Habitat Selection and Physiological Condition of Female Greater Sage-grouse in Relation to Western Juniper

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Authorization to Submit Thesis

This thesis of Jordan C. Rabon, submitted for the degree of Master of Science with a Major in Natural Resources and titled "Habitat Selection and Physiological Condition of Female Greater Sage-grouse in Relation to Western Juniper," has been reviewed in final form. Permission, as indicated by the signatures and dates below, is now granted to submit final copies to the College of Graduate Studies for approval.

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Abstract

Greater sage-grouse (*Centrocercus urophasianus*, hereafter, sage-grouse) in the Great Basin have experienced loss of habitat due to expansion of western juniper (*Juniperus occidentalis*; hereafter, juniper) woodlands into sagebrush steppe. Juniper expansion can alter the sagebrush understory by reducing cover and species richness of herbaceous plants and shrubs, which may influence the availability of resources required by sage-grouse. On average, sage-grouse avoid juniper, especially when cover is > 10%, and avoidance of juniper can increase survival rates. However, there is significant variation in habitat selection among sage-grouse individuals when juniper cover is < 10%, and some individuals demonstrate preference for these areas. This pattern is possibly related to condition of the understory; cover of sagebrush shrubs and herbaceous plants may not yet be affected in areas where juniper cover is < 10%. Thus, individuals could select areas with non-zero levels of juniper cover despite potential for higher risk of mortality in those areas because resources required for survival and reproduction are still available.

In this thesis, I sought to evaluate if reproductive status influences habitat selection among female sage-grouse under different reproductive status and if physiological condition among hens is influenced by juniper cover. Female sage-grouse under different reproductive status can vary in habitat selection, however, comparisons of selection among hens in landscapes undergoing juniper expansion have not been evaluated. In addition, effects that juniper may have on hen physiological condition have not been explored. I conducted my study in Owyhee County, Idaho 2017–18 where juniper expansion is considered one of the primary threats to local sage-grouse populations.

In chapter 2, I investigated if reproductive status among hens with and without broods

(hereafter, brooding and non-brooding hens, respectively) influences habitat selection at multiple spatial scales. Habitat selection patterns may be a function of reproductive status because specific conditions that support individuals with young may not yield the same benefits for individuals without young. I employed a use and available design and collected data on habitat through field-based surveys and using remotely-sensed layers in a Geographic Information System (GIS). I used resource selection functions to evaluate habitat selection for brooding and non-brooding hens during the brood-rearing period (30 April–26 July) and made comparisons between reproductive groups. I conducted field-based habitat surveys at 181 use and available locations from 10 (2017) and 18 (2018) hens. I collected geospatial data at 2,226 use and available locations for 11 (2017) and 21 (2018) hens. At my smallest spatial extent, brooding hens were more likely than non-brooding hens to select habitats with more cover (e.g., taller perennial grass and non-sagebrush shrubs). At greater spatial extents, both reproductive groups generally avoided cover class II (> 10–20% juniper cover) and III (> 20% juniper cover) but selected for cover class I (> 0–10% juniper cover), woody wetlands, and herbaceous wetlands with high perimeter to area ratios. Brooding hens may select for taller vegetation because these areas provide more concealment cover for chicks, thereby providing more protection from predators. In contrast, non-brooding hens may use grouping behavior as an anti-predator strategy and may not have to rely on areas with taller vegetation for protection. Hens avoided cover class II and III because resources that support demographic processes are less available in these areas. Both reproductive groups selected cover class I, possibly because food resources and concealment cover are not yet reduced to levels that result in habitat unsuitable for sage-grouse. Furthermore, brooding and non-brooding hens selected for wetland habitats because these areas may provide high amounts of food sources (i.e., forbs and insects) than the surrounding uplands.

In chapter 3, I investigated relationships between concentrations of stress hormones among hens and ecological factors. Along with possibly reducing the availability of food and concealment cover, juniper trees may create suitable habitat for avian predators, potentially increasing the risk of predation for sage-grouse. In several avian species, habitat characteristics can influence concentrations of stress hormones, and elevated levels of stress hormones can have negative influences on factors related to survival and reproductive success (e.g., suppress immune function, probability of nest and brood abandonment, and slower growth rates in offspring). Hormone concentrations in sage-grouse may be positively associated with juniper cover through decreased resource availability or increased pressure from predators. I collected fecal samples at nighttime roost locations of radio-collared hens during the lekking (4 March–8 May) and brood-rearing period (24 May–26 July) to estimate corticosterone concentrations (i.e., stress hormones; hereafter, $FCORT_m$). I evaluated relationships between vegetation cover (hereafter, ecological variables) and $FCORT_m$ in hens. I used remotely-sensed layers to estimate ecological variables within multiple spatial extents centered at breeding grounds (i.e., leks) and within separate, minimum convex polygons (MCP) that surrounded use locations of each hen. I used values from ecological variables estimated within leks and MCPs to evaluate relationships with $FCORT_m$ during the lekking and brood-rearing period, respectively. Prior to evaluating relationships with ecological variables, I accounted for factors previously shown to influence $FCORT_m$ in other vertebrate species, such as age, temperature, and sample mass. I collected 37 fecal samples from 34 hens during the lekking period (4 March–8 May) and 36 fecal samples from 22 hens during the brood-rearing period (24 May–26 July). During the lekking period, $FCORT_m$ had a negative relationship with dry mass of the fecal sample and there was no relationship with ecological variables. During the brood-rearing period, $FCORT_m$ had a positive relationship with total area of MCP but a negative relationship with the number of days of reproductive activity, maximum daily temperature (°F), and proportion of cover class I (> 0–10% juniper cover) within MCP. I may not have observed relationships between ecological variables and $FCORT_m$ during the lekking period because hens arrive on breeding grounds at different times and could vary temporally and spatially in their use of habitat surrounding each lek. During the brood-rearing period, $FCORT_m$ may decrease with greater proportions of cover class I because of density dependent factors and high productivity of shrubs and herbaceous plants in areas with young stands of juniper. Because interpretation of relationships between stress and ecological factors can be influenced by sampling and extraction procedures, my results lay the groundwork for additional studies that employ the same laboratory methods to evaluate $FCORT_m$ in sage-grouse.

