# Grouse and Grazing 2015 Report

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## INTRODUCTION

The distribution of the greater sage-grouse (hereafter sage-grouse; *Centrocercus urophasianus*) has declined to 56% of its pre-settlement distribution (Schroeder et al. 2004) and abundance of males attending leks has decreased substantially over the past 50 years throughout the species' range (Garton et al. 2011, Garton et al. 2015). Livestock grazing is a common land use in the sagebrush ecosystems that support sage-grouse, and livestock grazing has been implicated by some experts as one of numerous factors contributing to sage-grouse population declines (Beck and Mitchell 2000, Schroeder et al. 2004). However, there are also numerous mechanisms by which livestock grazing might benefit sage-grouse (Beck and Mitchell 2000, Crawford et al. 2004). Federal and state agencies often attempt to limit grazing levels on public lands so that livestock grazing has minimal effects on populations of plants and animals, but we lack scientific studies that have explicitly examined the effects of livestock grazing on sage-grouse.

The objective of the Grouse & Grazing study is to document the effects of spring cattle grazing on sage-grouse demographic traits, nest-site selection, and habitat features. We focus on spring cattle grazing because spring is considered the time when livestock grazing is most likely to adversely affect sage-grouse.

## STUDY AREA

We conducted our research in 2014 and 2015 in Owyhee, Twin Falls, Cassia, and Butte counties, Idaho (Fig. 1). Our study sites are located in Sage-grouse Management Zone IV: The Snake River Plain (Knick 2011). Elevations at study sites range from 1400 m to 1900 m. Wyoming sagebrush (*Artemisia tridentata wyomingensis*) is common in the overstory at all sites. Other overstory shrub species include low sagebrush (*Artemisia arbuscula*), three-tip sagebrush (*Artemisia tripartita*), and green rabbitbrush (*Chrysothamnus viscidiflorus*). Major understory grasses include blue bunch wheatgrass (*Pseudoroegneria spicata*), sandberg bluegrass (*Poa secunda*), squirreltail (*Elymus elymoides*), crested wheatgrass (*Agropyron cristatum*), Indian ricegrass (*Achnatherum hymenoides*), Thurber's needlegrass (*Achnatherum thurberianum*), and cheatgrass (*Bromus tectorum*).

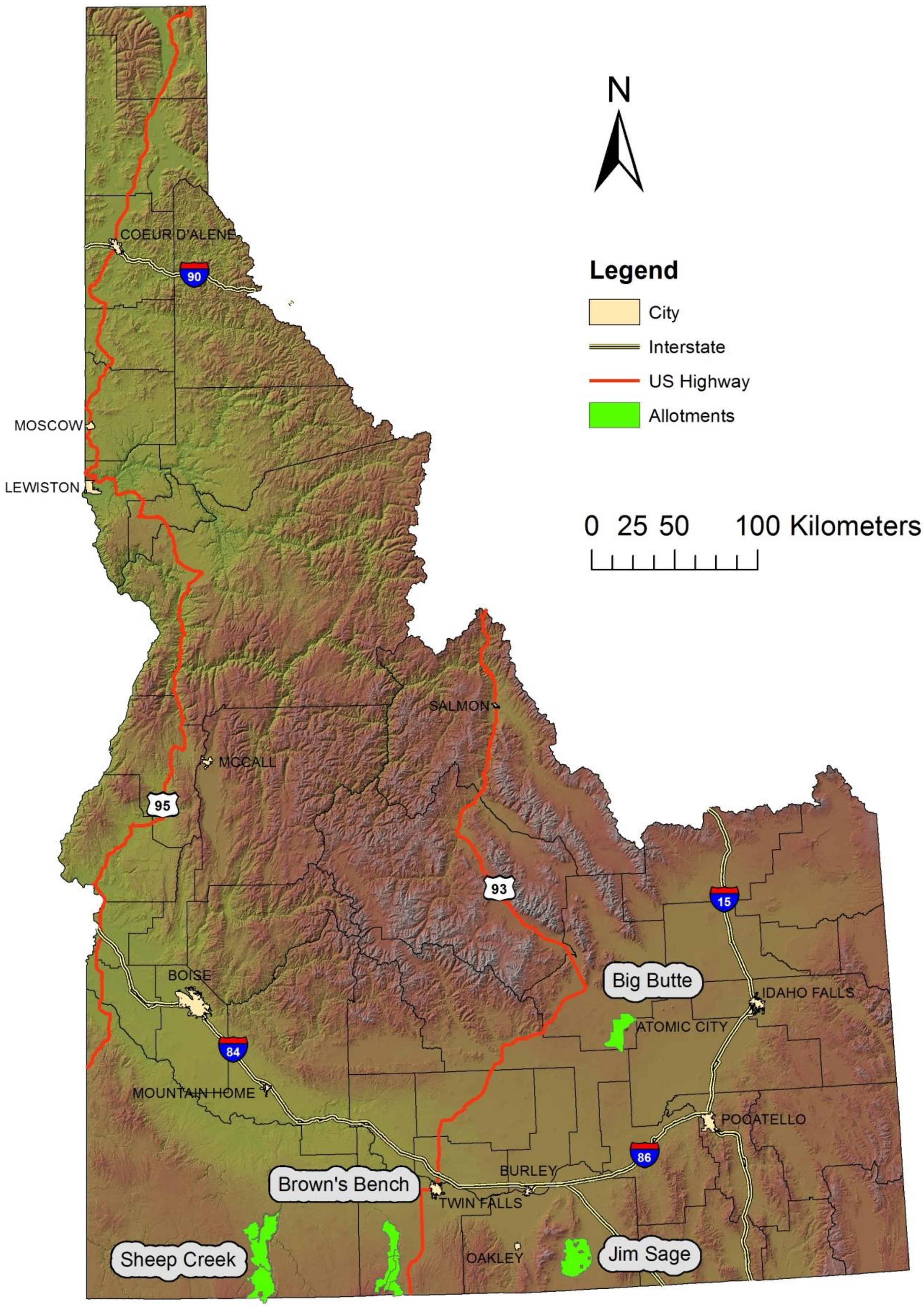


Figure 1. Four study sites in southern Idaho where we conducted field work in 2014 and 2015.

METHODS

**Experimental Design**

We began field work at 2 study sites in 2014 (Browns Bench, Jim Sage) and began work at 2 more sites in 2015 (Big Butte, Sheep Creek). These are the first 4 of an eventual 9 study sites in southern Idaho. Each study site was selected based on the following characteristics:

1. ≥15% sagebrush cover, including a *Artemisia tridentata wyomingensis* component in the overstory
2. Herbaceous understory that is dominated by native grasses and forbs
3. At least one sage-grouse lek of ≥ 25 males
4. Adequate road access in spring
5. Cooperative permittees
6. ≤ 38 cm of annual precipitation
7. ≥5,700 acres largely free of infrastructure development (i.e., few wind turbines, powerlines)
8. Spring turn out dates

We will apply a Before-After-Control-Impact (BACI) design to evaluate the effects of spring cattle grazing on sage-grouse demographic traits and habitat characteristics. We plan to gather data at each study site for a minimum of six years (≥2 years before experimental changes in grazing intensity and ≥4 years after changes in grazing intensity). We will employ a 'staggered entry' design so that experimental changes in grazing intensity will not be initiated at all study sites in the same year. Precipitation can have large effects on biomass of grasses and forbs and on sage-grouse demographic traits (Moynahan et al. 2006, Hovick et al. 2015, Skinner et al. 2002, La Pierre et al. 2011) and the staggered entry design will help us differentiate effects caused by changes in grazing intensity from those caused by annual variation in weather.

We have completed the second year of this 10-year study. At each study site, we gather baseline data (e.g., nest locations) for two years prior to experimental changes in grazing intensity (Fig. 2). These first two years of data allow us to delineate experimental grazing pastures in negotiation with permittees and BLM managers. In the spring of the third year, we will alter the grazing regime in 3 pastures and begin grazing according to one of three grazing treatments: 1) spring-only grazed in even years, 2) spring-only grazed in odd years, 3) no grazing (Fig. 2). All 3 of these treatments will not be grazed during summer, fall or winter. We will include a 4$^{th}$ experimental treatment (alternating years of spring grazed and fall grazed) at study sites whenever possible. We define spring grazing as 1 March through 15 June and fall grazing as 1 September through 15 December.

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

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



**Capture and Radio-collaring**

We used a spotlighting technique to capture female sage-grouse at night in February and March (Wakkinen et al. 1992) and used plumage characteristics to assign captured sage-grouse to one of two age classes: yearling and adult (Braun and Schroeder 2015). We attached a necklace-type radiotransmitter (23.7 - 25.2 g, including all components; Advanced Telemetry Systems, Isanti, MN) to female sage-grouse.

**Nest Searching and Monitoring**

We used telemetry to locate radio-collared sage-grouse hens every 2-3 days unless logistically infeasible (e.g., weather events). We monitored hens that migrated to the periphery of the study sites less frequently (~ once per week depending on accessibility). Once a female became localized (consistent location for 3 consecutive visits), we approached cautiously to confirm if she was nesting. We used telemetry equipment to identify potential nest shrubs and confirmed a nest if we obtained a visual via binoculars. If we could not obtain a visual, we identified a cluster of shrubs aided by telemetry, as the approximate location of the nest to avoid disturbing a nesting hen. If the hen was found in the same location subsequently, we assumed it was nesting at that approximate location. To monitor nests, we established a monitoring point from which we listened for the telemetry signal of the radio-collared hen every 2-3 days. If the hen was located at a consistent bearing from the monitoring point, we assumed she was incubating. If the bearing indicated the hen was not located on the nest, we inspected the nest location. We determined the fate of the nest (hatched or failed) based on the condition/presence of egg shells. We estimated minimum clutch size by searching the nest and surrounding area for egg shells and estimated the number of eggs based on the egg shell fragments.

**Critical Dates**

*Hatch Date* - For hatched nests, we estimated the hatch date by calculating the midpoint between the date the hen was first observed off the nest and the last date the hen was observed on the nest. We estimated to the nearest half day. We further refined the estimated hatch date if we had additional information (e.g., egg shells were still wet when we inspected the nest, etc.) that suggested the hatch day was something other than the midpoint. For failed nests, we determined the range of possible projected hatch dates based on the number of days we observed the nest. We used the midpoint of this range to estimate the projected hatch date (i.e., had the nest not failed). If we observed a failed nest for more than 27 days, we estimated the projected hatch date by adding 0.5 days to the estimated fail date.

*Date of Onset of Full Incubation* – The incubation period for sage-grouse averages 27 days (range 25-29 days; Schroeder 1997, Schroeder et al. 1999). For hatched nests, we subtracted 27 days (median of reported incubation period) from the estimated hatch date to estimate the date of onset of full incubation. If the estimate of the date of onset of full incubation was later than the date we first confirmed the nest, we assumed we had found the nest while the hen was laying because sage-grouse are known to sit on nests during the laying period (Schroeder 1997). If we had information on nest contents during laying (e.g., the hen was accidentally flushed, the hen was off nest during nest check and observer inspected nest, etc.), we estimated the date of onset of full incubation to be consistent with those data. For failed nests, we determined the range of possible dates of onset of full incubation based on the number of days we observed the nest and we used the midpoint of this range to estimate the date of onset of full incubation.

*First Egg Date* - Greater sage-grouse lay 1 egg every 1.5 days (Schroeder et al. 1999) and average clutch size is approximately 7 eggs in Idaho (Connelly et al. 2011, Schroeder et al. 1999, Wakkinen 1990). Therefore, we estimated the first egg date by subtracting 1.5 times 7 (the average clutch size) from the estimated incubation initiation date. If we observed greater than 7 eggs in the nest, we used the number of eggs observed in our calculation for that individual nest. We did not adjust our calculation if we observed fewer than 7 eggs in the nest because our estimate of minimum clutch size was based on egg shell fragments after the nest was no longer active.

**Brood Monitoring**

*Brood Flush Count Surveys* – For nests that hatched, we conducted flush count surveys to document brood survival at three time intervals: 14, 28, and 42 days after the estimated hatch date. We varied from this timeframe when we were unable to locate a hen because of long distance movement or because of logistical reasons (e.g. weather). We conducted these brood flush count surveys >2 hours after sunrise and >2 hours before sunset so as not to disturb broods while foraging during the critical early morning and late evening hours. We did not conduct flush counts in inclement weather. On each flush count survey, we approached the radio-collared sage-grouse hen by homing with telemetry equipment and attempted to flush the hen and chicks. We counted the number of chicks that flushed and searched the surrounding 15 m from the approximate location the hen flushed for chicks that did not flush.

*Brood Spotlight Surveys* – We also conducted brood spotlight surveys as an additional approach for estimating brood survival at 42 days (i.e., to ensure that flush count surveys were accurate). We conducted brood spotlight surveys >1 hour after sunset and >1 hour before sunrise to ensure complete darkness. We conducted spotlight surveys 42 days after hatch, randomly choosing which we conducted first: the 42-day brood spotlight survey or the 42-day brood flush count survey. The 42-day brood surveys for the same hen (flush count survey and spotlight survey) were conducted > 6 hours apart. We varied from the 42-day timeframe when we were unable to locate a hen because of long distance movement or because of logistical reasons (e.g. weather). We used telemetry equipment to get ~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.

**Vegetation Sampling**

We measured vegetation at three types of plots: nest plots, dependent random plots, and independent random plots. Nest plots were centered on sage-grouse nests. Each dependent random plot was associated with an individual nest and was centered on a randomly selected sagebrush shrub 100-200 m from the nest. Independent random plots were also centered on sagebrush shrubs and randomly located within experimental grazing pastures or potential experimental grazing pastures.

*Concealment* – We placed a ~4187 $cm^3$ pink ball in sage grouse nest bowls or in the most concealed location in a focal shrub (for random plots). We took photos of the ball from 3 m away in the four cardinal directions and with the camera 1 m from the ground. We will use ENVI 5.3 (Exelis Visual Information Solutions 2015) to estimate the percent of the ball (and hence the nest area) concealed by vegetation. We will average the 4 estimates to obtain a concealment value. We could not report results from the concealment measures for this report because the data is currently being processed.

*Nest Shrub Patch* – A nest shrub patch consisted of a single shrub or multiple shrubs with an intertwined and continuous canopy. We identified the shrub species, measured the height, measured the maximum length, and measured the maximum width (measured perpendicularly to the maximum length).

