Prepared in cooperation with the Bureau of Land Management and Nevada Department of Wildlife

# Greater Sage-Grouse (*Centrocercus urophasianus*) Nesting and Brood-Rearing Microhabitat in Nevada and California—Spatial Variation in Selection and Survival Patterns

Open-File Report 2017–1087

U.S. Department of the Interior
U.S. Geological Survey

**Cover:**
**Background:** Photograph showing Bodie Hills field site at the southwestern edge of the Great Basin, Mono County, California, April 19, 2016.
**Inset:** Photograph of greater sage-grouse (*Centrocercus urophasianus*) chick during early brood-rearing at the Long Valley field site at the southwestern edge of the Great Basin, Mono County, California, May 23, 2016.
Photographs by Adam Mohr, U.S. Geological Survey.

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# Preface

This report was developed to provide scientific information regarding microhabitat factors that influence nesting and brood-rearing of greater sage-grouse (*Centrocercus urophasianus*) for land managers to consider for conservation and management planning and policy decisions within sage-grouse habitat. The report provides summary statistics of factors related to microhabitat selection as well as success of nests and broods using data collected from extensive sampling plots across 16 study areas within the Great Basin over a 7-year timeframe. Given these summary statistics, we provide an example of habitat quality classes for each variable to help guide management actions and decisions. These initial findings are intended to immediately fill a prominent information gap impeding the revision of existing State and Federal agency resource management plans following a listing decision by the U.S. Fish and Wildlife Service under the Endangered Species Act of 1973. Within a second phase of research, additional analysis of these data is underway currently, using a statistical modeling framework to further define complex relationships between environmental variables and to identify links between selection and demographic response within reproductive life stages of sage-grouse.

# Acknowledgments

We greatly appreciate the logistical and funding support from Nevada Department of Wildlife, Bureau of Land Management, U.S. Forest Service, Ormat Technologies, Inc., GRP Minerals, Midway Gold, LS Power, and NV Energy. We also appreciate logistical support from California Department of Fish and Wildlife and U.S. Fish and Wildlife Service. This project would not have been possible without the help of numerous administrative staff, wildlife biologists, biological technicians, student interns, and volunteers throughout the past 7 years. We especially thank Lisa Parker, Curtis Hettich, Zachary Lockyer, Erik Blomberg, Katie Andrle, Rebecca Kelble, John Severson, Mary Meyerpeter, Ian Dudley, Michael Chenaille, Tatiana Gettelman, Joseph Ragni, Christopher Tulimiero, Caitlan Bowman, Daniel Disbrow, Brent Cunningham, Josh Malinowski, Emmy Tyrrell, Greg Thompson, Christian Britton, Sam Malone, John Pitman, Nicole St. John, Sean Burns, Desmond Mackell, Philip Kavouriaris, Joshua Kuhn, John Pitman, Greg Thompson, Rachel Gardner, Nicole Dotson, Tam Tran, Tyler Allen, Sam Reibman, Jackie Lucchese, and Karl Reinhold. We extend gratitude to reviews of previous manuscript drafts by Mark Herzog (U.S. Geological Survey), John Tull (U.S. Fish and Wildlife Service), Steven Mathews (U.S. Geological Survey), and Tom Kimball (U.S. Geological Survey).

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# Conversion Factors

International System of Units to U.S. customary units

| Multiply | By | To obtain |
|---|---|---|
| | Length | |
| centimeter (cm) | 0.3937 | inch (in.) |
| meter (m) | 3.281 | foot (ft) |
| kilometer (km) | 0.6214 | mile (mi) |
| | Area | |
| square meter ($m^2$) | 0.0002471 | acre |
| hectare (ha) | 2.471 | acre |
| | Mass | |
| kilogram (kg) | 2.205 | pound avoirdupois (lb) |

# Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88). Elevation, as used in this report, refers to distance above the vertical datum.

# Acronyms and Abbreviations

| | |
|---|---|
| USGS | U.S. Geological Survey |
| GPS | Global Positioning System |
| VHF | very high frequency |
| PTT | platform transmitter terminal |
| CI | confidence interval |

# Greater Sage-Grouse (*Centrocercus urophasianus*) Nesting and Brood-Rearing Microhabitat in Nevada and California—Spatial Variation in Selection and Survival Patterns

By Peter S. Coates[1], Brianne E. Brussee[1], Mark A. Ricca[1], Jonathan E. Dudko[2], Brian G. Prochazka[1], Shawn P. Espinosa[3], Michael Casazza[1], and David J. Delehanty[2]

## Abstract

Greater sage-grouse (*Centrocercus urophasianus*; hereinafter, "sage-grouse") are highly dependent on sagebrush (*Artemisia* spp.) dominated vegetation communities for food and cover from predators. Although this species requires the presence of sagebrush shrubs in the overstory, it also inhabits a broad geographic distribution with significant gradients in precipitation and temperature that drive variation in sagebrush ecosystem structure and concomitant shrub understory conditions. Variability in understory conditions across the species' range may be responsible for the sometimes contradictory findings in the scientific literature describing sage-grouse habitat use and selection during important life history stages, such as nesting. To help understand the importance of this variability and to help guide management actions, we evaluated the nesting and brood-rearing microhabitat factors that influence selection and survival patterns in the Great Basin using a large dataset of microhabitat characteristics from study areas spanning northern Nevada and a portion of northeastern California from 2009 to 2016. The spatial and temporal coverage of the dataset provided a powerful opportunity to evaluate microhabitat factors important to sage-grouse reproduction, while also considering habitat variation associated with different climatic conditions and areas affected by wildfire. The summary statistics for numerous microhabitat factors, and the strength of their association with sage-grouse habitat selection and survival, are provided in this report to support decisions by land managers, policy-makers, and others with the best-available science in a timely manner.

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## Introduction

Greater sage-grouse (*Centrocercus urophasianus*; hereinafter, "sage-grouse") are sagebrush (*Artemisia* spp.) obligates, requiring sagebrush-dominated vegetation communities across all life history stages (Braun and others, 1976), including breeding, nesting, brood-rearing, and wintering. Sage-grouse distribution has contracted substantially since Euro-American settlement of Western North America (Schroeder and others, 2004), and populations within their current range have experienced declining trends in recent decades (Garton and others, 2011), largely attributed to loss of sagebrush (Connelly and others, 2004). A recent species status review by the U.S. Fish and Wildlife Service concluded that protection for the sage-grouse under the Endangered Species Act of 1973 was not warranted and, thus, the species was withdrawn from the candidate list (U.S. Fish and Wildlife Service, 2015). However, this decision followed unprecedented conservation partnerships and planning efforts by State and Federal agencies range-wide to manage for sage-grouse habitat and significantly reduce threats to the species' persistence. The Bureau of Land Management in cooperation with the U.S. Forest Service developed national planning strategies that amended all existing resource management plans within sage-grouse habitats, with an overarching goal of restoring, conserving, and enhancing sage-grouse populations and sagebrush ecosystems (Bureau of Land Management, 2015). Central to these plans are scientifically founded conservation measures for managing habitats at multiple spatial scales for sage-grouse across each of their life history stages.

Although sage-grouse generally require contiguous landscapes dominated by sagebrush shrubs (Connelly and others, 2004), populations also rely on a mosaic of different vegetation communities within sagebrush ecosystems to complete specific life-history stages (for example, nesting, late brood-rearing, and wintering). Some life stages are nearly entirely dependent on sagebrush of sufficient height and cover (for example, winter), whereas other life-history stages may require the presence of robust vertical and horizontal cover of perennial grasses and forbs in addition to sagebrush (Connelly, 2000; Hagen and others, 2007). Thus, monitoring sage-grouse behavioral and demographic responses in relation to multiple habitat factors across all life stages is often considered a valuable indicator for health of sagebrush ecosystems (Patterson, 1952; Rowland and others, 2006; Hanser and others, 2011). Because sage-grouse require multiple habitat types throughout the year and often use relatively large areas of sagebrush ecosystems, conservation and management actions that promote stable or increasing population growth rates for sage-grouse are likely to help other obligate and non-obligate sagebrush species (Hanser and others, 2011; Copeland and others, 2014).

The extensive sagebrush biome of Western North America is a composite of different ecosystems that each share the presence of sagebrush species as the dominant woody overstory. However, sagebrush ecosystem structure and function varies strongly along gradients of precipitation and temperature and corresponding ecological response to disturbances such as wildfire (West and Young, 2000; Miller and Eddleman, 2001; Chambers and others, 2014). For example, wetter and colder conditions tend to favor more perennial herbaceous vegetation and different structural architecture of sagebrush canopies that results from the degree of spreading versus columnar form of individual sagebrush shrubs. Warmer and drier conditions favor invasive annual grasses and forbs. The relative importance of environmental factors that define a species' habitat often vary across spatial scales (Johnson, 1980). For instance, sage-grouse might prefer to inhabit large contiguous patches of sagebrush-dominated vegetation at broad spatial extents (third order selection) but require a mix of various grass and forbs with shrubs at site-scale extents (fourth order selection). Accordingly, sage-grouse must make behavioral decisions to use site-scale habitat resources (hereinafter, "microhabitat") based on the local availability of those resources, which also vary significantly across different sagebrush ecosystems. Such underlying variation may be responsible for the sometimes contradictory findings in the scientific literature describing sage-grouse microhabitat use and selection during important life history stages such as nesting. For example, in sage-grouse range in North Dakota (Herman-Brunson and others, 2009), South Dakota (Kaczor and others, 2011), Wyoming (Doherty and others, 2011, 2014), southern Canada (Aldridge and Brigham, 2002), south-central Washington (Sveum and others, 1998), and Oregon (Gregg and others, 1994) grass height has been identified as important for sage-grouse nesting. Studies in other areas of sage-grouse range have found a weak effect (Holloran and others, 2005; Davis and others, 2014; Dinkins and others, 2016) or no effect of grass height (Popham and Gutierrez, 2003; Kolada and others, 2009; Lockyer and others, 2015). These inconsistencies in sage-grouse microhabitat from published reports may be a result of variability of vegetation and abiotic characteristics across the species' range and variability in how sage-grouse respond to those different characteristics.

Information on microhabitat characteristics is largely lacking in many areas of sage-grouse range, particularly in the Great Basin. Previous published guidelines (Connelly and others, 2004; Crawford and others, 2004; Hagen and others, 2007) of microhabitat indicators for sage-grouse exist and have been helpful. However, these guidelines have been limited to extrapolating findings from localized studies to other areas range-wide based on studies that disproportionally represent the northern part of sage-grouse range. Thus, using such guidelines for populations within the Great Basin or other areas that might be underrepresented may be misleading because sage-grouse responses to environment factors may vary among different biotic and abiotic conditions.

The objective of this report is to provide summary statistics of microhabitat factors that influence sage-grouse reproductive life stages across a large part of the Great Basin. To accomplish this objective, we sampled vegetation factors at sage-grouse nest sites, brood sites (day and night), and random sites (dependent and independent of used sites) in the field using telemetry methods at 16 field study areas to characterize microhabitat within different sagebrush ecosystems of the Great Basin in Nevada and California from 2009 to 2016. Although the Great Basin sagebrush landscapes are largely dominated by sagebrush shrubs, this region consists of distinct sagebrush ecosystems composed of a mosaic of different vegetation communities that vary across the region and likely elicit varying responses from sage-grouse to individual microhabitat factors such as grass and forb cover and height. Northern parts of the Great Basin typically consist of sagebrush steppe, which is relatively mesic and characterized by the co-dominance of sagebrush and caespitose bunchgrasses (West, 1983a; West and Young, 2000). Hereinafter, we term study areas with these characteristics as *mesic habitats*. Conversely, the southern parts typically consist of sagebrush semi-desert, or Great Basin sagebrush, which is relatively xeric and characterized by woody sagebrush and less herbaceous growth (West, 1983b; West and Young, 2000). Hereinafter, we term study areas with these characteristics as *xeric habitats*. For the purposes of this study, we refer to *site* as the point and immediately surrounding areas of sage-grouse locations where microhabitat factors were measured at relatively small spatial scales. We investigated differences in the relative importance of microhabitat factors that influence reproductive stages of sage-grouse across study areas characterized as mesic or xeric habitats.

Wildfire is a common disturbance for which effects on ecosystem processes vary spatiotemporally (Bowman, 2009) and influence thresholds that govern shifts to alternative ecological states post-disturbance (Suding and others, 2004; Standish and others, 2014). In sagebrush ecosystems, invasion by non-native species following wildfire often promotes strong feedback that drives ecosystems further from their original states (Chambers and others, 2014). For example, nearly all subspecies of big sagebrush (*A. tridentata*) have slow growth rates and do not re-sprout following wildfire. Hence, wildfire kills sagebrush shrubs and results in invasive grasses, particularly cheatgrass (*Bromus tectorum*), that dominate burned landscapes and facilitates the spread of subsequent wildfire to nearby sagebrush stands that would otherwise be less prone to burning (Brooks and others, 2004; Balch and others, 2013). Thus, we considered differences in relative importance of microhabitat factors across our field study areas affected and unaffected by wildfire within mesic and xeric habitats.

Herein, we provide summary statistics regarding numerous microhabitat factors that influence site selection and success of nests and broods specifically to meet timely and best-available science needs for land managers and policy-makers. Current information in the literature is sparse and the summary statistics reported here are uniquely suited to fill this important information gap in a timely manner. The findings reported here are meant to provide land and resource managers with an initial understanding of the relative importance of habitat variability, and provide a foundational framework for deriving habitat quality categories. Future research will use a rigorous modeling approach to further investigate potential complex relationships between biotic and abiotic microhabitat characteristics and incorporate other environmental factors that function at larger spatial extents.

## Study Areas

Microhabitat data were collected from 2009 to 2016 within 16 field study areas located in Nevada and northeastern California, within the Great Basin (fig. 1). These study areas spanned Nevada's western border with California to Nevada's eastern border with Utah, immediately north and south of Ely, Nevada. Study areas were distributed across a large part of the Great Basin and were thought to provide appropriate representation for estimating sage-grouse microhabitats during sage-grouse reproductive stages. The widespread distribution of these areas (fig. 1) allowed for an examination of variation in microhabitat factors across different bioclimatic environments. The northwestern areas represented sagebrush steppe ecosystems and received relatively more precipitation. The south central areas represented sagebrush desert ecosystems and were typically drier with warmer soil types. The southwestern areas were at relatively higher elevations on the boundary of California and Nevada and were more similar to the northwestern areas with relatively high precipitation and wetter and cooler soil types.

We calculated precipitation based on 30-year averages for each study area generated from spatially explicit precipitation data from the PRISM Climate Group (Daly and others, 2008). Study area boundaries were calculated using minimum convex polygons using all telemetry data. For the purpose of our analyses, areas that received less than the average annual precipitation (average, 35.0 centimeters [cm]; range, 24.9–47.7 cm) were considered xeric sagebrush habitats ($n$=6). Study areas with greater than or equal to 35.0 cm (averaged annual) of annual precipitation were considered mesic ($n$=10). Using 35.0 cm as the cutoff was appropriate because the location of xeric versus mesic habitats aligned with the hydrographic delineation for seasonal habitat mapping in Coates, Casazza, and others (2016).

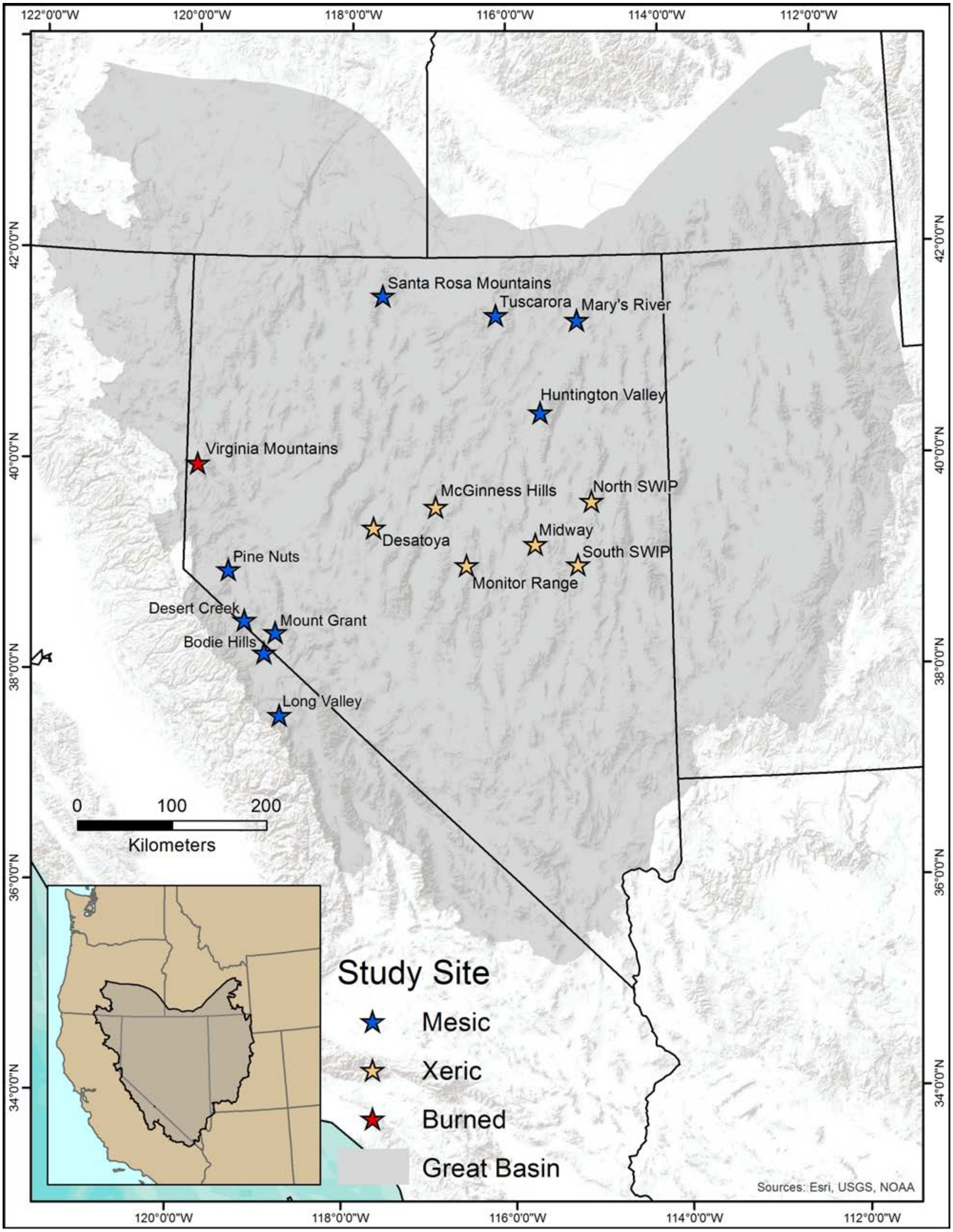


Figure 1. Map showing study sites for greater sage-grouse (*Centrocercus urophasianus*) microhabitat data collection within the Great Basin of Western United States.

Northern study areas within the Great Basin typically consisted of sagebrush steppe (West, 1983a; West and Young, 2000) and tended to have more cool and moist soils than those found in xeric Great Basin sagebrush (West, 1983b; West and Young, 2000) within southerly parts of the Great Basin. Sage-grouse populations in the southwestern parts of their range (that is, Bi-State area) that fell outside of the mapped hydrographic regions were assigned to the mesic group based on annual precipitation values that were similar to most northern hydrographic regions, although they typically occurred at higher elevations. Overall, these groupings allowed partitioning of factors influencing sage-grouse microhabitat selection across mesic and xeric sagebrush ecosystems. Just as these two types of ecosystems respond differently to perturbations (West 1983b), biotic and abiotic variation may contribute to varied habitat interactions within a species across ecotones. For sage-grouse, this could be expressed as variation in responses to similar environmental characteristics across different sagebrush communities.

Generally, each study area was dominated by species of big and little sagebrush, with a heterogeneous mixture of saltbrush species at low elevations that included greasewood (*Sarcobatus baileyi*), horsebrush (*Tetradymia* spp.), and rabbitbrush (*Chrysothamnus* and *Ericameria* spp.). High elevations consisted of mountain shrub-steppe communities that included big and little sagebrush as well as ephedra (*Ephedra* spp.), serviceberry (*Amelanchier* spp.), snowberry (*Symphoricarpos* spp.), and antelope bitterbrush (*Purshia tridentata*). Non-woody plants included grasses such as basin wildrye (*Leymus cinereus*) and Idaho fescue (*Festuca idahoensis*), and forbs such as balsamroot (*Balsamorhiza* spp.) and lupine (*Lupinus* spp.). The mesic habitats tended to have more herbaceous growth and the xeric included more bare ground. Stands of pinyon-juniper woodlands consisting of singleleaf pinyon (*Pinus monophylla*) and Utah juniper (*Juniperus* spp.) were found in varying densities across the different study areas, as were patches of invasive cheatgrass. All areas were topographically diverse with a heterogeneous mixture of landscape features. The elevations among study areas ranged from 1,158 to 3,770 m.

Wildfire profoundly alters habitat availability to sage-grouse because it kills sagebrush and promotes invasion of annual grasses, and is ubiquitous across the Great Basin (Brooks and others, 2015; Coates and others, 2016). Hence, we separately analyzed a mesic study area that was impacted by frequent wildfire over the past 2 decades (Virginia Mountains, fig. 1), allowing us to investigate microhabitat relationships within a fire-impacted area for comparison with areas unburned or only lightly impacted by more localized and less frequent fires. The largest wildfire to occur at the fire-impacted area, known as the “Fish Fire,” was 19,288-hectares (ha) during 1999. Recurring fires at this study area have reduced shrub abundance and have increased the presence of cheatgrass within burned areas. Rehabilitation efforts by aerial reseeding occurred post-fire in February 2000 on approximately 12,626 ha. Seed mixes primarily consisted of various wheatgrasses (*Agropyron* spp.), smooth brome (*Bromusinermis*), basin wildrye, Idaho fescue (*Festuca idahoensis*), alfalfa (*Medicago sativa*), fourwing saltbush (*Atriplex canescens*), big sagebrush, and antelope bitterbrush. A detailed description of dominant shrub and understory species for this study area was described in Coates and others (2011) and Lockyer and others (2015).

# Study Methods

## Capture and Handling

We captured and handled female sage-grouse in accordance with WERC Animal Care and Use Protocol WERC-2015-02. For each study year, sage-grouse were captured during the spring (March–May), summer (June–July), and autumn (August–October). Sage-grouse were located between sunset and sunrise with spotlights and were captured with long-handled nets or hand-held net launching devices (SuperTalon®, Advanced Weapons Technology, La Quinta, California). We equipped captured sage-grouse with battery powered, necklace-style very high frequency (VHF) transmitters (<3 percent body mass; Advanced Telemetry Systems, Isanti, Minnesota) that included built-in mortality sensors. From 2012 to 2016, a randomly chosen subsample of sage-grouse were outfitted with a GPS-PTT (<3 percent body mass; North Star Science and Technology, LLC, King George, Virginia) and an ancillary VHF transmitter attached to the PTT device. The purpose of the GPS transmitter was to collect high-resolution data (10–12 positions per day) remotely and transmit these positions (using PTT) to a central database by Argos satellites. The attached VHF transmitter allowed us to relocate sage-grouse in the field to monitor survival and microhabitat use among life-stages and to facilitate retrieval of GPS-PTT devices following mortalities or equipment failures.

## Monitoring Sage-Grouse

### Radio and Global Positioning System-Telemetry

For the purposes of these analyses, we conducted intensive on-the-ground monitoring of sage-grouse movement, survivorship, and reproduction following release of marked birds throughout the year. All telemetry procedures were conducted according to the USGS sage-grouse telemetry protocol (U.S. Geological Survey, 2015) for VHF transmitters. A three-element Yagi antenna (Advanced Telemetry Systems, Inc., Isanti, Minnesota) and portable receiver (Communications Specialists, Inc., Orange, California) were used to track radio-marked sage-grouse during the nesting season. Location error was minimized by circling each grouse at a radius of 30–50 m. After the position of the grouse being tracked was estimated, the grouse's distance from the observer was approximated and the azimuth was recorded from the observer's position (using GPS) to predict the exact position coordinates (Universal Transverse Mercator) of the sage-grouse. Throughout the nesting season (March–May), attempts were made to locate both VHF- and GPS-marked female sage-grouse at least twice per week. Nesting females were relocated two or more times per week (see "Nest Site Selection and Success"), and non-nesting or brood-rearing positions were obtained at approximately weekly intervals to monitor seasonal movements through August. Aerial fixed-wing telemetry flights were conducted to locate sage-grouse that could not otherwise be located from the ground.

### Nest Site Selection and Success

We identified nest sites for radio- and GPS-marked sage-grouse according to USGS-established protocols (U.S. Geological Survey, 2015). Specifically, we verified nests visually after females were found in the same position on two consecutive observations (Coates and Delehanty, 2010), but we avoided flushing grouse to prevent observer-induced abandonment. Female status (that is, alive or dead, on or off nests) during subsequent visitations was assessed from a 50-m distance using radio-telemetry to further prevent flushing grouse away from nests. Each nest was monitored two times or more per week until nest fate (hatch, fail, or nest abandonment) was determined. We visually inspected each nest to assess nest fate after we were certain that a female had left its nest (Rearden, 1951). Nests were considered successful if one or more chicks hatched, as determined by visual assessment of eggshell remains or observing one or more chicks in the nest bowl (Coates and Delehanty, 2010). Nests were considered unsuccessful when the entire clutch failed to hatch. Failed nests were scored as depredated, partially depredated (one or more intact eggs), or abandoned (all eggs left intact and unattended by female for greater than 72 hours).

We closely followed USGS protocol for measuring nest microhabitat factors in the field (U.S. Geological Survey, 2015). Horizontal and vertical cover at the nest bowl were recorded using a cover board technique (modified from Jones, 1968). Measurements were collected 2 m from the board at 0-, 45-, and 90-degree (°) angles. Board direction from the nest bowl was assigned randomly for the first set of measurements, and a total of three measurement sets were collected, with each separated by a 120° rotation of the cover board. Horizontal cover was measured using the 0 and 45° angle measurements (Jones, 1968; Ritchie and others, 1994). Vertical cover was measured using the 90° measurement. Herbaceous understory vegetation cover also was measured at multiple subplots (20×50 cm) less than or equal to 25 m from each nest using the Daubenmire method (Daubenmire, 1959), where cover class 1=0–5 percent cover, 2=6–15 percent, 3=16–25 percent, 4=26–50 percent, 5=51–75 percent, 6=76–95 percent, and 7=96–100 percent. Understory cover was grouped into: perennial grass, annual grass, perennial forb, annual forb, residual vegetation, litter, bare ground, and rock. Droop heights of all understory vegetation were also measured and included perennial grass, annual grass, perennial forb, annual forb, and residual grass. Perennial grass and forbs represented new growth, whereas we considered grass that remained rooted from previous growing season but desiccated to be residual. Overstory canopy cover was measured using the line-intercept method (Canfield, 1941), along four (during 2009–13) and three (during 2014–16) 25-m transects extending from the nest bowl at equally spaced angles with random direction. Shrub cover measurements were recorded and quantified within 5, 10, and 25 m from the nest for all transects, which corresponded to 0.007, 0.031, 0.020 ha spatial scales, respectively. This allowed comparison between these three spatial scales centered on the nest. Percent shrub cover was recorded and quantified by groups of tall sagebrush (big sagebrush species), dwarf sagebrush (little sagebrush and black sagebrush species), and non-sagebrush shrubs (included montane and lowland shrub types). Heights of shrubs were also collected along the intercept line and recorded. Biotic (vegetation) and abiotic (rock) features directly over the nest were recorded. If the feature was vegetation, then the species was identified and recorded. If the species was a type of shrub, then we recorded crown width (cm) and height (cm).

We conducted a microhabitat survey at a random site centered at the nearest shrub for every microhabitat survey conducted at a used site using the exact same methodology as conducted at used sites. Random sites were generated throughout each study area, with study area boundaries formed by the minimum convex polygon surrounding measured sage-grouse space use based on telemetry positions of grouse at the population level. The purpose of the random surveys was to characterize availability at the population level of each microhabitat factor within the site. Comparison in measurements for each factor between used and available sites allowed for inferences regarding habitat selection (defined as disproportionate use to availability; Manly and others, 2007). Specifically, we assessed overlap in the limits of the 95 and 85 percent confidence intervals (hereinafter, "CIs") around mean estimates for factors measured at used versus available sites. We further investigated differences in each microhabitat variable between successful nests and failed nests using a similar evaluation of means and CIs.

Although microhabitat surveys were conducted near predicted hatch date, we followed a modified date-adjustment recommendation by Gibson, Blomberg, and Sedinger (2016) to further prevent plant phenology (Hausleitner and others, 2005) from confounding differences between successful and failed nests. Specifically, we adjusted measurements of heights and cover for herbaceous vegetation (that is, perennial grass, annual grass, and perennial forb, annual forb) for both xeric and mesic habitats using a multiple step method. First, for each herbaceous vegetation type, we fit linear mixed effects models, where the response variable was the measurement at used sites and the fixed effect was ordinal date. We also inspected the data for non-linear relationships, but these were not well-supported. To account for interannual and spatial variation in our observations, we fit random effects to year and site for all models. The slope coefficients of these linear mixed-effects models provided an estimated growth rate for each microhabitat variable within xeric and mesic habitats. Second, we evaluated support for changes in growth rate for each microhabitat factor by evaluating 95-percent CIs of the slope coefficient. If the interval overlapped zero, then growth rate was not considered different from zero. Third, for all factors with evidenced growth rates (CI did not overlap zero) we used the estimated coefficient to adjust the vegetation measurement to predicted hatch date for success and fail analyses. Lastly, we report the average date-corrected measurements and variance for successful and failed nests, whereby plant phenology should not confound differences between successful and unsuccessful nests.

We report averages and standard errors (SE) for each microhabitat variable at used and random sites across xeric, mesic, and burned habitats. More detailed summary statistics are available in Coates and others (2017). Used values that were greater than available values were considered selected by sage-grouse, whereas used values less than available values were considered avoided. For the purposes of this report, we considered marginal evidence for differences between used and available where no overlap was found at the 85-percent CI and strong evidence where no overlap occurred at the 95-percent CI. We report mean, standard error, standard deviation, quartiles, and coefficient of variation among all variables. For those factors that required date-adjustment to account for phenology, estimates were adjusted to a mean peak nesting date (greatest frequency of females incubating) of May 8. For investigation of potential confounding factors, we report variables with evidence of correlation ($R > |0.65|$). These results provide valuable information regarding factors explaining selection and survival but should be interpreted with caution. A robust modeling approach is underway and outcomes might be modified.