Although hens preferred cover class I, previous research has demonstrated lower survival among sage-grouse that occupy areas with low levels of juniper cover, and removal of cover class I would likely benefit sage-grouse. My results do suggest lower stress levels among hens that use habitats with cover class I, but this benefit likely does not outweigh the cost to survival. Given the avoidance of cover class II and III, I also suggest targeted removal of juniper around wetlands dominated by woody vegetation, patchy, herbaceous wetlands with high edge ratios, and mesic habitats with taller non-sagebrush shrubs may be the most beneficial because these habitats were preferred by hens. Wetlands and mesic habitats with tall shrubs likely benefit sage-grouse, perhaps by positively influencing survival of chicks and adults. However, additional monitoring is needed to assess benefits and costs to demographic processes among sage-grouse that select woody wetlands and tall shrubs.

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I would like to acknowledge my advisor, Dr. Tracey Johnson, for her support, guidance, and mentorship during my graduate education. I'd like to thank the Idaho BLM for funding this research, Peter Coates for his collaboration and support, and USGS biologists, Rebecca Kelble, John Severson, Brian Prochazka, and Steven Matthews for supplying field equipment and assistance during my two field seasons. I thank BLM and IDFG biologists Ethan Ellsworth, Bruce Scheoberl, Chel Curtis, and Ann Moser for assisting with field research, contacting landowners, and providing me with lek count data. Thank you to my field technicians Sarah McIntire, Jeffrey Snowdon, Miranda Castillo, and Benjamin MacFarland for their hard work through the long nights of trapping and hot days of vegetation sampling. Many thanks to the landowners who allowed me to conduct research on their property. I also want to thank my lab mates for their helpful feedback on presentations and assistance with R code.

Dedication

I dedicate this thesis to my parents, David and Deborah Rabon, who supported me financially throughout my undergraduate and graduate education. They always were supportive of my career decisions, even if it meant moving from our home state and only seeing me a few times each year. Our annual camping trips were the foundation of my love for the outdoors, which laid the groundwork for me to become an avid hunter and fisherman, support conservation efforts, and pursue a career in wildlife research.

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Statement of Contribution

Jordan C. Rabon was the primary in conducting statistical analyses and writing the following chapters, and Tracey N. Johnson assisted with editing content in chapters.

Chapter 1: Introduction

Sagebrush ecosystems in the northern Great Basin have been negatively impacted by the expansion of western juniper (*Juniperus occidentalis*; hereafter, juniper) woodlands (Bunting et al. 1999, Bates et al. 2000, Miller et al. 2000, Rowland et al. 2011). Juniper occupies ~3.6 million ha across Oregon, California, Nevada, Washington, and Idaho, and ~90% of its current range has developed over the past 100–130 years (Miller and Tausch 2001, Miller et al. 2005). Indeed, ~90% of the area now occupied by juniper was once dominated by sagebrush steppe (Miller and Tausch 2001). The dramatic increase of juniper woodlands into shrub-dominated landscapes has been attributed to reduced frequency of wildland fires (Miller and Tausch 2001). Juniper expansion can influence sagebrush ecosystems by reducing cover and species richness of shrubs and herbaceous plants, and can fragment large expanses of sagebrush (Bunting et al. 1999, Miller et al. 2000, Bates et al. 2017). Juniper is classified into three categories based on percent cover: Phase I remains dominated by sagebrush (> 0–10% juniper cover), Phase II is co-dominated by sagebrush and juniper (> 10–30% juniper cover), and Phase III is dominated by juniper (> 30% juniper cover; Miller et al. 2005, Boyd et al. 2017). Juniper expansion possibly affects resource availability in sagebrush steppe and adds new challenges for conservation efforts of sagebrush-associated wildlife, like the greater sage-grouse (*Centrococercus urophasianus*, hereafter, sage-grouse).

Sage-grouse have undergone a dramatic loss of habitat since the mid-1800s and in certain areas of the Great Basin, juniper expansion is considered one of the primary threats to sage-grouse and their habitats (Connelly et al. 2004, Davies et al. 2011). Because shrubs and herbaceous plants can reduce in cover and diversity as juniper cover increases, juniper expansion could reduce the availability of food sources and concealment cover for sage-grouse (Bates et al. 2017). Juniper can also negatively influence demographic processes of sage-grouse (Baruch-Mordo et al. 2013, Coates et al. 2017, Severson et al. 2017). Across life-stages, sage-grouse avoid Phase II and III juniper, but use of Phase I is variable and some individuals prefer low levels of juniper cover (≤ 10%; Coates et al. 2017). However, juniper cover as low as 2–4 % can reduce annual survival, lower the probability of nesting, and can lower attendance rates of males at breeding grounds (i.e., leks; Baruch-Mordo et al. 2013, Coates et al. 2017, Prochazka et al. 2017, Severson et al. 2017). Additionally, nest and brood survival can decline with increasing juniper cover (Sandford et al. 2017). Lower annual survival may be a result of increased movement rates by sage-grouse when encountering juniper, thereby increasing susceptibility to predation from visually acute predators (Prochazka et al. 2017). Despite consequences to demographic processes, some individual sage-grouse select areas with juniper while other individuals avoid it, and mechanisms explaining this variation in habitat selection have not been fully evaluated.

One possible mechanism explaining variation in selection of juniper among sage-grouse may be reproductive status. Habitat selection can differ between hens with and without broods and may be affected by variable benefits of particular habitat characteristics to juveniles versus adults (Gregg et al. 1993, Kirol et al. 2015, Mangelinckx et al. 2018, Smith et al. 2018). For example, females with broods could select habitats that primarily promote the survival and growth of juveniles, such as greater cover of forbs or abundance of invertebrates (Gregg and Crawford 2009, Casazza et al. 2011). In contrast, females without broods may select habitats that primarily promote adult survival, for example greater visual obstruction, thereby improving odds of her reproductive output in future breeding periods

(Boggs et al. 1992, Smith et al. 2018). Hen survival is often one of the most influential reproductive parameters on the growth of sage-grouse populations (Taylor et al. 2012, Dahlgren et al. 2016); thus, hens without broods should select habitats that maximize potential for future breeding opportunities. A better understanding of the role that female reproductive status may play in habitat selection could aid in juniper removal efforts that contribute not only to the production of offspring, but also the survival of hens with future reproductive potential (e.g., Blomberg et al. 2013, Mangelinckx et al. 2018, Smith et al. 2018).