*Shrub Cover* – We used the line intercept method to measure shrub cover (Stiver et al. 2015). We used two 30-m transects that intersected at the nest or focal shrub (for random plots). One transect was oriented from north to south and the other transect was oriented from east to west.

*Grass Height* – We collected perennial grass data along two 30-m transects (one oriented north-south, one oriented east-west) that intersected at the nest or focal shrub. Every 2 m along the transects and within 1 m of each respective meter mark, we identified the nearest individual perennial grass of up to 3 species. For each individual perennial grass, we measured 5 traits: maximum droop height, the maximum height sans flower stalk, the effective height (Musil 2011), we noted if the grass was under a shrub canopy, and we took an ocular estimate (Coulloudon et al. 1999) of percent removed by herbivores by weight.

*Daubenmire Canopy Cover* – We collected Daubenmire canopy cover (Daubenmire 1959) data along two 30-m transects (one oriented north-south, one oriented east-west) that intersected at the nest or focal shrub. We placed a 50 cm x 20 cm frame along the transects at every 3rd meter mark for a total of 20 Daubenmire frames per plot. We modified the traditional Daubenmire method by estimating percent cover to the nearest 5%. We averaged the percent cover readings from the 20 frames to estimate percent cover for each plant species, forb group, or other cover class (Table 1) to estimate percent cover for the plot.

*Herbivore Droppings* – We searched within 5 m of two 30-m transects (one oriented north-south, one oriented east-west) that interested at the nest or focal shrub. We counted the number of current year cattle bowel movements (new cattle droppings) and the number of past year cattle bowel movements (old cattle droppings). We also recorded the presence or absence of elk, rabbit, and mule deer/pronghorn antelope droppings (considered as a group because of difficulty distinguishing mule deer from pronghorn antelope droppings).

Table 1. Cover class definitions for cover classes estimated using Daubenmire canopy cover method.

| Cover Class | Common Name | Genera or description |
|---|---|---|
| COMP | Composites | Other than daisies & dandelions including *Malacothrix, Sonchus, Stephanomeria, Artemesia, Balsamorhiza, Chaenactis, Helianthella, Iva, Lygodesmia, Solidago, Townsendia, Chaenactis, Lygodesmia, Senecio, Wythia* |
| DAIS | Daisies | *Aster, Erigeron (non-milky sap)* |
| TARAX | Dandelion, Common | *Taraxacum officinale* |
| AGOS | Dandelion, Prairie | *Agoseris, Microseris* |
| CREP | Hawksbeard | *Crepis* |
| LACT | Prickly lettuce | *Lactuca serriola* |
| ANT | Pussytoes | *Antennaria* |
| TRAG | Salsify | *Tragopogon* |
| ACH | Yarrow | *Achillea* |
| LEGU | Legumes | other than Lupine including *Dalea, Lathyrus, Vicia* |
| CLOV | Alfalfa, Clovers, & Vetches | *Medicago, Melilotus, Trifolium, Hedysarum* |
| TREF | Bird's-foot trefoil | *Lotus* |
| ASTRAG | Milkvetch | *Astragalus* |
| LOMAT | Desertparsley | *Lomatium, Cymopterus, Perideridia* |
| PENS | Penstemons | *Penstemon* |
| CAST | Indian Paintbrush | *Castilleja* |
| ERIO | Knotweed, Buckwheats | *Polygonum, Eriogonum, Rumex* |
| FLAX | Blue Flax | *Linum* |
| PHLOX | Phlox | *Gilia, Linanthus, Microsteris, Phlox* |
| LILY | Lily | *Calochortus, Fritillaria* |
| LITHO | Woodland-star | *Lithophragma* |
| OPF | Other Preferred Forbs | Listed as Preferred in Stiver et al. (2015), but not in group above |
| OTHER | Other Forb | Not listed as Preferred in Stiver et al. (2015) and not in group above |
| Litter | Litter | dead vegetation from previous year's growth including wood, masticated juniper chips, dung, leaves, and twigs |
| Rock | Rock | rocks (> 0.5 cm in diameter) or bedrock |
| Bare | Bare ground | Bare ground and gravel (small rocks < 0.5 cm in diameter) |
| BSC | Biological Soil Crust | includes mosses and lichens |
| AGCR | Crested Wheatgrass | *Agropyron cristatum* |
| BRTE | Cheatgrass | *Bromus tectorum* |
| ELEL5 | Squirreltail | *Elymus elymoides* |
| FEID | Idaho Fescue | *Festuca idahoensis* |
| POSE | Sandberg Bluegrass | *Poa secunda* |
| PSSP6 | Blue Bunch Wheatgrass | *Pseudoroegneria spicata* |
| STIPA | Needlegrasses | Includes *Achnatherum hymenoides*, *Achnatherum thurberianum, Hesperostipa comata,* and other needlegrasses |
| KOMA | Prairie Junegrass | *Koeleria macrantha* |

**Utilization**

*Ocular Estimate Method* – We resampled independent random plots from 20 July 2015 to 4 August 2015. We collected perennial grass data along two 30-m transects (one oriented north-south, one oriented east-west) that intersected at a focal shrub. Every 2 m along the transects and within 1 m of each respective meter mark, we identified the nearest individual perennial grasses of up to 3 species. For each individual perennial grass, we measured 5 traits: the maximum droop height, the maximum height sans flower stalk, the effective height (Musil 2011), whether the grass was under a shrub canopy, and an ocular estimate (Coulloudon et al. 1999) of percent of the above-ground biomass removed by herbivores by weight.

*Landscape Appearance Method* – We used the landscape appearance method (Coulloudon et al. 1999) to estimate utilization in experimental pastures and potential experimental pastures. We used ArcGIS to randomly place a grid of north-south transects in experimental pastures and potential experimental pastures spacing them 500 m apart. We placed sampling points 100 m apart along the transects. At each sampling point, an observer estimated utilization according to the utilization classes in Coullouden et al. (1999; Table 2). We assigned each point the midpoint of the utilization class range. We averaged these values to estimate utilization by pasture.

Table 2. Utilization classes used to estimate utilization taken from Coullouden 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 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. 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. |

## Insect Sampling

We sampled insects at a subset of independent random points.

*Ant Mound Surveys* - We used distance sampling to survey ant mounds. We laid a 50-m transect tape in a random azimuth from the independent random vegetation plot; the origin of the transect was ~40 m from the plot center to avoid trampling vegetation at independent random plots or surveying in areas disturbed by pitfall traps (see below). We walked the transect, recording the perpendicular distance from the transect to ant mounds. Distance was measured using a range finder (if > 10 m) or with a measuring tape (if < 10 m) because the range finders could not estimate distances < 10 m. We recorded dimensions of the mound (length, width, and height) and ant activity on the mound (i.e., the presence of ≥1 ant on the mound).

*Sweep Netting* – In a random azimuth and beginning ~40 m from the independent random plot center, we walked 3-4 km/hr while sweeping 50 times, attempting to perform one sweep per meter. We used standard sweep nets (38.1 cm diameter). Each sweep consisted of moving the sweep net left and right 1-10 cm above the ground, maintaining momentum of the net to avoid allowing insects to escape. Sweep net contents were stored in a plastic bag and frozen.

*Pitfall Traps* – Pitfall trap arrays were placed 35 m from independent random plot centers to avoid disturbing vegetation during installation of pitfall traps. A pitfall trap array consisted of four pitfall traps arranged in a 5-m by 5-m square, with pitfall traps located in the corners. Two of the four pitfall traps in each array were conventional (cups buried flush with ground) and two pitfall traps were modified with a ramp to address potential difficulty burying pitfall traps flush with the ground. We placed four 60 cm x 3.7 cm x 1 cm drift fences made of wood approximately evenly spaced around each pitfall trap. Pitfall traps were partially filled with propylene glycol. We collected samples from pitfall traps once every week and the traps were deployed for three weeks. We stored the collected samples in ethanol for up to two weeks and then transferred them to a freezer.

## Statistical Analysis

We calculated apparent nest success by dividing the number of hatched nests by the total number of nests, excluding nests with an unknown nest fate. Apparent nest success was calculated for individual pastures and study sites. We calculated average clutch size separately for hatched and failed nests because predated nests tend to have less egg shell fragments remaining than hatched nests (Schroeder 1997). We excluded definite renest attempts when calculating critical date averages and ranges. We calculated apparent brood success by dividing the number of females with ≥ 1 chick present through 42 days after hatch by the total number of females with hatched nests. To analyze grass heights, we first calculated the average grass height for each grass species within individual plots because the plot is the sample unit. We then calculated the average maximum droop grass height, maximum grass height sans flower stalk, and effective height across plots for each plot type (nest, dependent random, independent random) for each grass species. For Daubenmire canopy cover, we calculated the mean percent cover and 95% confidence interval for each cover class and for each plot type. We compared percent cover between plot types by examining whether confidence intervals overlapped. We used 95% confidence intervals to compare the mean number of current year and past year cattle droppings among plot types. We used a test of equal proportions to evaluate if the proportion of plots with presence of elk, rabbit, or mule deer/pronghorn droppings differed among plot types (prop.test; R core Team 2014).

*Daily Nest survival* – We used an information theoretic approach (Aikaike's Information Criterion adjusted for small sample sizes [AICc]; Anderson 2008) to assess relative influence of several variables (Table 3) on daily nest survival rate. We used R statistical software 3.1.2 (R core team 2014) to create logistic exposure models (Shaffer 2004). We evaluated evidence of multicollinearity using variance inflation factors (VIFs) of the global model, considering VIFs > 10 to be evidence of multicollinearity (Ott and Longnecker 2010) and used a Hosmer–Lemeshow goodness-of-fit test to assess goodness of fit of the global model (Hosmer and Lemeshow 2000). We constructed 29 models based on the hypothesis that higher concealment results in higher daily nest survival because predators will less frequently detect well concealed nests. We also included an age model and each of the 29 original models plus age because sage grouse age has been shown to affect nest success (Wallestad and Pyrah 1974). We included a site model and each of the original 29 models plus site to account for inherent differences in sites. We also included a site plus age model and each of the original 29 models plus site and age. For models receiving substantial support ($\Delta AIC_c < 2$), we report model-averaged coefficient estimates; we used 95% unconditional confidence intervals (Anderson 2008) to evaluate variables. We generated an overall estimate of daily nest survival using the highest ranked logistic exposure model. We also separately generated estimates of daily nest survival using the Mayfield method (Mayfield 1975) by site and pasture.

Table 3. Variables included in logistic exposure models predicting daily nest survival rate of greater sage-grouse nests in southern Idaho, 2015.

| Variable | Definition (units if applicable) |
|---|---|
| New Cattle Droppings | number of current year cattle bowel movements within searched area of nest plot |
| Old Cattle Droppings | number of non-current year cattle bowel movements within searched area of nest plot |
| Nest Shrub Height | Height of nest shrub from ground to highest point of shrub (cm) |
| Nest Shrub Length | Maximum length of nest shrub patch (cm) |
| Nest Shrub Width | Maximum Width of nest shrub patch measured perpendicularly to nest shrub length (cm) |
| Shrub Cover | Percent shrub cover within a 15 m radius of nest (%) |
| AGCR Cover | Percent *Agropyron cristatum* cover averaged from 20 Daubenmire frames measured at nest plot (%) |
| ELEL5 Cover | Percent *Elymus elymoides* cover averaged from 20 Daubenmire frames measured at nest plot (%) |
| POSE Cover | Percent *Poa secunda* cover averaged from 20 Daubenmire frames measured at nest plot (%) |
| PSSP6 Cover | Percent *Pseudoroegneria spicata* cover averaged from 20 Daubenmire frames measured at nest plot (%) |
| STIPA Cover | Percent needle grass cover including *Achnatherum hymenoides*, *Achnatherum thurberianum*, *Hesperostipa comata*, and others averaged from 20 Daubenmire frames measured at nest plot (%) |
| BRTE Cover | Percent *Bromus tectorum* cover averaged from 20 Daubenmire frames measured at nest plot (%) |
| Total Forb Cover | Percent cover of all forbs averaged from 20 Daubenmire frames measured at the nest plot (%) |
| Maximum Droop Height | Average maximum droop height of all perennial grass species measured at nest plots (cm) |
| Maximum Leaf Height | Average maximum height sans flower stalk of all perennial grass species measured at nest plots (cm) |
| Effective Height | Average effective height of all perennial grass species measured at nest plots (inches) |
| Removed | Average percent removed by herbivores of all perennial grass species measured at nest plots (%) |
| Age | Age of sage grouse hen (adult or yearling) |
| Site | Study site |

## RESULTS

We deployed 90 new VHF radio transmitters on 93 hens in spring 2015 (3 transmitters were re-deployed following their recovery from hens that died). In addition, 48 radio-marked hens whose VHF collars were deployed in past years were present at our sites in February 2015. Including all VHF-transmittered hens, 101 were adults (72%) and 40 were yearlings (28%). We also deployed small VHF transmitters on 10 chicks and GPS transmitters on 2 hens and 9 adult males (Table 4). We observed 15 adult hen mortalities across all sites from February to July 2015 (Table 4). Of the 10 chicks, we confirmed 4 mortalities and 6 went missing before possible independence from their biological mother (and hence were presumed to have died).

Table 4. Number of radio-marked adult sage-grouse that were present and whose signal was detectable at the start of the 2015 field season by year collared, the number of new transmitters deployed in 2015, the number of mortalities documented Feb-July 2015, and the number of dropped collars documented Feb-July 2015.

| Site | Sex | Collar Type | Collared in 2013 - Detectable Feb 2015 | Collared in 2014 - Detectable Feb 2015 | Collared 2015 | Mortalities | Dropped Collars[1] |
|---|---|---|---|---|---|---|---|
| Browns Bench | F | VHF | 0 | 30 | 23 | 9 | 1 |
| Browns Bench | F | GPS | 0 | 0 | 2 | 0 | 0 |
| Browns Bench | M | GPS | 0 | 0 | 9 | 0 | 0 |
| Jim Sage | F | VHF | 6 | 12 | 20 | 0 | 0 |
| Jim Sage | M | VHF | 7 | 2 | 0 | 1 | 0 |
| Jim Sage | F | PTT | 2 | 3 | 0 | 0 | 0 |
| Big Butte | F | VHF | 0 | 0 | 34 | 5 | 0 |
| Sheep Creek | F | VHF | 0 | 0 | 16 | 0 | 1 |
| TOTAL | | | 15 | 47 | 104 | 15 | 2 |

[1]collar found intact, bird presumed to be still alive

*Apparent Nest Success* - At Browns Bench, apparent nest success for first nest attempts was 54% (*n* = 26) in 2014 and 67% (*n* = 30) in 2015 (Table 6; Appendix A). At Jim Sage, apparent nest success for first nest attempts was 29% (*n* = 21) in 2014 and 44% (*n* = 18) in 2015 (Table 6; Appendix A). Apparent nest success for first nest attempts was 30% (*n* = 30) at Big Butte in 2015 and 33% (*n* = 15) at Sheep Creek in 2015 (Table 6; Appendix A). Apparent nest success for re-nest attempts was similar to first attempts (Table 7; Appendix A).