### Brood Site Selection and Success

Following the completion of a successful nest, brood-rearing females were located and broods were counted every 10 days until the brood reached 50 days post-hatch. Each day position was immediately followed by a night position (within the 24-hour period) using night-lighting techniques at roost locations. We sought to prevent flushing broods when conducting chick surveys. If no chicks were counted, we scored the brood as unsuccessful. To confirm unsuccessful broods and to prevent false negative values, an additional search for chicks was conducted within 24–48 hours of initially finding females without broods. A brood was considered successful if one or more chicks survived to 50 days post-hatch, modified from Casazza and others (2011). At the 50-day period, broods were flushed to obtain a final count of chicks.

Microhabitat surveys were completed at each brood site every 10 days. Surveys were conducted at day, night, and random sites. To accurately relocate a site where a brood was observed, the telemetry point was recorded by GPS, and a bearing and distance or photograph was taken from the telemetry point. Habitat methodology carried out at brood sites was similar to that of nest sites. Vegetation measurements were taken every 10 days from the first day after estimated actual hatch date (that is, midpoint between last known date female was observed on nest and date of observed hatch) and carried out for 50 days to evaluate vegetation change in relation to brood positions through time. Differences in habitat use between night (roosting) and day (foraging) sites were also evaluated. To characterize available habitat, the same habitat measurements were conducted at dependent random sites from 50 to 850 m of each day position. Independent sites were not generated for broods because these areas arguably are not accessible to broods because of limitations in movement of the flightless chicks.

Sage-grouse require specific vegetation components during brood-rearing that are functionally different than those required for nesting. When the two habitats are not overlapping females must move their broods in order to meet the requirements of this later reproductive life stage. Vegetation characteristics used during this transitional period (defined as 20 days following hatch) were classified as early brood-rearing habitat, whereas those used from 21 to 51 days post hatch were classified as late brood-rearing habitat. We report differences in means among day, night, and random sites separately for early and late brood-rearing measurements, and compare overlap between 85- and 95-percent CIs. More detailed summary statistics are available in Coates and others (2017). As with nesting habitat measurements, we again considered evidence to be marginal for differences in cases of no overlap between 85-percent CI and evidence to be substantial for no overlap in 95-percent CIs. We also used the same criteria for comparing differences among used day to used night sites. We further investigated differences in each microhabitat variable between successful broods and failed broods in a similar manner. The same evaluations of means and CIs were conducted to identify factors that were important to brood success. We report mean, standard deviation, quartiles, and coefficient of variation among all variables. We report variables with evidence of correlation ($R > |0.65|$). We also calculated Euclidean distance between day use and night use sites among xeric, mesic, and burned habitats.

### Example of Management Application

We report an example of microhabitat quality categories for each life stage separately by xeric and mesic habitats to illustrate how the summary statistics might be used to help guide actions and decisions for land and wildlife managers. We designated the categories (unsuitable, marginal, and suitable) for vegetation factors that revealed evidence of influencing selection or nest success. Because this example is intended to help guide management-related decisions, we only developed categories for those microhabitat factors, such as vegetation, that could be manipulated with management actions (for example, grass cover as opposed to rock cover). We demarcated the three categories by two cutpoints based on information collected from the used sites for each influential microhabitat factor. However, the criteria for demarcation was slightly different for factors that influenced selection compared to those with evidence of selection coupled with success. For factors that were found to influence selection only (not success), we assigned all values greater than the mean of used sites as suitable and values less than the 25th percentile of the distribution of used sites were scored as unsuitable. All values that fell between these two cutpoints were designated as marginal. We chose the mean value to demarcate suitability to remain consistent with similar criteria for classifying habitat in other published guidelines (Connelly and others, 2000). We chose the 25th percentile as cutpoint between unsuitable and marginal because we recognize that individual variation occurs among sage-grouse and we assumed some individuals were likely to make unusual behavioral decisions and occupy habitat that would normally not be selected.

Because additional information was available for microhabitat factors evidenced to influence success as well as selection, for this subset of factors we chose a different criterion for demarcation between unsuitable and marginal. In these cases, values less than the mean of failed nests (or broods) were considered unsuitable (instead of 25th percentile). This allowed us to incorporate the demographic consequences of using unsuitable conditions.

For microhabitat factors that were avoided by sage-grouse, we assigned all values greater than the 75th percentile as unsuitable. We chose this cut-point using a similar rationale as stated in previous sentence for variables that were selected. That is, variation exists and some individuals were likely to make unusual behavioral decisions and occupy sites that would likely be avoided. Microhabitat was considered suitable when values were less than the mean and values between the mean and 75th percentile were interpreted as marginal microhabitat. Similar, if the avoided factor negatively influenced success, then more information was available to inform the unsuitable cutpoint and we used the mean of failed nests (or broods) to demarcate marginal from unsuitable. Although most variables exhibited close to normal distributions, if the distribution was considered highly skewed (that is, for our purposes the 75th percentile was less than the mean value) and the variable influenced selection only, then we chose the mean as the upper cutpoint between marginal and unsuitable habitat. In these cases, less than the 50th percentile was chosen to demarcate marginal from suitable values.

We provide example tables for nesting and late brood-rearing. For brood-rearing, we present values based on day location effects. We did not provide an example table for early brood-rearing because data collected during this period likely reflects transitional microhabitat use between factors required for nests versus those for chicks. Nonetheless, if habitat quality categories specific to early brood-rearing are needed by wildlife and land adminstrators for management purposes, then the values provided here could readily be applied using similar criteria.

## Greater Sage-Grouse Microhabitat Findings

### Nest Site Selection and Success

We located 703 nests (*n*=322, xeric-unburned; *n*=232, mesic-unburned; *n*=149, mesic-burned) for this analysis from 2009 to 2016 (table 1). Of the nests that were sampled in areas unaffected by wildfires, nearly all were collected from 2012 to 2016. For all habitat types, the number of sampled nests increased progressively through the years. We removed re-nests to prevent biases associated with plant phenology, and we also removed abandoned nests that otherwise may confound interpretation of microhabitat relationships in relation to predation as the source of nest failure. Following these removals, the sample consisted of 662 independent nests. All nests consisted of some type of biotic (that is, vegetation) or abiotic (for example, rock overhang) cover directly above the nest. We found that the type of overhead cover associated with nests varied by mesic and xeric habitats, and most substantially by whether or not the site was affected by wildfires (fig. 2). The majority (72.0 percent) of sage-grouse nested under sagebrush species (predominantly, *A. t. wyomingensis, A. t. tridentata, A. t. vaseyana, A. arbuscula, A. nova).* The second most commonly used overhead cover was non-sagebrush shrub (20.5 percent; mostly *Ericameria nauseosa, Chrysothamnus viscidiflorus, Purshia tridentata, Symphoricarpos* spp.). Other cover types that were used rarely consisted of trees (3.3 percent; mostly *Pinus edulis* and *Juniperus* spp.), perennial bunch grass (2.7 percent; mostly *Leymus cinereus*), and rock overhang (0.8 percent). Of the 703 nests, 328 were successful (*n*=156, xeric; *n*=104, mesic; *n*=68, burned) and 364 failed (*n*=163, xeric; *n*=128, mesic; *n*=73, burned), and 11 were of unknown fate (*n*=3, xeric; *n*=8, burned). We found that vegetation types with the greatest proportion of failed nests were perennial bunch grass (15 failures of 19 nests, 78.9 percent failed) and lowland non-sagebrush shrub (49 failures of 83 nests, 59.0 percent failed), both of which had the highest use and availability at the burned site (fig. 2).

**Table 1.** Sample size of nests and broods (late period) of greater sage-grouse (*Centrocercus urophasianus*) in areas unaffected and affected by wildfire areas across xeric and mesic sites by year in the Great Basin, Nevada and California, 2009–16.

| Stage | Year | Unburned | | Burned | Total |
|---|---|---|---|---|---|
| | | Xeric | Mesic | | |
| Nests | 2009 | 0 | 0 | 18 | 18 |
| | 2010 | 0 | 0 | 20 | 20 |
| | 2011 | 0 | 3 | 33 | 36 |
| | 2012 | 12 | 39 | 11 | 62 |
| | 2013 | 62 | 35 | 16 | 113 |
| | 2014 | 74 | 31 | 12 | 117 |
| | 2015 | 73 | 29 | 24 | 126 |
| | 2016 | 101 | 95 | 15 | 211 |
| | Total | 322 | 232 | 149 | 703 |
| Broods | 2009 | 0 | 0 | 4 | 4 |
| | 2010 | 0 | 0 | 6 | 6 |
| | 2011 | 0 | 2 | 18 | 20 |
| | 2012 | 2 | 13 | 8 | 23 |
| | 2013 | 26 | 20 | 6 | 52 |
| | 2014 | 32 | 9 | 5 | 46 |
| | 2015 | 15 | 15 | 10 | 40 |
| | 2016 | 37 | 37 | 5 | 79 |
| | Total | 112 | 96 | 62 | 270 |

Specific microhabitat factors were supported by these data for influencing nest selection and nest success across xeric and mesic habitats (tables 2–4). Two factors that garnered the most support across all habitat types were horizontal and vertical cover directly at the nest site (table 2). We detected strong differences in horizontal cover between availability (67.4 ±1.1 percent, xeric; 66.6 ±1.6 percent, mesic) and used (82.3 ± 0.8 percent, xeric; 83.8 ± 0.8 percent, mesic) across both climatic regions (appendix 1). Horizontal cover was positively associated with nest success. For example, successful nests consisted of greater horizontal cover (84.2 ±1.1 percent, xeric; 86.3 ±1.2 percent, mesic) than failed nests (79.9 ±1.1 percent, xeric; 81.1 ± 1.2 percent, mesic; appendix 2). This variable also demonstrated the least amount of variability relative to its mean compared to all other variables (CV=15.7, xeric; CV=14.5, mesic; tables 3 and 4). Although vertical cover tended to be less than horizontal cover at both sites, similar patterns of selection and success were observed (58.7 ±1.8 percent, xeric-available versus 72.7 ±1.5 percent, xeric-used; 59.2 ±2.4 percent, mesic-available versus 74.4 ±1.8 percent, mesic-used; 75.0 ±2.1 percent, xeric-success versus 69.7 ±2.2 percent, xeric-failed; 77.0 ±2.5 percent, mesic-success versus 71.2 ±2.7 percent, mesic-failed). Within the burned study area, cover was less at both types of sites, available (72.4 ±1.4 percent, horizontal; 52.9 ±2.5 percent, vertical) and used (79.0 ±1.2 percent, horizontal; 62.7 ±2.6 percent, vertical), than those sites unaffected by wildfire (appendix 3). Additionally, we found similar associations between cover and survival, in that successful nests (83.1 ±1.6 percent, horizontal; 69.1 ±3.6 percent, vertical) were associated with greater cover than failed nests (74.8 ±1.9 percent, horizontal; 58.3 ±4.2 percent, vertical; appendix 4).

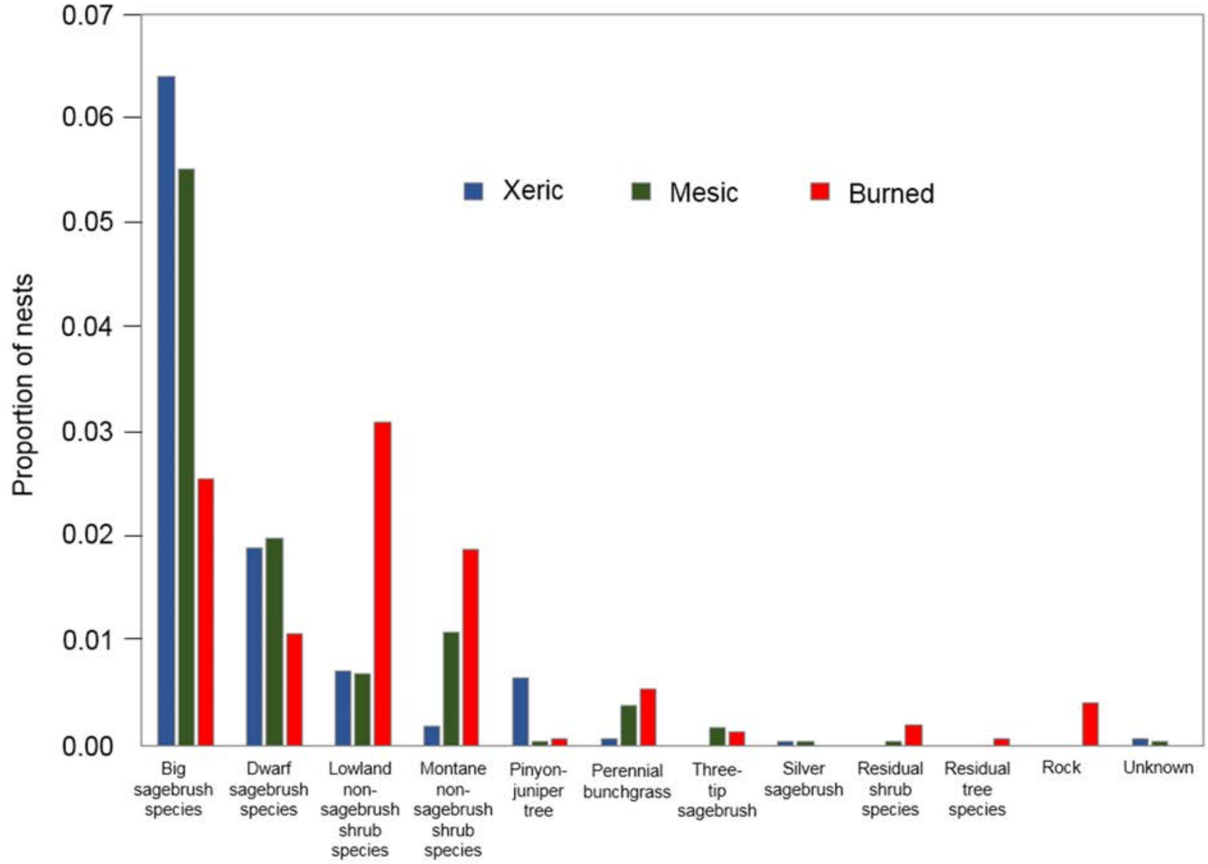


Figure 2. Proportion of greater sage-grouse (*Centrocercus urophasianus*) nests located under different types overhead canopy at 16 study areas within the Great Basin, California and Nevada, 2009–16.

**Table 2.** Influential microhabitat factors for nesting greater sage-grouse (*Centrocercus urophasianus*) within xeric and mesic habitats unaffected by wildfire in the Great Basin, Nevada and California, 2009–2016.

[**Bold** represents influences on selection and survival of nests and non-bold was selection only. Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| | Xeric | | | | Mesic | | | |
|---|---|---|---|---|---|---|---|---|
| Variable | Selection | | Survival | | Selection | | Survival | |
| **Horizontal cover** | ** | **Select** | ** | **Positive** | ** | **Select** | ** | **Positive** |
| Vertical cover | ** | Select | | | ** | Select | | |
| Maximum height (cm) | * | Select | | | * | Select | | |
| **Perpendicular width (cm)** | ** | **Select** | * | **Positive** | ** | **Select** | | |
| **Perennial grass height** | ** | **Select** | ** | **Positive** | * | **Select** | | |
| Perennial forb height | ** | Select | | | | | | |
| Residual grass height | ** | Select | | | ** | Select | | |
| Sagebrush height | ** | Select | | | ** | Select | | |
| **Non-sagebrush height** | * | **Select** | * | **Positive** | | | | |
| **Tall sagebrush cover** | ** | **Select** | | | ** | **Select** | * | **Positive** |
| Dwarf sagebrush cover | | | | | ** | Select | | |
| **Total sagebrush cover** | ** | **Select** | | | ** | **Select** | * | **Positive** |
| Non-sagebrush shrub cover | | | | | | | * | Positive |
| **Total shrub cover** | ** | **Select** | | | ** | **Select** | * | **Positive** |
| Bare ground cover | ** | Avoid | | | * | Avoid | | |
| Perennial grass cover | ** | Select | | | | | | |
| **Perennial forb cover** | * | **Select** | * | **Positive** | | | | |
| Annual forb cover | | | | | * | Avoid | | |
| Litter cover | * | Select | | | | | | |

**Table 3.** Summary statistics for microhabitat factors evaluated for used sites of nesting greater sage-grouse (*Centrocercus urophasianus*) within xeric habitats unaffected by wildfire in the Great Basin, Nevada and California, 2009–16.

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). **Bold** denotes most influential variable and spatial scale on nest site selection (used versus available) and/or success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | **NB** | **82.3** | **13** | **75.3** | **84.7** | **92.7** | **15.7** |
| Vertical cover (%) | **NB** | **72.7** | **25.9** | **56** | **80** | **96** | **35.6** |
| Maximum height (cm) | **NB** | **72.8** | **33.9** | **53** | **65** | **80** | **47** |
| Average height (cm) | NB | 43.7 | 13.7 | 33.4 | 41.6 | 51.8 | 32.9 |
| Perpendicular width (cm) | **NB** | **92.5** | **50.9** | **65** | **84** | **109** | **56.7** |
| Sagebrush height (cm) | NB | 59.9 | 25.8 | 47 | 60 | 75 | 43 |
| | **0.03** | **43.2** | **19** | **30** | **42** | **57** | **44** |
| | 0.20 | 40 | 17 | 27.9 | 38.6 | 51.4 | 42.4 |
| Non-sagebrush height (cm) | NB | 23.9 | 31.7 | 0 | 16.5 | 40 | 132.7 |
| | 0.03 | 20.8 | 20.1 | 6.5 | 17 | 31.3 | 96.9 |
| | 0.20 | 21.1 | 18.6 | 9.3 | 16.6 | 28.6 | 88.1 |
| Perennial grass height (cm)[1] | NB | 12.2 | 12.9 | 3.7 | 10.1 | 17.2 | 105.6 |
| | 0.03 | 12.1 | 8 | 6.8 | 10.6 | 15.7 | 66.6 |
| | **0.20** | **12.1** | **7.6** | **6.8** | **10.6** | **15.7** | **63.1** |
| Perennial forb height (cm)[1] | **NB** | **5.5** | **9.4** | **0** | **1.3** | **7.4** | **170.1** |
| | 0.03 | 5.5 | 6.2 | 0.9 | 3.9 | 8.3 | 114.3 |
| | 0.20 | 5.1 | 5.5 | 1.2 | 3.6 | 7.8 | 106.9 |
| Residual grass height (cm) | NB | 7.7 | 11.1 | 2 | 4 | 9 | 144.7 |
| | 0.03 | 7.4 | 7.2 | 3 | 5.3 | 9 | 97.7 |
| | **0.20** | **7.5** | **6.4** | **3.4** | **5.3** | **9.6** | **84.4** |
| Perennial grass cover (%) | 0.03 | 7.1 | 7.6 | 2.5 | 4.5 | 8.5 | 107.2 |
| | **0.20** | **6.8** | **6.2** | **2.5** | **5.2** | **8.5** | **91.8** |
| Annual grass cover (%) | 0.03 | 4.8 | 7.1 | 2.5 | 2.5 | 2.5 | 149.2 |
| | 0.20 | 4.9 | 6.6 | 2.5 | 2.5 | 3.8 | 134.7 |
| Perennial forb cover (%)[1] | **0.03** | **4.9** | **5.9** | **2.1** | **3** | **5.7** | **120.4** |
| | 0.20 | 4.8 | 4.5 | 2.2 | 3.3 | 5.7 | 94.1 |
| Annual forb cover (%) | 0.03 | 3.5 | 3.1 | 2.5 | 2.5 | 2.5 | 88.5 |
| | 0.20 | 3.5 | 3 | 2.5 | 2.5 | 2.5 | 86 |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Residual vegetation cover (%) | 0.03 | 8.5 | 8 | 2.5 | 5.2 | 11.2 | 93.8 |
| | 0.20 | 8.7 | 6.9 | 3.8 | 6.5 | 11.4 | 79.2 |
| Litter cover (%) | **0.03** | **24.2** | **23.6** | **5.2** | **15.5** | **34.5** | **97.6** |
| | 0.20 | 23.5 | 21.1 | 8.2 | 16.7 | 32.2 | 90 |
| Bare ground cover (%) | 0.03 | 43.8 | 27 | 20.3 | 43 | 64.7 | 61.7 |
| | **0.20** | **44.2** | **24.3** | **24.9** | **46.1** | **63.9** | **55** |
| Rock cover (%) | 0.03 | 9.7 | 14 | 2.5 | 2.5 | 8.5 | 145.1 |
| | 0.20 | 10.2 | 13.9 | 2.5 | 3.5 | 11.3 | 136.4 |
| Tall sagebrush cover (%) | **0.01** | **14.9** | **15.3** | **0** | **13.5** | **24.1** | **102.3** |
| | 0.03 | 13.9 | 13.8 | 0 | 11.9 | 22.1 | 99.5 |
| | 0.20 | 12.2 | 12 | 1.3 | 9.6 | 19.3 | 99.1 |
| Dwarf sagebrush cover (%) | 0.01 | 7.7 | 10.3 | 0 | 1 | 13.9 | 133.4 |
| | 0.03 | 7.8 | 9.7 | 0 | 2.2 | 15.3 | 124.2 |
| | 0.20 | 8.2 | 9.3 | 0 | 3.8 | 15.7 | 112.9 |
| Total sagebrush cover (%) | 0.01 | 22.8 | 12.9 | 14.1 | 22 | 30.5 | 56.4 |
| | 0.03 | 21.8 | 11.3 | 14.6 | 21.5 | 27.9 | 51.9 |
| | **0.20** | **20.4** | **10** | **14.1** | **20.2** | **26.1** | **49.2** |
| Non-sagebrush shrub cover (%) | 0.01 | 5 | 9.2 | 0 | 1.8 | 5.5 | 184.3 |
| | 0.03 | 5.3 | 8.7 | 0.5 | 2.6 | 6.1 | 165 |
| | 0.20 | 5.1 | 8.2 | 0.9 | 2.5 | 5.3 | 162.2 |
| Total shrub cover (%) | **0.01** | **27.8** | **15** | **18.7** | **26.6** | **35.1** | **53.9** |
| | 0.03 | 27.1 | 14 | 17.4 | 26 | 33.8 | 51.7 |
| | 0.20 | 25.5 | 13.1 | 17.2 | 24 | 31.6 | 51.2 |

[1]Denotes variables that have been date adjusted to mean peak nesting date (May 8) to account for plant phenology (see section, "Study Methods").

**Table 4.** Summary statistics for microhabitat factors evaluated for used sites of nesting greater sage-grouse (*Centrocercus urophasianus*) within mesic habitats unaffected by wildfire in the Great Basin, Nevada and California, 2009–16.

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). **Bold** denotes influential variable and spatial scale on nest site selection (used versus available) and/or success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | **NB** | **83.8** | **12.2** | **77.8** | **86.7** | **92.8** | **14.5** |
| Vertical cover (%) | **NB** | **74.4** | **25.8** | **60** | **84** | **96** | **34.7** |
| Average height (cm) | NB | 50.5 | 19.8 | 32.4 | 50.1 | 61 | 41.2 |
| Greatest width (cm) | **NB** | **128.7** | **51.3** | **90** | **123.5** | **156** | **40.7** |
| Perpendicular width (cm) | **NB** | **96.3** | **40.1** | **68** | **89** | **119** | **42.9** |
| Sagebrush height (cm) | **NB** | **59.1** | **34.6** | **40** | **56** | **78** | **58.6** |
| | 0.03 | 44.3 | 24.8 | 29 | 41 | 59.3 | 56.1 |
| | 0.20 | 41.2 | 21.6 | 27 | 36.6 | 55.3 | 52.6 |
| Non-sagebrush height (cm) | **NB** | **37** | **38.4** | **0** | **28** | **71** | **103.9** |
| | 0.03 | 32 | 26.5 | 9 | 30.8 | 47 | 83 |
| | 0.20 | 30.9 | 23.7 | 10.7 | 28.5 | 43.1 | 76.7 |
| Perennial grass height (cm)[1] | NB | 18.6 | 18.5 | 7.5 | 13.4 | 26.1 | 99.7 |
| | **0.03** | **17.8** | **11.7** | **9.9** | **15.5** | **23.8** | **65.4** |
| | 0.20 | 17.4 | 9.6 | 11.9 | 16.4 | 21.9 | 55.4 |
| Perennial forb height (cm)[1] | NB | 7.6 | 9.2 | 1.4 | 5.7 | 11.2 | 122.3 |
| | 0.03 | 8.3 | 7.1 | 3.9 | 7.4 | 11.5 | 86.3 |
| | 0.20 | 8.2 | 6.9 | 4.4 | 7.3 | 11.8 | 84.1 |
| Residual grass height (cm) | NB | 15.3 | 20.8 | 4 | 8 | 18 | 135.6 |
| | 0.03 | 12.7 | 11.3 | 5.8 | 9.6 | 16.3 | 89.3 |
| | **0.20** | **12.5** | **9.7** | **6.3** | **10** | **15.3** | **78** |
| Perennial grass cover (%) | 0.03 | 12.8 | 10.9 | 5.2 | 10.5 | 17.2 | 85.5 |
| | 0.20 | 12.8 | 9.5 | 6.5 | 10.5 | 17.9 | 73.8 |
| Annual grass cover (%) | 0.03 | 5.1 | 7 | 2.5 | 2.5 | 2.5 | 138.2 |
| | 0.20 | 5.2 | 6 | 2.5 | 2.5 | 3.8 | 116.6 |
| Perennial forb cover (%)[1] | 0.03 | 8.6 | 10 | 2.5 | 5.2 | 10.1 | 116 |
| | 0.20 | 7.7 | 7.7 | 3.2 | 5.4 | 9.5 | 99.4 |
| Annual forb cover (%) | **0.03** | **3.9** | **4.4** | **2.5** | **2.5** | **2.5** | **113.2** |
| | 0.20 | 4.1 | 4.3 | 2.5 | 2.5 | 3.8 | 103.7 |
| Residual vegetation cover (%) | 0.03 | 11.4 | 9.9 | 4.1 | 8.5 | 14.8 | 87 |
| | 0.20 | 11.8 | 8.8 | 5.2 | 9.8 | 15.7 | 74.2 |
| Litter cover (%) | 0.03 | 27.7 | 22.3 | 10.5 | 20.5 | 41.8 | 80.6 |
| | 0.20 | 26.6 | 20.1 | 10.5 | 21.5 | 40 | 75.4 |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Bare ground cover (%) | **0.03** | **29.8** | **23.9** | **10.5** | **22.7** | **44.7** | **80.3** |
| | 0.20 | 30.2 | 21.4 | 11.9 | 25.1 | 45.5 | 70.8 |
| Rock cover (%) | 0.03 | 10.1 | 15 | 2.5 | 2.5 | 11.4 | 147.8 |
| | 0.20 | 10 | 12.6 | 2.5 | 3.8 | 12.8 | 125.5 |
| Tall sagebrush cover (%) | **0.01** | **12** | **14.3** | **0** | **6.1** | **23.1** | **119.3** |
| | 0.03 | 11.1 | 12.6 | 0 | 5.2 | 20.7 | 114 |
| | 0.20 | 10.2 | 11.4 | 0 | 6.2 | 18.7 | 112.3 |
| Dwarf sagebrush cover (%) | 0.01 | 7.6 | 11.6 | 0 | 0 | 13.7 | 152.8 |
| | 0.03 | 7.8 | 11.3 | 0 | 0 | 13.6 | 145.5 |
| | **0.20** | **7.5** | **10** | **0** | **1.9** | **12.7** | **133.8** |
| Total sagebrush cover (%) | 0.01 | 20.3 | 13.7 | 9.7 | 21.1 | 29 | 67.5 |
| | **0.03** | **19.6** | **12.4** | **10.3** | **19.4** | **27.3** | **63.1** |
| | 0.20 | 18.3 | 11.1 | 10 | 18.7 | 25.1 | 60.6 |
| Non-sagebrush shrub cover (%) | 0.01 | 5.6 | 9.2 | 0 | 1.3 | 7.7 | 165.5 |
| | 0.03 | 5.6 | 8.7 | 0 | 1.9 | 7.2 | 155.9 |
| | 0.20 | 5.2 | 7.2 | 0.5 | 1.9 | 7.5 | 138.4 |
| Total shrub cover (%) | **0.01** | **25.8** | **15.9** | **14.8** | **25.4** | **35.8** | **61.5** |
| | 0.03 | 25 | 15.3 | 14.3 | 23.1 | 35.4 | 61.3 |
| | 0.20 | 23.3 | 13.6 | 13.6 | 22.5 | 33.4 | 58.4 |

[1]Denotes variables that have been date adjusted to mean peak nesting date (May 8) to account for plant phenology (see section, "Study Methods").

Although horizontal and vertical cover directly at the nest (fourth order selection) provided substantial support from these data, specific habitat characteristics near the nest site (third order selection) also were important for nesting sage-grouse across xeric and mesic habitats. For instance, our results universally supported selection for taller sagebrush cover, taller perennial grass, taller residual grass, greater sagebrush cover, and greater total shrub cover, while avoiding bare ground, at extents that encompass the area immediately surrounding the nest. Correlations were not supported among these microhabitat characteristics (appendix 5), indicating that effects of these variables are likely not confounding but rather functioning independently. Total shrub cover at the 0.03 ha scale garnered the most evidence of influencing nest site selection from the data across both xeric and mesic habitats (27.1 ±0.8 percent, used-xeric versus 21.4 ±0.8 percent, available-xeric; 25.0 ±1.1 percent, used-mesic versus 18.3 ±1.0 percent, available-mesic) and also relatively less variable in relation to its mean compared to other variables (CV=53.9, xeric; CV=61.5, mesic; tables 3 and 4). Numerically, mesic environments consisted of a lower percentage of total shrub cover than sites sampled in xeric habitats. Within these mesic habitats, increased total shrub cover was more likely to be associated with successful nests (27.4 ±0.6 percent, successful versus 22.3 ±1.5 percent, unsuccessful). No differences were detected in total shrub cover between successful and failed nests in xeric habitats where cover was relatively high.

Available total shrub cover was much lower at the fire affected study area (8.5 ±1.0 percent), on average, than the unaffected study areas, and we found a clear difference between the availability and use (14.8 ±1.1 percent) measurements. Additionally, sagebrush species provided less total shrub cover than non-sagebrush at the burned area but was found to be positively associated with nest success (7.4 ±1.4 percent, successful versus 3.5 ±0.9 percent, unsuccessful).

Height and cover of understory herbaceous vegetation (perennial and residual grasses and perennial forbs) also played a key role in selection of nest sites and subsequent nest success. Some associations varied across xeric and mesic habitats. Sage-grouse were more likely to select sites with relatively taller perennial grass, on average, within both xeric (12.5 ±0.5 cm, used versus 10.1 ±0.4 cm, available) and mesic habitats (18.9 ±0.7 cm, used versus 16.6 ±0.7 cm, available), as well as taller residual grasses (table 2).