Relationships between juniper expansion and demographic rates of sage-grouse have become clearer in recent years but effects of juniper on physiological traits of individuals have not been evaluated. Because juniper expansion may affect resource availability and increase risk of predation, physiological condition among sage-grouse could be impacted. Physiological condition can be assessed using various metrics, including morphometric (e.g., body condition indices) and physiological measurements (e.g., hormone levels or plasma-lipid metabolites; Labocha and Hayes 2012), and several metrics are correlated with demographic performance in birds (Bety et al. 2003, Hayward and Wingfield 2004, Strauss et al. 2005, Milenkaya et al. 2015). For example, elevated concentrations of stress hormones can affect reproductive processes in several avian species by suppressing growth and development of chicks (Hayward et al. 2006, Wada and Bruener 2008) and the number of fledglings produced (Saino et al. 2005, Bonier et al. 2009). Concentrations of stress hormones can be influenced by the presence of predators (Boonstra et al. 1998, Saino et al. 2005), or simply predatory cues (Clinchy et al. 2013), through tradeoffs between foraging and predator evasion (Clinchy et al. 2004), and habitat availability (Janin et al. 2011). Stress hormones in sage-grouse could therefore be an indicator of habitat availability or quality associated with juniper expansion.

I sought to provide insight into the role of juniper in habitat selection and physiological condition for female sage-grouse. My research was conducted during the first two years of a longer-term study aimed at evaluating demographic responses in sage-grouse following juniper removal. In chapter 2, I compare habitat selection at multiple spatial scales between hens with and without chicks during the brood-rearing season (late-April–July). In chapter 3, I investigate ecological correlates that influence stress levels of female sage-grouse during the entire breeding season (lekking, nesting, and brood-rearing; March–July). Because data collection occurred prior to juniper removal, it provided an opportunity to investigate if habitat selection by hens occupying a juniper-dominated landscape is affected by reproductive status and if physiological condition is influenced by juniper.

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Chapter 2: Habitat Selection of Female Greater Sage-grouse in a Landscape with Western Juniper

Abstract

Greater sage-grouse (*Centrocercus urophasianus*, hereafter, sage-grouse) in the Great Basin have experienced loss of habitat due to expansion of conifer woodlands into sagebrush steppe. Conifer expansion can alter the sagebrush understory by reducing cover and species richness of herbaceous plants and shrubs, which may influence the availability of resources required by sage-grouse. Sage-grouse that occupy landscapes undergoing expansion of conifer woodlands may alter patterns of habitat selection in order to survive and reproduce successfully. Additionally, habitat selection in response to low levels of conifer cover (> 0–10%) can vary among sage-grouse individuals and mechanisms explaining this variation have not been explored. Habitat selection patterns may be a function of reproductive status because specific conditions that support individuals with young may not yield the same benefits for individuals without young. I evaluated habitat selection at multiple spatial scales among hens under different reproductive status in a landscape undergoing conifer expansion. I conducted my study in southwestern Idaho 2017–18 where the expansion of western juniper (*Juniperus occidentalis*, hereafter, juniper) is a primary threat to local sage-grouse populations. I employed a use and available design and collected data on habitat through field-based surveys and using remotely-sensed layers in a Geographic Information System (GIS). I used resource selection functions to evaluate habitat selection for hens with (hereafter, brooding hens) and without chicks (hereafter, non-brooding hens) during the brood-rearing period (30 April–26 July) and made comparisons between both reproductive groups. I captured a total of 39 hens (2017: 15 hens; 2018: 24 hens). I conducted field-based

habitat surveys at 181 use and available locations from 10 (2017) and 18 (2018) hens. I collected geospatial data from 2,226 use and available locations for 11 (2017) and 21 (2018) hens. At my smallest spatial extent, brooding hens were more likely than non-brooding hens to select habitats with more cover (e.g., taller perennial grass and non-sagebrush shrubs). At greater spatial extents, both reproductive groups generally avoided cover class II (> 10–20% juniper cover) and III (> 20% juniper cover) but selected for cover class I (> 0–10% juniper cover), woody wetlands, and herbaceous wetlands with high perimeter to area ratios. Although hens preferred cover class I, previous research has demonstrated lower survival among sage-grouse that occupy areas with low levels of juniper cover, and removal of cover class I would likely benefit sage-grouse. I also suggest targeted removal of juniper around wetlands dominated by woody vegetation, patchy, herbaceous wetlands with high edge ratios, and mesic habitats with taller non-sagebrush shrubs may be the most beneficial because these habitats were preferred by hens. Wetlands and mesic habitats with tall shrubs likely benefit sage-grouse, perhaps by positively influencing survival of chicks and adults. However, additional monitoring is needed to assess benefits and costs to demographic processes among sage-grouse that select woody wetlands and tall shrubs.

Introduction

Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) in the Great Basin have experienced loss of habitat due to expansion of conifer woodlands into sagebrush steppe (Miller and Tausch 2001, Davies et al. 2011). Conifer woodlands, dominated by juniper (*Juniperus* spp.) and pinyon pine (*Pinus* spp.), have expanded their range since the mid-1800s and currently occupy ~19 million ha across the intermountain west (Miller et al.

1999, Miller and Tausch 2001). Up to 90% of the current area occupied by conifer woodlands was once dominated by sagebrush (Miller et al. 2008). Conifer expansion can alter the sagebrush understory by reducing cover and species richness of herbaceous plants and shrubs, which may influence the availability of resources required by sage-grouse for breeding, nesting, brood-rearing, and survival (Bunting et al. 1999, Crawford et al. 2004, Coultrap et al. 2008, Bates et al. 2017, Miller et al. 2017). Additionally, conifer expansion may fragment previously contiguous areas of sage-grouse habitat, possibly concentrating individuals into smaller areas of remaining suitable habitat (e.g., Fuhlendorf et al. 2002). Because of the potential effect on resource availability and associated density-dependent processes, sage-grouse that occupy landscapes undergoing expansion of conifer woodlands may alter patterns of habitat selection in order to survive and reproduce successfully.