*Daily Nest Survival* - Our dataset consisted of 640 survival intervals from 80 nests. We excluded 2014 nests and some 2015 nests from the dataset for this analysis because some predictor variables were not recorded in 2014 and nest vegetation was not measured at all nests in 2015. The global model fit the data (Hosmer-Lemeshow goodness-of-fit: $\chi^2 = 10.25$, $P = 0.25$). The predictor variables in the global model did not exhibit multicollinearity (VIFs < 10). Eight models received substantial support as the best model ($\Delta AIC_c < 2$; Appendix B). STIPA cover appeared in seven of the eight top models including the highest ranked model and the model-averaged coefficient indicated daily survival rate of a nest decreased as STIPA cover increased (Figure 3; Table 5). AGCR cover appeared in five of the eight top models and the model-averaged coefficient suggested as AGCR cover increased daily nest survival increased but the confidence interval overlapped 0 (Table 5). ELEL5 cover, PSSP6 cover, POSE Cover, BRTE Cover, and Removed also appeared in models receiving substantial support ($\Delta AIC_c < 2$) but STIPA cover and AGCR cover were also included in each of those models. Additionally, the model-averaged coefficient estimates were all near 0 (Table 5) and 95% confidence intervals overlapped 0 indicating a lack of an effect of those variables. Overall daily nest survival as estimated by the top logistic exposure model was 0.932 ± 0.002.

Table 5. Model-averaged coefficients and 95% unconditional confidence intervals from models predicting daily nest survival sage-grouse nests monitored in southern Idaho in 2015.

| Variable | B[1] | LCI[2] | UCI[3] |
|---|---|---|---|
| STIPA Cover | -0.189 | -0.341 | -0.037 |
| AGCR Cover | 0.896 | -0.323 | 2.115 |
| ELEL5 Cover | -0.078 | -0.215 | 0.059 |
| PSSP6 Cover | 0.043 | -0.031 | 0.118 |
| POSE Cover | 0.044 | -0.022 | 0.111 |
| BRTE Cover | -0.030 | -0.092 | 0.031 |
| Removed | -0.037 | -0.117 | 0.043 |

[1]Model-averaged coefficient.
[2]Lower 95% unconditional confidence interval
[3]Upper 95% unconditional confidence interval

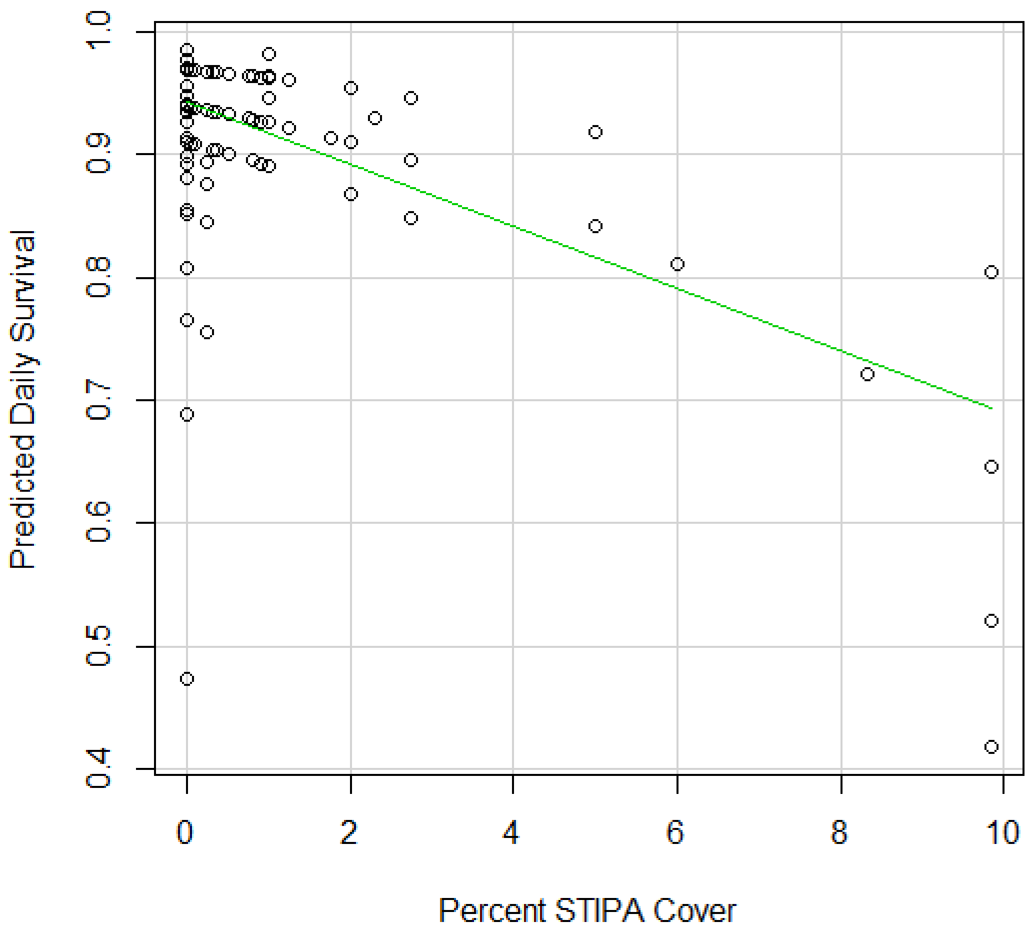


Figure 3. Predicted daily survival of sage grouse nests plotted against percent STIPA cover. We used the best fit logistic exposure model of a nest, based on nests monitored in southern Idaho in 2015. STIPA is a group of needlegrasses including *Achnatherum hymenoides*, *Achnatherum thurberianum, Hesperostipa comata.*

Table 6. Fate of sage-grouse nests (first nest attempts only) in 2014 and 2015 across four study sites in southern Idaho.

| Study Site | Year | Pasture | Hatch | Fail | Unk. Fate | Apparent Nest Success (%) | Clutch Size Hatched Nests ± SE | Clutch Size Failed Nests ± SE | Mayfield Daily Nest Survival | Mayfield Daily Nest Survival SE |
|---|---|---|---|---|---|---|---|---|---|---|
| Browns Bench | 2014 | Overall | 14 | 12 | 0 | 54 | 7.3 ± 0.5[1] | 4 ± 1.4[1] | 0.975[2] | 0.008[2] |
| | | Indian Cave North | 0 | 1 | 0 | 0 | - | 5.0 ± - | 0.000 | 0.000 |
| | | Indian Cave South | 5 | 1 | 0 | 83 | 7.8 ± 0.5 | 0.0 ± - | 0.993 | 0.007 |
| | | Corral Creek East | 0 | 3 | 0 | 0 | - | 5.5 ± 5.5[1] | 0.909[2] | 0.061[2] |
| | | Browns Creek East | 1 | 0 | 0 | 100 | 2.0 ± - | - | 1.000 | 0.000 |
| | | China Creek | 3 | 6 | 0 | 33 | 7 ± 0[1] | 4.0 ± 1.4[1] | 0.957[2] | 0.019[2] |
| | | Other Pastures Combined | 5 | 1 | 0 | 83 | 8.25 ± 0.5[1] | - | 0.990[2] | 0.010[2] |
| | 2015 | Overall | 20 | 10 | 1 | 67 | 6.3 ± 0.6 | 5.9 ± 0.8 | 0.983 | 0.005 |
| | | Indian Cave North | 2 | 0 | 0 | 100 | 7.5 ± 0.5 | - | 1.000 | 0.000 |
| | | Indian Cave South | 2 | 0 | 0 | 100 | 4.0 ± 3.0 | - | 1.000 | 0.000 |
| | | Corral Creek East | 2 | 1 | 0 | 67 | 7.0 ± 3.0 | 8.0 ± - | 0.981 | 0.018 |
| | | Browns Creek East | 1 | 0 | 0 | 100 | 2.0 ± - | - | 1.000 | 0.000 |
| | | China Creek | 5 | 4 | 1 | 56 | 8 ± 0.3 | 5.0 ± 1.7 | 0.972 | 0.014 |
| | | Other Pastures Combined | 8 | 5 | 0 | 62 | 5.9 ± 0.8 | 6.2 ± 0.9 | 0.982 | 0.008 |
| Jim Sage | 2014 | Overall | 6 | 15 | 3 | 29 | 7 ± 0.4[1] | 5.2 ± 1.2[1] | 0.946[2] | 0.017[2] |
| | | Sheep Mountain North | 1 | 2 | 0 | 33 | -[1] | 7.0 ± -[1] | 0.867[2] | 0.124[2] |
| | | Sheep Mountain South | 0 | 6 | 0 | 0 | - | 4.0 ± -[1] | 0.942 | 0.028 |
| | | Kane Springs East | 0 | 1 | 1 | 0 | - | - | 0.600[2] | 0.310[2] |
| | | Other Pastures Combined | 5 | 6 | 2 | 45 | 7 ± 0.4[1] | 5.0 ± 2.1[1] | 0.966[2] | 0.019[2] |
| | 2015 | Overall | 8 | 10 | 0 | 44 | 6.4 ± 0.7 | 3.5 ± 0.9 | 0.966 | 0.011 |
| | | Sheep Mountain North | 4 | 0 | 0 | 100 | 6.8 ± 1.0 | - | 1.000 | 0.000 |
| | | Sheep Mountain South | 0 | 2 | 0 | 0 | - | 4.5 ± 1.5 | 0.818 | 0.116 |
| | | Kane Springs East | 1 | 2 | 0 | 33 | 4.0 ± - | 4.5 ± 4.5 | 0.970 | 0.021 |
| | | Other Pastures Combined | 3 | 6 | 0 | 33 | 6.7 ± 0.9 | 2.8 ± 0.8 | 0.952 | 0.019 |
| Big Butte | 2015 | Overall | 9 | 21 | 0 | 30 | 6.6 ± 0.8 | 3.8 ± 0.6 | 0.952 | 0.010 |
| | | Frenchmans | 2 | 7 | 0 | 22 | 4.5 ±1.5 | 3 ± 1.2 | 0.955 | 0.017 |
| | | Big Lake | 1 | 5 | 0 | 17 | 8 ± - | 3.4 ± 1.0 | 0.950 | 0.022 |
| | | Serviceberry | 3 | 1 | 0 | 75 | 6.7 ± 1.9 | 3.0 ± - | 0.982 | 0.017 |
| | | Other Pastures Combined | 3 | 8 | 0 | 27 | 7.3 ± 0.9 | 4.8 ± 1.0 | 0.935 | 0.022 |
| Sheep Creek | 2015 | Overall | 5 | 10 | 0 | 33 | 5.4 ± 0.7 | 3.9 ± 0.9 | 0.948 | 0.016 |
| | | East Blackleg | 1 | 3 | 0 | 25 | 5.0 ± - | 3.3 ± 1.7 | 0.941 | 0.033 |
| | | Tokum-Bambi West | 2 | 1 | 0 | 67 | 6.5 ± 1.5 | 0.0 ± - | 0.966 | 0.033 |
| | | Slaughterhouse/Cat Creek | 0 | 4 | 0 | 0 | - | 5.3 ± 1.2 | 0.931 | 0.033 |
| | | Other Pastures Combined | 2 | 2 | 0 | 50 | 4.5 ± 0.5 | 4.0 ± 3.0 | 0.964 | 0.025 |
| Overall | | | 62 | 78 | 4 | 44 | 6.5 ± 0.3[1] | 4.2 ± 0.4[1] | 0.966[2] | 0.004[2] |

[1]Sample size less than indicated in hatch or fail column because clutch size was not recorded consistently in 2014.
[2]Sample size less than indicated in hatch or fail column because some nests were not observed when active (some data from PTT-transmittered hens).

Table 7. Fate of sage-grouse nests (re-nest attempts only) in 2014 and 2015 across four study sites in southern Idaho.

| Study Site | Year | Pasture | Hatch | Fail | Unk. Fate | Apparent Nest Success (%) | Clutch Size Hatched Nests ± SE | Clutch Size Failed Nests ± SE | Mayfield Daily Nest Survival | Mayfield Daily Nest Survival SE |
|---|---|---|---|---|---|---|---|---|---|---|
| Browns Bench | 2014 | Overall | 2 | 0 | 0 | 100 | 7.0 ± 0.0 | - | 1.000 | 0.000 |
| | | Indian Cave North | 1 | 0 | 0 | 100 | 7.0 ± - | - | 1.000 | 0.000 |
| | | Indian Cave South | - | - | - | - | - | - | - | - |
| | | Corral Creek East | 1 | 0 | 0 | 100 | 7.0 ± - | - | 1.000 | 0.000 |
| | | Browns Creek East | - | - | - | - | - | - | - | - |
| | | China Creek | - | - | - | - | - | - | - | - |
| | | Other Pastures Combined | - | - | - | - | - | - | - | - |
| | 2015 | Overall | 1 | 0 | 0 | 100 | 6.0 ± - | - | 1.000 | 0.000 |
| | | Indian Cave North | - | - | - | - | - | - | - | - |
| | | Indian Cave South | - | - | - | - | - | - | - | - |
| | | Corral Creek East | - | - | - | - | - | - | - | - |
| | | Browns Creek East | - | - | - | - | - | - | - | - |
| | | China Creek | 1 | 0 | 0 | 100 | 6.0 ± - | - | 1.000 | 0.000 |
| | | Other Pastures Combined | - | - | - | - | - | - | - | - |
| Jim Sage | 2014 | Overall | 1 | 3 | 0 | 25 | 6.0 ± - | 3.5 ± 0.5[1] | 0.942[2] | 0.040[2] |
| | | Sheep Mountain North | 0 | 2 | 0 | 0 | - | 3.0 ± -[1] | 0.882[2] | 0.078[2] |
| | | Sheep Mountain South | 1 | 1 | 0 | 50 | 6.0 ± - | 4.0 ± - | 0.943[2] | 0.055[2] |
| | | Kane Springs East | - | - | - | - | - | - | - | - |
| | | Other Pastures Combined | - | - | - | - | - | - | - | - |
| | 2015 | Overall | - | - | - | - | - | - | - | - |
| | | Sheep Mountain North | - | - | - | - | - | - | - | - |
| | | Sheep Mountain South | - | - | - | - | - | - | - | - |
| | | Kane Springs East | - | - | - | - | - | - | - | - |
| | | Other Pastures Combined | - | - | - | - | - | - | - | - |
| Big Butte | 2015 | Overall | 5 | 2 | 0 | 71 | 5.2 ± 0.7 | 2 ± 2.0 | 0.980 | 0.014 |
| | | Frenchmans | 2 | 0 | 0 | 100 | 5.5 ± 0.5 | - | 1.000 | 0.000 |
| | | Big Lake | 1 | 0 | 0 | 100 | 7.0 ± - | - | 1.000 | 0.000 |
| | | Serviceberry | - | - | - | - | - | - | - | - |
| | | Other Pastures Combined | 2 | 2 | 0 | 50 | 4.0 ± 1.0 | 2.0 ± 2.0 | 0.951 | 0.034 |
| Sheep Creek | 2015 | Overall | 1 | 3 | 0 | 25 | 4.0 ± - | 4.0 ± 2.1 | 0.951 | 0.027 |
| | | East Blackleg | 0 | 2 | 0 | 0 | - | 6.0 ± 1.0 | 0.818 | 0.116 |
| | | Tokum-Bambi West | 0 | 1 | 0 | 0 | - | 0.0 ± - | 0.960 | 0.039 |
| | | Slaughterhouse/Cat Creek | - | - | - | - | - | - | - | - |
| | | Other Pastures Combined | 1 | 0 | 0 | 100 | 4.0 ± - | - | 1.000 | 0.000 |
| Overall | | | 10 | 8 | 0 | 56 | 5.6 ± 0.4 | 3.3 ± 1.0[1] | 0.974[2] | 0.010[2] |

[1]Sample size less than indicated in hatch or fail column because clutch size was not recorded consistently in 2014.
[2]Sample size less than indicated in hatch or fail column because some nests were not observed when active (some data from PTT-transmittered hens).

