	26	48	58	37
Browns Bench	57	57	38	21	50	42	42	53	46
Jim Sage	28	43	33	23	32	20	45	34	34
Pahsimeroi	-[a]	-[a]	-[a]	28	26	33	32	38	33
Sheep Creek	-[a]	30	33	30	40	30	34	39	34
Total	43	44	32	27	32	31	39	43	37

[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 in 2021. Apparent nest success and nest success calculated using RMark for all study sites.

Study Site	Pasture Name	Failed	Hatched	Total	Apparent Nest Success	RMark Nest Success
Big Butte	Butte South	1	2	3		
	Serviceberry	1	3	4		
	Sunset North	0	1	1		
	Frenchman South	2	0	2		
	Other Pastures	7	9	16		
	Total	11	15	26	57.7	28.0
Brown's Bench	Browns Creek East	0	2	2		
	Corral Creek East	1	0	1		
	Indian Cave North	1	0	1		
	Indian Cave South	3	2	5		
	Other Pastures	3	3	6		
	Total	8	7	15	46.7	37.6
Jim Sage	Kane Springs (Line Canyon)	3	2	5		
	Sheep Mountain North	4	2	6		
	Sheep Mountain South	8	2	10		
	Other Pastures	9	7	16		
	Total	24	13	37	35.1	29.8
Pahsimeroi Valley	Goldburg NE - Big Gulch	3	2	5		
	Goldburg SE - Summit	2	0	2		
	Goldburg SW - Donkey Creek	4	0	4		
	River East	0	1	1		
	River West	1	0	1		
	West River Flat North	1	0	1		
	Other Pastures	16	11	27		
	Total	27	14	41	34.1	31.7
Sheep Creek	East Blackleg (North)	4	1	5		
	Slaughterhouse North	0	0	0		
	(North) Tokum-Bambi East	2	0	2		
	(North) Tokum-Bambi West	0	0	0		
	Other Pastures	5	6	11		
	Total	11	7	18	38.9	26.1
	2021 Overall Estimate	81	56	137	39.1	30.4

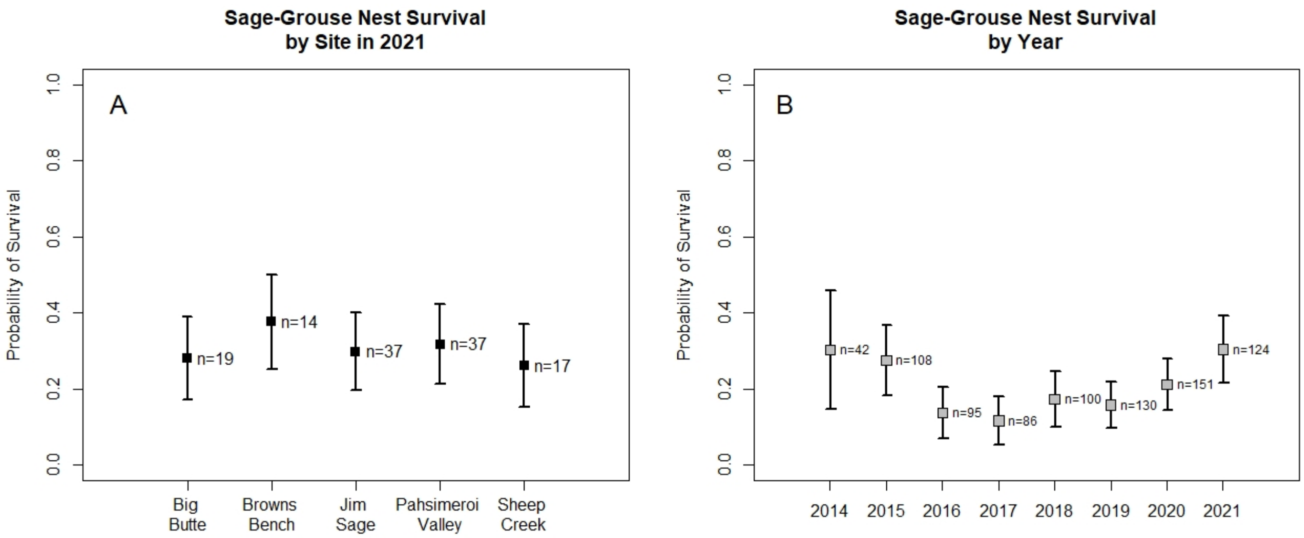

Figure 8. Probability of nest survival for each study site in 2021 (A) and for each year (combined across all study sites) of the study, 2014-2021 (B). All estimates were calculated using RMark. Estimates were extrapolated from daily nest survival to estimate the overall nest survival across the laying and incubation period (37 days). Bars represent 95% confidence intervals that were calculated using the delta method.