Sage-grouse individuals can vary in selection and avoidance patterns in sagebrush habitat under different percent classes of conifer cover (Coates et al. 2017). Areas undergoing conifer expansion are classified into three phases to aid management to prioritize removal at areas that would most benefit sage-grouse: Phase I remains dominated by sagebrush (> 0–10% conifer cover), Phase II is co-dominated by sagebrush and conifers (> 10–30% conifer cover), and Phase III is dominated by conifers (> 30% conifer cover; Miller et al. 2005, Boyd et al. 2017). Sage-grouse can show strong avoidance towards all three Phases of conifer expansion but there is variation in habitat selection among individual males and females towards Phase I, where some individuals demonstrate preference for these areas (Coates et al. 2017). This pattern is likely related to condition of the understory; cover of sagebrush shrubs and herbaceous plants may not yet be affected in areas where conifer cover is < 10% (Miller et al. 2000, 2005). However, Phase I can negatively impact demographic rates of sage-grouse. For example, lek attendance, the probability of selecting sites for nesting, and annual survival begin to decline among sage-grouse when conifer cover is ~2% (Baruch-mordo et al. 2013, Coates et al. 2017, Severson et al. 2017a). Though our understanding of the consequences incurred on sage-grouse is becoming clearer, sources of variation on habitat selection in relation to conifer trees have not been fully evaluated.

Sage-grouse individuals of different reproductive status (i.e. males, females with chicks, and females without chicks) can vary in life history, survival rates, and reproductive effort (e.g., males do not contribute to nesting or rearing chicks; Schroeder et al. 1999, Dinkins et al. 2014a, Apa et al. 2017). As a result of variation in trade-offs in survival and reproduction likely faced by individuals with and without chicks present, habitat selection patterns may be a function of reproductive status because specific conditions that support individuals with young may not yield the same benefits for individuals without young (Kohlsmann et al. 1996, Erikstad et al. 1998, Bunnell et al. 2004, Smith et al. 2018). For example, females with broods could select habitats with characteristics that primarily promote the survival and growth of juveniles, such as greater cover of forbs or abundance of invertebrates (Gregg and Crawford 2009, Casazza et al. 2011). In contrast, females without broods may select habitats with characteristics that primarily promote adult survival, for example greater visual obstruction, thereby improving odds of her reproductive output in future breeding periods (Boggs et al. 1992, Smith et al. 2018). Hen survival is often one of the most influential reproductive parameters on the growth of sage-grouse populations (Taylor et al. 2012, Dahlgren et al. 2016); thus, hens without broods should select habitat that maximizes potential for future breeding opportunities.

A better understanding of the role that female reproductive status may play in habitat selection could aid in habitat management efforts that contribute not only to the production of offspring, but also the survival of hens with future reproductive potential (e.g., Blomberg et al. 2013, Mangelinckx et al. 2018, Smith et al. 2018). However, it is unknown whether reproductive status influences selection or avoidance of conifer among sage-grouse individuals. Removal of conifers has been a management strategy for the conservation of sagebrush steppe and sage-grouse for the past 30 years (Bombaci and Pejchar 2016), and lekking, nesting, and brood-rearing habitats are generally prioritized areas for conifer removal treatments (BLM 2011, 2018). The removal of conifers can increase male attendance at leks (Commons et al. 1999), the availability of nesting sites (Severson et al. 2017a), and hen survival (Severson et al. 2017b). However, incorporating habitats selected by hens without broods into conifer removal strategies could potentially benefit survival rates for this reproductive group, and ultimately result in greater improvements in growth rates of sage-grouse populations (Dahlgren et al. 2016). Here, I evaluate habitat selection at multiple spatial scales for hens with and without broods within a sagebrush steppe landscape that has experienced significant conifer expansion. I aim to inform the design and implementation of conifer removal efforts by evaluating variation in habitat selection by hens as a function of reproductive status.

Methods and Materials

Study Site

I conducted my study in southwestern Idaho where the expansion of western juniper (*J. occidentalis*; hereafter, juniper) is considered one of the primary threats to local sage-grouse populations (Owyhee 2013; Figure 2.1). My study area included land managed by the Bureau of Land Management (BLM) and interspersed with private and state-owned sections. Land use primarily consisted of cattle grazing, hunting, camping, and localized off-road vehicle recreation.

Elevation at my study area varied from 1,200–2,400 m, and precipitation, temperature, and associated plant communities are influenced by this elevational gradient. Mean annual precipitation, the majority of which was received in winter and spring, ranged from 27–51 cm (NOAA 2018). Average high temperature in January and July at 1,200 m was 4°C and 31°C and at > 1,800 m was -2°C and 21°C, respectively (NOAA 2018, NRCS 2017). Low-mid elevation communities (1,200–2,000 m) primarily consisted of big sagebrush (*Artemisia tridentata*), low sagebrush (*A. arbuscula*), bitterbrush (*Purshia tridentata*), green rabbitbrush (*Chrysothamnus viscidiflorus*), Sandberg bluegrass (*Poa secunda*), cheatgrass (*Bromus tectorum*), Idaho fescue (*Festuca idahoensis*), and bluebunch wheatgrass (*Pseudoroegneria spicata*). High-elevation (> 2000 m) plant communities consisted of big sagebrush, snowberry (*Symphoricarpos* spp.), serviceberry (*Amelanchier* spp.), Idaho fescue, bluebunch wheatgrass, and big mountain brome (*B. marginatus*). Lupine (*Lupin* spp.), penstemon (*Penstemon* spp.), phlox (*Phlox* spp.), and buckwheat (*Eriogonum* spp.) were common forbs found across elevations and throughout my study area. Willow (*Salix* spp.), balsam poplar (*Populus balsamifera*), and quaking aspen (*P. tremuloides*) occurred within the drainages and riparian areas. Curl-leaf mountain mahogany (*Cercocarpus ledifolius*; hereafter, mahogany) was found in the southern end of my study area and juniper and Douglas-fir (*Pseudotsuga menziesii*) primarily occurred in the northern end. My study area was scheduled for extensive juniper removal in the near future on portions managed by BLM (BLM 2018).