*Clutch Size*

At Browns Bench, clutch size for hatched nests averaged 7.3 ± 1.9 in 2014 and 6.3 ± 0.1 in 2015. At Jim Sage, clutch size for hatched nests averaged 7.0 ± 0.2 in 2014 and 6.4 ± 0.2 in 2015. At Big Butte, clutch size for hatched nests averaged 6.6 ± 0.3 in 2015. At Sheep Creek, clutch size for hatched nests averaged 5.4 ± 0.3 in 2015. Clutch size tended to be smaller for failed nests (Table 6, Table 7).

*Nesting Propensity* – We included 2015 hens that we monitored every 2-3 days in our calculation of nesting propensity. Nest propensity varied among the 4 study sites: 90% (*n* = 29) at Browns Bench, 71% (*n* = 17) at Jim Sage, 100% (*n* = 15) at Sheep Creek, and 94% (*n* = 34) at Big Butte.

*Overall Hen Success* – We included 2015 hens that we monitored every 2-3 days in our calculation of overall hen success; hens that died during the breeding season were not included. Overall hen success varied among the 4 study sites: 71% (*n* = 28; 1 unknown nest fate) at Browns Bench, 31% (*n* = 16; 1 unknown nest fate) at Jim Sage, 40% (*n* = 15) at Sheep Creek, and 41% (*n* = 32) at Big Butte.

**Critical Dates**

*First Egg Date* – We excluded definite renest attempts in our analysis. At Browns Bench in 2014 hens began laying from 12 March to 4 May and averaged 9 April while in 2015 hens began laying from 13 March to 16 April and averaged 31 March. At Jim Sage in 2014 hens began laying from 20 March to 9 May and averaged 9 April while in 2015 hens began laying from 17 March to 24 April and averaged 2 April. At Big Butte in 2015 hens began laying from 13 March to 26 April and averaged 31 March. At Sheep Creek in 2015 hens began laying from 14 March to 31 March and averaged 21 March. The estimated average first egg dates tended to be different by year, study site, and pasture but sample sizes were extremely low (Table 9).

*Date of Onset of Full Incubation* – We excluded definite renest attempts in our analysis. At Browns Bench in 2014 hens began incubating from 28 March to 14 May and averaged 20 April while in 2015 hens began incubating from 27 March to 26 April and averaged 12 April. At Jim Sage in 2014 hens began incubating from 30 March to 19 May and averaged 20 April while in 2015 hens began incubating from 29 March to 4 May and averaged 13 April. At Big Butte in 2015 hens began incubating from 23 March to 6 May and averaged 11 April. At Sheep Creek in 2015 hens began incubating from 24 March to 10.5 April and averaged 1 April. The estimated average dates of onset of full incubation tended to be different by year, study site, and pasture but sample sizes were extremely low (Table 9).

*Hatch Date and Projected Hatch Date (for failed nests)* – We excluded definite renest attempts in our analysis. At Browns Bench in 2014 nest hatched or would have hatched from 24 April to 10 June and averaged 17 May while in 2015 nest hatched or would have hatched from 23 April to 23 May and averaged 9 May. At Jim Sage in 2014 nest hatched or would have hatched from 26 April to 16 May and averaged 9 May while in 2015 nest hatched or would have hatched from 25 April to 31 May and averaged 10 May. At Big Butte in 2015 nest hatched or would have hatched from 19 April to 2 June and averaged 8 May. At Sheep Creek in 2015 nest hatched or would have hatched from 20 April to 8 May and averaged 28 April. The estimated hatch date or projected hatch date tended to be different by year, study site, and pasture but sample sizes were extremely low (Table 9).

**Apparent Brood Survival**

We included only broods that we were able to survey at all three timeframes (*n* = 29) in our analysis (Table 8). Across all sites, 16 broods survived to 14 days (55%), 15 broods survived to 28 days (52%) and 13 broods survived to 42 days (45%).

Table 8. Percent of broods surviving to 14, 28, and 42 days after hatch across four study sites in southern Idaho in 2015.

| Study Site | Day 14 | Day 28 | Day 42 | *n* = |
|---|---|---|---|---|
| Browns Bench | 67 | 67 | 50 | 12 |
| Jim Sage | 33 | 33 | 33 | 9 |
| Big Butte | 60 | 60 | 60 | 5 |
| Sheep Creek | 67 | 33 | 33 | 3 |

Table 9. Nesting phenology with average dates of greater sage-grouse nests (excluding definite renests) for each of 4 study sites in southern Idaho in 2014 and 2015.

| Study Site | Year | Pasture | n | First Egg Date | Date of Onset of Full Incubation | Hatch Date/Projected Hatch Date |
|---|---|---|---|---|---|---|
| Browns Bench | 2014 | Overall | 23 | 9-Apr-2014 | 20-Apr-2014 | 17-May-2014 |
| | | Indian Cave North | 1 | 27-Mar-2014 | 6-Apr-2014 | 3-May-2014 |
| | | Indian Cave South | 6 | 9-Apr-2014 | 21-Apr-2014 | 18-May-2014 |
| | | Corral Creek East | 2 | 24-Mar-2014 | 7-Apr-2014 | 4-May-2014 |
| | | Browns Creek East | 1 | 4-May-2014 | 14-May-2014 | 10-Jun-2014 |
| | | All Other Pastures Combined | 13 | 10-Apr-2014 | 21-Apr-2014 | 18-May-2014 |
| | 2015 | Overall | 31 | 31-Mar-2015 | 12-Apr-2015 | 9-May-2015 |
| | | Indian Cave North | 2 | 30-Mar-2015 | 10-Apr-2015 | 7-May-2015 |
| | | Indian Cave South | 2 | 10-Apr-2015 | 21-Apr-2015 | 18-May-2015 |
| | | Corral Creek East | 3 | 30-Mar-2015 | 11-Apr-2015 | 8-May-2015 |
| | | Browns Creek East | 1 | 14-Apr-2015 | 25-Apr-2015 | 22-May-2015 |
| | | All Other Pastures Combined | 23 | 30-Mar-2015 | 10-Apr-2015 | 7-May-2015 |
| Jim Sage | 2014 | Overall | 13 | 9-Apr-2014 | 20-Apr-2014 | 9-May-2014 |
| | | Sheep Mountain North | 1 | 20-Mar-2014 | 30-Mar-2014 | 26-Apr-2014 |
| | | Sheep Mountain South | 4 | 2-Apr-2014 | 12-Apr-2014 | 9-May-2014 |
| | | Kane Springs East | 1 | 15-Apr-2014 | 26-Apr-2014 | 23-May-2014 |
| | | All Other Pastures Combined | 7 | 15-Apr-2014 | 26-Apr-2014 | 19-May-2014 |
| | 2015 | Overall | 18 | 2-Apr-2015 | 13-Apr-2015 | 10-May-2015 |
| | | Sheep Mountain North | 4 | 28-Mar-2015 | 9-Apr-2015 | 6-May-2015 |
| | | Sheep Mountain South | 2 | 26-Mar-2015 | 6-Apr-2015 | 3-May-2015 |
| | | Kane Springs East | 3 | 16-Apr-2015 | 27-Apr-2015 | 24-May-2015 |
| | | All Other Pastures Combined | 9 | 1-Apr-2015 | 12-Apr-2015 | 9-May-2015 |
| Big Butte | 2015 | Overall | 30 | 31-Mar-2015 | 11-Apr-2015 | 8-May-2015 |
| | | Frenchmans | 9 | 2-Apr-2015 | 13-Apr-2015 | 10-May-2015 |
| | | Big Lake | 6 | 4-Apr-2015 | 15-Apr-2015 | 12-May-2015 |
| | | Serviceberry | 4 | 23-Mar-2015 | 4-Apr-2015 | 1-May-2015 |
| | | All Other Pastures Combined | 11 | 30-Mar-2015 | 10-Apr-2015 | 7-May-2015 |
| Sheep Creek | 2015 | Overall | 15 | 21-Mar-2015 | 1-Apr-2015 | 28-Apr-2015 |
| | | East Blackleg | 4 | 19-Mar-2015 | 30-Mar-2015 | 26-Apr-2015 |
| | | Tokum-Bambi West | 3 | 14-Apr-2015 | 25-Apr-2015 | 22-May-2015 |
| | | Slaughterhouse/Cat Creek | 4 | 21-Mar-2015 | 1-Apr-2015 | 28-Apr-2015 |
| | | All Other Pastures Combined | 4 | 25-Mar-2015 | 4-Apr-2015 | 1-May-2015 |

**Vegetation**

We intensively measured vegetation at 89 nest plots, 89 dependent random plots, and 280 independent random plots (measurements taken 5 May 2015 - 8 July 2015). The number of days between when a nest hatched or was projected to hatch and when the nest plot was measured averaged 32 days (range: 2-71). We rotated measuring different plot types frequently so vegetation was measured proportionally across plot types as the season progressed.

*Nest Shrub Patch* – Forty-nine percent of 2014 and 2015 nests were located in Wyoming sagebrush ($n$ = 130). Nests were located in other species of shrubs less frequently (Table 10). Average height of nest shrubs ($n$ = 89) was 67.4 ± 2.3 cm, average length of nest shrubs was 134.3 ± 4.2 cm, and average width of nest shrubs was 97.8 ± 3.7 cm in 2015.

Table 10. Frequency of shrub species used by greater sage-grouse for nest placement across four study sites in southern Idaho in 2014 and 2015.

| Common Name | Scientific Name | Number of Nests | Percent of Nests |
|---|---|---|---|
| Wyoming Big Sagebrush | *Artemisia tridentata wyomingensis* | 63 | 48.5 |
| Low Sagebrush | *Artemisia arbuscula* | 20 | 15.4 |
| Black Sagebrush | *Artemisia nova* | 15 | 11.5 |
| Three-tip Sagebrush | *Artemisia tripartita* | 13 | 10.0 |
| Green Rabbitbrush | *Chrysothamnus viscidiflorus* | 5 | 3.8 |
| Basin Big Sagebrush | *Artemisia tridentata tridentata* | 3 | 2.3 |
| Rubber Rabbitbrush | *Ericameria nauseosa* | 3 | 2.3 |
| Mountain Big Sagebrush | *Artemisia tridentata vaseyana* | 2 | 1.5 |
| Antelope Bitterbrush | *Purshia tridentata* | 2 | 1.5 |
| Multiple Species | - | 2 | 1.5 |
| Shadscale Saltbush | *Atriplex confertifolia* | 1 | 0.8 |
| Dead Shrub | - | 1 | 0.8 |

*Shrub Cover* – Nest plots averaged 25.08% (CI: 23.01, 27.14) shrub cover, dependent random plots averaged 22.50% (CI: 20.78, 24.24) shrub cover, and independent random plots averaged 21.73% (CI: 20.51, 22.95). Nest plots had significantly more shrub cover than independent random plots; 95% confidence intervals did not overlap (Fig. 4).

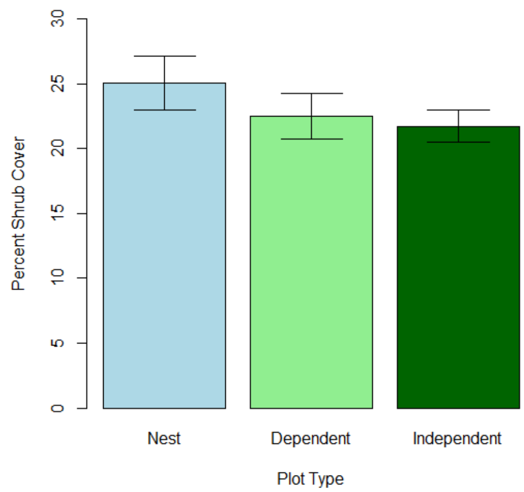


Figure 4. Mean shrub cover by plot type for data collected across four study sites in southern Idaho in 2015. Error bars represent 95% confidence intervals.

*Grass Height* - Mean maximum droop grass height did not differ between plot types for any of the 4 most common grass species or the STIPA group (all 95% confidence intervals overlapped), but heights tended to be slightly (but not significantly) higher at nest plots compared to independent random plots for squirreltail, Sandberg bluegrass, and the STIPA group (Fig. 5). Mean maximum grass height sans flower stalk for STIPA was shorter at nest plots (mean = 19.52, CI: 17.05, 21.99) than independent random plots (mean = 23.95, CI: 22.15, 25.74). We did not detect differences between plot types in the mean maximum grass height sans flower stalk for the 4 most common grass species (Fig. 6). We did not detect a difference between plot types in effective grass height for any of the 4 most common grass species or the STIPA group (95% confidence intervals overlapped; Fig. 7).