Evidence for selection for tall grass (perennial and residual) was greater in xeric habitats compared to mesic. We also found that successful nests consisted of taller perennial grasses (13.3 ±0.8 cm) than unsuccessful nests (10.6 ±0.6 cm) within xeric habitats. However, difference in grass height between successful and unsuccessful nests was not nearly as substantial within mesic habitats, where grasses were generally 5 cm taller than those within xeric habitats. Nevertheless, numerically taller grasses were still associated with successful nests within mesic habitats. Additionally, perennial forb height garnered some support in influencing site selection in xeric habitats, whereas no associations were found in mesic habitats (table 2). We discovered similar regional variation in perennial grass and forb cover. For example, perennial grass (5.4 ±0.2 percent, available versus 6.8 ±0.4 percent, used) and forb (4.2 ±0.2 percent, available versus 5.1 ± 0.3 percent, used) cover was only selected in xeric habitats (table 2).

Forb cover was also associated with successful nests in xeric habitats (5.3 ±0.6 percent, success versus 4.1 ±0.3 percent, failed; table 2). On average, grass and forb cover was 2.5 and 2 times greater, respectively, in mesic habitats than within xeric habitat (appendix 1). At the burned study area, where overstory shrub cover was relatively low, these data supported selection of perennial grass and forb cover, as well as taller forbs (table 5; appendix 3). However, associations with nest success were not supported (table 5; appendix 4).

Some microhabitat characteristics were avoided by sage-grouse. Annual grass cover showed varying effects related to wildfire on nest site selection. For example, in xeric and mesic habitats unaffected by wildfire, differences in percent cover of annual grass between used and available sites were not supported by these data (table 2). Burned habitats consisted of more than twice as much annual grass than the unaffected areas (appendixes 1–3), and within these burned areas annual grass was highly avoided (10.8 ± 0.8 percent, available versus 7.5 ± 0.7 percent, used; tables 5 and 6; appendix 3). Within both xeric and mesic habitats, we found evidence of avoidance of bare areas that lacked any source of vegetation cover (table 2). However, this effect was stronger within xeric areas (51.3 ± 1.4 percent, available versus 44.2 ± 1.4 percent, used), which consisted of substantially more bare ground (35.1 ± 1.5 percent, mesic-available).

We report an example of microhabitat quality categories for the nesting life stage separately by xeric and mesic habitats in table 7. All variables listed in the table were associated with nest site selection for sage-grouse and variables that influenced success of nests were also noted.

**Table 5.** Influential microhabitat factors for used sites of nesting greater sage-grouse (*Centrocercus urophasianus*) within burned habitats in the Great Basin, Nevada and California, 2009–16.

[**Bold** represents influences on selection and survival of nests. Single (*) and double (**) asterisks represent differences at the 85- and 95-confidence limits, respectively]

| Variable | Selection | | Success | |
|---|---|---|---|---|
| **Horizontal cover (%)** | ** | **Select** | ** | **Positive** |
| **Vertical cover (%)** | * | **Select** | * | **Positive** |
| Perennial forb height (cm) | ** | Select | | |
| Sagebrush height (cm) | * | Avoid | | |
| **Non-sagebrush height (cm)** | * | **Select** | * | **Negative** |
| Average height (cm) | * | Avoid | | |
| Non-sagebrush shrub cover (%) | ** | Select | | |
| Tall sagebrush cover (%) | | | * | Positive |
| Dwarf sagebrush cover (%) | * | Select | | |
| Total sagebrush cover (%) | | | * | Positive |
| **Total shrub cover (%)** | ** | **Select** | * | **Positive** |
| Perennial grass cover (%) | * | Select | | |
| Annual grass cover (%) | ** | Avoid | | |
| Perennial forb cover (%) | * | Select | | |
| Bare ground cover (%) | * | Avoid | | |

**Table 6.** Summary statistics for microhabitat factors evaluated for used sites of nesting greater sage-grouse (*Centrocercus urophasianus*) within burned habitats in the Great Basin, Nevada and California, 2009–16.

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). **Bold** denotes influential variable and spatial scale on nest site selection (used versus available) and (or) success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | **NB** | **79** | **14** | **69.2** | **82** | **90** | **17.7** |
| Vertical cover (%) | **NB** | **62.7** | **30.3** | **44** | **68** | **89** | **48.3** |
| Maximum height (cm) | NB | 76 | 40.9 | 57 | 67 | 87 | 54.4 |
| Average height (cm) | **NB** | **48.9** | **13.7** | **40.4** | **48.5** | **59.3** | **29.4** |
| Perpendicular width (cm) | NB | 99.3 | 44.4 | 72 | 90 | 124 | 46.1 |
| Sagebrush height (cm) | NB | 27.8 | 38.4 | 0 | 0 | 59.8 | 138.2 |
| | 0.03 | 23.5 | 26.7 | 0 | 9.9 | 44.2 | 113.5 |
| | **0.20** | **23.6** | **24.4** | **0** | **18.9** | **44.4** | **103.6** |
| Non-sagebrush height (cm) | **NB** | **50.7** | **56.6** | **0** | **54** | **73.5** | **111.4** |
| | 0.03 | 41.7 | 31.4 | 18.1 | 43.1 | 60 | 75.3 |
| | 0.20 | 40.2 | 26.8 | 18.4 | 43.1 | 56.8 | 66.7 |
| Perennial grass height (cm)[1] | NB | 30.5 | 23.4 | 15.8 | 27.8 | 43.2 | 76.7 |
| | 0.03 | 27.8 | 14.8 | 17.1 | 25.7 | 36.2 | 53.3 |
| | 0.20 | 26.4 | 13 | 17.8 | 25.3 | 34.6 | 49.2 |
| Perennial forb height (cm)[1] | NB | 13.4 | 16.5 | 1.1 | 10 | 20.6 | 122.8 |
| | **0.03** | **15.3** | **10.3** | **7.8** | **13.6** | **24.4** | **67.2** |
| | 0.20 | 15.1 | 9.3 | 7.8 | 13.8 | 22.3 | 61.8 |
| Residual grass height (cm) | NB | 33.4 | 27.3 | 12.5 | 26.5 | 51.8 | 81.6 |
| | 0.03 | 29.2 | 18.3 | 14.3 | 26 | 40.6 | 62.7 |
| | 0.20 | 27.6 | 16.4 | 14.7 | 24.1 | 39.1 | 59.3 |
| Perennial grass cover (%) | 0.03 | 11.3 | 10.9 | 4.5 | 8.9 | 14.3 | 96.9 |
| | **0.20** | **12.1** | **10.5** | **5.2** | **10.1** | **15.5** | **87** |
| Annual grass cover (%) | 0.03 | 7.3 | 8.3 | 2.5 | 2.5 | 9.3 | 113.9 |
| | **0.20** | **7.5** | **8** | **2.5** | **3.5** | **9.9** | **105.8** |
| Perennial forb cover (%)[1] | 0.03 | 8.3 | 8.8 | 2.5 | 5 | 10.8 | 106.4 |
| | **0.20** | **8** | **7.3** | **3.3** | **5.7** | **11.2** | **91.6** |
| Annual forb cover (%) | 0.03 | 5.3 | 6.9 | 2.5 | 2.5 | 5.7 | 131.3 |
| | 0.20 | 5.2 | 5 | 2.5 | 3.4 | 6.3 | 94.7 |
| Residual vegetation cover (%) | 0.03 | 11.3 | 9.8 | 4.5 | 8.5 | 14.4 | 86.3 |
| | 0.20 | 12.4 | 8.8 | 6.3 | 10.1 | 16 | 70.9 |
| Litter cover (%) | 0.03 | 18.5 | 12.6 | 9.3 | 14.9 | 25.1 | 68.3 |
| | 0.20 | 17 | 10.3 | 9.6 | 15.8 | 22.8 | 60.2 |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Bare ground cover (%) | 0.03 | 23 | 19.9 | 9.3 | 17.1 | 31.7 | 86.7 |
| | **0.20** | **22.3** | **16.5** | **11.1** | **17.6** | **28.5** | **73.8** |
| Rock cover (%) | 0.03 | 15.3 | 15.9 | 2.5 | 9.2 | 24.4 | 104.1 |
| | 0.20 | 15.8 | 13.9 | 4.3 | 11.1 | 23.4 | 88 |
| Tall sagebrush cover (%) | 0.01 | 3.9 | 8.1 | 0 | 0 | 3.1 | 207.3 |
| | 0.03 | 4.2 | 8.4 | 0 | 0 | 3.6 | 201.6 |
| | 0.20 | 3.7 | 7.4 | 0 | 0.5 | 3.4 | 197.9 |
| Dwarf sagebrush cover (%) | 0.01 | 1.4 | 4.5 | 0 | 0 | 0 | 308.9 |
| | 0.03 | 1.4 | 4.2 | 0 | 0 | 0 | 303.8 |
| | **0.20** | **1.3** | **3.8** | **0** | **0** | **0** | **283.3** |
| Total sagebrush cover (%) | 0.01 | 5.3 | 8.7 | 0 | 0 | 7.4 | 163.2 |
| | 0.03 | 5.5 | 8.9 | 0 | 1.1 | 8.8 | 160.4 |
| | 0.20 | 5.1 | 7.9 | 0 | 1.3 | 7.2 | 155.2 |
| Non-sagebrush shrub cover (%) | **0.01** | **9.4** | **11.5** | **0** | **5** | **15.7** | **122.2** |
| | 0.03 | 6.6 | 8.2 | 0.6 | 3 | 10 | 124.3 |
| | 0.20 | 6.9 | 7.8 | 1.1 | 4.3 | 10.6 | 112.2 |
| Total shrub cover (%) | **0.01** | **14.8** | **12.3** | **4.8** | **14.1** | **22.4** | **83.3** |
| | 0.03 | 12.2 | 10.9 | 3.9 | 9.8 | 17.2 | 89.3 |
| | 0.20 | 12 | 9.9 | 4.4 | 10 | 16.2 | 82.9 |

[1]Denotes variables that have been date adjusted to mean peak nesting date (May 8) to account for plant phenology (see section, "Study Methods").

Table 7. Example of habitat quality classes based on evidenced microhabitat factors evaluated for nesting greater sage-grouse (*Centrocercus urophasianus*) within xeric and mesic habitats in Nevada and California, 2009–2016.

[**Variable:** Variables not listed were not supported by these data for evidence of selection or survival. **Habitat type:** Evidence for nest selection/avoidance and success/failure was denoted with asterisks (*). **Unsuitable:** Value represents 25th percentile of used sites evidence of selection only and mean of failed nests with evidence of selection and success (see methods). **Suitable:** Value represents mean of used for variables supported by selection]

| Variable | Habitat type | Unsuitable | Marginal | Suitable |
|---|---|---|---|---|
| Horizontal cover (%) | Xeric* | <79.9 | 79.9–82.3 | >82.3 |
| | Mesic* | <81.1 | 81.1–83.8 | >83.8 |
| Vertical cover (%) | Xeric | <56.0 | 56.0–72.7 | >72.7 |
| | Mesic | <60.0 | 60.0–74.4 | >74.4 |
| Maximum height (cm) | Xeric | <53.0 | 53.0–72.8 | >72.8 |
| | Mesic | <52.8 | 52.8–73.0 | >73.0 |
| Average height (cm) | Xeric | <33.4 | 33.4–43.7 | >43.7 |
| | Mesic | <32.4 | 32.4–50.5 | >50.5 |
| Perpendicular width (cm) | Xeric* | <86.4 | 86.4–92.5 | >92.5 |
| | Mesic | <68.0 | 68.0–96.3 | >96.3 |
| Sagebrush height (cm) | Xeric | <30.0 | 30.0–43.2 | >43.2 |
| | Mesic | <40.0 | 40.0–59.1 | >59.1 |
| Non-sagebrush height (cm) | Xeric | <6.5 | 6.5–20.8 | >20.8 |
| | Mesic* | <31.7 | 31.7–37.0 | >37.0 |
| Perennial grass height (cm)[1] | Xeric* | <10.6 | 10.6–12.1 | >12.1 |
| | Mesic | <9.9 | 9.9–17.8 | >17.8 |
| Perennial forb height (cm)[1] | Xeric | 0 | 0.0–5.5 | >5.5 |
| | Mesic | <1.4 | 1.4–7.6 | >7.6 |
| Residual grass height (cm) | Xeric | <3.4 | 3.4–7.5 | >7.5 |
| | Mesic | <6.3 | 6.3–12.5 | >12.5 |
| Perennial grass cover (%) | Xeric | <2.5 | 2.5–6.8 | >6.8 |
| | Mesic | <5.2 | 5.2–12.8 | >12.8 |
| Annual grass cover (%) | Xeric | >4.8 | 2.5–4.8 | <2.5 |
| | Mesic | >5.2 | 2.5–5.2 | <2.5 |
| Perennial forb cover (%)[1] | Xeric* | <4.6 | 4.6–4.9 | >4.9 |
| | Mesic | <2.5 | 2.5–8.6 | >8.6 |
| Annual forb cover (%) | Xeric | >3.5 | 2.5–3.5 | <2.5 |
| | Mesic | >5.7 | 5.3–5.7 | <5.3 |
| Tall sagebrush cover (%) | Xeric | 0 | 0.0–14.9 | >14.9 |
| | Mesic* | <9.9 | 9.9–12.0 | >12.0 |
| Dwarf sagebrush cover (%) | Xeric | 0 | 0.0–8.2 | >8.2 |
| | Mesic | 0 | 0.0–7.5 | >7.5 |
| Total sagebrush cover (%) | Xeric | <14.1 | 14.1–20.4 | >20.4 |
| | Mesic* | <17.7 | 17.7–19.6 | >19.6 |
| Non-sagebrush shrub cover (%) | Xeric | 0 | 0.0–5.3 | >5.3 |
| | Mesic* | <4.3 | 4.3–5.2 | >5.2 |
| Total shrub cover (%) | Xeric | <18.7 | 18.7–27.8 | >27.8 |
| | Mesic* | <23.0 | 23.0–25.8 | >25.8 |

[1]Denotes variables that have been date adjusted to mean peak nesting date (May 8) to account for plant phenology (see section, "Study Methods").

## Brood Site Selection and Success

Following nest fate, we relocated 270 broods (*n*=112, xeric-unburned; *n*=96, mesic-unburned; *n*=62, mesic-burned) for this analysis from 2009 to 2016 (table 1). Similar to nesting, most samples were collected from 2012 to 2016, with the number of sampled broods progressively increasing through the years. Daily movements for broods between day and night sites was much greater during later stages of brood-rearing (409.1 ±20.7 m) compared to early stages (289.9 ±37.1 m). We also found movements were greater in xeric habitats (380.1 ±45.2 m, early versus 476.1 ±40.8 m, late) compared to mesic habitats (239.8 ±50.5 m, early versus 359.0 ±18.9 m, late). We found substantial differences in several microhabitat factors between nests and late brood-rearing sites. Early brood-rearing estimates generally fell between those during nesting and late brood-rearing. Because sites during early phases of brood-rearing reflect use of transitional habitat as broods travel from their nests to areas more conducive for chick survival and growth, we focus our results on later phases of brood-rearing, but still provide values during early phase in appendixes 6–8.

Similar to the microhabitat selection patterns observed in the nesting stage, overall horizontal and vertical cover played a key role in late brood-rearing (table 8). However, we found diel variation in selection for cover. For example, during late brood-rearing, sage-grouse used areas that consisted of approximately 10 percent more cover at day sites than night sites (61.6 ±1.3 percent, xeric-day versus 53.4 ±1.6 percent, xeric-night; 62.4 ±1.5 percent, mesic-day versus 51.6 ±1.9 percent, mesic-night; tables 9–12). Horizontal and vertical cover at night sites were similar to those at available sites (49.9 ±1.5 percent, xeric; 52.1 ±1.8 percent, mesic). We also found cover at used sites did not differ between xeric and mesic habitats, a finding similar to the nest site results. However, brood use sites consisted of approximately 30 percent less cover than at nest sites (tables 3and 4, and 9–12). As with nest sites, these brood cover variables exhibited relatively lower in coefficients of variation compared to others (tables 9 and 10).

Additional vegetation characteristics also were supported by the data including some vegetation relationships shared across xeric and mesic habitats. Furthermore, several factors selected by sage-grouse exhibited clear associations with success (table 8). Among the most strongly supported vegetative characteristics for late brood site use during daylight hours and consistent across xeric and mesic habitats were perennial forb cover (10.3 ±0.7 percent, xeric-used versus 7.0 ±0.6 percent, xeric-available; 9.3 ±0.6 percent, mesic-used versus 7.8 ±0.5 percent, mesic-available) and perennial forb height (12.4 ±0.7 cm, xeric-used versus 7.9 ±0.6 cm, xeric-available; 13.5 ±0.6 cm, mesic-used versus 11.7 ±0.7 cm, mesic-available; table 8). Although perennial forb cover at available sites was similar among xeric and mesic habitats (appendixes 8 and 9), differences among used and available sites garnered more support within xeric habitats compared to mesic. We also found stronger selection for taller forbs at xeric habitats, where forb heights were much shorter on average than those within mesic habitats (appendixes 8 and 9). Additionally, marginal evidence suggested that taller forbs were associated with more successful broods in xeric habitats (12.8 ±0.7 cm, successful versus 8.7 ±2.1 cm, failed) but not in mesic habitats (13.5 ±0.7 cm, successful versus 12.3 ±2.4 cm, failed) where forbs generally were relatively taller. Although sage-grouse selected areas with annual forbs as well, those forb types received less support from the data for selection but were associated with successful broods (table 8).

Height and cover of deep-rooted perennial grasses received support from the data, but the degree of effect varied between day use and night use sites, as well as between xeric and mesic habitats. Although we found xeric habitats consisted of substantially shorter perennial grasses than mesic at available sites (xeric, 13.7 ±0.6 cm, xeric versus 21.3 ±0.9 cm, mesic), taller grasses were associated with used sites within both xeric and mesic habitats (17.2 ±0.7 cm, xeric versus 25.0 ±1.0 cm, mesic). Successful broods within xeric habitats were associated with taller grasses (15.3 ±1.5 cm, successful versus 10.6 ±2.2 cm, failed). Perennial grasses averaged shorter overall within xeric versus mesic habitats by approximately 7.6 cm (appendixes 8 and 9) and the effects of perennial grass cover on habitat selection varied between mesic versus xeric habitats (table 8). Specifically, evidence of selection for perennial grass cover was marginal within xeric habitats (9.1 ±0.6 percent, used versus 7.4 ±0.5 percent, available; appendix 9) and did not receive support within mesic habitats (appendix 10). However, overall cover was much greater in mesic habitats (13.5 ±0.9 percent, available). Furthermore, we detected substantial differences in perennial grass cover between day and night sites within mesic habitats (14.9 ±0.9 cm, used-day versus 11.4 ±0.7 cm, used-night) but not within xeric habitats (9.1 ±0.6 cm, used-day versus 7.8 ±0.6 cm, used-night; appendixes 9 and 10). Lastly, after date-correcting grass heights at nests to reflect estimated grass heights at predicted hatch date, we found heights averaged approximately 3 cm taller at brood sites than nests sites within xeric and mesic.

Other variables related to overstory canopy cover influenced late brood site selection and brood success (table 8). Overall, total shrub cover within xeric and mesic habitats (27.0 ±1.0 percent, xeric day use versus 22.0 ±0.9 percent, available; 25.9 ±1.1 percent, mesic day use versus 21.3 ±1.0 percent, available) and successful broods were associated with greater total shrub cover within xeric habitats (28.2 ±1.0 percent, successful versus 23.3 ±2.7 percent, failed) and mesic habitats (26.2 ±1.2 percent, successful versus 17.9 ±4.0 percent, failed; appendix 13). Within mesic habitats, this effect is likely attributable to the use of areas with more non-sagebrush shrub species (table 8).

As was the case for grasses and forbs, we also detected diel patterns for total shrub cover. Total shrub cover was greater during day (26.9 ±1.0 percent, xeric; 25.9 ±1.1 percent mesic) compared to night (23.8 ±1.1 percent, mesic; 22.3 ±1.1 percent, xeric). Although total shrub cover consists of sagebrush and non-sagebrush species, we found evidence of selection for specific sagebrush species. For example, day use sites were associated with greater cover from taller sagebrush species (15.8 ±0.8 percent, xeric; 11.0 ±0.8 percent, mesic) than those available (10.8 ±0.8 percent, xeric; 7.6 ±0.7 percent, mesic), whereas broods clearly avoided cover associated with dwarf sagebrush species (6.7 ±0.6 percent, xeric-available versus 3.4 ±0.4 percent, xeric-used; 4.9 ±0.5 percent, mesic-available versus 3.2 ±0.5 percent, mesic-used).

We report an example of microhabitat quality categories for the late brood-rearing life stage separately by xeric and mesic habitats in table 13. All variables listed in the table were associated with late brood site selection for sage-grouse and variables that influenced success of broods were also noted.

**Table 8.** Influential microhabitat factors for late brood-rearing greater sage-grouse (*Centrocercus urophasianus*) within xeric and mesic habitats unaffected by wildfire in the Great Basin, Nevada and California, 2009–16.

[**Bold** represents influences on selection and survival of broods and non-bold was selection only. Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Xeric | | | Mesic | | |
|---|---|---|---|---|---|---|
| | Night | Day | Success | Night | Day | Success |
| **Horizontal cover (%)** | | ** **Select** | | | ** **Select** | ** **Positive** |
| **Vertical cover (%)** | | ** **Select** | * **Positive** | * **Avoid** | ** **Select** | ** **Positive** |
| Average height (cm) | | ** Select | | | ** Select | |
| **Sagebrush height (cm)** | * **Select** | ** **Select** | | | ** **Select** | ** **Positive** |
| **Non-sagebrush height (cm)** | | ** **Select** | | | ** **Select** | ** **Positive** |
| Perennial grass height (cm) | * Select | ** Select | | * Select | ** Select | |
| **Perennial forb height (cm)** | * **Select** | ** **Select** | * **Positive** | | * **Select** | |
| **Residual grass height (cm)** | | | * **Positive** | ** **Select** | * **Select** | * **Positive** |
| Perennial grass cover (%) | | * Select | | * Avoid | | |
| Annual grass cover (%) | * Avoid | * Avoid | | * Avoid | | |
| Perennial forb cover (%) | | ** Select | | | * Select | |
| **Annual forb cover (%)** | | * **Select** | ** **Positive** | | | ** **Positive** |
| **Residual vegetation cover (%)** | * **Select** | * **Select** | * **Positive** | * **Select** | | |
| **Litter cover (%)** | | * **Select** | | | | ** **Positive** |
| **Bare ground cover (%)** | | ** **Avoid** | * **Negative** | * **Select** | | |
| **Rock cover (%)** | | | ** **Positive** | | ** **Avoid** | * **Negative** |
| **Tall sagebrush cover (%)** | * **Select** | ** **Select** | * **Positive** | | ** **Select** | |
| Dwarf sagebrush cover (%) | | ** Avoid | | | * Avoid | |
| Total sagebrush cover (%) | * Select | * Select | | * Select | * Select | |
| **Non-sagebrush shrub cover (%)** | | ** **Select** | | | * **Select** | * **Positive** |
| **Total shrub cover (%)** | * **Select** | ** **Select** | * **Positive** | | ** **Select** | * **Positive** |

**Table 9.** Summary statistics for microhabitat factors evaluated for used day sites of late brood-rearing greater sage-grouse (*Centrocercus urophasianus*) within xeric habitat in the Great Basin, Nevada and California, 2009–16.

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to brood location. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). Bold denotes influential variable and spatial scale on brood site selection (used versus available) and/or success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | **BL** | **61.61** | **22.5** | **46.67** | **62** | **79.33** | **36.52** |
| Vertical cover (%) | **BL** | **30.19** | **37.29** | **0** | **8** | **64** | **123.5** |
| Average height (cm) | **BL** | **50.68** | **21.99** | **36.17** | **49.33** | **60.84** | **43.38** |
| Sagebrush height (cm) | BL | 64.62 | 44.74 | 3.75 | 74 | 99 | 69.24 |
| | **0.03** | **40.88** | **26.55** | **23.94** | **39.17** | **56.17** | **64.96** |
| | 0.20 | 39.2 | 23.67 | 25.12 | 37.79 | 53.47 | 60.37 |
| Non-sagebrush height (cm) | BL | 23.25 | 27.17 | 0 | 18 | 39 | 116.86 |
| | 0.03 | 23.42 | 19.99 | 8.25 | 22.29 | 33 | 85.34 |
| | **0.20** | **23.37** | **18.73** | **10.14** | **21.79** | **32.41** | **80.13** |
| Perennial grass height (cm) | BL | 16 | 16.5 | 0 | 12 | 23 | 103.08 |
| | 0.03 | 17.23 | 12.48 | 9 | 14.67 | 24.75 | 72.41 |
| | **0.20** | **17.22** | **11.47** | **9** | **15.71** | **22.41** | **66.63** |
| Perennial forb height (cm) | BL | 11.18 | 14.1 | 0 | 6 | 17 | 126.1 |
| | **0.03** | **12.38** | **12.1** | **3.19** | **9.13** | **17.81** | **97.74** |
| | 0.20 | 12.44 | 11.17 | 4.24 | 9.69 | 18.43 | 89.85 |
| Residual grass height (cm) | BL | 6.68 | 9.02 | 1 | 4 | 8.25 | 135.11 |
| | 0.03 | 7.52 | 6.14 | 3 | 5.67 | 10.5 | 81.71 |
| | 0.20 | 7.79 | 6.06 | 3.19 | 6.36 | 10.9 | 77.86 |
| Perennial grass cover (%) | BL | 9.18 | 15.16 | 2.5 | 2.5 | 10.5 | 165.13 |
| | 0.03 | 9.07 | 11.39 | 2.5 | 4.5 | 10.63 | 125.57 |
| | **0.20** | **9.05** | **10.08** | **2.5** | **5.93** | **9.93** | **111.38** |
| Annual grass cover (%) | BL | 4.15 | 6.71 | 2.5 | 2.5 | 2.5 | 161.55 |
| | **0.03** | **4.31** | **5.29** | **2.5** | **2.5** | **2.5** | **122.69** |
| | 0.20 | 4.57 | 5.25 | 2.5 | 2.5 | 3.64 | 114.99 |
| Perennial forb cover (%) | BL | 9.33 | 15.95 | 2.5 | 2.5 | 10.5 | 170.91 |
| | **0.03** | **10.29** | **12.62** | **2.5** | **4.5** | **11.5** | **122.61** |
| | 0.20 | 10.1 | 12.24 | 2.5 | 5.07 | 11.23 | 121.26 |
| Annual forb cover (%) | BL | 3.54 | 4.12 | 2.5 | 2.5 | 2.5 | 116.57 |
| | 0.03 | 3.77 | 4.38 | 2.5 | 2.5 | 2.5 | 116.1 |
| | **0.20** | **3.91** | **4.15** | **2.5** | **2.5** | **3.64** | **106.13** |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Residual vegetation cover (%) | BL | 8 | 11.92 | 2.5 | 2.5 | 10.5 | 149.01 |
| | 0.03 | 8.64 | 7.82 | 2.5 | 6.5 | 11.22 | 90.49 |
| | **0.20** | **9.09** | **7.2** | **3.64** | **7.19** | **12.43** | **79.21** |
| Litter cover (%) | BL | 26.94 | 28.81 | 2.5 | 15.5 | 38 | 106.93 |
| | **0.03** | **25.18** | **20.68** | **8.5** | **19.88** | **35.01** | **82.15** |
| | 0.20 | 24.42 | 18.99 | 8.79 | 19.83 | 34.07 | 77.76 |
| Bare ground cover (%) | BL | 37.99 | 34.03 | 2.5 | 33 | 63 | 89.57 |
| | 0.03 | 37.9 | 25.06 | 15.88 | 34.82 | 57.38 | 66.11 |
| | **0.20** | **37.54** | **23.19** | **19.02** | **33.15** | **55.93** | **61.76** |
| Rock cover (%) | BL | 6.99 | 14.97 | 2.5 | 2.5 | 2.5 | 214.28 |
| | 0.03 | 7.95 | 11.96 | 2.5 | 2.5 | 7 | 150.35 |
| | 0.20 | 8 | 11.26 | 2.5 | 2.5 | 7.57 | 140.84 |
| Tall sagebrush cover (%) | **0.01** | **15.11** | **15.34** | **0** | **11.27** | **26.65** | **101.53** |
| | 0.03 | 15.84 | 14.73 | 1.41 | 13.62 | 25.38 | 93.03 |
| | 0.20 | 16.3 | 14.73 | 3.15 | 14.38 | 24.83 | 90.38 |
| Dwarf sagebrush cover (%) | **0.01** | **3.04** | **7.79** | **0** | **0** | **0** | **255.91** |
| | 0.03 | 3.4 | 7.75 | 0 | 0 | 1.05 | 227.94 |
| | 0.20 | 3.68 | 7.57 | 0 | 0 | 3.32 | 205.47 |
| Total sagebrush cover (%) | 0.01 | 18.15 | 15.02 | 4.05 | 17.1 | 28.87 | 82.77 |
| | 0.03 | 19.24 | 14.23 | 8.22 | 18.12 | 28.63 | 73.98 |
| | **0.20** | **19.98** | **13.97** | **10.24** | **19.64** | **27.9** | **69.94** |
| Non-sagebrush shrub cover (%) | **0.01** | **8.73** | **11.83** | **0** | **4.33** | **12.55** | **135.49** |
| | 0.03 | 8.55 | 10.35 | 0.6 | 4.99 | 12.88 | 120.96 |
| | 0.20 | 8.31 | 9.64 | 1.58 | 4.72 | 11.93 | 115.95 |
| Total shrub cover (%) | **0.01** | **26.89** | **17.39** | **14.58** | **27.6** | **37.29** | **64.68** |
| | 0.03 | 27.79 | 16.58 | 15.9 | 27.68 | 37.88 | 59.65 |
| | 0.20 | 28.29 | 16.34 | 16.15 | 27.84 | 39.12 | 57.74 |

**Table 10.** Summary statistics for microhabitat factors evaluated for used night sites of late brood-rearing greater sage-grouse (*Centrocercus urophasianus*) within xeric habitat in the Great Basin, Nevada and California, 2009–16.