Site Selection

I identified five leks for capture and monitoring of sage-grouse. I included leks in my study design that would likely yield hens that experience a gradient of juniper cover throughout the nesting and brood-rearing seasons. Additionally, I included birds from two subpopulations in my study design; one subpopulation was expected to experience higher juniper cover than the other (Figure 2.1). To increase the likelihood that I achieved these criteria in my sample of marked hens, I identified focal leks for captures by first evaluating tree cover within 10 km of all active leks in my study area using ArcGIS 10.5.1 (GIS, Overwatch Systems, Sterling, VA). I used a raster layer that estimated percent canopy cover of trees in Owyhee County, Idaho (Falkowski et al. 2017). Additionally, I used a 10-km buffer around each lek because this scale is expected to include a majority of the nesting habitat used by hens at each lek and for the same reason, this is the scale at which juniper removal treatments will take place in my study area (Schroeder et al. 1999, Wakkinen et al. 1992, Coates et al. 2013, BLM 2018). I then identified five leks for which canopy cover of trees was > 1% within the 10-km buffer (range = 9–60% of area with > 1% canopy cover; Table 2.2.1).

Sage-grouse Capture and Monitoring

I captured female sage-grouse at roost locations during nighttime hours (2000–0500) using spotlighting and netting techniques and by rocket-netting at leks during morning hours

(0700–1000) from March–May in 2017 and 2018 (Giesen et al. 1982, Wakkinen et al. 1992). All hens received a numbered aluminum leg band (National Band and Tag, Newport, KY, size 14) for unique identification and a 22-gram necklace-style Very High Frequency (VHF) radio transmitter (model A4060; Advanced Telemetry Systems, Isanti, MN, < 3% body mass) to identify use locations following release. All sage-grouse were captured, marked, and monitored in accordance with approved protocols (Idaho Department of Fish and Game Research Permit #161213 and #180205 and University of Idaho Institutional Animal Care and Use Committee Protocol 2016-58).

I located hens via radio-telemetry from 1 April–27 July in 2017 and 1 March–30 July in 2018. I acquired use locations by homing in on collar signals with a three element yagi antenna and a receiver (model R2000; Advanced Telemetry Systems, Isanti, MN). I approached and circled the source of the signal ~30–50 m away by walking perpendicular to the direction of the strongest signal. Once the source of the signal was within the circled area, I marked the observer's location using a Global Positioning System (GPS) and estimated a compass bearing and a distance from the observer to the hen. I estimated the use location by projecting a point using a GPS from the observer's location with the estimated bearing and distance. If a hen flushed, then I marked the area on the ground from which the hen flushed as the use location.

During the nesting season, I tracked hens twice weekly during daytime hours (0700-2000) to identify nesting attempts. I found nests by observing localized movements of hens between two consecutive tracking events and using binoculars to visually confirm incubating hens (Connelly et al. 1993, Kolada et al. 2009). I monitored hens on nests via telemetry three times per week until I determined a nest fate. I conducted a visual inspection of the nest when a hen was absent from her nest for two consecutive tracking events and determined nest fate (successful or failed) using evidence at the nest. I used criteria from Gibson et al. (2015) to classify nest fates, and considered nests successful when ≥ 1 egg met criteria for hatched eggs (Gregg et al. 1994). I installed video cameras connected to continuously recording DVR systems at a subset of nests during my study, which aided in determining if a nest was successful or had failed. No nests were abandoned (e.g., eggs cold but intact; Gibson et al. 2015) during my study. For successful nests that did not have video cameras, I identified the hatch date as the median date between the last date a hen was observed incubating and the first date the hen was observed absent from the nest. I identified hatch dates for successful nests with cameras by reviewing the video. Observers wore rubber boots while locating hens to reduce risk of influencing nest predation.

I attempted to locate all hens twice weekly during daytime hours following completion of the nesting attempt, regardless of whether a nest hatched or failed. One of the twice-weekly locations for hens with successful nests was conducted within three days of 10, 20, 30, 40, and 50 days post-hatch (Casazza et al. 2011). Additionally, I attempted to locate hens with successful nests during nighttime hours (2200-0500) within 24 hours of the daytime 10, 20, 30, 40, and 50 days post-hatch to determine if hens were accompanied by chicks. I obtained visuals on hens and chicks via spotlight and binoculars at nighttime locations. I located hens during nighttime hours until 50 days post-hatch, at which time the brood was considered successful, or until there were no chicks observed with the hen for two consecutive nighttime locations (i.e. failed brood; Casazza et al. 2011, Gregg and Crawford 2009, Schreiber et al. 2016).

Reproductive Status

I classified hens accompanied by chicks at nighttime locations as brooding hens; I classified hens that were not accompanied by chicks (i.e., hens with failed nests) as non-brooding hens. Furthermore, I reclassified brooding hens that lost all chicks before the 50-day brood count as non-brooding hens on the median date between the last date I observed chicks and the first date I did not observe chicks (Smith et al. 2018). Although I did not conduct brood counts past day 50, hens with successful broods located after the 50-day night check remained classified as brooding hens until 70 days post-hatch. Brood break up typically begins at 70 days and chicks can have > 95% daily survival rates from 50–70 days post-hatch (Schroeder et al. 1999, Schreiber et al. 2016). Thus, I assume brooding hens are accompanied by chicks 50–70 days post-hatch and decisions in habitat selection during this period are still influenced by the presence of a brood. Brooding hens located ≥ 70 days post-hatch were reclassified as non-brooding hens because regardless of whether hens still have chicks present at that point, I assumed chicks are operating relatively independently from the hen and that the hen's decisions in habitat selection are likely no longer driven by the needs of her offspring (Schroeder 1986, Small and Rusch 1989). There is potential error associated with my assignment of dates for change in reproductive status. However, only two brooding hens lost all chicks prior to 50 days post-hatch and only three brooding hens were located ≥ 70 days post-hatch during my study, affecting at most ~5% of all use locations for the entire breeding season.