Critical Dates

Hatch Date

Mean hatch date in 2021 varied slightly among the 5 study sites: from 16-May (Sheep Creek) to 31-May (Pahsimeroi Valley; Table 11). Across all 5 study sites, mean hatch date was approximately the same as in 2020, and was similar to the 8-year average (Table 12).

Table 11. Mean clutch size and hatch date of hatched nests at 5 study sites across southern Idaho in 2021.

Study Site	Clutch Size			Hatch Date		
	Mean	SE	n	Mean	SE	n
Big Butte	6.6	0.388	15	26-May	2.5	15
Brown's Bench	6.8	0.526	8	21-May	2.9	8
Jim Sage	7.2	0.469	13	18-May	3.4	13
Pahsimeroi Valley	6.3	0.445	16	31-May	2.5	16
Sheep Creek	6.1	0.800	7	16-May	2.9	7
All Sites	6.6	0.219	59	24-May	1.5	59

Clutch Size

Mean clutch size at our 5 study sites ranged from 6.1 – 7.2 eggs per hatched nest in 2021 (Table 11). These represent minimum number of eggs at each hatched nest because they are based on the number of eggshells left at nest sites after hatch. The largest clutch we recorded was 10 eggs and the smallest was 3 eggs. Mean clutch size across all 5 study sites in 2021 was 6.6 eggs per hatched nest. The mean clutch size in 2021 was slightly higher than the 8-year average (Table 12).

Table 12. Mean clutch size and hatch date of hatched nests for each of the past 8 years (all study sites combined) across southern Idaho from 2014-2021.

Year	Clutch Size			Hatch Date		
	Mean	SE	*n*	Mean	SE	*n*
2014	7.0	0.330	23	22-May	2.7	20
2015	5.9	0.272	61	13-May	2.0	58
2016	6.4	0.273	42	23-May	2.3	41
2017	5.9	0.267	25	1-Jun	2.8	25
2018	6.4	0.237	36	27-May	1.9	36
2019	6.4	0.305	41	26-May	1.4	41
2020	6.6	0.235	63	24-May	1.6	63
2021	6.6	0.219	59	24-May	1.5	59
All Years	6.4	0.097	350	23-May	0.7	350

Brood Monitoring

In 2021, we tracked broods for 58 of the 59 hatched nests. One hen died the same day the nest hatched, so we were unable to conduct a brood survey for that hen. We conducted 341 brood surveys on these 58 broods: 149 visual surveys, 164 fecal surveys, and 38 spotlight surveys. We flushed the hen on 36 of 164 fecal surveys (22%), 2 of 28 (7%) spotlight surveys, and 132 of the 149 daytime visual surveys (89%). For daytime visual surveys, our protocol instructs observers to purposely flush the focal hen if a chick is not detected on the 1st visual survey.

Of the 59 hens who had a hatched nest, 18 had at least one chick survive to 42 days of age (Table 13). As in previous years, we calculated a more conservative and a less conservative estimate of brood success to account for our lack of certainty regarding the fate of 13 broods. These broods can be lost before 42 days post-hatch due to sudden long-distance movements by some hens (or signals that disappear entirely). Methods for estimating brood survival and the factors that affect brood survival were part of Ian Riley's graduate thesis (Riley 2019).

Table 13. Fate of sage-grouse broods at 5 study sites across southern Idaho in 2021.