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to brood location. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). Bold denotes influential variable and spatial scale on brood site selection (used versus available) and/or success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | BL | 53.44 | 23.33 | 38 | 50 | 68.67 | 43.66 |
| Vertical cover (%) | BL | 23.17 | 34.72 | 0 | 0 | 44 | 149.86 |
| Average height (cm) | BL | 40.77 | 15.97 | 29.79 | 38.55 | 51.39 | 39.18 |
| Sagebrush height (cm) | BL | 60.66 | 39.94 | 24 | 67 | 92 | 65.85 |
| | **0.03** | **33.72** | **20.59** | **20.75** | **30.75** | **46.67** | **61.06** |
| | 0.20 | 33.44 | 18.88 | 22.57 | 31.43 | 45.57 | 56.46 |
| Non-sagebrush height (cm) | BL | 17.44 | 21.36 | 0 | 10 | 28 | 122.5 |
| | 0.03 | 18.64 | 15 | 7 | 17.25 | 28 | 80.45 |
| | 0.20 | 19.58 | 14.33 | 7.57 | 18.8 | 27.71 | 73.2 |
| Perennial grass height (cm) | BL | 14.05 | 13.62 | 3 | 12 | 21 | 96.95 |
| | **0.03** | **15.4** | **10.29** | **7.75** | **13.33** | **21** | **66.8** |
| | 0.20 | 15.39 | 9.62 | 8.43 | 13.71 | 21 | 62.53 |
| Perennial forb height (cm) | BL | 7.72 | 10.68 | 0 | 3 | 12 | 138.41 |
| | **0.03** | **9.92** | **10.39** | **1.5** | **7** | **15.75** | **104.74** |
| | 0.20 | 9.92 | 10.04 | 2 | 6.86 | 15 | 101.24 |
| Residual grass height (cm) | BL | 6.56 | 7.97 | 2 | 4 | 8 | 121.52 |
| | 0.03 | 7.92 | 6.83 | 3.5 | 6.5 | 10.5 | 86.28 |
| | 0.20 | 7.88 | 5.91 | 3.57 | 6.43 | 10.43 | 74.95 |
| Perennial grass cover (%) | BL | 7.81 | 12.94 | 2.5 | 2.5 | 10.5 | 165.65 |
| | 0.03 | 7.83 | 9.44 | 2.5 | 4.5 | 9 | 120.57 |
| | 0.20 | 7.75 | 8.56 | 2.5 | 4.79 | 9.93 | 110.53 |
| Annual grass cover (%) | BL | 4.25 | 8.69 | 2.5 | 2.5 | 2.5 | 204.48 |
| | 0.03 | 4.53 | 6.43 | 2.5 | 2.5 | 2.5 | 141.96 |
| | **0.20** | **4.4** | **5.17** | **2.5** | **2.5** | **3.64** | **117.36** |
| Perennial forb cover (%) | BL | 7.42 | 11.84 | 2.5 | 2.5 | 10.5 | 159.5 |
| | 0.03 | 8.05 | 10.14 | 2.5 | 4.5 | 9 | 125.91 |
| | 0.20 | 7.95 | 8.89 | 2.5 | 4.79 | 9.86 | 111.79 |
| Annual forb cover (%) | BL | 2.92 | 2.91 | 2.5 | 2.5 | 2.5 | 99.6 |
| | 0.03 | 3.2 | 2.14 | 2.5 | 2.5 | 2.5 | 66.88 |
| | 0.20 | 3.23 | 1.92 | 2.5 | 2.5 | 2.5 | 59.4 |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Residual vegetation cover (%) | BL | 8.31 | 13.1 | 2.5 | 2.5 | 10.5 | 157.66 |
| | 0.03 | 8.94 | 9.42 | 2.5 | 6.5 | 11 | 105.29 |
| | **0.20** | **9.05** | **8.81** | **3.64** | **6.21** | **11.29** | **97.36** |
| Litter cover (%) | BL | 22.69 | 27.06 | 2.5 | 10.5 | 20.5 | 119.26 |
| | 0.03 | 22.73 | 21.36 | 6.5 | 15.38 | 32.17 | 93.99 |
| | 0.20 | 22.68 | 20.47 | 7.07 | 15.29 | 32.93 | 90.23 |
| Bare ground cover (%) | BL | 44.33 | 34.2 | 10.5 | 38 | 85.5 | 77.14 |
| | 0.03 | 41.7 | 26.72 | 19.63 | 38.38 | 63.63 | 64.08 |
| | 0.20 | 41.58 | 26.12 | 19.71 | 40.79 | 63.71 | 62.83 |
| Rock cover (%) | BL | 8.56 | 14.69 | 2.5 | 2.5 | 10.5 | 171.58 |
| | 0.03 | 9.77 | 13.41 | 2.5 | 4.5 | 11 | 137.24 |
| | 0.20 | 9.64 | 12.54 | 2.5 | 4.79 | 11.14 | 129.98 |
| Tall sagebrush cover (%) | 0.01 | 10.62 | 14.28 | 0 | 2.4 | 18.8 | 134.48 |
| | 0.03 | 12.48 | 14.45 | 0 | 7.57 | 21.87 | 115.81 |
| | **0.20** | **13.68** | **15.1** | **0** | **9.53** | **21.53** | **110.37** |
| Dwarf sagebrush cover (%) | 0.01 | 6.77 | 10.95 | 0 | 0 | 10.4 | 161.71 |
| | 0.03 | 6.8 | 10.64 | 0 | 0 | 11.17 | 156.47 |
| | 0.20 | 6.72 | 9.84 | 0 | 0 | 11.68 | 146.35 |
| Total sagebrush cover (%) | 0.01 | 17.39 | 14.26 | 4.67 | 16.73 | 26.8 | 81.99 |
| | 0.03 | 19.27 | 13.46 | 9.33 | 19.43 | 27.8 | 69.85 |
| | **0.20** | **20.41** | **13.74** | **11.35** | **20.51** | **27.95** | **67.34** |
| Non-sagebrush shrub cover (%) | 0.01 | 6.37 | 9.67 | 0 | 2.6 | 9.27 | 151.86 |
| | 0.03 | 6.6 | 9.57 | 0 | 2.77 | 8.53 | 144.95 |
| | 0.20 | 6.52 | 8.38 | 0.64 | 3.45 | 9.41 | 128.57 |
| Total shrub cover (%) | 0.01 | 23.76 | 16.58 | 10.87 | 22.87 | 34.07 | 69.76 |
| | 0.03 | 25.88 | 16.2 | 14 | 25.53 | 34.63 | 62.6 |
| | **0.20** | **26.92** | **15.67** | **17.04** | **26.44** | **35.15** | **58.19** |

Table 11. Summary statistics for microhabitat factors evaluated for used day sites of late brood-rearing greater sage-grouse (*Centrocercus urophasianus*) within mesic habitat in the Great Basin, Nevada and California, 2009–16.

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to brood location. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). Bold denotes influential variable and spatial scale on brood site selection (used versus available) and/or success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | **BL** | **62.42** | **25.55** | **47.33** | **68** | **82** | **40.93** |
| Vertical cover (%) | **BL** | **43.33** | **39.88** | **0** | **36** | **84** | **92.03** |
| Average height (cm) | **BL** | **56.74** | **22.89** | **42.22** | **55.46** | **70.32** | **40.33** |
| Sagebrush height (cm) | BL | 59.62 | 48.89 | 2 | 70 | 104 | 82.01 |
| | 0.03 | 38.22 | 29.99 | 11.69 | 40.17 | 56.56 | 78.48 |
| | **0.20** | **37.73** | **26.75** | **16.86** | **39.96** | **54.49** | **70.88** |
| Non-sagebrush height (cm) | BL | 38.68 | 52.83 | 0 | 20 | 64 | 136.6 |
| | **0.03** | **37.02** | **33.34** | **9.81** | **32.5** | **56.88** | **90.06** |
| | 0.20 | 35.51 | 29.84 | 11.28 | 32 | 54.18 | 84.03 |
| Perennial grass height (cm) | BL | 26.43 | 24.28 | 9 | 19.5 | 37 | 91.85 |
| | **0.03** | **24.98** | **16.64** | **13.75** | **21.25** | **33.75** | **66.61** |
| | 0.20 | 24.71 | 14.68 | 14.68 | 21.69 | 33.07 | 59.4 |
| Perennial forb height (cm) | BL | 12.94 | 14.73 | 0 | 9 | 19.25 | 113.87 |
| | **0.03** | **13.46** | **10.49** | **6** | **11.88** | **19** | **77.88** |
| | 0.20 | 13.3 | 9.39 | 6.71 | 12.16 | 18.39 | 70.63 |
| Residual grass height (cm) | **BL** | **13.06** | **14.49** | **4** | **9** | **16** | **110.94** |
| | 0.03 | 12.81 | 9.2 | 6.44 | 11.29 | 17.75 | 71.87 |
| | 0.20 | 12.6 | 8.08 | 6.78 | 11 | 17.18 | 64.09 |
| Perennial grass cover (%) | BL | 15.09 | 18.8 | 2.5 | 10.5 | 20.5 | 124.6 |
| | 0.03 | 14.89 | 14.57 | 5.17 | 11 | 18 | 97.88 |
| | 0.20 | 14.96 | 13.89 | 5.93 | 11.25 | 17.64 | 92.79 |
| Annual grass cover (%) | BL | 4.8 | 8.83 | 2.5 | 2.5 | 2.5 | 183.88 |
| | 0.03 | 4.79 | 6.8 | 2.5 | 2.5 | 2.5 | 141.93 |
| | 0.20 | 4.41 | 5.01 | 2.5 | 2.5 | 3.39 | 113.62 |
| Perennial forb cover (%) | BL | 8.09 | 10.65 | 2.5 | 2.5 | 10.5 | 131.63 |
| | 0.03 | 9.34 | 10.05 | 2.5 | 5.17 | 11.5 | 107.6 |
| | **0.20** | **9.46** | **9.1** | **3.64** | **6.61** | **12.31** | **96.17** |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Annual forb cover (%) | BL | 3.38 | 3.99 | 2.5 | 2.5 | 2.5 | 118.15 |
| | 0.03 | 3.62 | 3.24 | 2.5 | 2.5 | 2.5 | 89.43 |
| | 0.20 | 3.73 | 3.15 | 2.5 | 2.5 | 3.64 | 84.25 |
| Residual vegetation cover (%) | BL | 13.49 | 17.21 | 2.5 | 10.5 | 20.5 | 127.55 |
| | 0.03 | 14.5 | 12.54 | 5.17 | 11 | 19.88 | 86.5 |
| | 0.20 | 14.44 | 11.41 | 7.07 | 12.18 | 19.32 | 79.03 |
| Litter cover (%) | BL | 35.49 | 31 | 10.5 | 20.5 | 63 | 87.36 |
| | 0.03 | 30.98 | 24.33 | 11.33 | 24.25 | 45.5 | 78.54 |
| | 0.20 | 30.13 | 22.8 | 12.21 | 24.29 | 41.09 | 75.68 |
| Bare ground cover (%) | BL | 24.12 | 27.8 | 2.5 | 10.5 | 38 | 115.26 |
| | 0.03 | 26.45 | 18.29 | 11.17 | 23.25 | 39.25 | 69.16 |
| | 0.20 | 26.6 | 16.75 | 13.82 | 23.9 | 36.57 | 62.99 |
| Rock cover (%) | BL | 5.21 | 8.34 | 2.5 | 2.5 | 2.5 | 160.14 |
| | 0.03 | 5.65 | 7.22 | 2.5 | 2.5 | 4.5 | 127.74 |
| | **0.20** | **5.85** | **6.84** | **2.5** | **2.5** | **5.41** | **116.95** |
| Tall sagebrush cover (%) | 0.01 | 11.07 | 14.17 | 0 | 4 | 20.48 | 128.05 |
| | **0.03** | **10.97** | **12.8** | **0** | **5.64** | **19.33** | **116.67** |
| | 0.20 | 10.94 | 12.22 | 0 | 6.84 | 18.99 | 111.68 |
| Dwarf sagebrush cover (%) | 0.01 | 3.51 | 8.91 | 0 | 0 | 0 | 253.72 |
| | 0.03 | 3.52 | 8.53 | 0 | 0 | 0.45 | 242.15 |
| | **0.20** | **3.21** | **7.42** | **0** | **0** | **1.12** | **231.59** |
| Total sagebrush cover (%) | **0.01** | **14.58** | **14.82** | **0** | **11** | **24.03** | **101.64** |
| | 0.03 | 14.49 | 13.4 | 1.32 | 12.22 | 23.71 | 92.46 |
| | 0.20 | 14.15 | 12.48 | 1.76 | 12.84 | 22.85 | 88.2 |
| Non-sagebrush shrub cover (%) | 0.01 | 10.83 | 15.36 | 0 | 3.73 | 14.75 | 141.81 |
| | **0.03** | **11.35** | **14.95** | **0.19** | **5.33** | **16** | **131.69** |
| | 0.20 | 11.02 | 13.14 | 1.33 | 5.82 | 17.11 | 119.26 |
| Total shrub cover (%) | 0.01 | 25.41 | 20.13 | 7.87 | 23.44 | 39.92 | 79.2 |
| | **0.03** | **25.85** | **18.62** | **10.75** | **25.17** | **38.84** | **72.04** |
| | 0.20 | 25.17 | 17.12 | 12.12 | 24.34 | 36.89 | 68.01 |

**Table 12.** Summary statistics for microhabitat factors evaluated for used night sites of late brood-rearing greater sage-grouse (*Centrocercus urophasianus*) within mesic habitat in Nevada and California, 2009–16.

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to brood location. Columns represent mean, standard deviation (SD), quartiles (25, 50, and 75 percentile), minimum (min), midrange (mid), maximum (max), and coefficient of variation (CV). Bold denotes influential variable and spatial scale on brood site selection (used versus available) and/or success (successful versus failed)]

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Horizontal cover (%) | BL | 51.63 | 27.17 | 28.67 | 51 | 72.67 | 52.63 |
| Vertical cover (%) | **BL** | **25.47** | **35.67** | **0** | **0** | **54** | **140.02** |
| Average height (cm) | BL | 43.56 | 20.67 | 28.18 | 44.99 | 60.4 | 47.44 |
| Sagebrush height (cm) | BL | 59.13 | 43.69 | 2 | 65 | 94.75 | 73.89 |
| | 0.03 | 31.7 | 24.1 | 13.56 | 29.25 | 48.44 | 76.03 |
| | 0.20 | 31.34 | 22.31 | 14.47 | 29.77 | 46.08 | 71.19 |
| Non-sagebrush height (cm) | BL | 21.07 | 31.99 | 0 | 4.5 | 29.75 | 151.83 |
| | 0.03 | 26.54 | 24.01 | 6 | 22.5 | 40.73 | 90.47 |
| | 0.20 | 27.47 | 21.24 | 10.1 | 25.42 | 40.67 | 77.33 |
| Perennial grass height (cm) | BL | 23.16 | 21.28 | 9 | 17.5 | 31.75 | 91.88 |
| | **0.03** | **23.95** | **15.14** | **12.81** | **20.38** | **30.63** | **63.23** |
| | 0.20 | 23.6 | 14.56 | 13.04 | 20.47 | 31.72 | 61.71 |
| Perennial forb height (cm) | BL | 10.99 | 12.11 | 2 | 8 | 14.75 | 110.17 |
| | 0.03 | 12.88 | 10.12 | 5.37 | 10.67 | 18.69 | 78.55 |
| | 0.20 | 12.8 | 9.73 | 5.29 | 10.65 | 17.46 | 76.05 |
| Residual grass height (cm) | BL | 13.23 | 11.95 | 5 | 10 | 17 | 90.32 |
| | **0.03** | **13.83** | **8.85** | **7.25** | **12** | **17.75** | **64.02** |
| | 0.20 | 13.74 | 8.59 | 7.73 | 11.49 | 17.32 | 62.53 |
| Perennial grass cover (%) | BL | 11.16 | 13.09 | 2.5 | 10.5 | 10.5 | 117.31 |
| | **0.03** | **11.43** | **9.94** | **4.5** | **8.5** | **14.5** | **87.02** |
| | 0.20 | 11.54 | 9.89 | 5.07 | 9.1 | 14.9 | 85.69 |
| Annual grass cover (%) | **BL** | **3.49** | **5.48** | **2.5** | **2.5** | **2.5** | **156.79** |
| | 0.03 | 4.21 | 6.21 | 2.5 | 2.5 | 2.5 | 147.48 |
| | 0.20 | 4.22 | 5.38 | 2.5 | 2.5 | 2.5 | 127.43 |
| Perennial forb cover (%) | BL | 6.49 | 8.77 | 2.5 | 2.5 | 10.5 | 135.1 |
| | 0.03 | 8.33 | 8.25 | 2.5 | 4.5 | 10.97 | 99.02 |
| | 0.20 | 8.24 | 7.52 | 2.5 | 4.93 | 11 | 91.22 |

| Variable | Scale (ha) | Mean | SD | 25% | 50% | 75% | CV |
|---|---|---|---|---|---|---|---|
| Annual forb cover (%) | BL | 3.1 | 2.68 | 2.5 | 2.5 | 2.5 | 86.53 |
| | 0.03 | 3.12 | 2.47 | 2.5 | 2.5 | 2.5 | 79 |
| | 0.20 | 3.21 | 2.87 | 2.5 | 2.5 | 2.5 | 89.23 |
| Residual vegetation cover (%) | BL | 13.19 | 15.12 | 2.5 | 10.5 | 20.5 | 114.59 |
| | 0.03 | 15.06 | 12.15 | 6.5 | 11.09 | 19.88 | 80.7 |
| | **0.20** | **15.38** | **11.14** | **7.13** | **12.76** | **21.38** | **72.43** |
| Litter cover (%) | BL | 29.93 | 31.2 | 10.5 | 10.5 | 38 | 104.24 |
| | 0.03 | 27.6 | 24.33 | 8.5 | 18 | 41.76 | 88.14 |
| | 0.20 | 27.12 | 23.18 | 9.42 | 19.72 | 36.79 | 85.46 |
| Bare ground cover (%) | **BL** | **29.81** | **28.97** | **2.5** | **20.5** | **63** | **97.16** |
| | 0.03 | 28.97 | 18.72 | 13.41 | 26.36 | 42.76 | 64.63 |
| | 0.20 | 29.02 | 17.29 | 14.9 | 25.75 | 39.43 | 59.58 |
| Rock cover (%) | BL | 8.18 | 11.43 | 2.5 | 2.5 | 10.5 | 139.77 |
| | 0.03 | 10.36 | 13.02 | 2.5 | 2.5 | 13.38 | 125.66 |
| | 0.20 | 10.39 | 12.6 | 2.5 | 3.64 | 12.27 | 121.23 |
| Tall sagebrush cover (%) | 0.01 | 9.37 | 13.17 | 0 | 1.84 | 15.5 | 140.59 |
| | 0.03 | 8.95 | 11.84 | 0 | 2.02 | 16.6 | 132.37 |
| | 0.20 | 9.2 | 11.06 | 0 | 4.5 | 16.54 | 120.24 |
| Dwarf sagebrush cover (%) | 0.01 | 5.99 | 10.19 | 0 | 0 | 10.05 | 169.95 |
| | 0.03 | 5.8 | 9.8 | 0 | 0 | 9.86 | 168.88 |
| | 0.20 | 5.48 | 9.02 | 0 | 0 | 9.97 | 164.64 |
| Total sagebrush cover (%) | **0.01** | **15.36** | **13.6** | **2.95** | **13.37** | **23.6** | **88.54** |
| | 0.03 | 14.75 | 12.24 | 2.8 | 14.14 | 23.12 | 83.01 |
| | 0.20 | 14.67 | 11.26 | 3.68 | 14.87 | 21.95 | 76.74 |
| Non-sagebrush shrub cover (%) | 0.01 | 6.95 | 10.96 | 0 | 1.37 | 8.59 | 157.55 |
| | 0.03 | 7.54 | 10.74 | 0 | 2.73 | 10.76 | 142.5 |
| | 0.20 | 7.75 | 10.52 | 0 | 3.12 | 12.31 | 135.78 |
| Total shrub cover (%) | 0.01 | 22.31 | 15.86 | 9.49 | 21.17 | 34.02 | 71.07 |
| | 0.03 | 22.29 | 14.84 | 11.38 | 21.72 | 33.45 | 66.61 |
| | 0.20 | 22.42 | 14.05 | 13.16 | 20.89 | 32.21 | 62.69 |

**Table 13.** Example of habitat classes based on evidenced microhabitat factors evaluated for late brood-rearing greater sage-grouse (*Centrocercus urophasianus*) based on day locations within xeric and mesic habitats in Nevada and California, 2009–16.

[**Variable:** Variables not listed were not supported by these data for evidence of selection or survival. **Habitat type:** Evidence for brood selection/avoidance and success/failure was denoted with asterisks (*). **Unsuitable:** Value represents 25th percentile of used sites evidence of selection only and mean of failed broods with evidence of selection and success (see methods). **Suitable:** Value represents mean of used for variables supported by selection]

| Variable | Habitat type | Unsuitable | Marginal | Suitable |
|---|---|---|---|---|
| Horizontal cover (%) | Xeric | <46.7 | 46.7–61.6 | >61.6 |
| | Mesic* | <52.3 | 52.3–62.4 | >62.4 |
| Vertical cover (%) | Xeric* | <19.7 | 19.7–30.2 | >30.2 |
| | Mesic* | <6.8 | 6.8–43.3 | >43.3 |
| Average height (cm) | Xeric | <36.2 | 36.2–50.7 | >50.7 |
| | Mesic* | <42.2 | 42.2–56.7 | >56.7 |
| Sagebrush height (cm) | Xeric | <23.9 | 23.9–40.9 | >40.9 |
| | Mesic* | <22.8 | 22.8–37.7 | >37.7 |
| Non-sagebrush height (cm) | Xeric | <10.1 | 10.1–23.4 | >23.4 |
| | Mesic* | <20.6 | 20.6–37.0 | >37.0 |
| Perennial grass height (cm) | Xeric | <9.0 | 9.0–17.2 | >17.2 |
| | Mesic | <13.8 | 13.8–25.0 | >25.0 |
| Perennial forb height (cm) | Xeric* | <8.7 | 8.7–12.4 | >12.4 |
| | Mesic | <6.0 | 6.0–13.5 | >13.5 |
| Residual grass height (cm) | Xeric* | <6.0 | 6.0–7.8 | >7.8 |
| | Mesic* | <8.4 | 8.4–13.1 | >13.1 |
| Perennial grass cover (%) | Xeric | <2.5 | 2.5 – 9.1 | >9.1 |
| | Mesic | <5.9 | 5.9–15.0 | >15.0 |
| Annual grass cover (%) | Xeric | >4.3 | 2.5–4.3 | <2.5 |
| | Mesic | >4.8 | 2.5–4.8 | <2.5 |
| Perennial forb cover (%) | Xeric | <2.5 | 2.5–10.3 | >10.3 |
| | Mesic | <3.6 | 3.6–9.5 | >9.5 |
| Annual forb cover (%) | Xeric* | <2.8 | 2.8–3.9 | >3.9 |
| | Mesic* | <2.8 | 2.8–3.6 | >3.6 |
| Residual vegetation cover (%) | Xeric* | <7.1 | 7.1–9.1 | >9.1 |
| | Mesic | <7.1 | 7.1–14.4 | >14.4 |
| Tall sagebrush cover (%) | Xeric* | 0 | 0.0–15.1 | >15.1 |
| | Mesic | 0 | 0.0–11.0 | >11.0 |
| Dwarf sagebrush cover (%) | Xeric | 0 | 0.0–3.0 | >3.0 |
| | Mesic | 0 | 0.0–3.2 | >3.2 |
| Total sagebrush cover (%) | Xeric | <10.2 | 10.2–20.0 | >20.0 |
| | Mesic | 0 | 0.0–14.6 | >14.6 |
| Non-sagebrush shrub cover (%) | Xeric | 0 | 0.0–8.7 | >8.7 |
| | Mesic* | <7.0 | 7.0–11.4 | >11.4 |
| Total shrub cover (%) | Xeric* | <22.6 | 22.6–26.9 | >26.9 |
| | Mesic* | <17.9 | 17.9–25.9 | >25.9 |

## Interpretation

This research clearly demonstrates substantial variation in patterns of microhabitat selection and success across reproductive life stages of sage-grouse and across distinct precipitation zones within the Great Basin. Overall, the most important microhabitat factor for sage-grouse selection and success was horizontal, or lateral, cover directly at the nest and brood locations. Vertical, or overhead, cover also was well-supported as an important factor. Both vertical and horizontal cover variables were comprised of an assemblage of biotic and abiotic factors associated directly with a sage-grouse location. The cover attributes provided visual obstruction that would act to conceal nests and chicks from predators. The cover consisted of mixed shrubs, grasses, forbs, and rocks.

Vertical cover was mostly comprised of sagebrush and other shrubs that contribute to direct overhead visual obstruction, whereas horizontal cover (measured at 0 and 45 degree angles) was comprised of overstory mixed with understory vegetation (that is, grasses and forbs). Although substantial differences in lateral cover were detected between nesting and brood-rearing sites, cover used by sage-grouse was remarkably similar between xeric and mesic habitats for both life stages despite substantial variation within any given individual vegetation component (for example, grass cover and height). Interestingly, the functions of horizontal and vertical cover may be fundamentally different between nesting and brood-rearing sites. During nesting, female grouse deliberately seek areas concealed within vegetation while during non-nesting periods (that is, brood-rearing) female grouse use vegetation within the interspace as opposed to hiding underneath shrubs, forbs, or bunchgrasses. Across both life stages, the use of cover exemplifies the importance of structurally diverse microhabitats that consist of mixed vegetation to conceal sage-grouse nests and their chicks (figs. 3 and 4).

Diel patterns in the use of cover during brood-rearing likely reflect important anti-predator strategies based on diurnal and nocturnal predators. For example, sage-grouse selected day sites with relatively more structural cover which likely concealed their chicks from visually cued diurnal predators while foraging. However, during night hours when sage-grouse are still inconspicuous, roosting broods used open canopy areas. Sage-grouse in open areas likely are difficult for terrestrial predators to approach cryptically and open areas likely are more conducive for detecting and escaping approaching terrestrial predators. Thus, the same vegetation that conceals moving and foraging grouse from diurnal predators during daylight hours may hinder predator detection by grouse and is avoided nocturnally when grouse are inactive.

Sage-grouse regularly move daily between day and night sites, averaging approximately 350 m. Such daily movements were greater in xeric habitats. Although a high-cover environment is important for brood rearing during the day, the diel patterns we observed indicate that optimal late-brood rearing habitats consist of a mix of patchy, open and closed, vegetation within 350 m. Accordingly, sage-grouse that nest in close proximity to brood rearing habitats would minimize long distance and risky movements to areas with late brood rearing habitat.

Based on our comparisons, wildfire has long-term effects on microhabitat factors associated with sage-grouse reproduction. These data were collected 10–17 years following the major wildfire at the burned study area. Wildfire influences shrub composition by killing sagebrush (Schlaepfer and others, 2014) and favoring less desirable shrubs that re-sprout from the roots and crown (Young and Evans, 1974), such as rabbitbrush and horsebrush.

Figure 3. Photographs of successful (top and bottom left) and failed (top and bottom right) greater sage-grouse (*Centrocercus urophasianus*) nesting sites in xeric habitats within the Great Basin, Nevada and California.

Within the burned areas, nest bowl overhead cover consisted of more non-sagebrush shrubs than at any of the study areas unaffected by wildfire. Specifically, the most common non-sagebrush type of shrub chosen for nesting was rabbitbrush. Sage-grouse also nested under perennial bunchgrass and overhanging rocks (fig. 5), which sage-grouse typically do not select in unperturbed sagebrush habitats. Nests using these non-sagebrush cover conditions were much more likely to fail. In burned environments, sage-grouse still seek to nest in areas with the highest available cover often provided by herbaceous vegetation or less structurally robust shrubs. Hence, these results suggest that wildfire causes substantial loss of important nesting habitat and structure, specifically sagebrush cover (table 6). These data help to understand evidence of long-lasting adverse effects of wildfire on sage-grouse population growth rates across the Great Basin (Coates, Ricca, and others, 2016) and decreases in population recruitment (Blomberg and others, 2012).

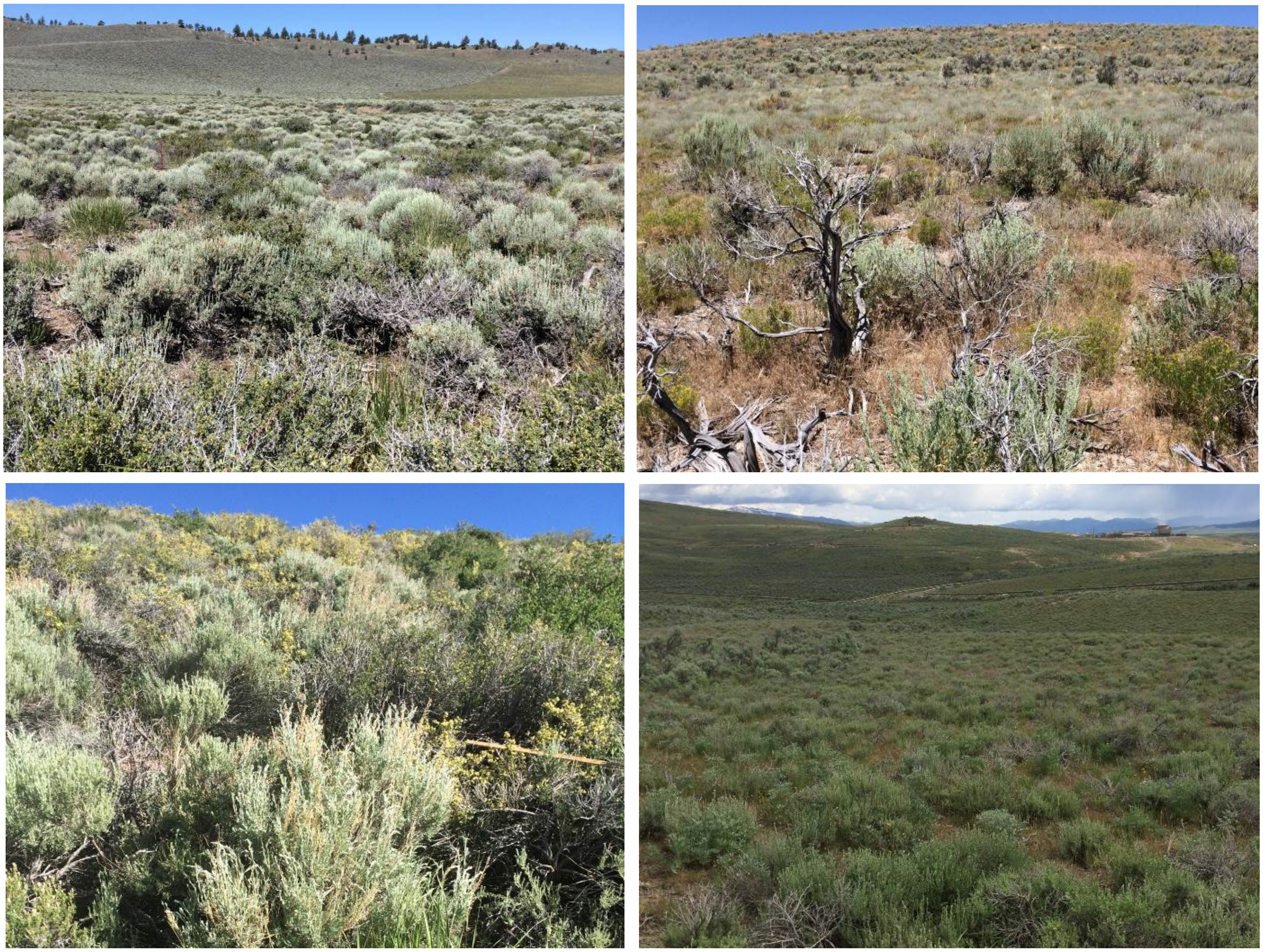

Figure 4. Photographs of successful (top and bottom left) and failed (top and bottom right) greater sage-grouse (*Centrocercus urophasianus*) nesting sites in mesic habitats within the Great Basin, Nevada and California.