Habitat Sampling

To quantify habitat selection, I measured habitat variables of interest at use and available locations at multiple spatial scales (Appendix A: Tables A.1 and A.7). Values of habitat variables were estimated with each spatial scale centered on use and available locations. At the finest scale, I used ground-based data collection to estimate habitat variables within circular plots of 0.03 ha (hereafter, micro-scale; Appendix A: Table A.1). This spatial scale has been used in previous studies of habitat selection for brooding and non-brooding hens (Gregg et al. 1993, Drut et al. 1994, Casazza et al. 2011). At broader scales, I used remotely sensed GIS layers to estimate the proportion of landcover types. Relevant spatial scales were determined using information from daily movements from sampled hens. To calculate distances of daily movement, I used the pointDistance function in the raster package in R to estimate the distances (m) between pairs of sequential use locations (n = 333 pairs) for each hen within each year (Hijmans 2019). I estimated distances from all daytime use locations (excluding nests) from 30 April–26 July; the first date a nest hatched, and the latest date all broods were considered successful during both years of my study, respectively. For each hen, I divided distances between each pair of consecutive use locations by the number of days between each pair of consecutive use locations to calculate the distance of daily movement. I then calculated the average mean and maximum distances of daily movement for all hens (excluding $n = 4$ hens that each had < 2 pairs of consecutive use locations) based on reproductive status ($n = 11$ brooding hens, $n = 19$ non-brooding hens). I used the following distances: 150.6 m and 549.0 m which represented average mean and maximum distance of daily movement for brooding hens, respectively; 218.5 m and 803.1 m which represented average mean and maximum distance of daily movement for non-brooding hens, respectively. I used these distances as radii to create circular plots at the following spatial scales for my analyses: 7.1-ha and 94.7-ha (brooding hens), and 15.0-ha and 202.6-ha (non-brooding hens; hereafter, macro-scales; Appendix A: Table A.7).

Micro-scale sampling

To evaluate habitat selection at the micro-scale for brooding hens, I conducted habitat surveys at daytime use locations from 10, 20, 30, 40, and 50 days post-hatch. Because I only had one brooding hen in 2017, I conducted additional ground surveys at 1 location < 10 days post-hatch and 1 location between 10–20 days post-hatch. For non-brooding hens, I conducted habitat surveys at one use location/individual/week from June–July in 2017 and at one use location per individual every two weeks from May–July in 2018.

To quantify available habitat at the micro-scale, I created locations by projecting coordinates from a use location in a GPS using a bearing and distance of 50–850 m created with a random number generator. Because I did not have information on movements of sage-grouse in my study area prior to data collection, I used the average maximum distance of daily movement for sage-grouse (850 m) reported by Casazza et al. (2011). If available locations fell within unsuitable features such as standing water ≥ 0.03 ha, on gravel roads, or on cliffs, then I moved the available location 10–20 meters from the edge of the unsuitable feature and recorded new GPS coordinates.

I placed four 10-m transects perpendicular to each other and centered at the use or available location. I assigned a bearing to the first transect using a random number generator and sequentially added 90° to determine directions of the other three transects. To describe ground cover, I used a 20 cm x 50 cm Daubenmire frame to estimate percent cover of the following categories: perennial grass, annual grass, perennial forb, annual forb, residual cover (i.e. standing dead grass and forb), bare ground, litter, rock, and shrub at the intersection of the transects, and at 0.7 m, 5 m, and 10 m along each transect (Daubenmire 1959). I used seven categories to estimate cover: 1 = 0–5%, 2 = > 5–15%, 3 = > 15–25%, 4 = > 25–50%, 5 = > 50–75%, 6 = > 75–95%, and 7 = > 95–100%. To describe vegetation height, I recorded the species and heights of the nearest perennial grass, perennial forb, residual grass, sagebrush shrub, and non-sagebrush shrub at the intersection of the transects, and at 0.7 m, 5 m, and 10 m along each transect. I also recorded the height and species of ≤ 40 additional shrubs within the entire plot. I estimated visual obstruction using a 25 cm x 25 cm Jones' cover board at the intersection of the transects and at 5 m and 10 m along each transect (Jones 1968). I estimated shrub canopy cover with a 5-cm gap interval along each transect using the line intercept method and recorded species for each shrub that was measured (Canfield 1941). To measure stem density of trees, I counted any tree within the micro-scale. I categorized each stem in one of four height classes (Class I = 0–1 m, Class II = 1–2 m, Class III = 2–3 m, and Class IV = 3+ m) and measured the diameter at breast height (DBH) for stems ≥ 1.5 m tall. Diameter at breast height was measured using a metric Biltmore stick placed ~1.4 m above the ground and held perpendicular to the tree trunk 62.5 cm from the observer's eyes (Hill 1998).

Macro-scale sampling

To quantify available habitat at the macro-scale, I created random points within two polygons that surrounded all locations from daytime use from 30 April–26 July in GIS. Because I sampled from two subpopulations of sage-grouse in my study area, I created two separate polygons; one polygon surrounding all use locations of each subpopulation separately (Figure 2.1). I did not observe individuals moving between subpopulations and thus assumed the area between subpopulations was not available habitat. I created each polygon by applying an 803.1 m buffer (i.e., the distance of my largest spatial extent) around a minimum convex polygon (MCP) that surrounded all use locations of each subpopulation. I created five available locations per use location within each polygon (n = 495 and 1360 available locations). I used 193 m as a minimum distance between available locations because this was the maximum distance allowed for the number of locations I desired to quantify available habitat within each polygon.

I used raster layers from the 2016 National Land Cover Data (NLCD) fractional components, woody wetlands, and emergent herbaceous wetlands as habitat variables at macro-scales (Xian et al. 2015, Yang et al. 2018). Existing layers of juniper cover were not appropriate for my analysis because they were too coarse in spatial scale (i.e., 30 m x 30 m resolution) and are binned in different percentages (Landfire 2013, Falkowski et al. 2017). Therefore, Michael Chenaille, cartographic technician with the U. S. Geological Survey, created a continuous layer of percent tree cover derived from 2011 National Agricultural Imagery Program (NAIP) satellite imagery of my study area at a 1-m^2 resolution following methods of Gustafson et al. (2017) using object-based image analyses performed in Feature Analyst™ (Overwatch Systems, Sterling, VA). Michael also assisted me with refining our tree layer to primarily represent juniper and exclude other tree species (primarily Douglas-fir and mahogany) because: 1) juniper has increased in distribution throughout my study area while other tree species have not increased (Burkhardt and Tisdale 1969), and 2) juniper is the tree species proposed for removal on BLM lands (BLM 2018). The process for refining our tree layer was as follows. First, we removed polygons ≤ 5 m^2 to reduce the number of false positives in our juniper layer (i.e., sagebrush, grasslands, etc. classified as juniper). We then removed larger polygons that classified other land cover types as juniper using spatial layers from the 2011 NLCD and Landscape Fire and Resource Management Planning Tools (LANDFIRE) representing bare ground, cliff, crop, grassland, greasewood, meadow, open water, pasture, woody wetlands, saltbrush, and emergent herbaceous wetlands (Landfire 2013, Yang et al. 2018). Next, we removed polygons that classified non-juniper trees as juniper using NAIP imagery. From this juniper layer, we created a raster of 30 m x 30 m resolution with each pixel value representing percent cover of juniper to allow evaluation of habitat selection in relation to availability of juniper cover classes used in Coates et al. (2017) indexing transitional phases of expansion (i.e., cover class I = > 0–10% juniper cover, cover class II = > 10–20% juniper cover, and cover class III = > 20% juniper cover). We used an omission-commission analysis to assess the accuracy of our final tree layer (overall accuracy = 84%; Table 2.2). Because other conifer species may be indistinguishable from juniper in NAIP imagery, we were unable to remove all polygons that misclassified other conifers and our final juniper layer potentially over-estimates juniper cover. However, according to the Landfire (2013) data set, juniper represented 95% of all conifer trees within the extent of my study area (Table 2.3). Furthermore, ground observations and micro-scale habitat sampling yielded primarily observations of juniper except at the highest elevations where Douglas-fir occurred (*n* = 1 micro-scale plot). Therefore, misclassification of other conifer species as juniper in our final layer likely does not exert great influence on our results.