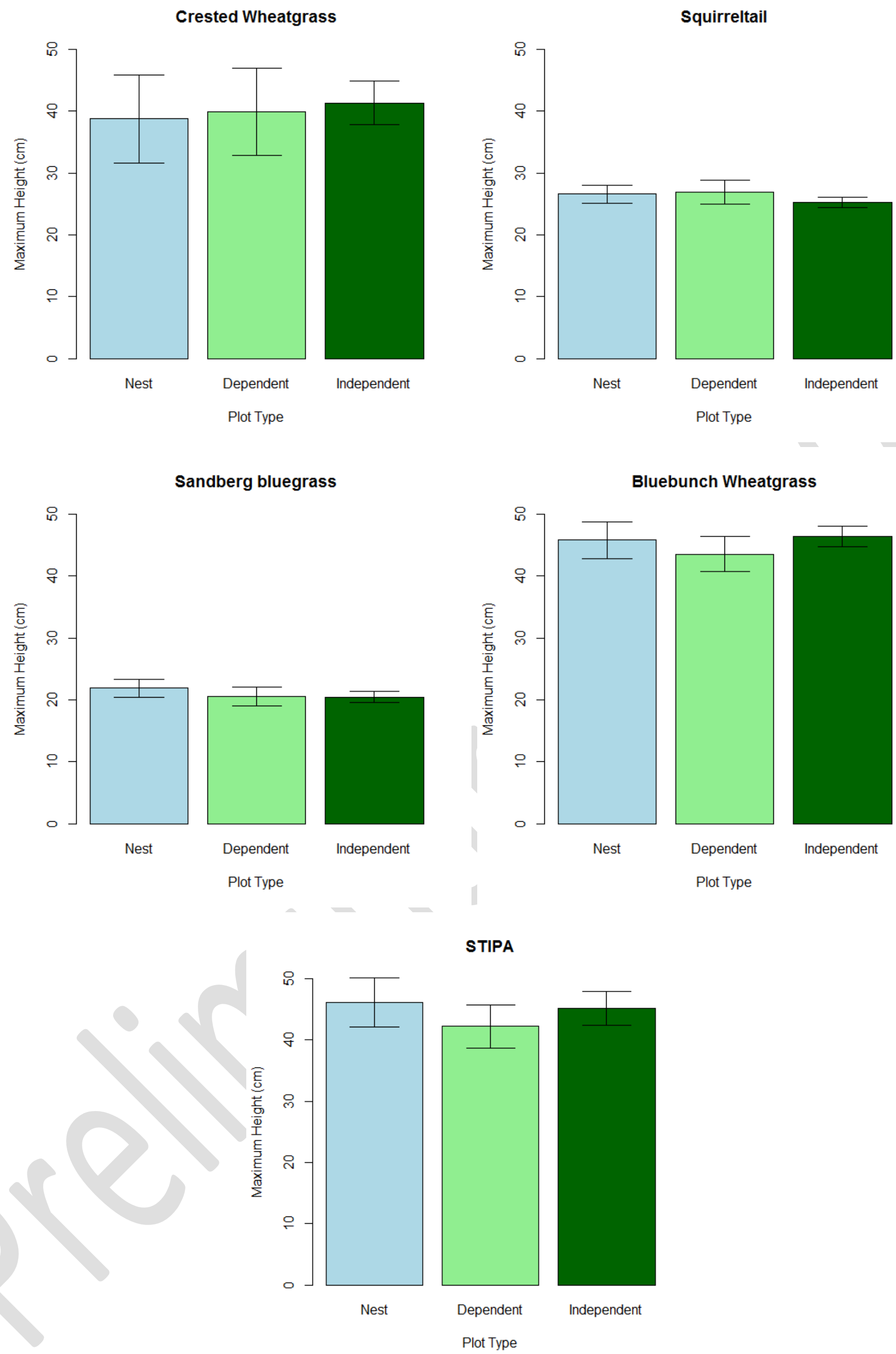


Figure 5. Maximum droop height by plot type and separated by grass species for data collected across four study sites in southern Idaho in 2015. Crested Wheatgrass = *Agropyron cristatum,* Squirreltail = *Elymus elymoides,* Sandberg bluegrass = *Poa secunda*, Bluebunch Wheatgrass = *Pseudoroegneria spicata*, STIPA = *Achnatherum hymenoides*, *Achnatherum thurberianum, Hesperostipa comata,* and other needlegrasses.

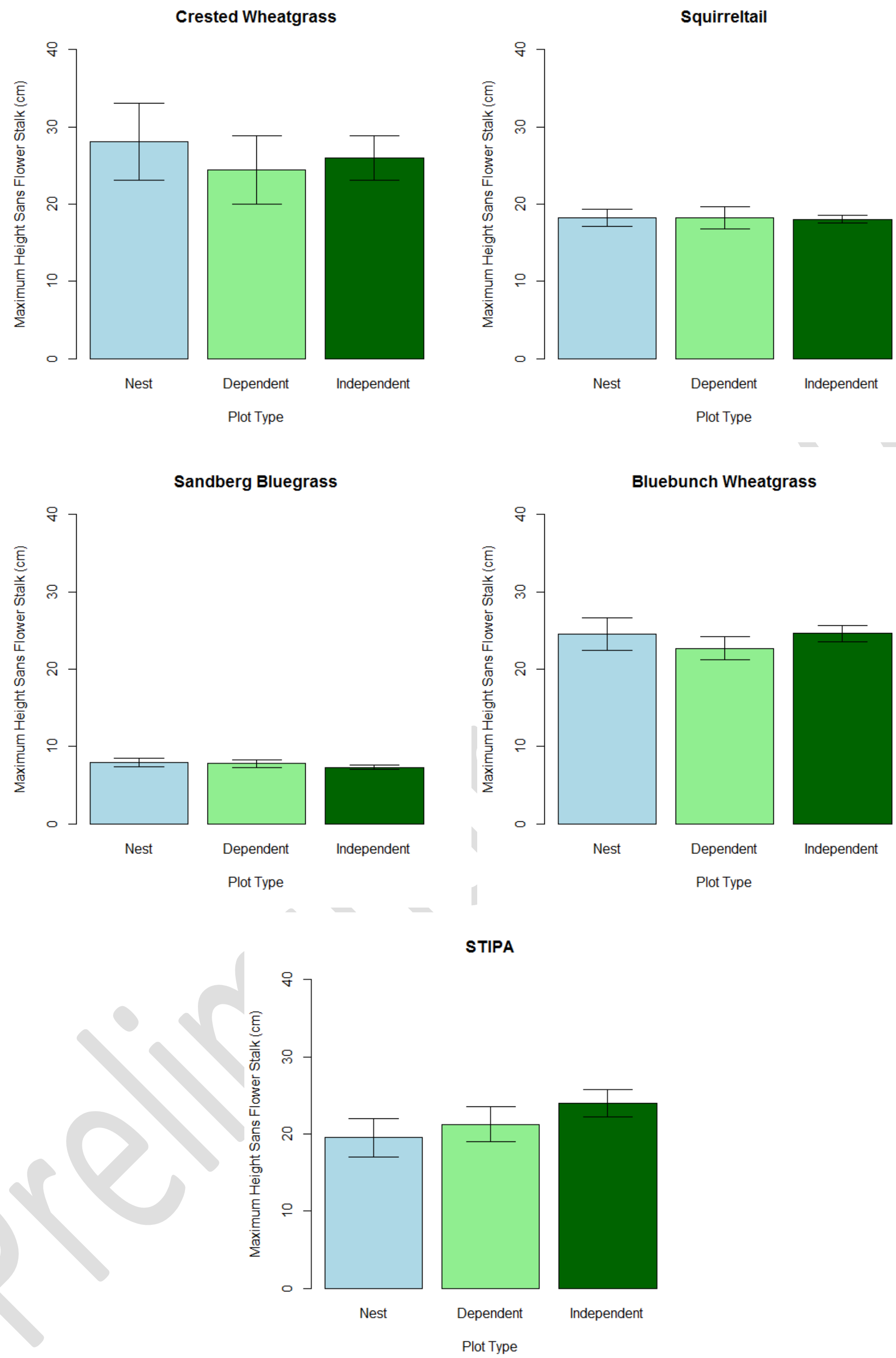


Figure 6. Maximum grass height sans flower stalk by plot type and separated by grass species for data collected across four study sites in southern Idaho in 2015. Crested Wheatgrass = *Agropyron cristatum,* Squirreltail = *Elymus elymoides,* Sandberg bluegrass = *Poa secunda*, Bluebunch Wheatgrass = *Pseudoroegneria spicata*, STIPA = *Achnatherum hymenoides*, *Achnatherum thurberianum, Hesperostipa comata,* and other needlegrasses.

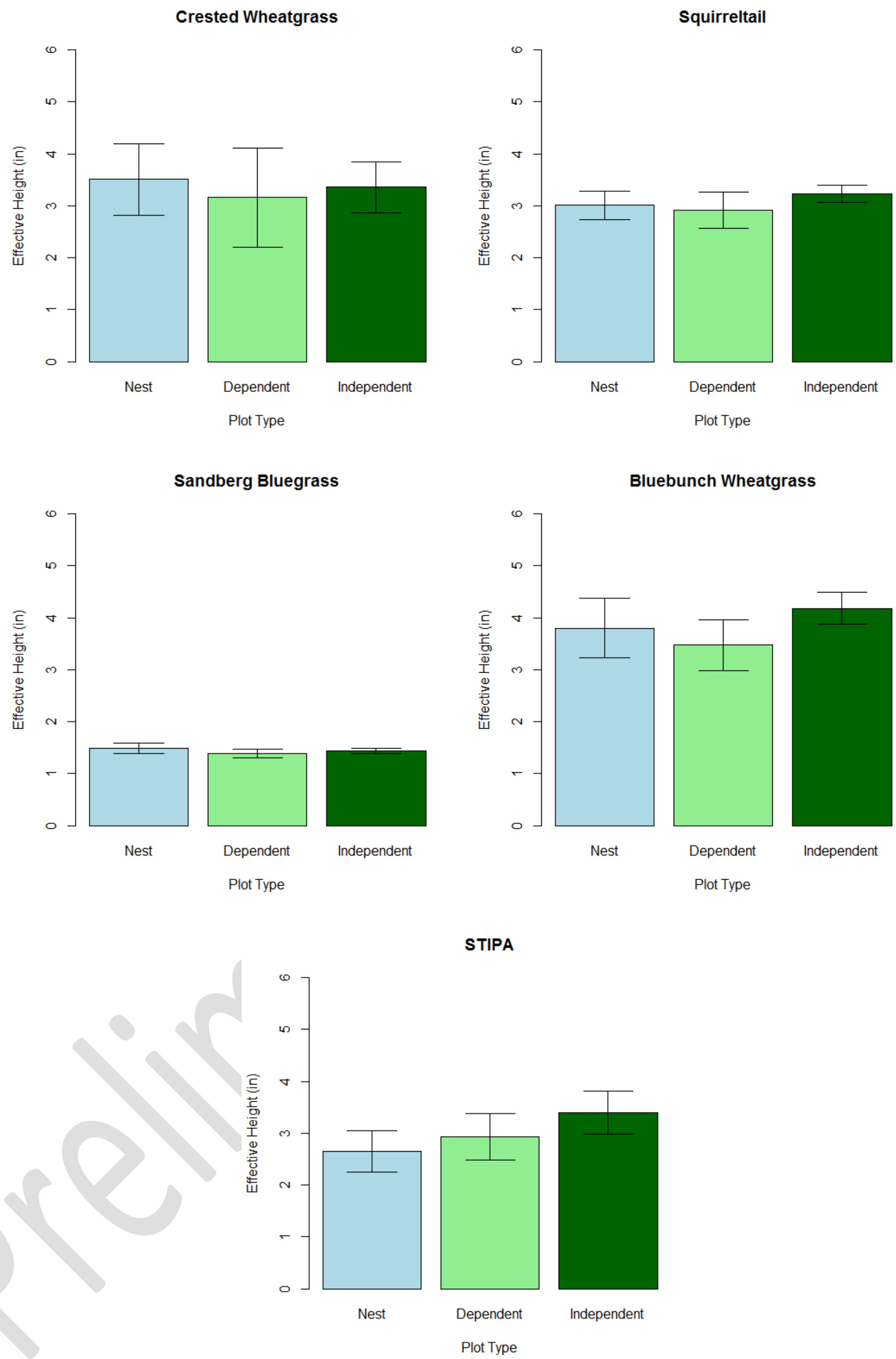


Figure 7. Effective Height by plot type and separated by grass species for data collected across four study sites in southern Idaho in 2015. Crested Wheatgrass = *Agropyron cristatum,* Squirreltail = *Elymus elymoides,* Sandberg bluegrass = *Poa secunda*, Bluebunch Wheatgrass = *Pseudoroegneria spicata*, STIPA = *Achnatherum hymenoides*, *Achnatherum thurberianum, Hesperostipa comata,* and other needlegrasses.

*Daubenmire Canopy Cover* – Percent cover of composites was lower at nest plots compared to dependent random and independent random plots (Table 11). Percent cover of Phlox and rock was lower and percent cover of bare ground was higher at nest plots compared to independent random plots. Mean percent cover of knotweed and buckwheats, daisies, prairie junegrass, and other prefferred forbs were approximately twice as high at nest plots compared to independent random plots but the differences were not significant due to the substantial variation in percent cover of these species among plots. Mean percent cover of crested wheatgrass was over twice as high at independent random plots compared to nest plots but the difference was not significant due to the substantial variation in percent cover among plots. There were no other differences in percent cover between plot types (Table 11).