Our findings have great potential benefit to restoration strategies focused on accelerating the growth and recovery of sagebrush overstory and targeting areas conducive to nesting immediately following wildfire. Results of this study suggest a focus on restoration of nesting habitat as quickly as possible would benefit sage-grouse. If existing nesting areas are unknown, then focusing efforts adjacent to lek sites might be advantageous because most nests are located near leks (Coates and others, 2013). Although our results indicate that sage-grouse prefer a mix of sagebrush and non-sagebrush overstory, our findings also recognize that sagebrush is the single most important shrub component within that mix especially in areas where sagebrush is sparse.

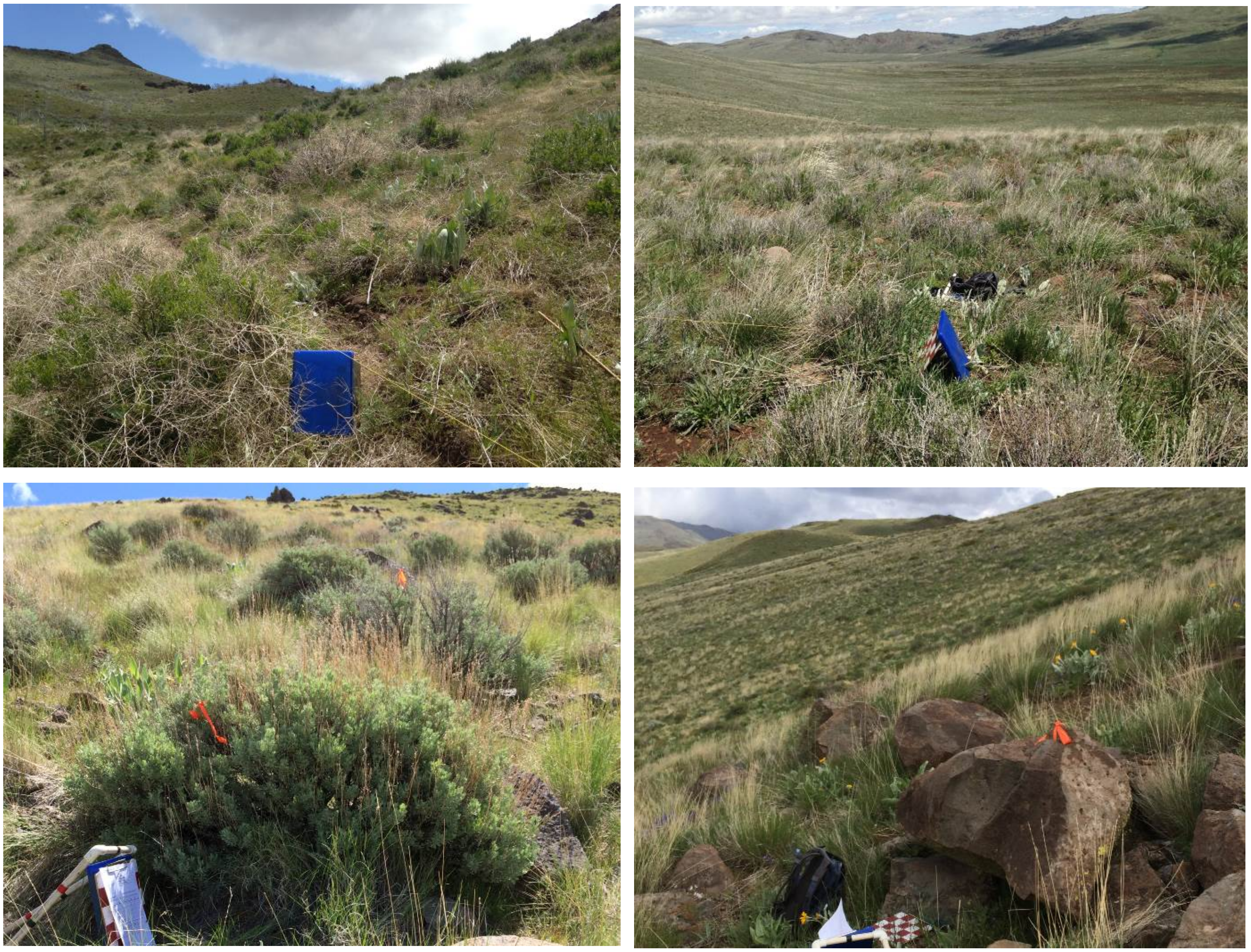

Figure 5. Photographs of successful (top and bottom left) and failed (top and bottom right) greater sage-grouse (*Centrocercus urophasianus*) nesting sites within burned mesic habitats within the Great Basin, Nevada and California.

Across mesic and xeric habitats, total shrub cover was among the most supported variables for selection of nest and brood sites, which indicates its relative importance to overall horizontal and vertical cover. However, the effects of shrub cover on reproductive success varied across xeric and mesic habitats. Increased total shrub cover was associated with increased nest and brood success within mesic habitats but not within xeric habitats. This can be explained by the relatively greater amount of shrub cover available in xeric environments and does not imply that shrub cover was unimportant. Further support for the overall importance of total shrub cover on nesting was observed when evaluating the burned study area. For example, sage-grouse preferred microhabitats with relatively high amount of total shrub cover, even though shrub cover was substantially lower at the burned area than those unaffected by wildfire. At the burned study area, marginal evidence indicated that sagebrush cover was related to nest success. Following wildfire sagebrush species are generally slow to recover and early successional species of non-sagebrush shrubs will dominate, and as seen in this case, for decades.

Additionally, evidence of selection for total shrub cover was greater than that of sagebrush-specific species of shrubs in both habitat types, which further indicates a mixture of shrub species likely provides heterogeneous structure more conducive for concealing nesting sage-grouse. It is also possible that these diverse shrub environments are preferred for increased food resources, especially in upland environments that tend to be wetter and more productive. Non-sagebrush shrub species have been shown to be an important microhabitat component in other studies within the Great Basin (Kolada and others, 2009; Coates and Delehanty, 2010; Lockyer and others, 2015). A 10-year study in Eureka County within the xeric area recently concluded that sage-grouse selected nest sites with increased total shrub cover, but non-sagebrush species better explained variation in nest survival (Gibson, Blomberg, Atamian, and others, 2016). A mixture of shrub cover can benefit nesting sage-grouse by providing a heterogeneous, structurally complex canopy that likely conceals sage-grouse and their nests from visually cued egg predators. For example, reducing total shrub cover by as little as 1 percent increases the odds of raven-caused predation by 7.5 percent (Coates and Delehanty, 2010).

Similar to the effects of total shrub cover during the nesting stage, shrub cover played a major role in both brood site selection and brood success. Interestingly, the diel pattern switched between early and late brood-rearing. That is, during the first couple weeks following hatch, broods selected increased cover at night, but as time progressed switched to increased shrub cover during day with relatively open overnight roost sites. Multiple non-mutually exclusive explanations are possible. First, chicks simply may be transitioning between nesting habitat that usually consists of relatively large homogenous patches of sagebrush and other shrub canopy (figs. 6a and 7a) to upland patchy habitat during later brood-rearing (Casazza and others, 2011; figs. 6b and 7b). Alternatively, young chicks in natal plumage may benefit from greater nocturnal thermal protection proved by heavy cover. In this scenario, as chicks molt into juvenile plumage, they are liberated into being able to use less risky open cover at night. As discussed previously, choosing open areas at night (figs. 8 and 9) might reflect a better ability to detect and avoid nocturnal predators especially considering the ability of older chicks to flush and fly from terrestrial predators.

Importantly, these findings regarding nocturnal habitat use should be distinguished from daytime habitat use. Our data indicated that using increased overhead shrub cover positively influenced chick survival during day hours. This supports hypotheses that sage-grouse prefer irregularly shaped upland wet meadows, rich in forbs with integration of sagebrush along the edge and other shrub species for overhead protection (Casazza and others, 2011). We also found that patterns in differential selection of sagebrush species were associated with height and explain differences in sagebrush and non-sagebrush heights among used and available sites. For example, cover provided by dwarf species of sagebrush was not avoided during the night but rather was used in proportion to its availability. Environments with a mix of sagebrush species likely provide heterogeneity in shrub canopy cover height and are most conducive to diel patterns of brood-rearing sage-grouse.

Figure 6. Photographs of early (right; located near nest) and late (left) brood-rearing habitat from the same brood within the Great Basin, Nevada and California.

The role of understory vegetation height (grasses and forbs) at nest and brood sites also varied between xeric and mesic habitats. For nesting, the selection of taller grasses (residual and new perennial growth) and forbs (perennial) was stronger within xeric habitats than mesic. Also, nest success was influenced by these microhabitat factors within xeric habitats, but not within mesic (fig. 3). These patterns can be explained by two major differences among habitats related to ecological potential. First, the mesic habitats that receive greater precipitation annually had much taller understories of grasses and forbs than within xeric habitats (figs. 3 and 4). On average, perennial grasses and forbs were approximately 6 and 5 cm, respectively, shorter within xeric habitats. Thus, within xeric habitats where grass height is relatively short, sage-grouse are more likely to seek out nesting sites with the tallest available understory grass and forb herbaceous vegetation. Additionally, overstory within xeric habitats consisted of greater cover from tall sagebrush species than those forming overstory cover within mesic habitats. Although both xeric and mesic habitats consisted of mixed forms of sagebrush plants, shrubs within xeric habitats usually appeared to be more columnar and less spreading than those in mesic.

Thus, in mesic environments with relatively tall grasses, a medium-sized spreading sagebrush enhances horizontal cover and may preclude the need to select taller grasses that help close the canopy and fully conceal nests. However, in xeric habitats, sage-grouse require taller understory of perennial vegetation to help close the gap between understory and overstory vegetation, especially considering relatively short average understory vegetation heights. Gaps in the canopy likely have strong consequences for nest survival. For example, these gaps result in less structural horizontal and vertical closure and likely increase detection by keen visually-cued predators, such as common ravens (*Corvus corax*), and might reduce scent barriers for olfactory-cued terrestrial predators. Additionally, relatively tall grasses and forbs off the nest but within the shrub interspace might help conceal females from predators as they move to and from their nests during incubation recesses (Coates and Delehanty, 2008).

Figure 7. Photographs of early (right; located near nest) and late (left) brood-rearing habitat from the same brood within the Great Basin, Nevada and California.

Figure 8. Photographs of differences in mesic habitat types between day (right) and night (left) used areas of a sage-grouse during the late brood-rearing period within the Great Basin. Photographs were taken within a 12-hour period.

Height of residual grasses did not appear to have the same influence on nest success as new growth perennials. Specifically, we did not detect associations between height of residual grass and nest success. Residual grasses were on average 5 cm shorter than perennial grasses in xeric and mesic habitats during mid-nesting season, which likely does not contribute enough to closing potential gaps between under- and over-story vegetation, especially in xeric habitats. A study at Hart Mountain Wildlife Refuge in Oregon emphasized the importance of residual grasses on nest survival (Gregg and others, 1994) where nests were more likely to survive with heights greater than 18 cm. In our study areas, residual grass heights were on average 10 cm shorter than those reported for the Oregon study, which may be largely related to primary productivity differences between Oregon and most of the southern Great Basin, especially in the xeric habitats. However, early in the nesting season, residual grass height might play a more important role in enhancing daily survival probabilities as this is a period of time when new growth grasses have likely not exceeded residual grass heights. Hence, residual grass is often the only herbaceous component available for early nesting sage-grouse that helps to fill gaps between understory and overstory vegetation and therefore provide greater concealment. These potentially important time-dependent effects merit further investigation.

Figure 9. Photographs displaying differences in xeric habitat types between day (right) and night (left) used areas of a sage-grouse during the late brood-rearing period within the Great Basin. Photographs were taken within a 12-hour period.

During late brood-rearing, sage-grouse chicks rely on wet meadow habitat for water and food resources (Casazza and others, 2011), which are generally areas rich in forbs (figs. 6 and 7; Casazza and others, 2011; Gibson, Blomberg, Atamian, and others, 2016). Sage-grouse selected areas with greater forb cover and taller forbs. Given the important effects of forb height identified here, forbs seem to not only provide a food resource for chicks but also provide important cover while foraging. Although sage-grouse selected taller forbs in both mesic and xeric environments, associations between forb height and brood success were only supported within xeric habitats. Forbs in these areas were on average approximately 4 cm shorter than those in mesic habitats. Average forb height for successful broods within xeric habitats was similar to available forb height in mesic habitats. Accordingly, despite selection for taller forbs in mesic habits, the average (approximately 11 cm) height is tall enough to help conceal sage-grouse chicks. Explanations for the importance of forb height for successful broods in mesic habitats are similar to those that we described for grass height, although there may be an additional explanation regarding forage value that could benefit from further study.

Forbs likely play an even more important role for brood-rearing sage-grouse within burned habitats, largely because of loss of overstory sagebrush and other shrubs that take decades to recover (fig. 5). Similar to xeric habitats, the association between taller forbs and successful broods was supported but marginal. Notably, available perennial forb height at the burned study area was much greater (exceeded 12 cm) than at both xeric and mesic areas unaffected by wildfire. Thus, it is possible that the effect of forb height has been intensified by helping to provide additional horizontal and vertical cover to compensate for severe loss of shrub cover, which in part explains why failed nests were still associated with average heights as high as 20 cm.

We found support for perennial grass height and cover across both nesting and brood-rearing life stages. Although we did not detect substantial differences in perennial grass cover between successful and failed nests in either xeric or mesic habitats, numerically successful nests consisted of greater perennial grass cover in both habitats. Additionally, taller perennial grass was associated with higher nest success in xeric habitats. Inconsistencies in the effects of grass height and cover on sage-grouse nest site selection and survival among studies might be explained by regional variation in sagebrush ecosystems and their ecological potential. For example, some range-wide studies have reported positive associations of microhabitat grass-related variables on selection and (or) survival of nests (Gregg and others, 1994; Sveum and others, 1998; Aldridge and Brigham 2002; Herman-Brunson and others, 2009; Kaczor and others, 2011; Doherty and others, 2011a; 2014) whereas others have reported those associations to be weak (Holloran and others, 2005; Davis and others, 2014; Dinkins and others, 2016) or absent (Popham and Gutierrez, 2003; Kolada and others, 2009; Lockyer and others, 2015). Additionally, others studies concluded little to no influential effects on nest survival with grass-related variables (Kolada and others, 2009; Coates and Delehanty, 2010; Lockyer and others, 2015; Gibson, Blomberg, Atamian, and others, 2016).

Inconsistencies among these nest success studies have been attributed to variable confounding effects based on timing of measurement and plant phenology (Gibson, Blomberg, and Sedinger, 2016). In short, positive effects might be an artifact of sampling failed nests earlier in the season (that is, as nests fail) when grass cover and height is less than at the sampling time of successful nests (Hausleitner and others, 2005). However, here we accounted for plant phenology and found that the effects varied between sagebrush ecosystems. Our results indicate that inconsistencies in the microhabitat factors of understory vegetation can likely be attributed to differences in primary productivity as expressed by the height and cover of understory, the availability of shrub overstory, and the growth form of sagebrush species as either tall and columnar or medium-short and spreading.

The most prevalent species of annual grass at the burned study area was cheatgrass. We did not detect differences in the amount of annual grass cover between successful and failed nests within any habitat types. Although annual grass likely provides a form of cover for sage-grouse, this plant often replaces more desirable perennial grasses, forbs, and shrubs and the loss of these native species likely explains relatively low horizontal and vertical cover in burned areas that influences nest survival (fig. 5). Habitats unaffected by wildfire had less than 5 percent cover of annual grass, whereas the burned area had twice as much annual grass cover, on average. Also, the only areas where we detected clear evidence of avoidance of annual grass were the burned habitats, where annual grass was 10.8 (±0.8) percent, on average. Within these habitats, sage-grouse used sites that consisted of 7.5 (±0.7) percent annual grass. It appears that sage-grouse are less tolerant of annual grass when it exceeds approximately 5 percent, and where annual grass is prevalent, they use sites with approximately 7 percent. Because of the variable effects of annual grass in relation to post-fire, these values might provide alternative thresholds to the habitat classes that we presented in Table 13. Lastly, bare ground was highly avoided within both xeric and mesic habitats and no correlations were evidenced between this variable and any of the cover variables. Interestingly, the avoidance of bare ground was most pronounced at xeric areas, where ecological potential is relatively less resulting in substantially more bare ground within the interspace of shrubs.

Differences in predator species composition may also be responsible for inconsistencies in the relative importance of microhabitat factors across studies range-wide and even within the Great Basin. For example, predation accounts for the majority of nest failure within the Great Basin (Coates and others, 2008; Lockyer and others, 2013) and specific predators have been linked to microhabitat characteristics (Coates and Delehanty, 2010). Lack of cover, particularly from shrubs, has been shown to favor predation by ravens largely as a result of loss of overhead and horizontal cover. However, positive associations have been found between increased understory vegetation and badger predation, apparently as a result of indirect relationships with increased ground squirrel or rodent presence (Coates and Delehanty, 2010). Thus, detecting influences of specific microhabitat characteristics on nest survival likely depends on which predators dominate an area. Nevertheless, raven populations are rising substantially with greater than 300 percent increases in abundance since 2005 within the Great Basin (Sauer and others, 2017), largely as a result of land cover changes and anthropogenic resource subsidies (Coates and others, 2014; Howe and others, 2014). Ravens are becoming a more prevalent predator at landscape scales within sage-grouse habitats and sage-grouse nest predation increases with raven abundance (Coates and Delehanty, 2010). Results of this study indicate that providing adequate over- and understory cover for sage-grouse can prevent nest failure.

Several caveats need to be considered when interpreting these results. First, these are initial findings of summary statistics and are provided at this time to help guide management decisions using the best available scientific information. It is important to point out that a more rigorous modeling approach is underway and may identify important ecological additive or multiplicative effects using multivariate modeling techniques. Our understanding of the relative role of each microhabitat factor will likely improve within a modeling framework that accounts for nest exposure time. For example, such a framework will fit modeled covariates for nest survival to estimate the effects of each factor on daily survival probabilities. Additionally, a more comprehensive analysis will also account for spatiotemporal variation within xeric and mesic habitats by fitting random effects and evaluate differences in overall daily survival probabilities for nests and broods across xeric, mesic, and burned habitats. Second, upcoming analyses will evaluate effects across spatial scales, that exceed the largest scale in this study (0.2 ha), using geographic information systems (third order effects). Although the scope of our current study was focused solely on evaluating microhabitat characteristics (fourth order), omission of factors that function at larger spatial scales (third order) limits the understanding of microhabitat effects. For example, as little as 2 percent of pinyon-juniper land cover can influence sage-grouse avoidance of areas and adversely affect survival probabilities at 61-ha scales (Coates and others, 2017). Also, lek inactivity is likely to occur where conifers exceed 4 percent within 5 km of lek sites (Baruch-Mordo and others, 2013). For example, the larger scale adverse effects of conifers that has been reported in the literature (Baruch-Mordo and others, 2013; Coates and others, 2017) likely influence overall habitat suitability of an area regardless of the quality of microhabitat characteristics (for example, 0.03 or 0.2 ha). A multi-scale analysis would allow evaluation of variation in the effects of environmental factors across spatial scales to better represent the hierarchical process of which sage-grouse select habitat and factors that influence survival. Third, more rigorous modeling approaches will be sensitive to non-normal data distributions and could influence the outcomes. Lastly, large-scale disturbances may also influence microhabitat effects as revealed in our comparison between effects within burned and unburned habitats. However, other potential landscape disturbances that influence relationships were possible but difficult to represent. For example, estimates of herbaceous vegetation (percent cover and height) likely reflect limitations in plant productivity, differences in grazing regimes, or a combination of factors, which were often indistinguishable within the scope of this analysis. However, this potential additive influence should not change the biologically meaningful outcomes of specific cover and height estimates associated with selection and survival across xeric and mesic habitats.

If these findings are used to help evaluate sage-grouse microhabitat and guide management decisions, then additional caveats should be recognized. Comparisons of field measurements derived from different vegetation sampling methodology as those employed here should be interpreted with caution. Our data were collected using standardized vegetation sampling methods, including Daubenmire visual frame plots and line-intercept transect methods that have been used widely among sage-grouse researchers for decades. The purpose of carrying out similar methods as those previously for sage-grouse was to facilitate comparison among the vast amount of historical habitat studies on sage-grouse across the range. Nevertheless, estimates of height and vegetation overstory cover among methods should not be inconsistent. However, understory herbaceous cover estimates using Daubenmire methods opposed to line-point or point-frame methods should be interpreted carefully. Importantly, differences in methodology might have some potential influences on absolute values but should not influence consistency in the associations with selection and survival patterns that were identified here.

Secondly, if long-term monitoring strategies rely on sampling points randomly assigned across the landscape, then values reported in this study should be interpreted and used with caution. Assessment of microhabitat suitability across different life stages is only useful in conjunction with habitat identified at larger spatial scales (third order). For example, in this study microhabitat characteristics were collected from telemetered sage-grouse during each life stage located within their corresponding seasonal use areas. Thus, effective microhabitat assessment strategies might include an initial assessment of seasonal habitats using broad scale associations mapped within a geographic information system (third order). Then, once those areas are established, conducting further field assessments of microhabitat (for example, nest) at reduced scales (fourth order) within seasonal use areas (for example, nesting areas) could be conducted. Such a hierarchical analytical process would help guard against misappropriate placement of sampling point on the landscape that could lead to mischaracterization of assessing life stage specific microhabitat. For example, this hierarchical process would prevent assessing nesting microhabitat within wintering areas instead of nesting areas. The premise of this strategy is aligned with existing hierarchical frameworks described elsewhere in detail (for example, Habitat Assessment Framework; Stiver and others, 2010) and initial findings reported here might help to inform these existing efforts with specific target values to assess habitat quality given the regional variation in effects. Furthermore, in our management example, we chose the $25^{th}$ percentile of the used distribution to demarcate unsuitable habitat (as opposed to $50^{th}$) to prevent cutpoint values from being biased high as a result of measurements conducted directly at telemetry locations. For monitoring purposes, this percentile as a cutpoint seemed to produce sensible target values for random points generated within areas identified at the third order.

Third, values reported here were collected to account for plant phenology that corresponded to each sage-grouse reproductive life stage. Assessment sampling might be timed to correspond to each sage-grouse life stage in a similar manner to make meaningful comparisons. If this proves logistically difficult, then values can be predicted based on date-adjusted plant traits timed for the appropriate time of year for sage-grouse life stage of interest. Finally, the values chosen for microhabitat quality tables represent a defensible example of using empirical data describing habitat selection and life stage success. However, land and wildlife managers might choose other cutpoints for habitat categories than those presented as examples here.

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## Appendix 1. Average values of microhabitat characteristics at independent random sites to characterize availability (Avail) and used nest sites with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) in areas unaffected by wildfire at xeric and mesic sites in the Great Basin, Nevada and California, 2009–16

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. **Xeric and Mesic Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| | | Xeric | | | | | Mesic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Scale | Avail | SE | Used | SE | Effect | Avail | SE | Used | SE | Effect |
| Horizontal cover (%) | NB | 67.4 | 1.12 | 82.3 | 0.75 | ** | 66.6 | 1.58 | 83.8 | 0.83 | ** |
| Vertical cover (%) | NB | 58.7 | 1.76 | 72.7 | 1.49 | ** | 59.2 | 2.40 | 74.4 | 1.77 | ** |
| Maximum height (cm) | NB | 64.2 | 3.09 | 72.8 | 1.95 | * | 65.2 | 2.05 | 73 | 1.93 | * |
| Average height (cm) | NB | 42.8 | 1.47 | 43.7 | 0.79 | | 51.1 | 1.46 | 50.5 | 1.36 | |
| Perpendicular width (cm) | NB | 80.6 | 2.80 | 92.5 | 2.93 | ** | 80.3 | 2.80 | 96.3 | 2.75 | ** |
| Sagebrush height (cm) | NB | 50 | 1.56 | 59.9 | 1.48 | ** | 44.8 | 2.56 | 59.1 | 2.37 | ** |
| | 0.03 | 35.1 | 1.15 | 43.2 | 1.10 | ** | 36.1 | 1.86 | 44.3 | 1.70 | ** |
| | 0.20 | 33 | 1.06 | 40 | 0.98 | ** | 34.5 | 1.74 | 41.2 | 1.48 | ** |
| Non-sagebrush height (cm) | NB | 20.9 | 2.09 | 23.9 | 1.83 | | 30.2 | 2.61 | 37 | 2.63 | * |
| | 0.03 | 18.9 | 1.20 | 20.8 | 1.16 | | 32.7 | 2.20 | 32 | 1.82 | |
| | 0.20 | 20.7 | 2.17 | 21.1 | 1.07 | | 32.1 | 1.96 | 30.9 | 1.63 | |
| Perennial grass height (cm) | NB | 10.7 | 0.64 | 12.7 | 0.74 | * | 17.2 | 1.06 | 20.3 | 1.32 | * |
| | 0.03 | 10.4 | 0.46 | 12.5 | 0.47 | ** | 16.7 | 0.76 | 19.3 | 0.86 | * |
| | 0.20 | 10.1 | 0.41 | 12.5 | 0.45 | ** | 16.6 | 0.73 | 18.9 | 0.72 | * |
| Perennial forb height (cm) | NB | 3.9 | 0.38 | 5.8 | 0.54 | ** | 8.5 | 0.75 | 9.2 | 0.67 | |
| | 0.03 | 4.6 | 0.41 | 5.8 | 0.37 | * | 9.2 | 0.62 | 9.8 | 0.54 | |
| | 0.20 | 4.3 | 0.30 | 5.4 | 0.32 | * | 9.5 | 0.60 | 9.7 | 0.52 | |
| Residual grass height (cm) | NB | 8.1 | 0.75 | 7.7 | 0.64 | | 11.6 | 0.94 | 15.3 | 1.43 | * |
| | 0.03 | 6.4 | 0.35 | 7.4 | 0.42 | * | 9.8 | 0.54 | 12.7 | 0.78 | ** |
| | 0.20 | 6.2 | 0.30 | 7.5 | 0.37 | ** | 9.7 | 0.48 | 12.5 | 0.67 | ** |
| Perennial grass cover (%) | 0.03 | 5.8 | 0.33 | 7.1 | 0.44 | * | 13.7 | 1.04 | 12.8 | 0.75 | |
| | 0.20 | 5.4 | 0.24 | 6.8 | 0.36 | ** | 13.4 | 0.88 | 12.8 | 0.65 | |

| Variable | Scale | Xeric | | | | | Mesic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Avail | SE | Used | SE | Effect | Avail | SE | Used | SE | Effect |
| Annual grass cover (%) | 0.03 | 4.2 | 0.36 | 4.8 | 0.41 | | 4.7 | 0.48 | 5.1 | 0.48 | |
| | 0.20 | 4.5 | 0.35 | 4.9 | 0.38 | | 4.8 | 0.41 | 5.2 | 0.41 | |
| Perennial forb cover (%) | 0.03 | 4.2 | 0.20 | 5.1 | 0.34 | * | 8.2 | 0.68 | 9.2 | 0.70 | |
| | 0.20 | 4.3 | 0.18 | 5 | 0.26 | * | 8.5 | 0.63 | 8.3 | 0.54 | |
| Annual forb cover (%) | 0.03 | 3.7 | 0.23 | 3.5 | 0.18 | | 4.9 | 0.40 | 3.9 | 0.30 | * |
| | 0.20 | 3.6 | 0.20 | 3.5 | 0.17 | | 4.5 | 0.31 | 4.1 | 0.29 | |
| Residual vegetation cover (%) | 0.03 | 8.4 | 0.45 | 8.5 | 0.46 | | 11.6 | 0.84 | 11.4 | 0.68 | |
| | 0.20 | 8.1 | 0.39 | 8.7 | 0.40 | | 11.7 | 0.68 | 11.8 | 0.60 | |
| Litter cover (%) | 0.03 | 20.9 | 1.12 | 24.2 | 1.36 | * | 27.7 | 1.63 | 27.7 | 1.53 | |
| | 0.20 | 21.2 | 1.05 | 23.5 | 1.22 | | 27.6 | 1.51 | 26.6 | 1.37 | |
| Bare ground cover (%) | 0.03 | 50.7 | 1.49 | 43.8 | 1.56 | ** | 35.8 | 1.84 | 29.8 | 1.64 | * |
| | 0.20 | 51.3 | 1.40 | 44.2 | 1.40 | ** | 35.1 | 1.54 | 30.2 | 1.47 | * |
| Rock cover (%) | 0.03 | 8.8 | 0.82 | 9.7 | 0.81 | | 9.5 | 0.95 | 10.1 | 1.03 | |
| | 0.20 | 8.5 | 0.71 | 10.2 | 0.80 | | 9.2 | 0.82 | 10 | 0.86 | |
| Tall sagebrush cover (%) | 0.01 | 9.9 | 0.71 | 14.9 | 0.88 | ** | 6.9 | 0.77 | 12 | 0.98 | ** |
| | 0.03 | 9.5 | 0.67 | 13.9 | 0.80 | ** | 7.1 | 0.73 | 11.1 | 0.86 | ** |
| | 0.20 | 8.9 | 0.58 | 12.2 | 0.69 | ** | 6.9 | 0.67 | 10.2 | 0.78 | ** |
| Dwarf sagebrush cover (%) | 0.01 | 7.9 | 0.64 | 7.7 | 0.59 | | 4.6 | 0.66 | 7.6 | 0.79 | ** |
| | 0.03 | 7.7 | 0.61 | 7.8 | 0.56 | | 4.3 | 0.59 | 7.8 | 0.78 | ** |
| | 0.20 | 7.3 | 0.54 | 8.2 | 0.53 | | 4.2 | 0.57 | 7.5 | 0.68 | ** |
| Total sagebrush cover (%) | 0.01 | 17.8 | 0.71 | 22.8 | 0.74 | ** | 12.2 | 0.87 | 20.3 | 0.94 | ** |
| | 0.03 | 17.2 | 0.66 | 21.8 | 0.65 | ** | 12 | 0.80 | 19.6 | 0.85 | ** |
| | 0.20 | 16.2 | 0.57 | 20.4 | 0.58 | ** | 11.6 | 0.75 | 18.3 | 0.76 | ** |
| Non-sagebrush shrub (%) | 0.01 | 4 | 0.38 | 5 | 0.53 | | 6.1 | 0.70 | 5.6 | 0.63 | |
| | 0.03 | 4.2 | 0.39 | 5.3 | 0.50 | | 6.4 | 0.67 | 5.6 | 0.60 | |
| | 0.20 | 4.3 | 0.39 | 5.1 | 0.47 | | 6.6 | 0.65 | 5.2 | 0.49 | |
| Total shrub cover (%) | 0.01 | 21.8 | 0.79 | 27.8 | 0.86 | ** | 18.1 | 1.07 | 25.8 | 1.09 | ** |
| | 0.03 | 21.4 | 0.80 | 27.1 | 0.81 | ** | 18.3 | 1.02 | 25 | 1.05 | ** |
| | 0.20 | 20.5 | 0.73 | 25.5 | 0.75 | ** | 18.1 | 0.97 | 23.3 | 0.93 | ** |