Within each circular plot at macro-scales (7.1-, 15.0-, 94.7-, and 202.6-ha), I estimated the area of each landcover type using spatial analyst tools in GIS. I then converted the area of each landcover type into a proportion within each circular plot. I calculated proportions of non-sagebrush shrubs and perennial herbaceous plants using the difference in proportions between percent shrub and percent sagebrush fractional layers, and the difference in proportions between percent herbaceous and percent annual herbaceous fractional layers, respectively (Appendix A: Table A.7). I quantified proportions of wetlands dominated by woody or herbaceous vegetation separately because these areas could have a varying degree of preferred amounts of food resources and concealment cover for sage-grouse under different reproductive status, thus brooding and non-brooding hens may vary in habitat selection to wetlands with primarily woody or herbaceous vegetation. Furthermore, I estimated the perimeter of woody wetlands and herbaceous wetlands using the intersect tool and calculated edge density (perimeter divided by area) for both layers (Casazza et al. 2011). Wetlands with greater edge densities could provide sage-grouse with an optimal amount of food resources that are in close proximity to escape cover, and these habitats could positively influence survival rates in sage-grouse (see Casazza et al. 2011). I calculated edge density to evaluate differences in selection for habitats with fewer or greater woody and herbaceous wetlands between brooding and non-brooding hens (i.e. greater edge density = multiple woody wetlands or herbaceous wetlands; lower edge density = fewer woody wetlands or herbaceous wetlands; Casazza et al. 2011). I estimated the distance from each use and available location to the nearest woody wetlands, herbaceous wetlands, and cover class I, II, and III area using the Near tool in GIS. Lastly, I estimated elevation from all use and available locations using the elevatr package in R (Hollister and Shah 2017).

Statistical Analysis

The condition of herbaceous vegetation changes throughout spring and summer, and may influence sage-grouse habitat selection and movement towards riparian areas and higher elevations (Gregg et al. 1993, Pratt et al. 2017). Therefore, I separated my selection analysis into early- and late-season periods to reflect differences in plant conditions and available habitat between spring and summer. I determined exact dates for early- and late-season based on breeding phenology and core-use areas in my sample of hens. During my study, 30 April was the earliest a nest hatched, suggesting the earliest date hens had chicks and the beginning of what I define as the early-season period. To define the end of this early-season period, I used the median date of last known locations within early season core-use areas for my sample of hens. I defined core-use areas by creating 50% utilization distribution polygons (UDs) for each hen within each year by using the adehabitatHR package in R (Calenge 2006). I used all use locations (excluding nests) from 1 March–31 July in 2017–18 to create UDs. I only used UDs that displayed two, non-overlapping polygons (i.e. suggesting separate core use areas during the breeding season; n = 20 hens) to identify dates that each hen was last located in their early season core-use area (range = 17 May–10 July) and selected the median date from this sample of hens as the end date of the early-season period. I only used UDs to define the end of the early-season period and did not use them to evaluate habitat selection. I used 26 July as my end date for the late-season period because it was the last date all broods were ≥ 50 days post-hatch. During my study, all dates associated with 50 days post-hatch ranged from 19 June–26 July.

To create resource selection functions (RSFs) for brooding and non-brooding hens I first used multinomial models in the nnet package in R (Venables and Ripley 2002) to identify important differences in patterns of selection and avoidance influenced by reproductive status. Multinomial models have been used in previous studies to simultaneously evaluate habitat selection among individuals in different reproductive groups (Bañuelos et al. 2008, Mangelinckx et al. 2018, Smith et al. 2018). I created separate multinomial models for micro- and macro-scales within each early- and late-season period. I had three response categories for each multinomial model: 1) values from available locations (set as the reference category), 2) values from use locations of brooding hens, and 3) values from use locations of non-brooding hens. Because I had a relatively small number of hens in each reproductive group across both years (n = 11–21; Table 2.2 and 2.3), I pooled all habitat data from both years and did not evaluate differences in habitat selection between years. After important predictor variables were identified from final multinomial RSFs, I then made inferences on habitat selection separately for each reproductive group using generalized linear mixed-effects models (GLMM; Zuur et al. 2009) with a binomial distribution in the lme4 package in R (Bates et al. 2015). The structure of GLMMs account for non-independence among sampling units by allowing intercepts among units to vary (Zuur et al. 2009, Harrison et al. 2018). Thus, I used individual hens as a random intercept term for all models to account for repeated sampling of habitat use from the same individuals. I Z-standardized all values of predictor variables prior to building models (Marquardt 1980, Westover et al. 2016).