Table 11. Mean percent canopy cover and 95% confidence intervals for cover classes measured at three plot types in southern Idaho in 2015.

| | Nest | | | Dependent Random | | | Independent Random | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Cover Class | Mean | Lower 95% CI | Upper 95% CI | Mean | Lower 95% CI | Upper 95% CI | Mean | Lower 95% CI | Upper 95% CI | Non-overlapping 95% CIs |
| COMP | 0.0000 | 0.0000 | 0.0000 | 0.0798 | 0.0243 | 0.1352 | 0.0695 | 0.0251 | 0.1138 | x |
| DAIS | 0.4208 | 0.1238 | 0.7178 | 0.3163 | 0.1753 | 0.4573 | 0.2602 | 0.1820 | 0.3384 | |
| TARAX | 0.0146 | -0.0144 | 0.0436 | 0.0135 | -0.0025 | 0.0295 | 0.0077 | -0.0003 | 0.0157 | |
| AGOS | 0.0079 | -0.0001 | 0.0158 | 0.0197 | -0.0057 | 0.0450 | 0.0177 | -0.0033 | 0.0387 | |
| CREP | 0.1776 | 0.0445 | 0.3107 | 0.0803 | 0.0253 | 0.1354 | 0.1936 | 0.1269 | 0.2602 | |
| LACT | 0.0112 | -0.0111 | 0.0336 | 0.0000 | 0.0000 | 0.0000 | 0.0014 | -0.0006 | 0.0035 | |
| ANT | 0.0152 | -0.0003 | 0.0306 | 0.0202 | -0.0024 | 0.0428 | 0.1595 | -0.0016 | 0.3205 | |
| TRAG | 0.0287 | 0.0050 | 0.0523 | 0.0129 | -0.0007 | 0.0265 | 0.0174 | 0.0066 | 0.0282 | |
| ACH | 0.0056 | -0.0022 | 0.0135 | 0.0169 | -0.0166 | 0.0503 | 0.0172 | -0.0026 | 0.0370 | |
| LEGU | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0027 | -0.0026 | 0.0080 | |
| CLOV | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0002 | -0.0002 | 0.0005 | |
| TREF | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0054 | -0.0025 | 0.0132 | |
| ASTRAG | 0.1554 | 0.0572 | 0.2535 | 0.1399 | 0.0828 | 0.1970 | 0.1598 | 0.0970 | 0.2226 | |
| LOMAT | 0.0354 | 0.0100 | 0.0608 | 0.0422 | 0.0105 | 0.0738 | 0.0552 | 0.0244 | 0.0860 | |
| PENS | 0.0185 | -0.0028 | 0.0399 | 0.0264 | -0.0060 | 0.0588 | 0.0171 | 0.0012 | 0.0330 | |
| CAST | 0.0056 | -0.0055 | 0.0168 | 0.0303 | 0.0055 | 0.0552 | 0.0245 | 0.0055 | 0.0435 | |
| ERIO | 0.2506 | 0.1357 | 0.3654 | 0.1775 | 0.0660 | 0.2891 | 0.1308 | 0.0805 | 0.1812 | |
| FLAX | 0.0202 | -0.0200 | 0.0604 | 0.0657 | -0.0116 | 0.1431 | 0.0021 | -0.0021 | 0.0064 | |
| PHLOX | 0.8089 | 0.5888 | 1.0290 | 1.1282 | 0.7943 | 1.4621 | 1.2818 | 1.0396 | 1.5240 | x |
| LILY | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| LITHO | 0.0365 | -0.0361 | 0.1091 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | |
| OPF | 0.4157 | 0.1042 | 0.7273 | 0.3787 | -0.0279 | 0.7852 | 0.2336 | 0.0855 | 0.3817 | |
| OTHER | 1.1888 | 0.7174 | 1.6601 | 1.0406 | 0.4701 | 1.6110 | 0.9741 | 0.7477 | 1.2005 | |
| Litter | 21.2518 | 18.6196 | 23.8841 | 18.9556 | 16.6096 | 21.3016 | 19.1752 | 17.6622 | 20.6882 | |
| Rock | 15.3478 | 12.3765 | 18.3190 | 17.2204 | 13.5711 | 20.8697 | 22.2336 | 20.3012 | 24.1660 | x |
| Bare | 30.4938 | 26.7807 | 34.2068 | 31.6462 | 27.4660 | 35.8265 | 25.3953 | 23.4402 | 27.3505 | x |
| BSC | 7.5617 | 6.2030 | 8.9204 | 6.4015 | 5.0521 | 7.7510 | 7.8958 | 7.1280 | 8.6637 | |
| AGCR | 0.7320 | -0.0364 | 1.5004 | 1.1854 | 0.2868 | 2.0839 | 1.7298 | 1.0923 | 2.3673 | |
| BRTE | 5.0293 | 3.8008 | 6.2578 | 3.8345 | 2.6554 | 5.0135 | 6.0544 | 4.9895 | 7.1193 | |
| ELEL5 | 1.1371 | 0.5592 | 1.7150 | 1.1421 | 0.7160 | 1.5682 | 1.1475 | 0.9556 | 1.3394 | |
| FEID | 0.3837 | 0.0219 | 0.7455 | 0.7079 | 0.0533 | 1.3624 | 0.2264 | 0.0178 | 0.4351 | |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| POSE | 5.5835 | 4.4056 | 6.7614 | 6.1141 | 4.9154 | 7.3127 | 5.6793 | 5.1365 | 6.2221 |
| PSSP6 | 4.1961 | 2.8743 | 5.5178 | 3.8836 | 2.3368 | 5.4305 | 3.5016 | 2.7910 | 4.2122 |
| STIPA | 0.5479 | 0.2075 | 0.8883 | 0.6041 | 0.2274 | 0.9807 | 0.3732 | 0.1590 | 0.5874 |
| KOMA | 0.1507 | 0.0374 | 0.2641 | 0.1135 | -0.0039 | 0.2309 | 0.0421 | -0.0005 | 0.0848 |

*Herbivore Droppings* – The number of current year and past year cattle droppings did not statistically differ between plot types because the 95% confidence intervals overlapped (Fig. 8).

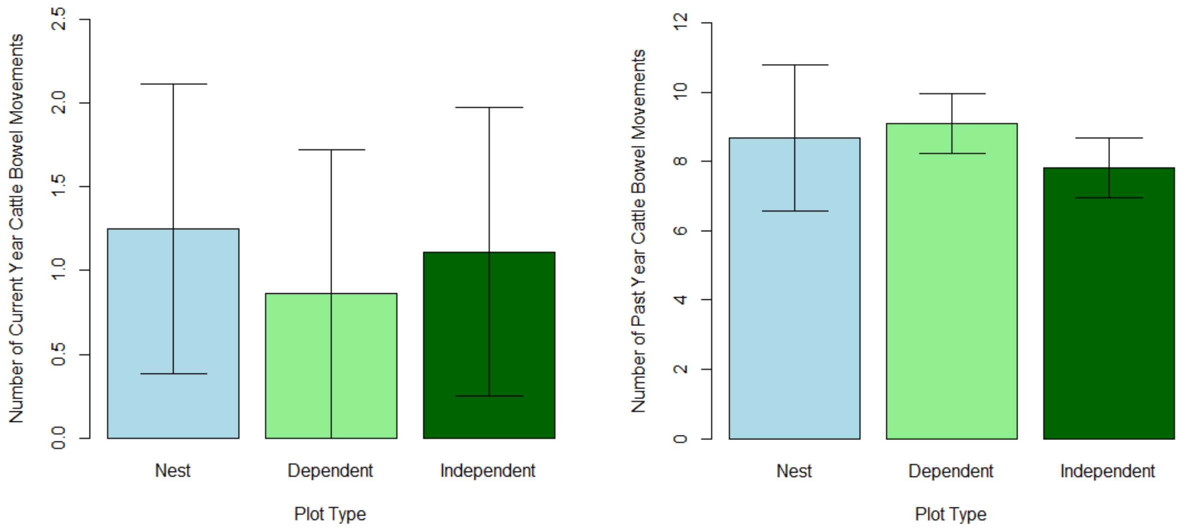


Figure 8. Current year and past year mean number of cattle droppings by plot type for data collected across four study sites in southern Idaho in 2015. Error bars represent 95% confidence intervals.

The frequency of deer or pronghorn antelope droppings did not differ ($P$ = 0.395, $\chi^2$ = 1.860, df = 2) among plot types: they were present at 36% of nest plots ($n$ = 85), 36% of dependent random plots ($n$ = 88), and 43% of independent random plots ($n$ = 275) . The frequency of elk droppings did not differ ($P$ = 0.271, $\chi^2$ = 2.615, df = 2) among plot types: they were present at 21% of nest plots ($n$ = 85), 18% of dependent random plots ($n$ = 88), and 14% of independent random plots ($n$ = 275). The frequency of rabbit droppings also did not differ ($P$ = 0.097, $\chi^2$ = 4.675, df = 2) among plot types: they were present at 80% of nest plots ($n$ = 87), 67% of dependent random plots ($n$ = 88), and 76% of independent plots ($n$ = 76%).

**Utilization**

*Ocular Estimate Method* – Utilization based on the ocular estimate method varied by pasture (Table 12). Estimates of utilization based on the ocular estimate method tended to be less than the estimates of utilization based on the landscape appearance method. When we used the ocular estimate method and excluded individual grasses under a shrub canopy (potentially unavailable to some herbivores), estimates of utilization were greater than the estimates including all grasses (Table 12).

*Landscape Appearance Method* – Utilization based on the landscape appearance method varied by pasture (Table 12). Estimates of utilization based on the landscape appearance method tended to be greater than both estimates of utilization based on the ocular estimate method.

Table 12. Utilization at 4 study site pastures in 2015.

| Site | Pasture | Ocular Estimate Method - All Grasses ± SE | Ocular Estimate Method - Available Grasses ± SE | Landscape Appearance Method ± SE |
|---|---|---|---|---|
| Big Butte | Frenchmans | 4.0 ± 1.2 | 4.5 ± 1.4 | 15.7 ± 1.1 |
| | Big Lake | 6.8 ± 2.3 | 9.0 ± 2.9 | not measured |
| | Serviceberry | 1.7 ± 0.6 | 1.8 ± 0.7 | 6.6 ± 0.6 |
| Browns Bench | Indian Cave | 0.5 ± 0.2 | 0.5 ± 0.2 | 18.0 ± 1.5 |
| | Corral Creek | 0.2 ± 0.1 | 0.2 ± 0.1 | 3.6 ± 0.5 |
| | Browns Creek | 1.0 ± 0.9 | 2.8 ± 0.5 | 13.3 ± 1.0 |
| | China Creek | 1.0 ± 0.9 | 1.7 ± 0.9 | 7.9 ± 0.3 |
| Jim Sage | Sheep Mountain | 10.6 ± 2.1 | 12.8 ± 2.4 | 17.7 ± 0.9 |
| | Kane Springs | 0.1 ± 0.1 | 0.1 ± 0.1 | not measured |
| Sheep Creek | Tokum-Bambi West | 6.0 ± 1.3 | 6.7 ± 1.3 | 14.3 ± 0.4 |
| | East Blackleg | 9.4 ± 2.1 | 10.0 ± 2.2 | 12.2 ± 0.5 |
| | Slaughterhouse/Cat Creek | 6.6 ± 1.3 | 7.6 ± 1.5 | 29.1 ± 0.5 |

**Insects**

We sampled insects from 14 June 2015 to 24 July 2015. We deployed an array of 4 pitfall traps at each of 60 independent random plots, sampling each plot for a total of 3 weeks. We also conducted line-transect surveys to estimate the density of ant mounds at the 60 independent random plots and we collected ~240 sweep net samples. Processing of samples is ongoing.

DISCUSSION

Our estimates of apparent nest success for study sites were within the range (15-86%) recorded by other researchers (Connelly et al. 2011). Our estimates of nesting propensity were also within the range (63-100%) recorded by other researchers (Connelly et al. 2011). Overall hen success at Browns Bench in 2015 was 1% higher than the range (15-70%) reported from other studies (Connelly et al. 2011); all other estimates were within the range. Our estimates of clutch size for hatched nests by study site were also in the range (6-9) recorded by other researchers (Connelly et al. 2011) except for the Sheep Creek Study site which was below this range. Caution should be taken when comparing our estimates of clutch size to other estimates as estimation methods vary substantially across studies. We observed a clutch after a nest was no longer active, meaning there is a chance the eggs could be disturbed by an animal before an observer counts them. Some researchers deliberately flush a sage-grouse hen off the nest to count the number of eggs when the nest is active. Though counting eggs when the nest is active may be more accurate, flushing sage-grouse from nests decreases daily nest survival (Gibson et al. 2015) which is why we wait until the nest is inactive before we attempt to visit the nest. Hence, our estimates are biased low and should only be compared to studies that used the same approach.

Our analysis to identify factors associated with daily nest survival rate indicated as STIPA cover increased daily survival rate decreased. This contradicts the concealment hypothesis. It is possible that STIPA cover could be correlated with some other important factor that we did not measure. Conversely, our analysis also supports the concealment hypothesis because it suggests that as AGCR cover increases so does nest survival. We plan to repeat this analysis including additional variables that may influence the daily survival rate of sage-grouse nests including weather variables, time of breeding season, nest concealment (data being processed so inclusion precluded), grazing treatment, and others which could elucidate important factors.

Similar to other studies (Musil 2011, Lockyer et al. 2015), our results suggest that sage-grouse select nest locations that have relatively high shrub cover which may help conceal nests from predators. Since grass and other plants also provide cover, we expected to see a similar pattern in percent cover of other plants and in heights of grasses, but we did not. It is possible the heights of grasses throughout our study sites in 2015 were above some threshold when grass height is less important. A second possibility is sage-grouse do not select nest locations based on grass heights; sage-grouse select first attempt nest sites mainly in March when grasses have not yet fully expressed.

Our estimates of utilization show that estimates differ depending on the method used. Even when we excluded grasses under shrubs, the estimates of utilization based on the ocular estimate method were generally much less than the estimates of utilization based on the landscape appearance method.