## Appendix 2. Average values with standard errors (SE) of microhabitat characteristics at successful and failed and used nest sites by greater sage-grouse (*Centrocercus urophasianus*) in areas unaffected by wildfire at xeric and mesic sites in the Great Basin, Nevada and California, 2009–16

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. **Xeric and Mesic Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| | | Xeric | | | | | Mesic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Scale | Success | SE | Fail | SE | Effect | Success | SE | Fail | SE | Effect |
| Horizontal cover (%) | NB | 84.2 | 1.06 | 79.9 | 1.10 | ** | 86.3 | 1.15 | 81.1 | 1.23 | ** |
| Vertical cover (%) | NB | 75 | 2.12 | 69.7 | 2.24 | | 77 | 2.49 | 71.2 | 2.65 | |
| Maximum height (cm) | NB | 74.1 | 2.94 | 72.4 | 2.91 | | 71.9 | 2.48 | 73.1 | 3.13 | |
| Average height (cm) | NB | 43.9 | 1.07 | 43.5 | 1.24 | | 51.9 | 1.97 | 48.9 | 2.02 | |
| Perpendicular width (cm) | NB | 97.6 | 5.31 | 86.4 | 2.76 | * | 95.7 | 4.21 | 95.1 | 3.79 | |
| Sagebrush height (cm) | NB | 57.5 | 2.10 | 62.2 | 2.32 | | 60 | 3.28 | 58.5 | 3.64 | |
| | 0.03 | 43.1 | 1.55 | 43.6 | 1.67 | | 44.8 | 2.25 | 43.7 | 2.73 | |
| | 0.20 | 39.9 | 1.38 | 40.6 | 1.49 | | 41 | 2.01 | 40.6 | 2.35 | |
| Non-sagebrush height (cm) | NB | 23.1 | 2.35 | 24.7 | 3.09 | | 41.4 | 3.85 | 31.7 | 3.63 | * |
| | 0.03 | 19.8 | 1.59 | 22.1 | 1.87 | | 33.6 | 2.60 | 29 | 2.60 | |
| | 0.20 | 19.3 | 1.32 | 23 | 1.83 | | 31 | 2.25 | 29 | 2.38 | |
| Perennial grass height (cm)[1] | NB | 14.3 | 1.29 | 10.2 | 0.81 | ** | 20.1 | 2.09 | 17.9 | 1.88 | |
| | 0.03 | 13.4 | 0.80 | 10.5 | 0.60 | ** | 18.9 | 1.46 | 17.5 | 1.08 | |
| | 0.20 | 13.3 | 0.75 | 10.6 | 0.58 | ** | 18.5 | 1.23 | 16.7 | 0.87 | |
| Perennial forb height (cm)[1] | NB | 6.4 | 0.89 | 4.6 | 0.71 | | 8 | 1.10 | 7.1 | 0.85 | |
| | 0.03 | 6.1 | 0.60 | 4.7 | 0.48 | | 9.2 | 0.95 | 7.6 | 0.61 | |
| | 0.20 | 5.5 | 0.54 | 4.6 | 0.43 | | 9 | 0.92 | 7.7 | 0.59 | |
| Residual grass height (cm) | NB | 8.2 | 1.02 | 7.2 | 0.85 | | 15.4 | 2.07 | 15.2 | 2.18 | |
| | 0.03 | 7.1 | 0.44 | 7.8 | 0.78 | | 12.5 | 1.00 | 12.2 | 1.24 | |
| | 0.20 | 7.6 | 0.45 | 7.7 | 0.64 | | 12.5 | 0.92 | 11.6 | 0.99 | |
| Perennial grass cover (%) | 0.03 | 7.3 | 0.71 | 6.9 | 0.57 | | 12.3 | 1.13 | 13.4 | 1.09 | |
| | 0.20 | 6.8 | 0.58 | 6.8 | 0.47 | | 12.4 | 0.94 | 13.5 | 0.98 | |
| Annual grass cover (%) | 0.03 | 4.5 | 0.50 | 5.2 | 0.73 | | 4.6 | 0.59 | 5.8 | 0.81 | |
| | 0.20 | 4.7 | 0.43 | 5.3 | 0.71 | | 4.8 | 0.54 | 5.7 | 0.67 | |

| Variable | Scale | Xeric Success | Xeric SE | Xeric Fail | Xeric SE | Xeric Effect | Mesic Success | Mesic SE | Mesic Fail | Mesic SE | Mesic Effect |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Perennial forb cover (%)[1] | 0.03 | 5.3 | 0.63 | 4.1 | 0.31 | * | 9.3 | 1.19 | 7.6 | 0.83 | |
| | 0.20 | 5 | 0.47 | 4.2 | 0.27 | | 8 | 0.89 | 7.1 | 0.65 | |
| Annual forb cover (%) | 0.03 | 3.4 | 0.25 | 3.7 | 0.27 | | 3.9 | 0.38 | 4.1 | 0.51 | |
| | 0.20 | 3.3 | 0.23 | 3.7 | 0.26 | | 4 | 0.34 | 4.4 | 0.51 | |
| Residual vegetation cover (%) | 0.03 | 7.9 | 0.60 | 8.8 | 0.74 | | 10.6 | 1.05 | 12.5 | 0.98 | |
| | 0.20 | 8.4 | 0.54 | 9 | 0.64 | | 10.9 | 0.90 | 12.8 | 0.89 | |
| Litter cover (%) | 0.03 | 24.6 | 2.02 | 24.2 | 1.99 | | 26 | 2.05 | 29.2 | 2.40 | |
| | 0.20 | 23.4 | 1.82 | 23.6 | 1.74 | | 25.6 | 1.81 | 27.5 | 2.16 | |
| Bare ground cover (%) | 0.03 | 43.4 | 2.32 | 43.7 | 2.29 | | 30.4 | 2.44 | 31 | 2.41 | |
| | 0.20 | 45 | 2.09 | 43.2 | 2.04 | | 31.2 | 2.15 | 31 | 2.16 | |
| Rock cover (%) | 0.03 | 10.6 | 1.26 | 8.7 | 1.07 | | 10.9 | 1.77 | 9.7 | 1.28 | |
| | 0.20 | 10.9 | 1.21 | 9.4 | 1.14 | | 10.5 | 1.42 | 9.6 | 1.13 | |
| Tall sagebrush cover (%) | 0.01 | 14 | 1.30 | 15.8 | 1.27 | | 13.2 | 1.49 | 9.9 | 1.31 | |
| | 0.03 | 13.1 | 1.18 | 14.7 | 1.15 | | 12.4 | 1.31 | 9.1 | 1.16 | * |
| | 0.20 | 11.9 | 1.05 | 12.4 | 0.98 | | 11.3 | 1.24 | 8.5 | 0.99 | |
| Dwarf sagebrush cover (%) | 0.01 | 8.4 | 0.86 | 7.4 | 0.89 | | 7.7 | 1.17 | 7.9 | 1.18 | |
| | 0.03 | 8.4 | 0.84 | 7.5 | 0.81 | | 8.2 | 1.21 | 7.8 | 1.11 | |
| | 0.20 | 8.5 | 0.80 | 8.1 | 0.76 | | 7.6 | 1.03 | 7.6 | 0.99 | |
| Total sagebrush cover (%) | 0.01 | 22.6 | 1.12 | 23.2 | 1.03 | | 21.4 | 1.42 | 18.6 | 1.33 | |
| | 0.03 | 21.7 | 0.97 | 22.1 | 0.92 | | 21 | 1.28 | 17.7 | 1.21 | * |
| | 0.20 | 20.6 | 0.86 | 20.5 | 0.81 | | 19.3 | 1.18 | 16.7 | 1.05 | |
| Non-sagebrush shrub cover (%) | 0.01 | 5.1 | 0.86 | 5.1 | 0.69 | | 7 | 1.12 | 4.4 | 0.74 | * |
| | 0.03 | 5.4 | 0.79 | 5.4 | 0.69 | | 6.8 | 1.02 | 4.6 | 0.76 | |
| | 0.20 | 5.2 | 0.70 | 5.3 | 0.72 | | 6 | 0.79 | 4.3 | 0.67 | |
| Total shrub cover (%) | 0.01 | 27.7 | 1.28 | 28.3 | 1.23 | | 28.1 | 1.70 | 23 | 1.50 | * |
| | 0.03 | 27.2 | 1.18 | 27.6 | 1.18 | | 27.4 | 1.63 | 22.3 | 1.46 | * |
| | 0.20 | 25.8 | 1.09 | 25.8 | 1.11 | | 25 | 1.46 | 21 | 1.27 | * |

[1]Denotes variables that have been date adjusted to predicted hatch date to account for plant phenology (see section, “Study Methods”).

## Appendix 3. Average values with standard errors (SE) of microhabitat characteristics at independent random sites to characterize availability (Avail) and used nest sites by greater sage-grouse (*Centrocercus urophasianus*) in burned sites in the Great Basin, Nevada and California, 2009–16

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale | Avail | SE | Used | SE | Effect |
|---|---|---|---|---|---|---|
| Horizontal cover (%) | NB | 72.4 | 1.38 | 79 | 1.20 | ** |
| Vertical cover (%) | NB | 52.9 | 2.46 | 62.7 | 2.60 | * |
| Maximum height (cm) | NB | 70.6 | 2.36 | 76 | 3.51 | |
| Average height (cm) | NB | 54.5 | 1.75 | 48.9 | 1.17 | * |
| Perpendicular width (cm) | NB | 91.5 | 3.61 | 99.3 | 3.81 | |
| Sagebrush height (cm) | NB | 34.5 | 3.34 | 27.8 | 3.30 | |
| | 0.03 | 29.2 | 2.82 | 23.5 | 2.29 | |
| | 0.20 | 30.9 | 2.72 | 23.6 | 2.10 | * |
| Non-sagebrush height (cm) | NB | 36.3 | 3.57 | 50.7 | 4.85 | * |
| | 0.03 | 39.3 | 4.09 | 41.7 | 2.69 | |
| | 0.20 | 41.2 | 3.69 | 40.2 | 2.30 | |
| Perennial grass height (cm) | NB | 34.3 | 1.90 | 34.3 | 1.97 | |
| | 0.03 | 30.9 | 1.50 | 31.6 | 1.22 | |
| | 0.20 | 30.7 | 1.37 | 30.1 | 1.05 | |
| Perennial forb height (cm) | NB | 13.2 | 1.40 | 16.8 | 1.47 | |
| | 0.03 | 14 | 1.00 | 18.7 | 0.95 | ** |
| | 0.20 | 14.7 | 0.95 | 18.5 | 0.87 | ** |
| Residual grass height (cm) | NB | 30.3 | 1.98 | 33.4 | 2.34 | |
| | 0.03 | 26.3 | 1.54 | 29.2 | 1.57 | |
| | 0.20 | 25.3 | 1.38 | 27.6 | 1.40 | |
| Perennial grass cover (%) | 0.03 | 9.4 | 0.73 | 11.3 | 0.94 | |
| | 0.20 | 9.9 | 0.70 | 12.1 | 0.90 | * |
| Annual grass cover (%) | 0.03 | 9.9 | 0.89 | 7.3 | 0.71 | * |
| | 0.20 | 10.8 | 0.82 | 7.5 | 0.68 | ** |
| Perennial forb cover (%) | 0.03 | 7.2 | 0.60 | 9.6 | 0.78 | * |
| | 0.20 | 7.1 | 0.54 | 9.3 | 0.65 | * |
| Annual forb cover (%) | 0.03 | 4.6 | 0.38 | 5.3 | 0.59 | |
| | 0.20 | 4.7 | 0.36 | 5.2 | 0.43 | |
| Residual vegetation cover (%) | 0.03 | 11.8 | 0.90 | 11.3 | 0.84 | |
| | 0.20 | 12.2 | 0.79 | 12.4 | 0.75 | |

| Variable | Scale | Avail | SE | Used | SE | Effect |
|---|---|---|---|---|---|---|
| Litter cover (%) | 0.03 | 18.1 | 1.05 | 18.5 | 1.08 | |
| | 0.20 | 17.3 | 0.92 | 17 | 0.88 | |
| Bare ground cover (%) | 0.03 | 26.5 | 1.93 | 23 | 1.71 | |
| | 0.20 | 27.5 | 1.84 | 22.3 | 1.41 | * |
| Rock cover (%) | 0.03 | 18.1 | 1.53 | 15.3 | 1.37 | |
| | 0.20 | 17.1 | 1.25 | 15.8 | 1.19 | |
| Tall sagebrush cover (%) | 0.01 | 3.4 | 0.57 | 3.9 | 0.69 | |
| | 0.03 | 3.4 | 0.52 | 4.2 | 0.72 | |
| | 0.20 | 3.6 | 0.48 | 3.7 | 0.63 | |
| Dwarf sagebrush cover (%) | 0.01 | 0.5 | 0.17 | 1.4 | 0.38 | * |
| | 0.03 | 0.5 | 0.16 | 1.4 | 0.36 | * |
| | 0.20 | 0.5 | 0.15 | 1.3 | 0.32 | * |
| Total sagebrush cover (%) | 0.01 | 3.9 | 0.59 | 5.3 | 0.75 | |
| | 0.03 | 3.9 | 0.53 | 5.5 | 0.76 | |
| | 0.20 | 4.1 | 0.49 | 5.1 | 0.67 | |
| Non-sagebrush shrub cover (%) | 0.01 | 4.6 | 0.74 | 9.4 | 0.99 | ** |
| | 0.03 | 3.6 | 0.59 | 6.6 | 0.71 | ** |
| | 0.20 | 4.1 | 0.56 | 6.9 | 0.67 | ** |
| Total shrub cover (%) | 0.01 | 8.5 | 0.96 | 14.8 | 1.05 | ** |
| | 0.03 | 7.5 | 0.81 | 12.2 | 0.93 | ** |
| | 0.20 | 8.1 | 0.76 | 12 | 0.85 | ** |

# Appendix 4. Average values with standard errors (SE) of microhabitat characteristics at successful and failed and used nest sites by greater sage-grouse (*Centrocercus urophasianus*) in burned areas in the Great Basin, Nevada and California, 2009–16

[**Scale:** NB represents measurements conducted at nest bowl; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 m transect lengths of measurement in relation to nest bowl. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale | Success | SE | Fail | SE | Effect |
|---|---|---|---|---|---|---|
| Horizontal cover (cm) | NB | 83.1 | 1.57 | 74.8 | 1.93 | ** |
| Vertical cover (cm) | NB | 69.1 | 3.56 | 58.3 | 4.20 | * |
| Maximum height (cm) | NB | 72 | 2.94 | 80.8 | 7.42 | |
| Average height (cm) | NB | 49.2 | 2.06 | 49.3 | 1.44 | |
| Perpendicular width (cm) | NB | 104.2 | 6.05 | 96.1 | 5.86 | |
| Sagebrush height (cm) | NB | 31.7 | 4.74 | 25 | 5.53 | |
| | 0.03 | 27 | 3.43 | 20.8 | 3.64 | |
| | 0.20 | 24.6 | 3.04 | 22.8 | 3.45 | |
| Non-sagebrush height (cm) | NB | 45.1 | 6.38 | 59.9 | 8.62 | |
| | 0.03 | 37.4 | 4.17 | 48.3 | 3.71 | * |
| | 0.20 | 35.9 | 3.58 | 45.7 | 3.16 | * |
| Perennial grass height (cm)[1] | NB | 30 | 2.74 | 32.5 | 2.95 | |
| | 0.03 | 28.2 | 1.84 | 28 | 1.84 | |
| | 0.20 | 26.8 | 1.62 | 27 | 1.60 | |
| Perennial forb height (cm)[1] | NB | 12.6 | 2.22 | 12.6 | 2.03 | |
| | 0.03 | 16 | 1.49 | 14.7 | 1.36 | |
| | 0.20 | 15.9 | 1.37 | 14.7 | 1.22 | |
| Residual grass height (cm) | NB | 30.2 | 3.84 | 36.8 | 3.24 | |
| | 0.03 | 27.7 | 2.47 | 30.9 | 2.32 | |
| | 0.20 | 25.5 | 2.20 | 29.5 | 2.08 | |
| Perennial grass cover (%) | 0.03 | 12.5 | 1.78 | 10.8 | 1.03 | |
| | 0.20 | 13.1 | 1.67 | 12 | 1.11 | |
| Annual grass cover (%) | 0.03 | 8.6 | 1.24 | 6.6 | 0.99 | |
| | 0.20 | 8.6 | 1.04 | 7 | 1.14 | |
| Perennial forb cover (%)[1] | 0.03 | 9.7 | 1.37 | 7.5 | 0.94 | |
| | 0.20 | 9 | 1.14 | 7.4 | 0.85 | |
| Annual forb cover (%) | 0.03 | 4 | 0.33 | 4.9 | 0.72 | |
| | 0.20 | 4.4 | 0.34 | 5 | 0.55 | |
| Residual vegetation cover (%) | 0.03 | 11.7 | 1.44 | 10.8 | 1.06 | |
| | 0.20 | 12.6 | 1.29 | 11.8 | 0.95 | |
| Litter cover (%) | 0.03 | 19 | 1.52 | 18.1 | 1.75 | |
| | 0.20 | 17.1 | 1.13 | 17 | 1.52 | |
| Bare ground cover (%) | 0.03 | 21.1 | 2.22 | 23.3 | 2.68 | |
| | 0.20 | 21.1 | 1.87 | 22.1 | 2.12 | |
| Rock cover (%) | 0.03 | 15.5 | 2.11 | 16.1 | 2.21 | |
| | 0.20 | 16 | 1.70 | 16.7 | 1.98 | |

| Variable | Scale | Success | SE | Fail | SE | Effect |
|---|---|---|---|---|---|---|
| Tall sagebrush cover (%) | 0.01 | 5.5 | 1.31 | 2.8 | 0.81 | * |
| | 0.03 | 5.8 | 1.30 | 2.8 | 0.92 | * |
| | 0.20 | 5.2 | 1.10 | 2.3 | 0.84 | * |
| Dwarf sagebrush cover (%) | 0.01 | 1.9 | 0.68 | 0.8 | 0.33 | |
| | 0.03 | 1.8 | 0.62 | 0.6 | 0.26 | |
| | 0.20 | 1.5 | 0.52 | 0.8 | 0.30 | |
| Total sagebrush cover (%) | 0.01 | 7.4 | 1.37 | 3.5 | 0.86 | * |
| | 0.03 | 7.6 | 1.34 | 3.5 | 0.94 | * |
| | 0.20 | 6.7 | 1.14 | 3.1 | 0.87 | * |
| Non-sagebrush shrub cover (%) | 0.01 | 10 | 1.74 | 9.1 | 1.26 | |
| | 0.03 | 6.4 | 1.06 | 7.4 | 1.16 | |
| | 0.20 | 7 | 1.05 | 7.1 | 1.04 | |
| Total shrub cover (%) | 0.01 | 17.4 | 1.76 | 12.6 | 1.39 | * |
| | 0.03 | 14 | 1.43 | 10.8 | 1.45 | |
| | 0.20 | 13.7 | 1.29 | 10.2 | 1.34 | * |

[1]Denotes variables that have been date adjusted to predicted hatch date to account for plant phenology (see section, “Study Methods”).

## Appendix 5. Table of pair-wise variables with evidence of correlation (|R≥0.65|) of greater sage-grouse (*Centrocercus urophasianus*) during nesting and late brood-rearing (day and night sites) within xeric, mesic, and burned habitats in the Great Basin, Nevada and California, 2009–16.

| Life stage | Habitat type | Variable 1 | Variable 2 | R |
|---|---|---|---|---|
| Nesting | Xeric | Tall sagebrush cover (%) | Total shrub cover (%) | 0.66 |
| | Mesic | Total sagebrush cover (%) | Total shrub cover (%) | 0.75 |
| | Fire | Maximum height (cm) | Non-sagebrush height (cm) | 0.68 |
| | | Perennial grass height (cm) | Residual grass height (cm) | 0.72 |
| | | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.89 |
| | | Non-sagebrush shrub cover (%) | Total shrub cover (%) | 0.73 |
| Brood (D) | Xeric | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.71 |
| | | Tall sagebrush cover (%) | Total shrub cover (%) | 0.70 |
| | Mesic | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.75 |
| | | Non-sagebrush shrub cover (%) | Total shrub cover (%) | 0.70 |
| | Fire | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.99 |
| | | Non-sagebrush shrub cover (%) | Total shrub cover (%) | 0.89 |
| Brood (N) | Xeric | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.77 |
| | | Tall sagebrush cover (%) | Total shrub cover (%) | 0.74 |
| | | Total sagebrush cover (%) | Total shrub cover (%) | 0.85 |
| | Mesic | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.71 |
| | | Total sagebrush cover (%) | Total shrub cover (%) | 0.66 |
| | Fire | Sagebrush height (cm) | Tall sagebrush cover (%) | 0.68 |
| | | Sagebrush height (cm) | Total sagebrush cover (%) | 0.70 |
| | | Tall sagebrush cover (%) | Total sagebrush cover (%) | 0.90 |
| | | Non-sagebrush shrub cover (%) | Total shrub cover (%) | 0.76 |

## Appendix 6. Average values of microhabitat characteristics at dependent random sites to characterize availability (Avail) and early brood sites during day and night with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) within xeric habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Horizontal cover (%) | BL | 54.72 | 2.23 | 57.27 | 2.02 | 59.54 | 3.03 | | | |
| Vertical cover (%) | BL | 23.61 | 3.20 | 26.50 | 3.35 | 31.57 | 6.03 | | | |
| Average height (cm) | BL | 39.24 | 1.39 | 39.11 | 1.22 | 37.74 | 2.07 | | | |
| Sagebrush height (cm) | BL | 40.01 | 2.79 | 36.54 | 2.54 | 42.84 | 4.08 | | | |
| | 0.03 | 32.75 | 1.99 | 32.23 | 1.55 | 33.32 | 2.96 | | | |
| | 0.20 | 32.02 | 1.84 | 32.07 | 1.36 | 32.32 | 2.87 | | | |
| Non-sagebrush height (cm) | BL | 13.20 | 1.92 | 15.32 | 2.50 | 14.87 | 3.31 | | | |
| | 0.03 | 14.69 | 1.26 | 17.97 | 1.90 | 14.38 | 2.46 | | | |
| | 0.20 | 15.43 | 1.08 | 18.39 | 1.57 | 14.13 | 2.29 | | | |
| Perennial grass height (cm) | BL | 15.32 | 1.40 | 14.39 | 1.26 | 14.00 | 2.10 | | | |
| | 0.03 | 14.93 | 1.05 | 14.60 | 0.85 | 14.14 | 1.62 | | | |
| | 0.20 | 14.45 | 0.92 | 14.99 | 0.80 | 13.68 | 1.52 | | | |
| Perennial forb height (cm) | BL | 5.00 | 0.64 | 7.23 | 1.01 | 7.92 | 1.61 | * | * | |
| | 0.03 | 5.66 | 0.67 | 7.33 | 0.80 | 7.21 | 1.29 | | | |
| | 0.20 | 6.13 | 0.63 | 7.48 | 0.73 | 7.20 | 1.29 | | | |
| Residual grass height (cm) | BL | 7.80 | 0.75 | 6.96 | 0.64 | 6.58 | 1.27 | | | |
| | 0.03 | 7.51 | 0.61 | 6.77 | 0.48 | 6.20 | 0.70 | | | |
| | 0.20 | 7.24 | 0.54 | 7.15 | 0.47 | 6.15 | 0.69 | | | |
| Perennial grass cover (%) | BL | 5.70 | 0.66 | 7.53 | 0.87 | 7.00 | 1.44 | | | |
| | 0.03 | 7.13 | 0.65 | 7.98 | 0.61 | 6.87 | 0.88 | | | |
| | 0.20 | 6.97 | 0.56 | 8.26 | 0.59 | 6.43 | 0.71 | | | * |
| Annual grass cover (%) | BL | 5.16 | 0.90 | 4.82 | 0.87 | 3.18 | 0.51 | | * | |
| | 0.03 | 5.91 | 0.92 | 5.06 | 0.61 | 3.05 | 0.35 | | ** | ** |
| | 0.20 | 6.56 | 1.00 | 5.21 | 0.63 | 2.91 | 0.25 | | ** | ** |

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Perennial forb cover (%) | BL | 4.82 | 0.98 | 5.86 | 0.96 | 4.50 | 0.76 | | | |
| | 0.03 | 5.42 | 0.81 | 6.99 | 0.91 | 6.10 | 1.01 | | | |
| | 0.20 | 5.89 | 0.75 | 7.19 | 0.80 | 6.61 | 1.26 | | | |
| Annual forb cover (%) | BL | 2.95 | 0.22 | 3.23 | 0.35 | 2.71 | 0.21 | | | |
| | 0.03 | 3.14 | 0.18 | 3.44 | 0.27 | 2.88 | 0.17 | | | |
| | 0.20 | 3.11 | 0.15 | 3.44 | 0.25 | 2.85 | 0.14 | | | * |
| Residual vegetation cover (%) | BL | 6.58 | 0.92 | 7.07 | 0.98 | 5.92 | 1.03 | | | |
| | 0.03 | 7.92 | 0.63 | 8.10 | 0.71 | 7.27 | 0.93 | | | |
| | 0.20 | 7.58 | 0.54 | 8.11 | 0.61 | 7.24 | 0.91 | | | |
| Litter cover (%) | BL | 26.27 | 2.92 | 27.47 | 3.00 | 34.14 | 4.80 | | | |
| | 0.03 | 23.07 | 1.82 | 24.63 | 2.01 | 28.28 | 4.07 | | | |
| | 0.20 | 22.79 | 1.79 | 23.91 | 1.91 | 27.57 | 3.71 | | | |
| Bare ground cover (%) | BL | 43.50 | 3.52 | 43.42 | 3.38 | 46.84 | 6.05 | | | |
| | 0.03 | 45.51 | 2.40 | 44.53 | 2.14 | 51.20 | 4.04 | | | |
| | 0.20 | 45.29 | 2.23 | 44.74 | 1.98 | 52.20 | 3.85 | | | * |
| Rock cover (%) | BL | 6.99 | 1.26 | 8.51 | 1.52 | 5.04 | 1.70 | | | |
| | 0.03 | 9.76 | 1.22 | 8.41 | 1.11 | 5.08 | 1.05 | | ** | * |
| | 0.20 | 10.64 | 1.32 | 8.61 | 1.01 | 5.18 | 0.93 | | ** | * |
| Tall sagebrush cover (%) | 0.01 | 10.86 | 1.28 | 10.01 | 1.03 | 13.46 | 2.17 | | | |
| | 0.03 | 11.60 | 1.25 | 10.26 | 0.94 | 13.93 | 2.37 | | | |
| | 0.20 | 11.45 | 1.18 | 10.31 | 0.89 | 13.59 | 2.39 | | | |
| Dwarf sagebrush cover (%) | 0.01 | 8.40 | 1.12 | 7.49 | 1.03 | 10.48 | 2.10 | | | |
| | 0.03 | 8.33 | 1.03 | 7.85 | 0.94 | 10.78 | 2.13 | | | |
| | 0.20 | 8.23 | 1.00 | 8.23 | 0.88 | 10.17 | 1.97 | | | |
| Total sagebrush cover (%) | 0.01 | 19.26 | 1.20 | 17.50 | 1.05 | 23.93 | 1.59 | | * | ** |
| | 0.03 | 19.93 | 1.09 | 18.12 | 0.88 | 24.71 | 1.90 | | * | ** |
| | 0.20 | 19.67 | 1.08 | 18.54 | 0.79 | 23.76 | 1.89 | | * | * |
| Non-sagebrush shrub cover (%) | 0.01 | 3.61 | 0.53 | 4.79 | 0.70 | 6.51 | 1.47 | | * | |
| | 0.03 | 3.99 | 0.55 | 4.75 | 0.61 | 5.38 | 1.06 | | | |
| | 0.20 | 4.01 | 0.55 | 4.84 | 0.57 | 5.68 | 1.07 | | | |
| Total shrub cover (%) | 0.01 | 22.87 | 1.25 | 22.28 | 1.23 | 30.44 | 1.65 | | ** | ** |
| | 0.03 | 23.91 | 1.18 | 22.86 | 0.99 | 30.09 | 1.80 | | ** | ** |
| | 0.20 | 23.68 | 1.19 | 23.38 | 0.92 | 29.43 | 1.92 | | * | ** |

## Appendix 7. Average values of microhabitat characteristics at dependent random sites to characterize availability (Avail) and used early brood sites during day and night with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) within mesic habitats in Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Horizontal cover (%) | BL | 58.59 | 2.95 | 60.75 | 2.54 | 44.02 | 3.17 | | ** | ** |
| Vertical cover (%) | BL | 40.28 | 4.15 | 40.60 | 3.80 | 17.64 | 4.07 | | ** | ** |
| Average height (cm) | BL | 42.84 | 1.97 | 42.04 | 1.91 | 36.92 | 2.16 | | * | |
| Sagebrush height (cm) | BL | 34.60 | 3.07 | 37.87 | 2.93 | 27.25 | 3.07 | | | * |
| | 0.03 | 31.73 | 2.25 | 34.85 | 2.22 | 28.56 | 2.78 | | | |
| | 0.20 | 29.83 | 1.83 | 34.52 | 2.10 | 28.47 | 2.64 | | | |
| Non-sagebrush height (cm) | BL | 25.27 | 3.49 | 21.88 | 3.41 | 15.84 | 3.05 | | * | |
| | 0.03 | 23.63 | 2.20 | 24.63 | 2.47 | 21.30 | 2.71 | | | |
| | 0.20 | 24.68 | 2.02 | 26.63 | 2.27 | 20.63 | 2.55 | | | |
| Perennial grass height (cm) | BL | 18.51 | 1.51 | 21.43 | 1.80 | 17.77 | 1.92 | | | |
| | 0.03 | 17.55 | 1.08 | 20.92 | 1.33 | 18.67 | 1.18 | * | | |
| | 0.20 | 18.17 | 1.07 | 20.44 | 1.25 | 19.03 | 1.09 | | | |
| Perennial forb height (cm) | BL | 8.90 | 1.38 | 10.28 | 1.22 | 10.52 | 1.68 | | | |
| | 0.03 | 9.62 | 1.10 | 11.55 | 0.90 | 11.23 | 1.18 | | | |
| | 0.20 | 9.45 | 0.92 | 11.40 | 0.90 | 11.37 | 1.03 | | | |
| Residual grass height (cm) | BL | 12.05 | 1.19 | 10.73 | 1.16 | 10.48 | 1.33 | | | |
| | 0.03 | 11.67 | 0.98 | 11.71 | 0.81 | 11.57 | 0.94 | | | |
| | 0.20 | 11.43 | 0.84 | 11.48 | 0.78 | 11.48 | 0.89 | | | |
| Perennial grass cover (%) | BL | 12.01 | 1.88 | 11.23 | 1.57 | 9.82 | 1.78 | | | |
| | 0.03 | 11.47 | 1.40 | 11.83 | 1.14 | 11.96 | 1.45 | | | |
| | 0.20 | 11.95 | 1.36 | 11.16 | 0.93 | 12.06 | 1.44 | | | |
| Annual grass cover (%) | BL | 5.05 | 1.08 | 3.14 | 0.30 | 3.05 | 0.31 | * | * | |
| | 0.03 | 5.60 | 1.02 | 4.25 | 0.41 | 3.54 | 0.38 | | * | |
| | 0.20 | 5.51 | 0.99 | 4.30 | 0.47 | 3.51 | 0.37 | | * | |