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	15	4	6	5	33%	45%
Brown's Bench	8	3	2	3	38%	60%
Jim Sage	13	1	10	2	15%	17%
Pahsimeroi Valley	16	3	6	7	44%	54%
Sheep Creek	7	2	2	3	43%	60%
Overall	59	13	26	20	34%	43%

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

In 2021, we observed similar brood survival as we did during previous years of the study (Figure 9B). Brood survival was lowest at Jim Sage in 2021, which is consistent with observed brood survival across all years of the study (Figure 9A). Pahsimeroi Valley had the highest apparent brood survival of all sites in 2021.

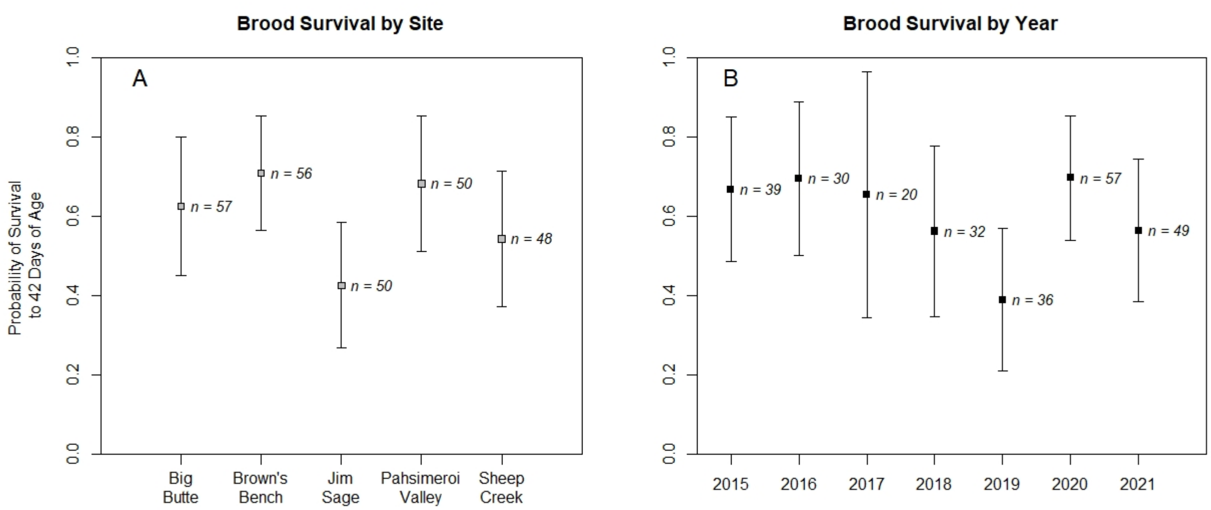

Figure 9. Probability of sage-grouse brood survival calculated using RMark from hatch to 42 days of age across all years (A) and by year (B) for 5 study sites across southern Idaho 2014-2021. Detection probability was held constant for each set of estimates and was 0.64 (SE=0.05).

Vegetation Sampling

In 2021, we measured vegetation metrics at 495 vegetation sampling plots (114 nest plots and 381 random plots) from 3 May – 2 July across 5 study sites (Table 14). We sampled grass height and grazing intensity metrics for 31,104 grass plants on the 495 vegetation sampling plots in 2021. We re-sampled 379 of the random plots again at the end of the growing season (21 July – 10 August). In 2021, we walked landscape appearance transects through all 19 experimental pastures to provide estimates of percent utilization (and the most common grass, the dominant shrub, and the percent cover of cheatgrass) at 3,103 sampling locations, and we used these data for pattern use mapping within the 19 experimental pastures. While conducting transects, we also measured height, species, and evidence of grazing for 8,143 individual grass plants at the 3,103 sampling locations. Summaries of these data are included in our site-specific grazing reports (see those reports here: https://idahogrousegrazing.wordpress.com/).

Table 14. Number of nesting and post-growing-season plots sampled each year and the earliest and latest date of completion of those plots at all 5 study sites, 2014-2021.