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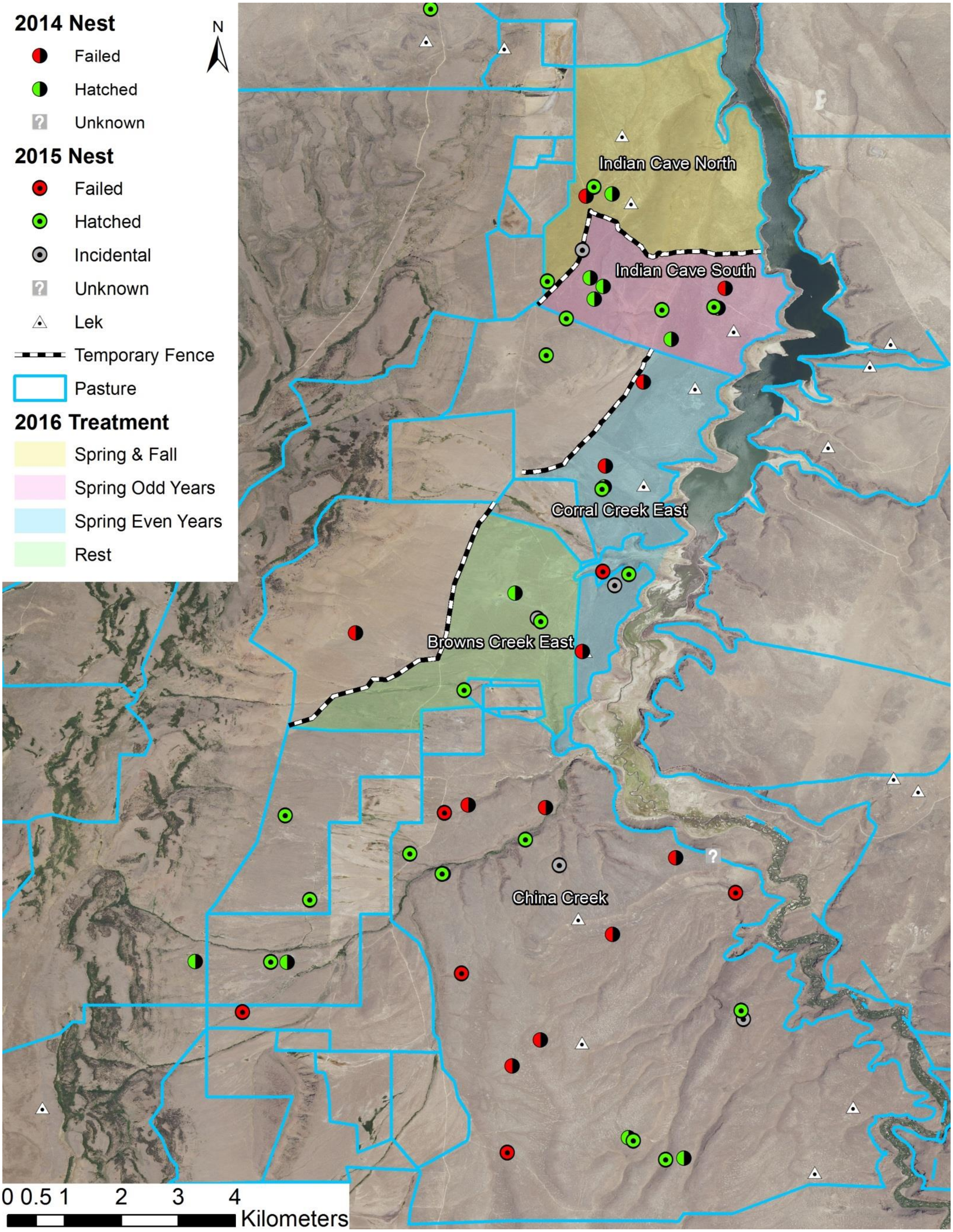
Appendix A – Nest Locations and Apparent Nest Fate



2014 Nest
Failed
Hatched
Unknown
2015 Nest
Failed
Hatched
Incidental
Unknown
Lek
Temporary Fence
Pasture
2016 Treatment
Spring & Fall
Spring Odd Years
Spring Even Years
Rest
N
Indian Cave North
Indian Cave South
Corral Creek East
Browns Creek East
China Creek
0 0.5 1 2 3 4
Kilometers

Figure 9. Sage-grouse apparent nest fate at Browns Bench in 2014 and 2015.

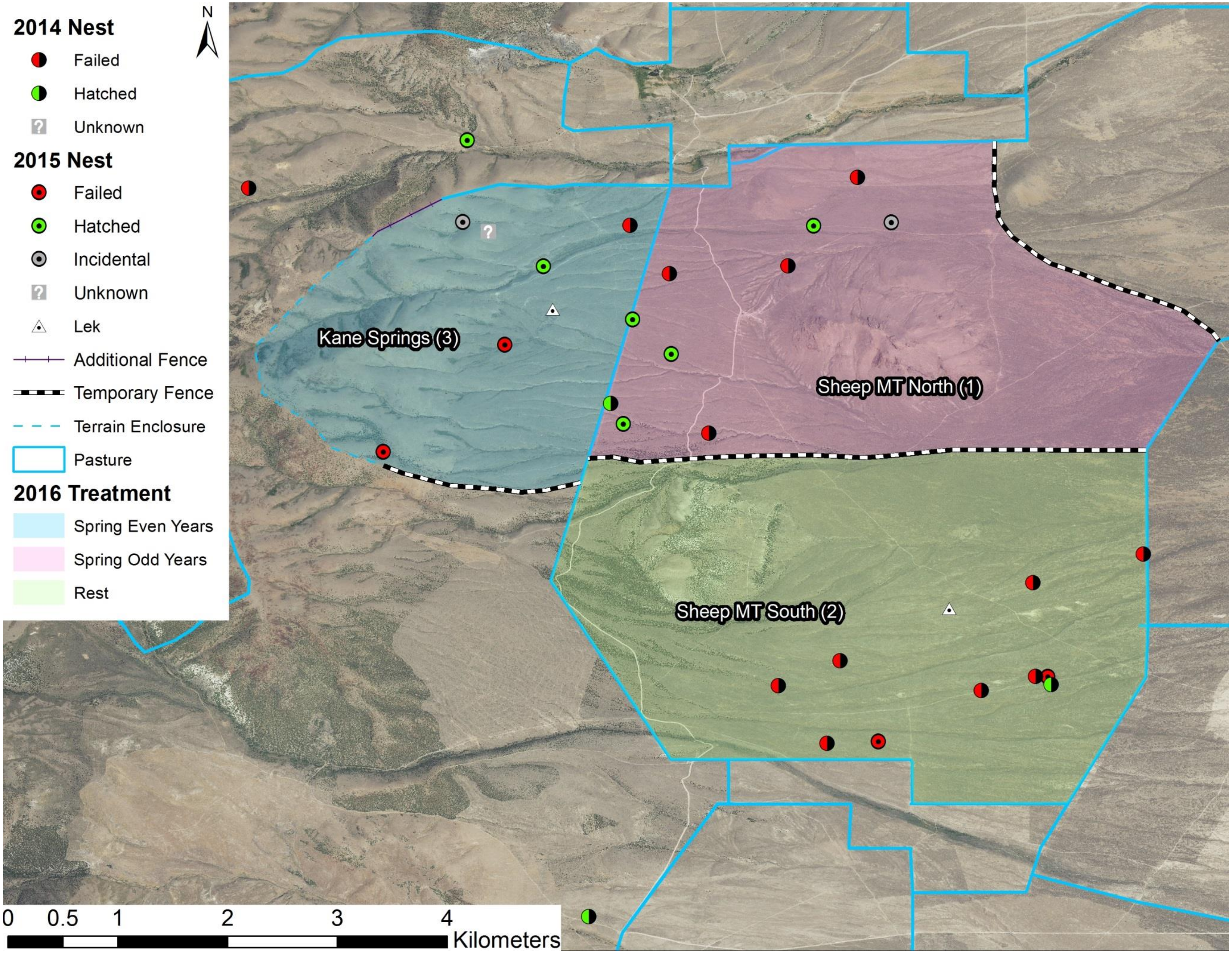
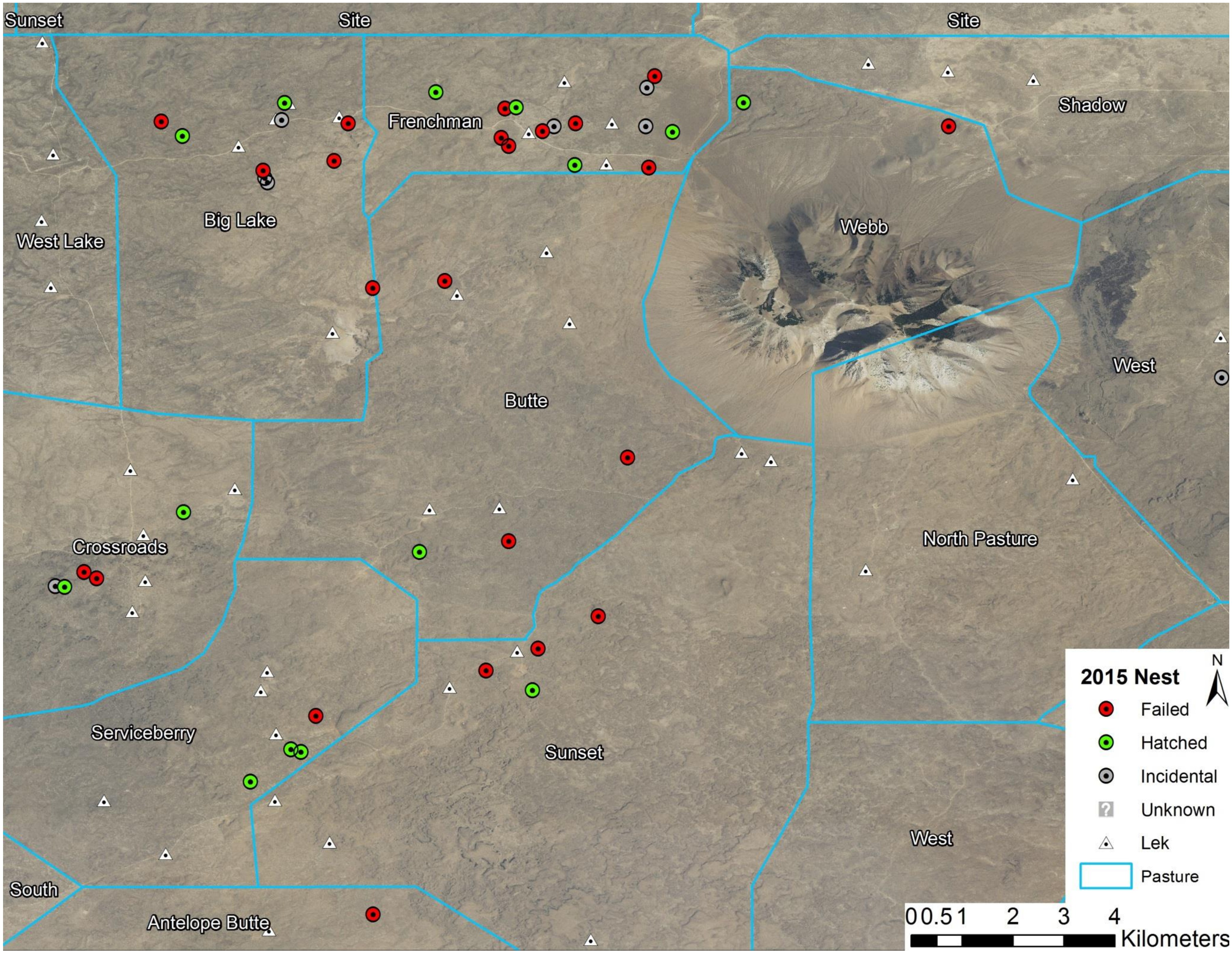
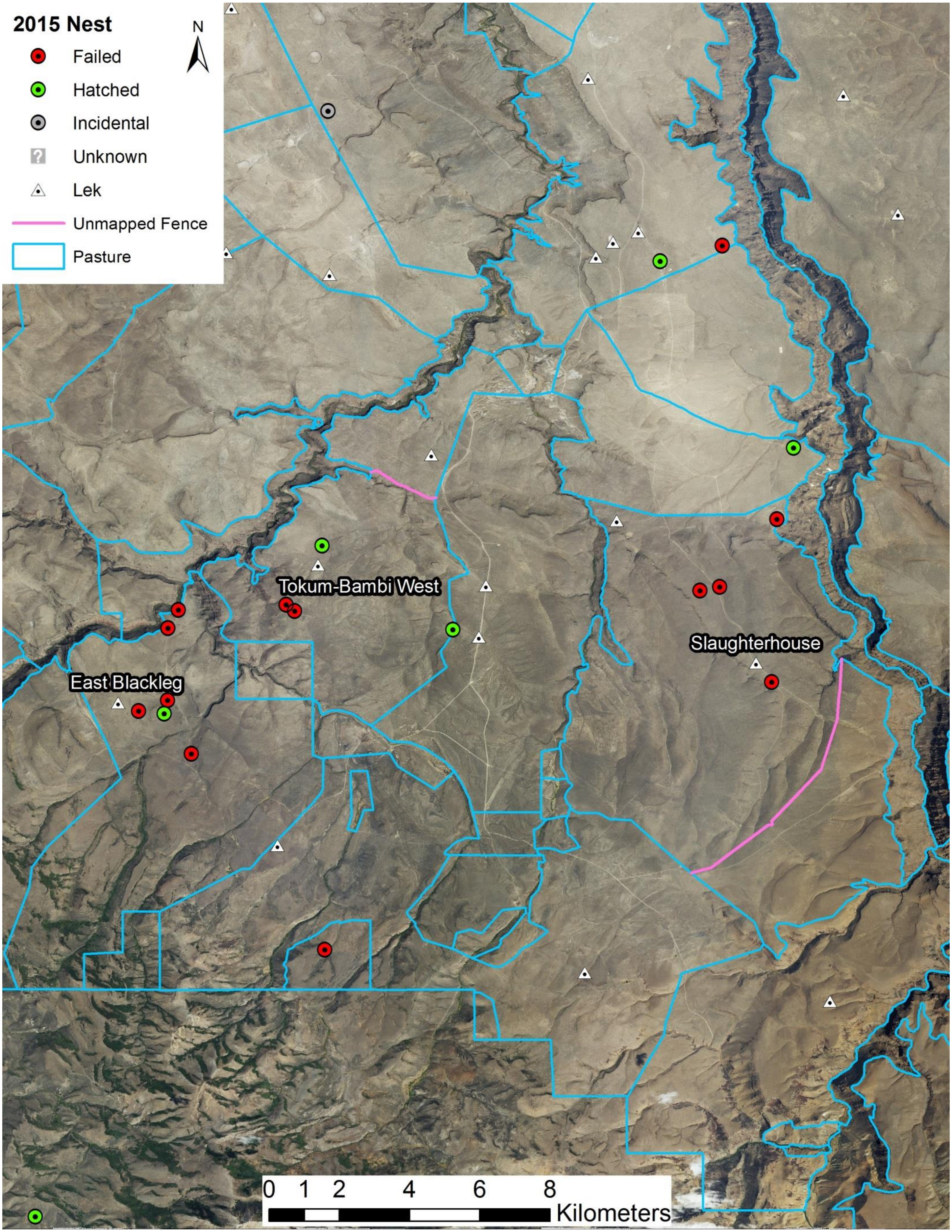

2014 Nest
Failed
Hatched
Unknown
2015 Nest
Failed
Hatched
Incidental
Unknown
Lek
Additional Fence
Temporary Fence
Terrain Enclosure
Pasture
2016 Treatment
Spring Even Years
Spring Odd Years
Rest
N
Kane Springs (3)
Sheep MT North (1)
Sheep MT South (2)
0 0.5 1 2 3 4 Kilometers

Figure 10. Sage-grouse apparent nest fate at Jim Sage in 2014 and 2015.