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Perennial forb cover (%) | BL | 5.28 | 0.76 | 9.61 | 1.74 | 7.42 | 1.41 | * | | |
| | 0.03 | 7.17 | 0.83 | 8.96 | 0.95 | 8.07 | 0.87 | | | |
| | 0.20 | 7.78 | 0.85 | 9.63 | 1.02 | 8.59 | 0.89 | | | |
| Annual forb cover (%) | BL | 3.32 | 0.26 | 4.77 | 0.86 | 2.68 | 0.18 | * | * | ** |
| | 0.03 | 3.88 | 0.30 | 4.49 | 0.45 | 2.73 | 0.11 | | ** | ** |
| | 0.20 | 4.04 | 0.30 | 4.43 | 0.41 | 2.85 | 0.11 | | ** | ** |
| Residual vegetation cover (%) | BL | 12.15 | 1.66 | 10.32 | 1.26 | 14.25 | 2.17 | | | |
| | 0.03 | 12.14 | 1.20 | 12.46 | 0.99 | 12.20 | 1.51 | | | |
| | 0.20 | 12.17 | 1.05 | 12.01 | 0.84 | 11.90 | 1.36 | | | |
| Litter cover (%) | BL | 30.79 | 3.30 | 29.99 | 2.99 | 16.40 | 2.31 | | ** | ** |
| | 0.03 | 24.70 | 2.23 | 24.77 | 2.10 | 15.91 | 2.37 | | * | ** |
| | 0.20 | 22.92 | 1.98 | 24.50 | 1.97 | 16.59 | 2.60 | | * | * |
| Bare ground cover (%) | BL | 25.44 | 2.80 | 24.21 | 2.66 | 36.45 | 4.77 | | * | * |
| | 0.03 | 30.63 | 2.00 | 30.10 | 2.02 | 35.38 | 3.08 | | | |
| | 0.20 | 32.83 | 1.86 | 31.74 | 1.89 | 35.11 | 3.03 | | | |
| Rock cover (%) | BL | 8.55 | 1.52 | 6.25 | 0.98 | 10.51 | 2.39 | | | |
| | 0.03 | 12.08 | 1.51 | 8.32 | 1.25 | 13.63 | 2.33 | * | | * |
| | 0.20 | 12.27 | 1.43 | 8.68 | 1.13 | 12.77 | 1.98 | * | | * |
| Tall sagebrush cover (%) | 0.01 | 8.02 | 1.42 | 9.56 | 1.38 | 7.73 | 2.09 | | | |
| | 0.03 | 8.42 | 1.30 | 9.45 | 1.27 | 8.43 | 2.03 | | | |
| | 0.20 | 8.05 | 1.08 | 9.16 | 1.18 | 9.23 | 2.01 | | | |
| Dwarf sagebrush cover (%) | 0.01 | 7.78 | 1.19 | 7.11 | 1.09 | 7.04 | 1.49 | | | |
| | 0.03 | 7.72 | 1.20 | 7.00 | 1.00 | 6.40 | 1.34 | | | |
| | 0.20 | 7.79 | 1.26 | 7.19 | 0.96 | 6.40 | 1.38 | | | |
| Total sagebrush cover (%) | 0.01 | 15.79 | 1.52 | 16.67 | 1.32 | 14.77 | 2.02 | | | |
| | 0.03 | 16.14 | 1.38 | 16.45 | 1.13 | 14.82 | 1.87 | | | |
| | 0.20 | 15.84 | 1.29 | 16.35 | 1.03 | 15.63 | 1.87 | | | |
| Non-sagebrush shrub cover (%) | 0.01 | 7.30 | 1.32 | 6.99 | 1.27 | 4.93 | 1.01 | | | |
| | 0.03 | 7.25 | 1.16 | 6.97 | 1.17 | 4.46 | 0.78 | | * | * |
| | 0.20 | 7.25 | 1.06 | 6.66 | 0.94 | 4.11 | 0.62 | | * | * |
| Total shrub cover (%) | 0.01 | 23.09 | 1.90 | 23.66 | 1.70 | 19.71 | 2.11 | | | |
| | 0.03 | 23.39 | 1.74 | 23.42 | 1.52 | 19.28 | 1.89 | | | |
| | 0.20 | 23.09 | 1.62 | 23.01 | 1.35 | 19.74 | 1.82 | | | |

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## Appendix 8. Average values of microhabitat characteristics at dependent random sites to characterize availability (Avail) and used early brood sites during day and night with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) within burned habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| | | | | | | | | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Scale | Avail | SE | Day | SE | Night | SE | DA | NA | DN |
| Horizontal cover (%) | BL | 47.37 | 4.42 | 58.43 | 3.02 | 46.91 | 4.52 | * | | * |
| Vertical cover (%) | BL | 11.92 | 4.61 | 13.41 | 3.72 | 4.16 | 2.23 | | | * |
| Average height (cm) | BL | 44.82 | 2.43 | 43.82 | 2.02 | 37.03 | 3.35 | | * | |
| Sagebrush height (cm) | BL | 7.41 | 3.48 | 15.73 | 5.36 | 11.36 | 4.17 | | | |
| | 0.03 | 8.99 | 2.95 | 12.84 | 3.09 | 10.59 | 3.11 | | | |
| | 0.20 | 15.11 | 3.47 | 12.92 | 2.90 | 12.60 | 3.50 | | | |
| Non-sagebrush height (cm) | BL | 25.76 | 4.86 | 28.43 | 4.15 | 20.64 | 4.52 | | | |
| | 0.03 | 33.97 | 4.41 | 31.92 | 3.55 | 25.30 | 3.66 | | | |
| | 0.20 | 35.94 | 3.52 | 29.98 | 3.28 | 25.98 | 3.41 | | * | |
| Perennial grass height (cm) | BL | 26.79 | 2.97 | 28.16 | 2.68 | 27.06 | 2.18 | | | |
| | 0.03 | 29.23 | 2.17 | 29.08 | 2.20 | 29.86 | 2.37 | | | |
| | 0.20 | 29.12 | 1.87 | 30.04 | 1.86 | 32.07 | 2.46 | | | |
| Perennial forb height (cm) | BL | 14.09 | 1.89 | 17.70 | 2.47 | 16.00 | 2.95 | | | |
| | 0.03 | 16.70 | 1.44 | 18.98 | 1.92 | 19.80 | 2.22 | | | |
| | 0.20 | 17.61 | 1.27 | 20.76 | 1.71 | 20.18 | 2.20 | | | |
| Residual grass height (cm) | BL | 21.62 | 4.17 | 22.43 | 3.77 | 23.52 | 3.82 | | | |
| | 0.03 | 23.41 | 2.93 | 22.66 | 3.02 | 25.08 | 3.53 | | | |
| | 0.20 | 24.77 | 2.81 | 24.24 | 2.77 | 24.10 | 3.27 | | | |
| Perennial grass cover (%) | BL | 14.94 | 3.45 | 13.26 | 2.52 | 6.46 | 1.29 | | * | * |
| | 0.03 | 15.90 | 2.72 | 12.27 | 1.60 | 12.04 | 2.28 | | | |
| | 0.20 | 14.94 | 1.90 | 12.13 | 1.13 | 12.36 | 2.13 | | | |
| Annual grass cover (%) | BL | 10.81 | 3.17 | 5.03 | 1.12 | 4.90 | 1.08 | * | * | |
| | 0.03 | 9.55 | 1.92 | 6.00 | 0.91 | 5.05 | 0.99 | | * | |
| | 0.20 | 9.42 | 2.21 | 6.90 | 0.84 | 5.51 | 0.97 | | | |

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Perennial forb cover (%) | BL | 6.66 | 1.10 | 7.24 | 1.08 | 6.10 | 0.98 | | | |
| | 0.03 | 9.31 | 1.15 | 11.22 | 1.26 | 10.76 | 1.25 | | | |
| | 0.20 | 8.78 | 0.99 | 11.21 | 1.10 | 12.33 | 1.59 | | * | |
| Annual forb cover (%) | BL | 4.26 | 0.81 | 4.77 | 0.79 | 5.38 | 0.78 | | | |
| | 0.03 | 4.85 | 0.53 | 5.42 | 0.64 | 4.98 | 0.83 | | | |
| | 0.20 | 5.01 | 0.50 | 5.67 | 0.60 | 4.59 | 0.67 | | | |
| Residual vegetation cover (%) | BL | 13.63 | 3.05 | 9.84 | 1.93 | 9.42 | 2.60 | | | |
| | 0.03 | 13.53 | 1.95 | 11.18 | 1.44 | 12.08 | 1.57 | | | |
| | 0.20 | 12.72 | 1.58 | 10.89 | 1.19 | 12.62 | 1.46 | | | |
| Litter cover (%) | BL | 16.85 | 3.99 | 12.09 | 2.17 | 17.46 | 4.38 | | | |
| | 0.03 | 13.63 | 2.16 | 13.36 | 1.71 | 14.54 | 2.05 | | | |
| | 0.20 | 13.55 | 2.10 | 13.69 | 1.55 | 14.89 | 1.98 | | | |
| Bare ground cover (%) | BL | 26.19 | 4.95 | 32.65 | 5.37 | 31.05 | 6.13 | | | |
| | 0.03 | 24.45 | 3.06 | 28.58 | 2.60 | 25.47 | 3.02 | | | |
| | 0.20 | 23.27 | 2.59 | 26.13 | 2.14 | 22.51 | 2.44 | | | |
| Rock cover (%) | BL | 14.07 | 3.39 | 11.55 | 2.00 | 17.00 | 4.25 | | | |
| | 0.03 | 19.18 | 3.17 | 11.87 | 1.76 | 19.24 | 3.17 | * | | * |
| | 0.20 | 19.64 | 2.61 | 13.93 | 1.81 | 19.54 | 3.08 | * | | |
| Tall sagebrush cover (%) | 0.01 | 1.65 | 0.77 | 2.13 | 0.71 | 2.55 | 1.00 | | | |
| | 0.03 | 1.96 | 0.67 | 1.75 | 0.57 | 2.26 | 0.91 | | | |
| | 0.20 | 2.12 | 0.68 | 1.96 | 0.67 | 2.69 | 1.14 | | | |
| Dwarf sagebrush cover (%) | 0.01 | 0.24 | 0.24 | 1.52 | 0.78 | 0.43 | 0.28 | | | |
| | 0.03 | 0.40 | 0.40 | 1.23 | 0.60 | 0.93 | 0.54 | | | |
| | 0.20 | 0.45 | 0.32 | 0.91 | 0.41 | 0.69 | 0.38 | | | |
| Total sagebrush cover (%) | 0.01 | 1.89 | 0.80 | 3.65 | 0.97 | 3.21 | 1.02 | | | |
| | 0.03 | 2.35 | 0.75 | 2.97 | 0.76 | 3.45 | 1.01 | | | |
| | 0.20 | 2.57 | 0.76 | 2.88 | 0.74 | 3.70 | 1.16 | | | |
| Non-sagebrush shrub cover (%) | 0.01 | 5.17 | 1.71 | 6.47 | 1.31 | 4.70 | 1.49 | | | |
| | 0.03 | 6.08 | 1.50 | 7.28 | 1.42 | 4.97 | 1.28 | | | |
| | 0.20 | 6.20 | 1.17 | 7.02 | 1.15 | 5.28 | 0.92 | | | |
| Total shrub cover (%) | 0.01 | 7.06 | 2.30 | 10.12 | 1.37 | 7.91 | 1.96 | | | |
| | 0.03 | 8.44 | 2.00 | 10.26 | 1.40 | 8.42 | 1.73 | | | |
| | 0.20 | 8.77 | 1.59 | 9.89 | 1.32 | 8.99 | 1.42 | | | |

# Appendix 9. Average values of microhabitat characteristics at dependent random sites to characterize availability (Avail) and used late brood sites during day and night with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) within xeric habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Horizontal cover | BL | 49.92 | 1.45 | 61.61 | 1.27 | 53.44 | 1.57 | ** | | ** |
| Vertical cover | BL | 21.89 | 1.92 | 30.19 | 2.11 | 23.17 | 2.34 | ** | | * |
| Average height (cm) | BL | 41.30 | 1.13 | 50.68 | 1.26 | 40.77 | 1.08 | ** | | ** |
| Sagebrush height (cm) | BL | 31.04 | 1.65 | 42.65 | 2.04 | 32.52 | 1.82 | ** | | ** |
| | 0.03 | 29.63 | 1.32 | 40.88 | 1.50 | 33.72 | 1.39 | ** | * | ** |
| | 0.20 | 30.20 | 1.25 | 39.20 | 1.34 | 33.44 | 1.27 | ** | * | ** |
| Non-sagebrush height (cm) | BL | 16.21 | 1.24 | 23.25 | 1.54 | 17.44 | 1.44 | ** | | * |
| | 0.03 | 18.40 | 1.28 | 23.42 | 1.13 | 18.64 | 1.01 | ** | | ** |
| | 0.20 | 18.31 | 0.98 | 23.37 | 1.06 | 19.58 | 0.96 | ** | | * |
| Perennial grass height (cm) | BL | 12.74 | 0.74 | 16.00 | 0.93 | 14.05 | 0.92 | * | | |
| | 0.03 | 13.70 | 0.58 | 17.23 | 0.71 | 15.40 | 0.69 | ** | * | * |
| | 0.20 | 13.86 | 0.56 | 17.22 | 0.65 | 15.39 | 0.65 | ** | | * |
| Perennial forb height (cm) | BL | 7.17 | 0.66 | 11.18 | 0.80 | 7.72 | 0.72 | ** | | ** |
| | 0.03 | 7.93 | 0.55 | 12.38 | 0.69 | 9.92 | 0.70 | ** | * | * |
| | 0.20 | 8.31 | 0.52 | 12.44 | 0.63 | 9.92 | 0.68 | ** | * | * |
| Residual grass height (cm) | BL | 7.05 | 0.52 | 6.68 | 0.51 | 6.56 | 0.54 | | | |
| | 0.03 | 7.63 | 0.41 | 7.52 | 0.35 | 7.92 | 0.46 | | | |
| | 0.20 | 7.32 | 0.36 | 7.79 | 0.34 | 7.88 | 0.40 | | | |
| Perennial grass cover (%) | BL | 7.61 | 0.75 | 9.18 | 0.86 | 7.81 | 0.87 | | | |
| | 0.03 | 7.40 | 0.50 | 9.07 | 0.64 | 7.83 | 0.63 | * | | |
| | 0.20 | 7.51 | 0.45 | 9.05 | 0.57 | 7.75 | 0.58 | * | | |
| Annual grass cover (%) | BL | 4.62 | 0.45 | 4.15 | 0.38 | 4.25 | 0.58 | | | |
| | 0.03 | 5.64 | 0.55 | 4.31 | 0.30 | 4.53 | 0.43 | * | | |
| | 0.20 | 5.52 | 0.49 | 4.57 | 0.30 | 4.40 | 0.35 | | * | |

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Perennial forb cover (%) | BL | 6.28 | 0.68 | 9.33 | 0.90 | 7.42 | 0.80 | * | | |
| | 0.03 | 7.04 | 0.58 | 10.29 | 0.71 | 8.05 | 0.68 | ** | | * |
| | 0.20 | 7.21 | 0.56 | 10.10 | 0.69 | 7.96 | 0.60 | ** | | * |
| Annual forb cover (%) | BL | 3.18 | 0.16 | 3.54 | 0.23 | 2.92 | 0.20 | | | * |
| | 0.03 | 3.23 | 0.13 | 3.77 | 0.25 | 3.20 | 0.14 | * | | * |
| | 0.20 | 3.33 | 0.14 | 3.91 | 0.23 | 3.23 | 0.13 | * | | * |
| Residual vegetation cover (%) | BL | 7.63 | 0.64 | 8.00 | 0.68 | 8.31 | 0.88 | | | |
| | 0.03 | 7.59 | 0.40 | 8.64 | 0.44 | 8.94 | 0.63 | | * | |
| | 0.20 | 7.62 | 0.34 | 9.09 | 0.41 | 9.05 | 0.59 | * | * | |
| Litter cover (%) | BL | 21.15 | 1.52 | 26.94 | 1.63 | 22.69 | 1.82 | * | | |
| | 0.03 | 20.69 | 1.16 | 25.18 | 1.17 | 22.73 | 1.44 | * | | |
| | 0.20 | 20.64 | 1.08 | 24.42 | 1.08 | 22.68 | 1.38 | * | | |
| Bare ground cover (%) | BL | 46.06 | 1.98 | 37.99 | 1.93 | 44.33 | 2.30 | ** | | * |
| | 0.03 | 45.14 | 1.53 | 37.90 | 1.42 | 41.70 | 1.80 | ** | | |
| | 0.20 | 44.68 | 1.39 | 37.54 | 1.31 | 41.58 | 1.76 | ** | | * |
| Rock cover (%) | BL | 6.96 | 0.64 | 6.99 | 0.85 | 8.56 | 0.99 | | | |
| | 0.03 | 9.16 | 0.74 | 7.95 | 0.68 | 9.77 | 0.90 | | | |
| | 0.20 | 9.23 | 0.69 | 8.00 | 0.64 | 9.64 | 0.84 | | | |
| Tall sagebrush cover (%) | 0.01 | 9.45 | 0.75 | 15.11 | 0.87 | 10.62 | 0.96 | ** | | ** |
| | 0.03 | 10.80 | 0.80 | 15.84 | 0.83 | 12.48 | 0.97 | ** | | * |
| | 0.20 | 11.17 | 0.75 | 16.30 | 0.83 | 13.68 | 1.02 | ** | * | * |
| Dwarf sagebrush cover (%) | 0.01 | 6.35 | 0.60 | 3.04 | 0.44 | 6.77 | 0.74 | ** | | ** |
| | 0.03 | 6.65 | 0.60 | 3.40 | 0.44 | 6.80 | 0.72 | ** | | ** |
| | 0.20 | 6.45 | 0.55 | 3.68 | 0.43 | 6.72 | 0.66 | ** | | ** |
| Total sagebrush cover (%) | 0.01 | 15.80 | 0.78 | 18.15 | 0.85 | 17.39 | 0.96 | * | | |
| | 0.03 | 17.45 | 0.79 | 19.24 | 0.81 | 19.28 | 0.91 | | | |
| | 0.20 | 17.62 | 0.73 | 19.98 | 0.79 | 20.41 | 0.92 | * | * | |
| Non-sagebrush shrub cover (%) | 0.01 | 6.17 | 0.56 | 8.73 | 0.67 | 6.37 | 0.65 | ** | | * |
| | 0.03 | 6.35 | 0.52 | 8.55 | 0.59 | 6.60 | 0.64 | ** | | * |
| | 0.20 | 6.55 | 0.46 | 8.31 | 0.55 | 6.52 | 0.56 | * | | * |
| Total shrub cover (%) | 0.01 | 21.97 | 0.92 | 26.89 | 0.98 | 23.76 | 1.12 | ** | | * |
| | 0.03 | 23.80 | 0.90 | 27.79 | 0.94 | 25.88 | 1.09 | ** | | |
| | 0.20 | 24.17 | 0.84 | 28.29 | 0.92 | 26.92 | 1.05 | ** | * | |

## Appendix 10. Average values of microhabitat characteristics at dependent random sites to characterize availability (Avail) and used late brood sites during day and night with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) within mesic habitats in the Great Basin, Nevada and California, 2009–2016

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Horizontal cover (%) | BL | 52.13 | 1.75 | 62.42 | 1.54 | 51.63 | 1.93 | ** | | ** |
| Vertical cover (%) | BL | 33.37 | 2.28 | 43.33 | 2.40 | 25.47 | 2.53 | ** | * | ** |
| Average height (cm) | BL | 46.86 | 1.29 | 56.74 | 1.39 | 43.56 | 1.48 | ** | | ** |
| Sagebrush height (cm) | BL | 32.06 | 2.13 | 41.82 | 2.36 | 32.38 | 2.07 | ** | | ** |
| | 0.03 | 30.28 | 1.70 | 38.22 | 1.81 | 31.70 | 1.71 | ** | | * |
| | 0.20 | 30.46 | 1.53 | 37.73 | 1.61 | 31.34 | 1.59 | ** | | ** |
| Non-sagebrush height (cm) | BL | 23.66 | 2.02 | 38.68 | 3.18 | 21.07 | 2.27 | ** | | ** |
| | 0.03 | 25.46 | 1.47 | 37.02 | 2.01 | 26.54 | 1.71 | ** | | ** |
| | 0.20 | 26.83 | 1.43 | 35.51 | 1.80 | 27.47 | 1.51 | ** | | ** |
| Perennial grass height (cm) | BL | 22.05 | 1.17 | 26.43 | 1.46 | 23.16 | 1.51 | * | | |
| | 0.03 | 21.30 | 0.87 | 24.98 | 1.00 | 23.95 | 1.08 | ** | * | |
| | 0.20 | 21.41 | 0.84 | 24.71 | 0.88 | 23.60 | 1.04 | * | | |
| Perennial forb height (cm) | BL | 11.65 | 0.83 | 12.94 | 0.89 | 10.99 | 0.86 | | | |
| | 0.03 | 11.72 | 0.69 | 13.46 | 0.63 | 12.88 | 0.72 | * | | |
| | 0.20 | 11.91 | 0.63 | 13.30 | 0.57 | 12.80 | 0.69 | | | |
| Residual grass height (cm) | BL | 10.96 | 0.64 | 13.06 | 0.87 | 13.23 | 0.85 | * | * | |
| | 0.03 | 11.54 | 0.50 | 12.81 | 0.55 | 13.83 | 0.63 | | ** | |
| | 0.20 | 11.77 | 0.50 | 12.60 | 0.49 | 13.74 | 0.61 | | * | |
| Perennial grass cover (%) | BL | 13.34 | 1.11 | 15.09 | 1.13 | 11.16 | 0.93 | | | * |
| | 0.03 | 13.53 | 0.92 | 14.89 | 0.88 | 11.43 | 0.71 | | * | ** |
| | 0.20 | 13.52 | 0.88 | 14.96 | 0.84 | 11.54 | 0.70 | | | ** |
| Annual grass cover (%) | BL | 5.52 | 0.70 | 4.80 | 0.53 | 3.49 | 0.39 | | * | * |
| | 0.03 | 5.06 | 0.46 | 4.79 | 0.41 | 4.21 | 0.44 | | | |
| | 0.20 | 4.92 | 0.38 | 4.41 | 0.30 | 4.22 | 0.38 | | | |

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Perennial forb cover (%) | BL | 6.23 | 0.56 | 8.09 | 0.64 | 6.49 | 0.62 | * | | |
| | 0.03 | 7.81 | 0.54 | 9.34 | 0.61 | 8.33 | 0.59 | * | | |
| | 0.20 | 7.83 | 0.49 | 9.46 | 0.55 | 8.24 | 0.53 | * | | |
| Annual forb cover (%) | BL | 3.09 | 0.14 | 3.38 | 0.24 | 3.10 | 0.19 | | | |
| | 0.03 | 3.31 | 0.15 | 3.62 | 0.19 | 3.12 | 0.18 | | | * |
| | 0.20 | 3.55 | 0.16 | 3.73 | 0.19 | 3.21 | 0.20 | | | * |
| Residual vegetation cover (%) | BL | 11.56 | 0.88 | 13.49 | 1.04 | 13.19 | 1.07 | | | |
| | 0.03 | 12.93 | 0.72 | 14.50 | 0.76 | 15.06 | 0.86 | | * | |
| | 0.20 | 13.11 | 0.67 | 14.44 | 0.69 | 15.38 | 0.79 | | * | |
| Litter cover (%) | BL | 33.85 | 1.97 | 35.49 | 1.87 | 29.93 | 2.22 | | | * |
| | 0.03 | 29.60 | 1.44 | 30.98 | 1.46 | 27.60 | 1.73 | | | |
| | 0.20 | 28.96 | 1.34 | 30.13 | 1.37 | 27.12 | 1.65 | | | |
| Bare ground cover (%) | BL | 23.19 | 1.55 | 24.12 | 1.67 | 29.81 | 2.06 | | * | * |
| | 0.03 | 28.22 | 1.17 | 26.45 | 1.10 | 28.96 | 1.33 | | | |
| | 0.20 | 28.59 | 1.07 | 26.60 | 1.01 | 29.02 | 1.23 | | | |
| Rock cover (%) | BL | 7.38 | 0.79 | 5.21 | 0.50 | 8.18 | 0.81 | * | | ** |
| | 0.03 | 8.78 | 0.73 | 5.65 | 0.43 | 10.36 | 0.93 | ** | | ** |
| | 0.20 | 9.33 | 0.71 | 5.85 | 0.41 | 10.39 | 0.90 | ** | | ** |
| Tall sagebrush cover (%) | 0.01 | 7.49 | 0.70 | 11.07 | 0.85 | 9.37 | 0.94 | ** | | |
| | 0.03 | 7.63 | 0.67 | 10.97 | 0.77 | 8.95 | 0.84 | ** | | |
| | 0.20 | 7.87 | 0.61 | 10.94 | 0.74 | 9.20 | 0.79 | ** | | |
| Dwarf sagebrush cover (%) | 0.01 | 4.75 | 0.58 | 3.51 | 0.54 | 5.99 | 0.72 | | | ** |
| | 0.03 | 4.77 | 0.53 | 3.52 | 0.51 | 5.80 | 0.70 | | | * |
| | 0.20 | 4.92 | 0.50 | 3.21 | 0.45 | 5.48 | 0.64 | * | | ** |
| Total sagebrush cover (%) | 0.01 | 12.26 | 0.79 | 14.58 | 0.89 | 15.36 | 0.97 | * | * | |
| | 0.03 | 12.41 | 0.73 | 14.49 | 0.81 | 14.75 | 0.87 | * | * | |
| | 0.20 | 12.81 | 0.66 | 14.15 | 0.75 | 14.67 | 0.80 | | * | |
| Non-sagebrush shrub cover (%) | 0.01 | 8.99 | 0.89 | 10.83 | 0.92 | 6.95 | 0.78 | | | ** |
| | 0.03 | 8.88 | 0.78 | 11.35 | 0.90 | 7.54 | 0.76 | * | | ** |
| | 0.20 | 8.96 | 0.74 | 11.02 | 0.79 | 7.75 | 0.75 | * | | ** |
| Total shrub cover (%) | 0.01 | 21.25 | 1.16 | 25.41 | 1.21 | 22.31 | 1.13 | * | | * |
| | 0.03 | 21.29 | 1.06 | 25.85 | 1.12 | 22.29 | 1.05 | ** | | * |
| | 0.20 | 21.77 | 1.00 | 25.17 | 1.03 | 22.42 | 1.00 | * | | * |