	Nesting Season						Post-Growing Season		
Year	Random Plots	Nest Plots	Dependent non-nest Plots	Total Plots	Earliest Survey	Latest Survey	Random Plots	Earliest Survey	Latest Survey
2014	39	54	54	147	20-May	2-Jul	0	-	-
2015	280	89	89	458	5-May	9-Jul	279	20-Jul	4-Aug
2016	367	97	61	525	17-Apr	5-Jul	346	18-Jul	18-Aug
2017	351	93	50	494	4-May	5-Jul	379	19-Jul	15-Aug
2018	385	102	0	487	7-May	3-Jul	360	19-Jul	10-Aug
2019	397	120	3	520	30-Apr	27-Jun	398	19-Jul	7-Aug
2020	399	144	0	547	4-May	3-Jul	375	21-Jul	10-Aug
2021	381	114	0	495	3-May	2-Jul	379	21-Jul	10-Aug
Totals	2,599	813	257	3,669	3-May	3-Jul	2,516	19-Jul	10-Aug

Arthropod Sampling

We conducted arthropod sampling at 119 sampling locations across 4 study sites in 2021: 40 plots at Brown's Bench, 30 plots at Big Butte, 29 plots at Jim Sage, and 20 plots at Sheep Creek (Table 15). Each of the 119 sampling locations had four pitfall traps which we emptied once per week. We deployed pitfall traps for 4 weeks at Brown's Bench, Jim Sage, and Sheep Creek and deployed pitfall traps for 3-4 weeks at Big Butte, yielding a total of 1,779 pitfall arthropod samples collected in 2021. For each visit, we also conducted 2 sweep-net transects per plot. These efforts yielded 838 sweep-net samples. Additionally, we conducted ant mound surveys at each arthropod sampling plot across each of the 4 study sites where we detected and measured the size of 159 ant mounds.

Table 15. Summary of arthropod sampling efforts at 5 study sites across southern Idaho, 2015-2021.

Year	Approx. Start Date	Approx. End Date	Study Sites Collected[a]	Total Plots	Pitfall Samples	Sweep-Net Samples	Ant Mounds Detected
2015	-[b]	-[b]	BIBU, BRBE, JISA, SHCR	59	-[b]	-[b]	106
2016	5-May	26-Jun	BIBU, BRBE, JISA, SHCR	120	3,556	1,958	354
2017	15-Jun	6-Jul	BIBU, BRBE, JISA, SHCR	92	1,100	-[c]	92
2018	31-May	30-Jun	BIBU, BRBE, JISA, PAVA, SHCR	178	2,540	1,728	309
2019[e]	23-May	13-Jun	BIBU, BRBE, JISA	129	1,960	1,105	264
2020	26-May	10-Jun	BRBE, JISA, SHCR	89	1,216	588	227
2021	19-May	3-Jun	BIBU, BRBE, JISA, SHCR	119	1,779	838	159
Overall	25-May	19-Jun	BIBU, BRBE[d], JISA[d], PAVA, SHCR	786	12,151	6,217	1,511

[a]BIBU = Big Butte, BRBE = Brown's Bench, JISA = Jim Sage, PAVA = Pahsimeroi Valley, SHCR = Sheep Creek,
[b]Part of David Gotsch's thesis research
[c]We did not have sufficient funding to collect sweep-net samples in 2017
[d]Data were collected at these study sites all 7 years in which we sampled arthropods
[e]Arthropod sampling also occurred at Idaho National Lab during this season

Utilization, Offtake, and Grazing Metrics

We generated estimates of utilization, grass height, and grazing pressure (stocking rate) in all 19 experimental treatment pastures in 2021. These metrics are summarized in our annual site-specific grazing reports (i.e., one grazing report for each study site). In general, utilization levels were higher than previous years at most study sites. Collecting these data will allow us to use utilization, grass height, and grazing pressure as covariates in subsequent analyses of sage-grouse demographic rates.

FINAL SUMMARY & GOALS

Overall, 2021 was a very successful field season. We captured 160 new hens this season, second only to our 2019 field season. Despite the drought that struck Idaho this breeding season, nest success and brooding success were similar to previous years. However, the drought across our study sites worsened as our field season progressed, which may have negative effects on sage-grouse demographics that we will not observe until 2022. The study continues to increase sample sizes that will provide more precise estimates of demographic traits and allow us to better achieve our goal of documenting the relationship between cattle grazing and sage-grouse habitat and vital rates.

Assessment of 2021 Goals

In 2021, we set forth the following goals to improve our data and better address our objectives. Assessments are shown in blue text.