Sunset
Site
Site
Shadow
Frenchman
Big Lake
West Lake
Webb
Butte
West
North Pasture
Crossroads
Serviceberry
Sunset
West
South
Antelope Butte
2015 Nest
N
Failed
Hatched
Incidental
Unknown
Lek
Pasture
0 0.5 1 2 3 4
Kilometers

Figure 11. Sage-grouse apparent nest fate at Big Butte in 2015.



2015 Nest
Failed
Hatched
Incidental
Unknown
Lek
Unmapped Fence
Pasture
N
Tokum-Bambi West
Slaughterhouse
East Blackleg
0 1 2 4 6 8
Kilometers

Figure 12.  Sage-grouse apparent nest fate at Sheep Creek in 2015.

Appendix B

Table 13. Logistic exposure models predicting daily nest survival rates of sage-grouse nests at 4 study sites in southern Idaho in 2015.

| Model | K | $AIC_c$ | $\Delta AIC_c$ | $W_i$ | LL |
|---|---|---|---|---|---|
| Site + STIPA Cover | 5 | 315.41 | 0.00 | 0.07 | -152.66 |
| Site + Age + STIPA Cover | 6 | 316.29 | 0.88 | 0.05 | -152.08 |
| AGCR Cover | 2 | 316.36 | 0.94 | 0.04 | -156.17 |
| AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 7 | 316.46 | 1.05 | 0.04 | -151.14 |
| STIPA Cover | 2 | 316.47 | 1.06 | 0.04 | -156.23 |
| Site + AGCR Cover | 5 | 316.58 | 1.17 | 0.04 | -153.24 |
| Age + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 317.06 | 1.64 | 0.03 | -150.41 |
| Removed + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 317.18 | 1.77 | 0.03 | -150.48 |
| Age + STIPA Cover | 3 | 317.38 | 1.97 | 0.03 | -155.67 |
| Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 317.47 | 2.06 | 0.03 | -150.62 |
| Site + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 10 | 317.59 | 2.17 | 0.02 | -148.62 |
| Age + Removed + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 318.07 | 2.66 | 0.02 | -149.89 |
| Age + AGCR Cover | 3 | 318.11 | 2.69 | 0.02 | -156.03 |
| Site + Age + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 318.12 | 2.71 | 0.02 | -147.85 |
| Site + Age + AGCR Cover | 6 | 318.17 | 2.75 | 0.02 | -153.02 |
| Age + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 318.18 | 2.77 | 0.02 | -149.95 |
| Site + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 318.31 | 2.90 | 0.02 | -147.94 |
| Maximum Droop Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 318.31 | 2.90 | 0.02 | -151.04 |
| Effective Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 318.42 | 3.01 | 0.02 | -151.10 |
| Maximum Leaf Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 318.48 | 3.07 | 0.02 | -151.13 |
| Shrub Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 8 | 318.51 | 3.10 | 0.02 | -151.14 |
| Site + Removed + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 318.81 | 3.40 | 0.01 | -148.20 |
| Age + Maximum Droop Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 318.84 | 3.43 | 0.01 | -150.28 |
| Age + Effective Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 319.05 | 3.64 | 0.01 | -150.38 |
| Site + Shrub Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 319.06 | 3.65 | 0.01 | -148.32 |
| Age + Shrub Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 319.11 | 3.69 | 0.01 | -150.41 |
| Age + Maximum Leaf Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 319.11 | 3.69 | 0.01 | -150.41 |
| Site + Age + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 319.11 | 3.70 | 0.01 | -147.31 |
| Site + Maximum Droop Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 319.14 | 3.73 | 0.01 | -148.36 |

| | | | | | |
|---|---|---|---|---|---|
| Site + Effective Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 319.19 | 3.78 | 0.01 | -148.39 |
| Site | 4 | 319.29 | 3.88 | 0.01 | -155.61 |

Table 13. Continued

| Model | K | $AIC_c$ | $\Delta AIC_c$ | $W_i$ | LL |
|---|---|---|---|---|---|
| Shrub Cover + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 9 | 319.52 | 4.10 | 0.01 | -150.62 |
| Site + Maximum Leaf Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 11 | 319.62 | 4.21 | 0.01 | -148.60 |
| Site + Age + Maximum Droop Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 319.66 | 4.25 | 0.01 | -147.58 |
| Site + Age + Shrub Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 319.67 | 4.26 | 0.01 | -147.59 |
| Nest Shrub Height | 2 | 319.72 | 4.31 | 0.01 | -157.85 |
| Site + Age + Removed + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 319.73 | 4.31 | 0.01 | -147.61 |
| Site + Nest Shrub Height | 5 | 319.80 | 4.39 | 0.01 | -154.85 |
| Nest Shrub Width | 2 | 319.81 | 4.40 | 0.01 | -157.90 |
| Site + Shrub Cover + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 319.90 | 4.49 | 0.01 | -147.70 |
| Site + Age + Effective Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 319.96 | 4.55 | 0.01 | -147.73 |
| Site + POSE Cover | 5 | 320.10 | 4.69 | 0.01 | -155.01 |
| Site + Age + Maximum Leaf Height + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 12 | 320.20 | 4.78 | 0.01 | -147.85 |
| Age + Shrub Cover + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 10 | 320.25 | 4.83 | 0.01 | -149.95 |
| Site + ELEL5 Cover | 5 | 320.46 | 5.04 | 0.01 | -155.18 |
| Site + Age | 5 | 320.47 | 5.06 | 0.01 | -155.19 |
| Site + Age + POSE Cover | 6 | 320.50 | 5.09 | 0.01 | -154.18 |
| Site + PSSP6 Cover | 5 | 320.51 | 5.10 | 0.01 | -155.21 |
| Site + Total Forb Cover | 5 | 320.66 | 5.24 | 0.01 | -155.28 |
| Site + Age + Nest Shrub Height | 6 | 320.71 | 5.30 | 0.01 | -154.29 |
| Site + Age + Shrub Cover + Total Forb Cover + AGCR Cover + ELEL5 Cover + PSSP6 Cover + STIPA Cover + POSE Cover + BRTE Cover | 13 | 320.77 | 5.35 | 0.00 | -147.09 |
| Site + Removed | 5 | 320.79 | 5.38 | 0.00 | -155.35 |
| Site + Nest Shrub Width | 5 | 320.86 | 5.44 | 0.00 | -155.38 |
| Site + Effective Height | 5 | 320.88 | 5.47 | 0.00 | -155.39 |
| Site + New Cattle Droppings | 5 | 320.92 | 5.51 | 0.00 | -155.41 |
| Age + Nest Shrub Height | 3 | 320.95 | 5.54 | 0.00 | -157.46 |
| Site + Maximum Droop Height | 5 | 321.06 | 5.65 | 0.00 | -155.48 |
| Null | 1 | 321.07 | 5.65 | 0.00 | -159.53 |
| Site + Shrub Cover | 5 | 321.11 | 5.70 | 0.00 | -155.51 |
| Site + Nest Shrub Length | 5 | 321.25 | 5.83 | 0.00 | -155.58 |
| Site + Old Cattle Droppings | 5 | 321.26 | 5.85 | 0.00 | -155.58 |

| | | | | | |
|---|---|---|---|---|---|
| Site + BRTE Cover | 5 | 321.31 | 5.89 | 0.00 | -155.61 |
| Nest Shrub Length | 2 | 321.32 | 5.90 | 0.00 | -158.65 |
| Site + Maximum Leaf Height | 5 | 321.32 | 5.91 | 0.00 | -155.61 |

Table 13. Continued

| Model | K | $AIC_c$ | $\Delta AIC_c$ | $W_i$ | LL |
|---|---|---|---|---|---|
| Site + Age + ELEL5 Cover | 6 | 321.36 | 5.94 | 0.00 | -154.61 |
| Age + Nest Shrub Width | 3 | 321.37 | 5.96 | 0.00 | -157.67 |
| Site + Age + New Cattle Droppings | 6 | 321.56 | 6.15 | 0.00 | -154.71 |
| Site + Age + PSSP6 Cover | 6 | 321.64 | 6.23 | 0.00 | -154.75 |
| ELEL5 Cover | 2 | 321.94 | 6.53 | 0.00 | -158.96 |
| Site + Age + Total Forb Cover | 6 | 321.97 | 6.56 | 0.00 | -154.92 |
| PSSP6 Cover | 2 | 322.13 | 6.72 | 0.00 | -159.05 |
| Site + Age + Nest Shrub Width | 6 | 322.21 | 6.79 | 0.00 | -155.04 |
| Site + Age + Effective Height | 6 | 322.21 | 6.80 | 0.00 | -155.04 |
| Site + Age + Maximum Droop Height | 6 | 322.24 | 6.83 | 0.00 | -155.05 |
| Site + Age + Shrub Cover | 6 | 322.27 | 6.85 | 0.00 | -155.07 |
| Site + Age + Removed | 6 | 322.28 | 6.86 | 0.00 | -155.07 |
| POSE Cover | 2 | 322.35 | 6.94 | 0.00 | -159.17 |
| Age | 2 | 322.37 | 6.95 | 0.00 | -159.17 |
| Removed | 2 | 322.42 | 7.01 | 0.00 | -159.20 |
| Site + Age + Old Cattle Droppings | 6 | 322.43 | 7.02 | 0.00 | -155.15 |
| Site + Age + Maximum Leaf Height | 6 | 322.46 | 7.05 | 0.00 | -155.16 |
| Site + Age + Nest Shrub Length | 6 | 322.48 | 7.07 | 0.00 | -155.18 |
| Site + Age + BRTE Cover | 6 | 322.51 | 7.09 | 0.00 | -155.19 |
| Site + Total Forb Cover + Shrub Cover | 6 | 322.51 | 7.10 | 0.00 | -155.19 |
| Site + Removed + Effective Height | 6 | 322.66 | 7.24 | 0.00 | -155.26 |
| Nest Shrub Height + Nest Shrub Length + Nest Shrub Width | 4 | 322.72 | 7.31 | 0.00 | -157.33 |
| Effective Height | 2 | 322.75 | 7.33 | 0.00 | -159.36 |
| Site + Removed + Maximum Droop Height | 6 | 322.79 | 7.38 | 0.00 | -155.33 |
| Age + Nest Shrub Length | 3 | 322.84 | 7.42 | 0.00 | -158.40 |
| Age + ELEL5 Cover | 3 | 322.91 | 7.50 | 0.00 | -158.44 |
| Old Cattle Droppings | 2 | 322.95 | 7.54 | 0.00 | -159.47 |
| Total Forb Cover | 2 | 322.96 | 7.55 | 0.00 | -159.47 |
| Maximum Leaf Height | 2 | 323.02 | 7.61 | 0.00 | -159.50 |

| | | | | | |
|---|---|---|---|---|---|
| Shrub Cover | 2 | 323.06 | 7.65 | 0.00 | -159.52 |
| Maximum Droop Height | 2 | 323.07 | 7.65 | 0.00 | -159.52 |
| BRTE Cover | 2 | 323.07 | 7.66 | 0.00 | -159.53 |
| New Cattle Droppings | 2 | 323.07 | 7.66 | 0.00 | -159.53 |

## Table 13. Continued

| Model | K | $AIC_c$ | $\Delta AIC_c$ | $W_i$ | LL |
|---|---|---|---|---|---|
| Age + PSSP6 Cover | 3 | 323.19 | 7.77 | 0.00 | -158.57 |
| Age + POSE Cover | 3 | 323.31 | 7.90 | 0.00 | -158.64 |
| Site + Age + Total Forb Cover + Shrub Cover | 7 | 323.81 | 8.40 | 0.00 | -154.82 |
| Site + Nest Shrub Height + Nest Shrub Length + Nest Shrub Width | 7 | 323.87 | 8.46 | 0.00 | -154.85 |
| Age + Removed | 3 | 323.92 | 8.51 | 0.00 | -158.94 |
| Age + Effective Height | 3 | 324.05 | 8.64 | 0.00 | -159.01 |
| Age + Nest Shrub Height + Nest Shrub Length + Nest Shrub Width | 5 | 324.14 | 8.73 | 0.00 | -157.02 |
| Site + Age + Removed + Effective Height | 7 | 324.17 | 8.75 | 0.00 | -155.00 |
| Site + Age + Removed + Maximum Droop Height | 7 | 324.22 | 8.81 | 0.00 | -155.02 |
| Age + Old Cattle Droppings | 3 | 324.26 | 8.84 | 0.00 | -159.11 |
| Removed + Effective Height | 3 | 324.26 | 8.85 | 0.00 | -159.11 |
| Age + Total Forb Cover | 3 | 324.30 | 8.89 | 0.00 | -159.13 |
| Global | 21 | 324.32 | 8.90 | 0.00 | -140.41 |
| Age + New Cattle Droppings | 3 | 324.34 | 8.93 | 0.00 | -159.15 |
| Age + Maximum Droop Height | 3 | 324.35 | 8.93 | 0.00 | -159.15 |
| Removed + Maximum Droop Height | 3 | 324.35 | 8.94 | 0.00 | -159.16 |
| Age + Maximum Leaf Height | 3 | 324.36 | 8.94 | 0.00 | -159.16 |
| Age + Shrub Cover | 3 | 324.37 | 8.96 | 0.00 | -159.17 |
| Age + BRTE Cover | 3 | 324.39 | 8.97 | 0.00 | -159.17 |
| Site + Age + Nest Shrub Height + Nest Shrub Length + Nest Shrub Width | 8 | 324.71 | 9.30 | 0.00 | -154.24 |
| Total Forb Cover + Shrub Cover | 3 | 324.94 | 9.53 | 0.00 | -159.45 |
| Age + Removed + Effective Height | 4 | 325.74 | 10.33 | 0.00 | -158.84 |
| Age + Removed + Maximum Droop Height | 4 | 325.92 | 10.51 | 0.00 | -158.93 |
| Age + Total Forb Cover + Shrub Cover | 4 | 326.30 | 10.89 | 0.00 | -159.12 |