## Appendix 11. Average values of microhabitat characteristics at dependent random sites to characterize availability (Avail) and used late brood sites during day and night with standard errors (SE) by greater sage-grouse (*Centrocercus urophasianus*) within burned habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Effect:** Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| | | | | | | | | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Scale | Avail | SE | Day | SE | Night | SE | DA | NA | DN |
| Horizontal cover (%) | BL | 52.32 | 1.96 | 55.23 | 1.65 | 47.40 | 1.97 | | | ** |
| Vertical cover (%) | BL | 8.15 | 1.98 | 6.03 | 1.37 | 6.23 | 1.96 | | | |
| Average height (cm) | BL | 46.35 | 1.41 | 48.11 | 1.14 | 44.37 | 1.24 | | | * |
| Sagebrush height (cm) | BL | 5.49 | 1.38 | 9.13 | 2.25 | 5.80 | 1.75 | | | |
| | 0.03 | 8.80 | 1.82 | 8.55 | 1.66 | 9.17 | 1.90 | | | |
| | 0.20 | 10.60 | 1.91 | 10.28 | 1.74 | 12.27 | 2.28 | | | |
| Non-sagebrush height (cm) | BL | 26.56 | 2.66 | 29.98 | 2.73 | 22.66 | 2.43 | | | * |
| | 0.03 | 33.87 | 2.15 | 35.00 | 2.02 | 31.51 | 1.97 | | | |
| | 0.20 | 34.89 | 1.92 | 38.25 | 2.12 | 33.54 | 1.74 | | | |
| Perennial grass height (cm) | BL | 30.10 | 1.74 | 30.78 | 1.70 | 30.94 | 2.02 | | | |
| | 0.03 | 32.09 | 1.31 | 32.80 | 1.26 | 33.24 | 1.47 | | | |
| | 0.20 | 32.20 | 1.25 | 32.16 | 1.12 | 33.54 | 1.39 | | | |
| Perennial forb height (cm) | BL | 17.29 | 1.47 | 22.76 | 1.68 | 18.39 | 1.70 | * | | * |
| | 0.03 | 22.06 | 1.26 | 25.30 | 1.20 | 24.49 | 1.39 | * | | |
| | 0.20 | 22.47 | 1.14 | 26.00 | 1.13 | 25.05 | 1.33 | * | | |
| Residual grass height (cm) | BL | 19.56 | 1.62 | 18.12 | 1.57 | 18.39 | 1.64 | | | |
| | 0.03 | 21.46 | 1.38 | 19.51 | 1.12 | 21.71 | 1.31 | | | |
| | 0.20 | 21.48 | 1.30 | 19.43 | 1.02 | 22.67 | 1.26 | | | * |
| Perennial grass cover (%) | BL | 10.63 | 1.08 | 10.19 | 1.11 | 5.94 | 0.70 | | ** | ** |
| | 0.03 | 11.46 | 0.88 | 12.33 | 0.87 | 10.27 | 0.79 | | | |
| | 0.20 | 11.74 | 0.75 | 11.82 | 0.72 | 11.20 | 0.72 | | | |
| Annual grass cover (%) | BL | 6.30 | 0.71 | 6.33 | 1.02 | 4.78 | 0.59 | | | |
| | 0.03 | 7.37 | 0.72 | 6.71 | 0.68 | 6.91 | 0.73 | | | |
| | 0.20 | 7.89 | 0.69 | 7.64 | 0.70 | 7.03 | 0.64 | | | |

| Variable | Scale | Avail | SE | Day | SE | Night | SE | Effect | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | DA | NA | DN |
| Perennial forb cover (%) | BL | 8.17 | 1.11 | 8.73 | 1.04 | 7.06 | 1.20 | | | |
| | 0.03 | 9.46 | 0.81 | 12.46 | 0.83 | 10.35 | 0.89 | * | | |
| | 0.20 | 10.43 | 0.69 | 13.35 | 0.70 | 11.34 | 0.91 | ** | | |
| Annual forb cover (%) | BL | 3.60 | 0.27 | 4.78 | 0.53 | 3.92 | 0.42 | * | | |
| | 0.03 | 3.69 | 0.21 | 4.66 | 0.32 | 4.08 | 0.30 | * | | |
| | 0.20 | 3.69 | 0.19 | 4.54 | 0.29 | 3.84 | 0.21 | * | | * |
| Residual vegetation cover (%) | BL | 10.90 | 1.22 | 9.10 | 1.15 | 8.71 | 1.19 | | | |
| | 0.03 | 13.54 | 0.98 | 13.16 | 1.05 | 14.23 | 1.03 | | | |
| | 0.20 | 13.50 | 0.93 | 13.24 | 0.98 | 14.98 | 0.95 | | | |
| Litter cover (%) | BL | 13.46 | 1.33 | 13.70 | 1.36 | 13.37 | 1.60 | | | |
| | 0.03 | 14.41 | 0.97 | 15.98 | 1.00 | 16.02 | 1.11 | | | |
| | 0.20 | 14.85 | 0.92 | 16.26 | 0.95 | 15.56 | 0.97 | | | |
| Bare ground cover (%) | BL | 30.38 | 2.83 | 35.34 | 2.91 | 38.83 | 3.22 | | * | |
| | 0.03 | 27.23 | 1.97 | 27.96 | 1.58 | 25.27 | 1.43 | | | |
| | 0.20 | 26.59 | 1.78 | 27.54 | 1.40 | 24.10 | 1.29 | | | * |
| Rock cover (%) | BL | 12.74 | 1.83 | 8.35 | 1.28 | 13.42 | 1.67 | * | | * |
| | 0.03 | 14.40 | 1.31 | 9.61 | 0.85 | 17.19 | 1.54 | ** | | ** |
| | 0.20 | 14.25 | 1.05 | 10.32 | 0.82 | 16.67 | 1.28 | ** | | ** |
| Tall sagebrush cover (%) | 0.01 | 1.51 | 0.40 | 1.25 | 0.38 | 1.51 | 0.42 | | | |
| | 0.03 | 1.59 | 0.40 | 1.24 | 0.34 | 1.57 | 0.40 | | | |
| | 0.20 | 1.37 | 0.31 | 1.35 | 0.35 | 1.46 | 0.34 | | | |
| Dwarf sagebrush cover (%) | 0.01 | 0.30 | 0.17 | 0.14 | 0.09 | 0.42 | 0.22 | | | |
| | 0.03 | 0.51 | 0.29 | 0.09 | 0.06 | 0.30 | 0.16 | | | |
| | 0.20 | 0.42 | 0.25 | 0.11 | 0.04 | 0.19 | 0.09 | | | |
| Total sagebrush cover (%) | 0.01 | 1.81 | 0.43 | 1.39 | 0.42 | 1.92 | 0.50 | | | |
| | 0.03 | 2.09 | 0.48 | 1.33 | 0.36 | 1.87 | 0.44 | | | |
| | 0.20 | 1.79 | 0.39 | 1.46 | 0.36 | 1.65 | 0.35 | | | |
| Non-sagebrush shrub cover (%) | 0.01 | 8.43 | 0.97 | 9.93 | 0.83 | 7.58 | 0.72 | | | * |
| | 0.03 | 9.13 | 0.92 | 11.26 | 0.98 | 8.34 | 0.80 | | | * |
| | 0.20 | 8.37 | 0.77 | 10.95 | 0.76 | 7.60 | 0.63 | * | | ** |
| Total shrub cover (%) | 0.01 | 10.24 | 1.01 | 11.31 | 0.84 | 9.51 | 0.74 | | | |
| | 0.03 | 11.22 | 0.98 | 12.60 | 0.98 | 10.21 | 0.80 | | | * |
| | 0.20 | 10.17 | 0.84 | 12.40 | 0.77 | 9.24 | 0.63 | * | | ** |

## Appendix 12. Average values with standard errors (SE) of microhabitat characteristics at successful and failed and early brood sites by greater sage-grouse (*Centrocercus urophasianus*) in areas unaffected within xeric and mesic habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Diff.:** .Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale (ha) | Xeric | | | | | Mesic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Success | SE | Fail | SE | Diff. | Success | SE | Fail | SE | Diff. |
| Horizontal cover (%) | BL | 56.84 | 2.25 | 58.59 | 5.11 | | 60.94 | 2.72 | 53.20 | 8.74 | |
| Vertical cover (%) | BL | 26.38 | 3.70 | 24.67 | 8.77 | | 42.23 | 4.02 | 22.40 | 14.68 | |
| Average height (cm) | BL | 38.81 | 1.36 | 40.64 | 3.03 | | 42.30 | 2.06 | 34.38 | 3.64 | * |
| Sagebrush height (cm) | BL | 36.31 | 2.79 | 33.56 | 6.30 | | 37.26 | 3.18 | 38.60 | 4.77 | |
| | 0.03 | 32.62 | 1.75 | 30.05 | 3.63 | | 34.21 | 2.38 | 33.20 | 3.37 | |
| | 0.20 | 32.37 | 1.53 | 30.30 | 3.32 | | 34.17 | 2.27 | 32.06 | 3.05 | |
| Non-sagebrush height (cm) | BL | 16.43 | 2.88 | 10.94 | 4.86 | | 22.01 | 3.64 | 9.00 | 5.62 | * |
| | 0.03 | 18.25 | 2.16 | 17.37 | 4.17 | | 24.99 | 2.58 | 9.50 | 5.08 | ** |
| | 0.20 | 18.65 | 1.79 | 17.31 | 3.53 | | 26.35 | 2.37 | 23.33 | 5.19 | |
| Perennial grass height (cm) | BL | 15.29 | 1.45 | 10.56 | 2.23 | * | 21.53 | 1.92 | 22.60 | 7.95 | |
| | 0.03 | 15.18 | 0.98 | 12.39 | 1.68 | | 21.21 | 1.43 | 17.25 | 4.81 | |
| | 0.20 | 15.65 | 0.90 | 12.24 | 1.61 | * | 20.70 | 1.35 | 16.83 | 4.18 | |
| Perennial forb height (cm) | BL | 7.11 | 1.08 | 8.44 | 3.07 | | 10.30 | 1.32 | 11.00 | 3.66 | |
| | 0.03 | 7.12 | 0.79 | 9.06 | 2.93 | | 11.53 | 0.96 | 10.65 | 3.24 | |
| | 0.20 | 7.40 | 0.74 | 8.56 | 2.58 | | 11.36 | 0.96 | 9.86 | 2.95 | |
| Residual grass height (cm) | BL | 6.86 | 0.69 | 7.00 | 1.85 | | 11.22 | 1.25 | 4.20 | 1.32 | ** |
| | 0.03 | 6.55 | 0.49 | 8.03 | 1.72 | | 11.96 | 0.88 | 7.55 | 1.22 | ** |
| | 0.20 | 7.00 | 0.49 | 7.99 | 1.57 | | 11.54 | 0.84 | 8.69 | 1.98 | |
| Perennial grass cover (%) | BL | 7.49 | 0.96 | 6.81 | 2.17 | | 11.65 | 1.69 | 4.10 | 1.60 | ** |
| | 0.03 | 8.13 | 0.71 | 7.34 | 1.20 | | 11.76 | 1.22 | 9.88 | 2.30 | |
| | 0.20 | 8.51 | 0.70 | 6.87 | 0.83 | | 10.99 | 0.98 | 10.19 | 2.74 | |
| Perennial forb cover (%) | BL | 4.88 | 0.48 | 11.36 | 5.50 | | 9.76 | 1.88 | 6.10 | 3.60 | |
| | 0.03 | 6.37 | 0.60 | 10.74 | 4.83 | | 8.82 | 1.02 | 9.18 | 3.29 | |
| | 0.20 | 6.68 | 0.65 | 10.20 | 3.80 | | 9.46 | 1.09 | 10.34 | 3.39 | |
| Annual forb cover (%) | BL | 3.30 | 0.42 | 2.94 | 0.44 | | 4.89 | 0.94 | 4.10 | 1.60 | |
| | 0.03 | 3.48 | 0.31 | 3.31 | 0.59 | | 4.60 | 0.49 | 3.30 | 0.49 | * |
| | 0.20 | 3.50 | 0.28 | 3.23 | 0.54 | | 4.55 | 0.45 | 3.19 | 0.46 | * |

| Variable | Scale (ha) | Xeric Success | SE | Fail | SE | Diff. | Mesic Success | SE | Fail | SE | Diff. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Residual vegetation cover (%) | BL | 7.32 | 1.15 | 4.83 | 1.17 | | 9.75 | 1.19 | 4.10 | 1.60 | ** |
| | 0.03 | 8.00 | 0.76 | 8.76 | 2.09 | | 12.36 | 1.00 | 8.95 | 2.47 | |
| | 0.20 | 7.89 | 0.62 | 9.14 | 2.16 | | 11.81 | 0.84 | 9.39 | 1.81 | |
| Litter cover (%) | BL | 26.65 | 3.39 | 31.56 | 7.10 | | 30.36 | 3.17 | 16.40 | 6.11 | * |
| | 0.03 | 23.27 | 2.15 | 30.63 | 5.72 | | 24.83 | 2.15 | 17.73 | 7.18 | |
| | 0.20 | 22.28 | 1.98 | 31.03 | 6.00 | | 24.52 | 2.02 | 18.79 | 7.29 | |
| Bare ground cover (%) | BL | 44.47 | 3.72 | 39.50 | 8.96 | | 24.01 | 2.82 | 25.00 | 9.76 | |
| | 0.03 | 45.39 | 2.30 | 40.81 | 6.07 | | 30.53 | 2.07 | 30.18 | 13.74 | |
| | 0.20 | 46.06 | 2.08 | 39.62 | 6.00 | | 32.32 | 1.90 | 31.04 | 14.00 | |
| Rock cover (%) | BL | 8.38 | 1.69 | 9.83 | 3.88 | | 6.20 | 1.05 | 7.70 | 3.56 | |
| | 0.03 | 8.43 | 1.20 | 8.94 | 3.29 | | 8.49 | 1.35 | 8.55 | 4.10 | |
| | 0.20 | 8.70 | 1.12 | 8.81 | 2.73 | | 8.82 | 1.22 | 9.43 | 3.11 | |
| Tall sagebrush cover (%) | 0.01 | 9.74 | 1.15 | 10.54 | 2.58 | | 8.73 | 1.40 | 21.23 | 7.99 | * |
| | 0.03 | 10.24 | 1.08 | 9.85 | 2.01 | | 8.67 | 1.32 | 16.39 | 6.53 | |
| | 0.20 | 10.55 | 1.02 | 8.43 | 1.66 | | 8.55 | 1.23 | 12.79 | 5.60 | |
| Dwarf sagebrush cover (%) | 0.01 | 7.98 | 1.17 | 5.79 | 2.11 | | 7.15 | 1.09 | 10.64 | 8.53 | |
| | 0.03 | 8.30 | 1.06 | 6.37 | 1.99 | | 7.17 | 1.04 | 8.39 | 5.65 | |
| | 0.20 | 8.65 | 0.99 | 6.85 | 1.96 | | 7.28 | 0.98 | 10.06 | 6.18 | |
| Total sagebrush cover (%) | 0.01 | 17.72 | 1.17 | 16.33 | 2.56 | | 15.88 | 1.34 | 31.87 | 5.63 | ** |
| | 0.03 | 18.54 | 0.99 | 16.22 | 1.94 | | 15.84 | 1.20 | 24.77 | 3.45 | * |
| | 0.20 | 19.19 | 0.87 | 15.28 | 1.93 | * | 15.83 | 1.09 | 22.85 | 3.21 | * |
| Non-sagebrush shrub cover (%) | 0.01 | 4.67 | 0.79 | 4.94 | 1.67 | | 7.26 | 1.38 | 0.33 | 0.33 | ** |
| | 0.03 | 4.48 | 0.65 | 5.94 | 1.87 | | 7.24 | 1.27 | 0.71 | 0.32 | ** |
| | 0.20 | 4.68 | 0.61 | 5.71 | 1.78 | | 6.88 | 1.02 | 1.09 | 0.23 | ** |
| Total shrub cover (%) | 0.01 | 22.39 | 1.37 | 21.27 | 3.13 | | 23.14 | 1.82 | 32.20 | 5.44 | |
| | 0.03 | 23.02 | 1.10 | 22.16 | 2.64 | | 23.09 | 1.65 | 25.49 | 3.42 | |
| | 0.20 | 23.87 | 0.99 | 20.99 | 2.72 | | 22.71 | 1.45 | 23.93 | 3.16 | |

## Appendix 13. Average values with standard errors (SE) of microhabitat characteristics at successful and failed and late brood sites by greater sage-grouse (*Centrocercus urophasianus*) in areas unaffected by wildfire within xeric and mesic habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Diff.:** .Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| | | Xeric | | | | | Mesic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Scale (ha) | Success | SE | Fail | SE | Diff. | Success | SE | Fail | SE | Diff. |
| Horizont | BL | 62.20 | 1.36 | 56.67 | 3.61 | | 62.98 | 1.65 | 52.25 | 3.80 | ** |
| Vertical | BL | 31.39 | 2.27 | 19.73 | 5.38 | * | 45.81 | 2.53 | 6.75 | 3.48 | ** |
| Average | BL | 50.93 | 1.34 | 50.19 | 3.89 | | 57.38 | 1.47 | 48.74 | 5.31 | |
| Sagebrus | BL | 43.51 | 2.20 | 35.90 | 5.13 | | 43.05 | 2.54 | 19.50 | 5.62 | ** |
| | 0.03 | 41.72 | 1.60 | 34.41 | 4.33 | | 38.85 | 1.94 | 24.62 | 4.99 | ** |
| | 0.20 | 39.96 | 1.43 | 33.37 | 3.88 | | 38.55 | 1.72 | 22.75 | 4.15 | ** |
| Non- | BL | 23.54 | 1.62 | 21.50 | 5.15 | | 40.67 | 3.43 | 17.63 | 8.07 | ** |
| | 0.03 | 23.72 | 1.22 | 21.07 | 2.96 | | 38.02 | 2.15 | 20.60 | 6.12 | ** |
| | 0.20 | 23.69 | 1.13 | 20.86 | 3.17 | | 36.52 | 1.92 | 19.76 | 5.66 | ** |
| Perennial | BL | 15.77 | 0.96 | 18.57 | 3.73 | | 26.53 | 1.53 | 23.56 | 4.51 | |
| | 0.03 | 17.19 | 0.71 | 18.33 | 3.08 | | 25.10 | 1.07 | 22.87 | 2.92 | |
| | 0.20 | 17.18 | 0.67 | 18.44 | 2.58 | | 24.99 | 0.95 | 20.99 | 2.63 | |
| Perennial | BL | 11.70 | 0.86 | 6.93 | 2.00 | * | 12.77 | 0.92 | 13.31 | 4.07 | |
| | 0.03 | 12.84 | 0.72 | 8.72 | 2.12 | * | 13.52 | 0.66 | 12.32 | 2.38 | |
| | 0.20 | 12.85 | 0.67 | 9.23 | 1.91 | * | 13.39 | 0.60 | 11.79 | 2.19 | |
| Residual | BL | 6.87 | 0.56 | 5.20 | 1.08 | | 13.17 | 0.94 | 8.38 | 1.55 | * |
| | 0.03 | 7.72 | 0.37 | 5.86 | 0.90 | * | 12.78 | 0.59 | 10.50 | 1.79 | |
| | 0.20 | 8.01 | 0.37 | 6.03 | 0.88 | * | 12.63 | 0.52 | 10.55 | 1.81 | |
| Perennial | BL | 9.30 | 0.94 | 7.95 | 1.56 | | 14.91 | 1.20 | 14.75 | 4.09 | |
| | 0.03 | 9.22 | 0.70 | 7.75 | 1.47 | | 14.89 | 0.95 | 15.07 | 2.70 | |
| | 0.20 | 9.22 | 0.62 | 7.75 | 1.26 | | 14.97 | 0.90 | 15.63 | 2.88 | |
| Annual | BL | 4.22 | 0.42 | 3.63 | 0.69 | | 4.96 | 0.58 | 3.88 | 1.14 | |
| | 0.03 | 4.30 | 0.32 | 4.52 | 0.98 | | 4.82 | 0.43 | 4.38 | 1.66 | |
| | 0.20 | 4.52 | 0.30 | 5.12 | 1.35 | | 4.37 | 0.31 | 4.34 | 1.27 | |
| Perennial | BL | 9.59 | 0.99 | 7.15 | 1.58 | | 7.93 | 0.69 | 9.25 | 1.87 | |
| | 0.03 | 10.59 | 0.78 | 8.02 | 1.63 | | 9.28 | 0.64 | 9.70 | 2.09 | |
| | 0.20 | 10.38 | 0.75 | 7.80 | 1.75 | | 9.31 | 0.57 | 10.43 | 2.77 | |

| | | Xeric | | | | | Mesic | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Scale (ha) | Success | SE | Fail | SE | Diff. | Success | SE | Fail | SE | Diff. |
| Annual | BL | 3.63 | 0.26 | 2.77 | 0.27 | * | 3.28 | 0.22 | 3.25 | 0.54 | |
| | 0.03 | 3.88 | 0.27 | 2.87 | 0.19 | ** | 3.67 | 0.21 | 2.83 | 0.18 | ** |
| | 0.20 | 4.03 | 0.26 | 2.84 | 0.19 | ** | 3.82 | 0.21 | 2.76 | 0.16 | ** |
| Residual | BL | 8.24 | 0.74 | 6.15 | 1.37 | | 13.20 | 1.04 | 18.13 | 7.44 | |
| | 0.03 | 8.85 | 0.47 | 6.39 | 1.29 | * | 14.04 | 0.71 | 21.57 | 6.70 | |
| | 0.20 | 9.29 | 0.44 | 7.07 | 1.04 | * | 14.19 | 0.68 | 18.68 | 5.20 | |
| Litter | BL | 27.06 | 1.72 | 26.67 | 5.51 | | 37.14 | 2.00 | 22.19 | 5.53 | ** |
| | 0.03 | 25.06 | 1.21 | 26.24 | 4.51 | | 31.96 | 1.57 | 23.15 | 4.49 | * |
| | 0.20 | 24.33 | 1.11 | 25.13 | 4.15 | | 31.14 | 1.48 | 21.63 | 3.54 | * |
| Bare | BL | 36.99 | 2.03 | 47.62 | 6.13 | * | 23.48 | 1.75 | 30.72 | 7.10 | |
| | 0.03 | 37.51 | 1.52 | 42.79 | 3.94 | | 26.74 | 1.16 | 24.13 | 4.96 | |
| | 0.20 | 37.15 | 1.41 | 42.54 | 3.61 | | 26.94 | 1.07 | 25.73 | 4.20 | |
| Rock | BL | 7.29 | 0.93 | 3.30 | 0.45 | ** | 4.76 | 0.47 | 12.75 | 4.16 | * |
| | 0.03 | 7.94 | 0.71 | 6.47 | 1.50 | | 5.42 | 0.44 | 10.32 | 2.60 | * |
| | 0.20 | 8.05 | 0.68 | 6.24 | 1.17 | | 5.62 | 0.42 | 9.89 | 2.31 | * |
| Tall | 0.01 | 15.52 | 0.93 | 11.32 | 2.30 | * | 11.22 | 0.89 | 8.39 | 3.70 | |
| | 0.03 | 16.26 | 0.89 | 12.11 | 2.41 | | 11.11 | 0.80 | 8.63 | 3.37 | |
| | 0.20 | 16.56 | 0.85 | 14.15 | 3.41 | | 11.02 | 0.76 | 9.18 | 3.56 | |
| Dwarf | 0.01 | 2.84 | 0.43 | 3.73 | 1.74 | | 3.67 | 0.59 | 2.70 | 1.12 | |
| | 0.03 | 3.22 | 0.43 | 3.91 | 1.65 | | 3.69 | 0.56 | 2.18 | 0.95 | |
| | 0.20 | 3.54 | 0.43 | 3.79 | 1.41 | | 3.36 | 0.49 | 2.03 | 0.93 | |
| Total | 0.01 | 18.36 | 0.90 | 15.05 | 2.48 | | 14.89 | 0.94 | 11.10 | 3.61 | |
| | 0.03 | 19.48 | 0.85 | 16.02 | 2.61 | | 14.80 | 0.85 | 10.81 | 3.29 | |
| | 0.20 | 20.10 | 0.80 | 17.94 | 3.29 | | 14.38 | 0.78 | 11.21 | 3.48 | |
| Non- | 0.01 | 8.90 | 0.72 | 7.59 | 1.90 | | 10.88 | 0.97 | 6.14 | 1.85 | * |
| | 0.03 | 8.73 | 0.62 | 7.32 | 1.77 | | 11.40 | 0.94 | 7.03 | 2.42 | * |
| | 0.20 | 8.53 | 0.57 | 6.68 | 1.84 | | 11.24 | 0.84 | 6.59 | 2.13 | * |
| Total | 0.01 | 27.26 | 1.06 | 22.64 | 2.45 | * | 25.77 | 1.28 | 17.23 | 3.92 | * |
| | 0.03 | 28.21 | 1.00 | 23.33 | 2.73 | * | 26.20 | 1.18 | 17.85 | 3.99 | * |
| | 0.20 | 28.62 | 0.95 | 24.62 | 3.58 | | 25.62 | 1.09 | 17.80 | 4.11 | * |

## Appendix 14. Average values with standard errors (SE) of microhabitat characteristics at successful and failed and early and late brood sites by greater sage-grouse (*Centrocercus urophasianus*) within burned habitats in the Great Basin, Nevada and California, 2009–16

[**Scale:** BL represents measurements conducted at brood location; 0.01, 0.03, and 0.20 ha scales represent 5, 10, and 25 meter transect lengths of measurement in relation to brood location. **Diff.:** .Single (*) and double (**) asterisks represent differences between means using 85 and 95 percent confidence intervals, respectively]

| Variable | Scale (ha) | Early | | | | | Late | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Success | SE | Fail | SE | Diff. | Success | SE | Fail | SE | Diff. |
| Horizontal cover (%) | BL | 56.07 | 3.52 | 68.57 | 3.34 | * | 56.41 | 1.76 | 50.96 | 7.22 | |
| Vertical cover (%) | BL | 7.47 | 2.31 | 38.86 | 13.99 | * | 5.98 | 1.46 | 11.20 | 7.47 | |
| Average height (cm) | BL | 44.32 | 1.99 | 41.69 | 6.83 | | 48.14 | 1.24 | 49.40 | 4.32 | |
| Sagebrush height (cm) | BL | 10.47 | 3.58 | 38.29 | 23.27 | | 7.21 | 2.16 | 26.10 | 11.41 | * |
| | 0.03 | 11.48 | 3.38 | 18.68 | 7.78 | | 6.89 | 1.49 | 18.79 | 7.60 | * |
| | 0.20 | 11.52 | 3.03 | 18.93 | 8.34 | | 8.96 | 1.65 | 16.92 | 7.46 | |
| Non-sagebrush height (cm) | BL | 27.00 | 4.57 | 34.57 | 10.29 | | 31.65 | 2.97 | 14.60 | 7.64 | * |
| | 0.03 | 33.15 | 4.13 | 26.65 | 6.43 | | 36.24 | 2.15 | 28.62 | 8.39 | |
| | 0.20 | 31.69 | 3.82 | 22.68 | 5.31 | | 39.81 | 2.29 | 26.46 | 7.93 | * |
| Perennial grass height (cm) | BL | 25.97 | 2.92 | 37.57 | 5.79 | * | 31.18 | 1.80 | 25.10 | 5.48 | |
| | 0.03 | 28.39 | 2.34 | 32.02 | 6.17 | | 33.15 | 1.33 | 27.60 | 4.44 | |
| | 0.20 | 29.49 | 2.05 | 32.38 | 4.73 | | 32.25 | 1.17 | 29.54 | 4.07 | |
| Perennial forb height (cm) | BL | 16.70 | 2.67 | 22.00 | 6.52 | | 23.36 | 1.84 | 20.00 | 6.66 | |
| | 0.03 | 18.16 | 1.93 | 22.49 | 6.09 | | 25.61 | 1.33 | 21.07 | 2.99 | |
| | 0.20 | 20.15 | 1.82 | 23.37 | 4.72 | | 26.39 | 1.24 | 19.80 | 2.44 | * |
| Residual grass height (cm) | BL | 18.27 | 3.70 | 40.29 | 10.05 | * | 18.56 | 1.70 | 11.40 | 4.89 | |
| | 0.03 | 20.07 | 2.95 | 33.79 | 9.17 | | 18.79 | 1.16 | 20.77 | 4.93 | |
| | 0.20 | 22.96 | 2.88 | 29.74 | 8.10 | | 18.48 | 1.03 | 22.45 | 4.89 | |
| Perennial grass cover (%) | BL | 10.83 | 2.39 | 23.64 | 7.82 | | 10.12 | 1.15 | 12.75 | 5.89 | |
| | 0.03 | 10.76 | 1.55 | 18.74 | 4.72 | | 12.77 | 0.98 | 10.37 | 2.40 | |
| | 0.20 | 10.98 | 1.04 | 17.05 | 3.66 | * | 12.17 | 0.81 | 11.02 | 2.01 | |
| Annual grass cover (%) | BL | 5.02 | 1.26 | 5.07 | 2.57 | | 6.23 | 1.13 | 6.85 | 3.55 | |
| | 0.03 | 6.52 | 1.08 | 3.74 | 0.88 | * | 6.45 | 0.72 | 8.57 | 3.18 | |
| | 0.20 | 7.54 | 0.98 | 4.16 | 0.74 | * | 7.36 | 0.73 | 10.29 | 3.40 | |

| Variable | Scale (ha) | Early | | | | | Late | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Success | SE | Fail | SE | Diff. | Success | SE | Fail | SE | Diff. |
| Perennial forb cover (%) | BL | 7.55 | 1.28 | 5.93 | 1.62 | | 8.59 | 1.08 | 12.75 | 5.89 | |
| | 0.03 | 10.25 | 1.31 | 15.39 | 3.34 | | 13.01 | 0.90 | 9.87 | 2.97 | |
| | 0.20 | 9.81 | 1.07 | 17.23 | 2.60 | ** | 13.54 | 0.76 | 13.69 | 2.80 | |
| Annual forb cover (%) | BL | 4.43 | 0.78 | 6.21 | 2.63 | | 4.84 | 0.59 | 4.10 | 1.07 | |
| | 0.03 | 5.80 | 0.75 | 3.81 | 0.94 | | 4.55 | 0.32 | 4.88 | 1.45 | |
| | 0.20 | 6.05 | 0.69 | 4.01 | 1.02 | | 4.49 | 0.31 | 4.52 | 0.86 | |
| Residual vegetation cover (%) | BL | 9.82 | 2.29 | 9.93 | 3.05 | | 9.33 | 1.31 | 5.90 | 1.93 | |
| | 0.03 | 10.89 | 1.67 | 12.46 | 2.67 | | 13.37 | 1.17 | 10.43 | 2.84 | |
| | 0.20 | 10.90 | 1.42 | 10.83 | 1.64 | | 13.37 | 1.07 | 9.76 | 2.13 | |
| Litter cover (%) | BL | 10.85 | 1.92 | 17.43 | 8.18 | | 14.37 | 1.55 | 11.50 | 3.00 | |
| | 0.03 | 12.58 | 1.65 | 16.70 | 5.86 | | 16.39 | 1.13 | 12.81 | 2.22 | |
| | 0.20 | 13.16 | 1.55 | 15.97 | 4.97 | | 16.57 | 1.08 | 14.89 | 2.40 | |
| Bare ground cover (%) | BL | 37.38 | 6.21 | 12.36 | 5.55 | ** | 33.39 | 3.02 | 42.10 | 12.80 | |
| | 0.03 | 28.51 | 2.94 | 28.88 | 5.96 | | 27.26 | 1.62 | 34.44 | 8.35 | |
| | 0.20 | 25.14 | 2.46 | 30.37 | 3.95 | | 27.00 | 1.43 | 32.12 | 7.38 | |
| Rock cover (%) | BL | 12.47 | 2.34 | 7.64 | 3.32 | | 8.95 | 1.46 | 3.30 | 0.80 | ** |
| | 0.03 | 12.65 | 2.09 | 8.55 | 2.52 | | 9.84 | 0.94 | 8.41 | 2.12 | |
| | 0.20 | 14.04 | 2.09 | 13.47 | 3.68 | | 10.69 | 0.92 | 8.54 | 2.26 | |
| Tall sagebrush cover (%) | 0.01 | 2.40 | 0.85 | 0.97 | 0.97 | | 0.95 | 0.33 | 5.56 | 3.09 | * |
| | 0.03 | 1.80 | 0.62 | 1.50 | 1.50 | | 0.98 | 0.30 | 5.22 | 2.67 | * |
| | 0.20 | 1.86 | 0.66 | 2.42 | 2.29 | | 1.10 | 0.27 | 5.26 | 3.15 | |
| Dwarf sagebrush cover (%) | 0.01 | 0.38 | 0.24 | 6.36 | 3.61 | * | 0.14 | 0.11 | 0.00 | 0.00 | |
| | 0.03 | 0.44 | 0.28 | 4.62 | 2.72 | * | 0.10 | 0.07 | 0.00 | 0.00 | |
| | 0.20 | 0.47 | 0.29 | 2.82 | 1.70 | | 0.10 | 0.04 | 0.05 | 0.05 | |
| Total sagebrush cover (%) | 0.01 | 2.78 | 0.86 | 7.33 | 3.46 | | 1.10 | 0.39 | 5.56 | 3.09 | * |
| | 0.03 | 2.24 | 0.65 | 6.12 | 2.71 | | 1.08 | 0.33 | 5.22 | 2.67 | * |
| | 0.20 | 2.33 | 0.70 | 5.23 | 2.43 | | 1.19 | 0.29 | 5.31 | 3.14 | |
| Non-sagebrush shrub cover (%) | 0.01 | 7.17 | 1.57 | 3.50 | 1.37 | | 10.18 | 0.88 | 7.13 | 3.06 | |
| | 0.03 | 7.98 | 1.70 | 4.30 | 1.56 | | 11.38 | 0.95 | 11.56 | 6.53 | |
| | 0.20 | 7.72 | 1.36 | 3.98 | 1.34 | * | 11.40 | 0.81 | 7.31 | 2.75 | |
| Total shrub cover (%) | 0.01 | 9.95 | 1.59 | 10.83 | 2.67 | | 11.28 | 0.88 | 12.69 | 3.32 | |
| | 0.03 | 10.22 | 1.69 | 10.42 | 1.92 | | 12.45 | 0.94 | 16.78 | 6.40 | |
| | 0.20 | 10.05 | 1.53 | 9.22 | 2.62 | | 12.59 | 0.80 | 12.63 | 3.98 | |

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