1. Begin to produce products in the form of management-related publications. The following manuscripts were recently published or have been submitted:
    a. Hohbein, R. and C. J. Conway. 2018. Pitfall traps: a review of methods for estimating arthropod abundance. Wildlife Society Bulletin 42:597-606.
    b. 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.
    c. Riley, I. P. and C. J. Conway. 2020. Methods for estimating vital rates of greater sage-grouse broods: A review. Wildlife Biology 2020:wlb00700.
    d. 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.
    e. 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.

    And the following 4 graduate theses have been produced:

    a. Julson, J. 2017. Variation in perennial grass height within greater sage-grouse nesting habitat. M.S. Thesis, University of Idaho.
    b. Riley, I. 2019. Sampling methods for lek and brood counts of greater sage-grouse: accounting for imperfect detection. M.S. Thesis, University of Idaho.
    c. Laurence-Traynor, A.C.E. 2020. Evaluating field-based grazing intensity measurements for adaptive rangeland monitoring. M.S. Thesis, University of Idaho.
    d. 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.

2. Recruit another excellent field crew with as many returning members as possible.
    a. We had an excellent field crew this year that worked hard and accomplished everything we set out to do. The 2021 crew included 6 returnees from the 2020 field crew.

3. Secure full funding for the final years of the project so that we can focus more effort on the objectives above.
    a. We received full-funding for the project.

ACKNOWLEDGMENTS

We would like to thank the following returning technicians and crew leaders who joined us again in the 2021 field season and helped make our trapping and monitoring efforts an overwhelming success: Ian Riley, Kylie Denny, Reese Wray, Eric Juers, Tracy Melville, Seth Rifkin, Heather Zimba, and Sam Siller. The following new crew leaders and technicians provided invaluable data and we hope to have some of them return for 2022: Sky Gennette, Lane Justus, Mikel Newberg, Peter Hasik, Odin Bernardo, Taylor Pichler, Ashley Niece, Natasha Nemmers, Ian Scott, Marina McCreary, Nathan Joakim, Jeremy Fuller, Tim Andrews, Josh Jaeger, Erin Stewart, Walker Field, Matt Desko, Ties Thompson, Bridger Giglio, Alex Barton, Kaitlyn Cooper, Jacquelynn Tran, Kyle Yorke, and Evan Priebe. Thanks also to the countless agency (BLM, IDFG, and University of Idaho) personnel that helped provide training and logistical support to field crews!

The following organizations have provided funding to support the Grouse & Grazing Project: Bureau of Land Management, Idaho Department of Fish and Game, U.S. Fish & Wildlife Service, Western Association of Fish and Wildlife Agencies, Great Basin Landscape Conservation Cooperative, Public Lands Council, Idaho Cattle Foundation, Idaho Governor's Office of Species Conservation, and University of Idaho. The Natural Resource Conservation Service (NRCS) funded an affiliated project that provided funds for the cattle GPS collars and efforts to estimate utilization via remote sensing images. The Idaho Cattle Association and the University of Idaho provided administrative support. We would like to especially thank the district BLM offices that manage the grazing allotments where we conducted field work for all the help they provided in logistics and plant identification training. Finally, this project would not be possible without the support from the numerous ranchers who donated time and made considerable concessions to allow the randomized experiments to occur on their allotments and to allow our experimental design to dictate where and when they graze their cattle in different pastures. Thank you!

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APPENDIX I. PRODUCTS FROM THE GROUSE & GRAZING PROJECT THUS FAR.

CONFERENCE CALLS

- 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://idahogrousegrazing.wordpress.com/

PROJECT PROSPECTUS

2-page summary of project

ANNUAL REPORTS

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

Conway, C. J., C. Tisdale, K. Launchbaugh, A. Meyers, D. Musil, P. Makela, and S. Roberts. 2020. The Grouse & Grazing Project: Effects of cattle grazing on sage-grouse demographic traits – 2020 Annual Report. College of Natural Resources, University of Idaho.

Conway, C. J., A. Meyers, K. Launchbaugh, D. Musil, P. Makela, and S. Roberts. 2019. The Grouse & Grazing Project: Effects of cattle grazing on sage-grouse demographic traits – 2019 Annual Report. College of Natural Resources, University of Idaho.

Conway, C. J., A. Meyers, K. Launchbaugh, D. Musil, P. Makela, and S. Roberts. 2018. The Grouse & Grazing Project: Effects of cattle grazing on sage-grouse demographic traits – 2018 Annual Report. College of Natural Resources, University of Idaho.

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

Conway, C. J., K. Launchbaugh, D. Musil, S. Roberts, P. Makela, A. Locatelli, and A.R. Meyers. 2016. Grouse & Grazing: 2016 Annual Report. Idaho Cooperative Fish & Wildlife Research Unit, Moscow, ID.

Locatelli, A., C. J. Conway, K. 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.

MEDIA OUTREACH

1. Tiernan, C., Massive Idaho study hopes to explain impact of livestock on imperiled sage grouse. Times-News. 18 April 2021.

2. Conway, C.J. 2019. Grouse & Grazing Projects: information for land managers and ranchers. Video interview for Idaho Range Livestock Symposium. University of Idaho Extension Program.

MEETINGS WITH RANCHERS and SCHOOL GROUPS

1. Meyers, A. R., and E. Juers. Sage-grouse in schools program. Arco school. 24 April 2019.

2. Meeting with BLM, USFS, ranchers. Challis, ID. 26 Nov 2018.

GRAD STUDENTS ON PROJECT

1. David Gotsch, M.S. Student, Wildlife Sciences, University of Idaho, Thesis Title: *Effects of cattle grazing on abundance of arthropod prey of the greater sage-grouse*. Jan 2014-(medical leave of absence).

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, Ph.D. student, Wildlife Sciences, University of Idaho, Dissertation Title: *Ontogenetic shifts in diet of sage-grouse chicks based on DNA metabarcoding*. May 2018-present.

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 cattle grazing on sage-grouse nest predators*. Aug 2019-present.

8. Grace Overlie, Entomology, University of Idaho, Thesis Title: *Effects of cattle grazing on arthropod biomass*. Aug 2021-present.

9. J.B. Playfair, Rangeland Sciences, University of Idaho, Thesis Title: *Effects of cattle grazing on fuel biomass and fire*. Aug 2021-present.

PUBLICATIONS

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. Conway, C.J., et al. Habitat guidelines for sage-grouse. *Journal of Wildlife Management* (estimated submission date: 31 December 2021).

COMPLETED THESES

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

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. Launchbaugh, K., 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.

2. 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.

3. Conway, C. J., K. Launchbaugh, D. Musil, P. Makela, S. Roberts, A. Meyers, 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.

4. 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.

5. Launchbaugh, K., 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.

6. 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.

7. 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.

8. 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.

9. 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.

10. 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.

11. Conway, C.J., K. 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.

12. Conway, C.J. A. Meyers, D. Musil, P. Makela, S. Roberts, and K. 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.

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

14. Musil, D., Conway, C. J. A. Meyers, P. Makela, S. Roberts, and K. 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.

15. 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.

16. 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.

17. 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.

18. 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.

19. 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.

20. 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.

21. 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.

22. 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.

23. 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.

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

25. 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.

26. Meyers, A.R., C.J. Conway, D.D. Musil, K. 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.

27. 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.

28. Musil, D., C. J. Conway, K. 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.

29. Conway, C. J., K. 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.

30. Conway, C. J., K. 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.

31. Conway, C.J., K. 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.

32. Conway, C. J., K. 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.

33. 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.

34. Conway, C. J., K. 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.

35. Julson, J., K. 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 Annual Conference. St. George, UT. 29 Jan 2017.

36. Julson, J., K. 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.

37. 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.

38. 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.

39. Conway, C. J., K. 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.

40. Conway, C. J., K. 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.

41. 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.

42. Conway, C. J., A. Locatelli, D. Musil, S. Roberts, K. 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.

43. Conway, C. J., K. 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. Annual Meeting of the Idaho Chapter of The Wildlife Society, Coeur d' Alene, ID. 23 Feb 2016.

44. Locatelli, A., C. J. Conway, D. Musil, K. 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.

45. Conway, C. J., K. 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.

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

47. 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.

48. Conway, C. J., J. W. Connelly, K. 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.

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

50. 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.

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

52. Connelly, J.W., C. J. Conway, D. Kemner, K. 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