<u>Micro-scale habitat selection</u>

At the micro-scale, I took a two-step approach to create my multinomial RSFs. First, I created single variable models and assessed model rank relative to a null model using

Akaike Information Criterion adjusted for small sample sizes (AIC_c; Burnham and Anderson 2004; Appendix A: Tables A.3 and A.4). I included a fixed term representing percent canopy cover of sagebrush as the null model to account for the well-established relationship between sage-grouse andsagebrush cover (Dunn and Braun 1986, Schroeder et al. 1999, Bunnell et al. 2004, Smith et al. 2018). I considered variables important to habitat selection if AIC_c was lower than the null model and 85% confidence intervals around the parameter estimate did not include zero (Arnold 2010). I used Pearson correlation index (r) to evaluate correlation among variables and considered variables with $|r| \geq 0.6$ as highly correlated. If two variables were highly correlated, then I removed the lower ranking variable based on AIC_c from future analyses. After this initial screening of single variables for importance and collinearity, the second step of my analysis explored combinations of remaining variables and evaluated model fit via AIC_c in reference to a model with only sagebrush canopy cover (Appendix A: Tables A.5 and A.6). I allowed up to four variables per model, including my sagebrush canopy cover term. I considered models competitive with each other if the difference in AIC_c from the top model (ΔAIC_c) was ≤ 2 (Burnham and Anderson 2002). My approach to inference was conservative in that I made inferences only on models including variables that were present in all competitive models, and do not report inferences about habitat selection on variables that were present in competitive models but did not overcome the AIC penalty for including the additional term (Arnold et al. 2010).

Macro-scale habitat selection

At the macro-scale, I took a two-step approach to create my multinomial RSFs. First, I determined the best spatial scale for each variable of interest by creating separate sets of single variable models with each variable at the four different spatial extents determined using daily movements (7.1 ha, 15.0 ha, 94.7 ha, and 202.6 ha; Appendix A: Tables A.9 and A.10). I ranked these models by AIC_c in reference to an intercept-only model and considered the model with the lowest AIC_c as the best spatial scale, as long as the 85% confidence intervals around the parameter estimate did not include zero (Arnold 2010). Furthermore, in this initial modeling stage, I evaluated distance to nearest woody wetlands and herbaceous wetlands, distance to nearest cover class I, II, and III, and elevation, and considered variables important to habitat selection if AIC_c was lower than an intercept-only model and 85% confidence intervals around the parameter estimate did not include zero (Appendix A: Tables A.9 and A.10). I evaluated correlations among the top variables from each model set and considered variables with $|r| \geq 0.6$ as highly correlated. Because I was primarily interested in selection patterns related to cover classes of juniper cover for brooding and non-brooding hens, I removed variables that were highly correlated with the best scales of juniper cover and sagebrush. I then evaluated correlations among the remaining top variables and retained the variable among highly correlated variables that had the most biological justification (Dinkins et al. 2014b).

After finalizing a set of variables that minimized collinearity, in step 2 I explored combinations of top variables and evaluated model fit via AIC_c (Appendix A: Tables A.11 and A.12). I included terms representing the proportion of sagebrush cover and all three cover classes of juniper cover in the null model. This approach to structuring the set of candidate models assumes that hens respond to juniper cover when making habitat selection decisions (Atamian et al. 2010, Coates et al. 2017, Dinkins et al. 2014b, Severson et al. 2017a), but allows them to vary in their responses based on reproductive status and cover class; this variation was central to my research question of whether reproductive status influences habitat selection patterns in a landscape with conifer expansion. In addition to the four terms included in the null model, I included up to four additional variables of the remaining top variables in each model. I considered models competitive with each other if the difference in AIC_c from the top model was ≤ 2 (Burnham and Anderson 2002). I made inferences on variables that were present in all competitive models and do not report those variables that were present in competitive models but whose presence did not overcome the penalty for inclusion of the additional term (Arnold 2010).

Results

I captured a total of 39 hens (2017: 15 hens; 2018: 24 hens). I conducted field-based habitat surveys at 181 micro-scale use and available locations from 10 (2017) and 18 (2018) hens (Table 2.4). I collected geospatial data for macro-scale surveys from 2,226 use and available locations for 11 (2017) and 21 (2018) hens (Table 2.5). Eleven hens were excluded from my analysis of habitat selection for the following reasons: in 2017 three hens were captured during the late-season period, after most habitat surveys were completed; I was unable to re-locate one hen shortly after capture. In 2018, seven hens were excluded from my analysis: 1) three due to mortality from predation before 30 April and two because they died from predation before the first brood check at day 10 and a brood could not be confirmed, and 2) I was unable to re-locate one hen shortly after capture and one hen shortly after hatch but prior to the first brood check. In 2018, I was unable to re-locate two brooding hens and three non-brooding hens during the early-season period, but I retained data from use locations based on their last-known status for my analysis. In 2018, only three brooding hens were located after the 70-day mark and use locations after that date were therefore reclassified as non-brooding. One brooding hen in each year lost all chicks prior to 20 days post-hatch during the early-season period, and were reclassified as non-brooding.

Micro-scale Habitat Selection

During the early-season period, the best predictors of habitat selection at the micro-scale included perennial grass height and % cover of sagebrush (Table 2.6). Both brooding and non-brooding hens selected habitats with taller perennial grasses relative to available habitats (Figure 2.2). However, brooding hens were 2.2 times more likely (odds = 3.94, 85% CI: 1.77–11.25) to select habitats with taller grasses than non-brooding hens (odds = 1.75, 85% CI: 1.07–3.19; Figure 2.2 and 2.3). I did not observe strong selection patterns in relation to % sagebrush cover from either reproductive group during the early-season period at the micro-scale (Figure 2.2).

During the late-season period, the best predictors of habitat selection included height of non-sagebrush shrubs, % cover of bare ground, and % cover of sagebrush (Table 2.6). Brooding hens selected habitats with taller non-sagebrush shrubs and less bare ground than available habitats (Figure 2.2). Non-brooding hens similarly selected for less bare ground, but height of non-sagebrush shrubs was uninformative for this reproductive group (Figure 2.2). Brooding hens were 22.1 times more likely to select habitats with taller non-sagebrush shrubs than non-brooding hens (odds = 17.71, 85% CI: 4.35–122.73 and odds = 0.81, 85% CI: 0.51–1.30, respectively; Figure 2.2 and 2.3). I did not observe strong selection patterns in relation to % sagebrush cover from either reproductive group during the late-season period at the micro-scale (Figure 2.2). Additionally, I did not observe strong selection patterns for stem density and DBH of trees at the micro-scale during early- and late-season periods. All modeling results from steps 1 and 2 of model selection at the micro-scale are presented in Appendix A: Tables A.3–A.6.

Macro-scale Habitat Selection

During the early-season period, the best predictors of habitat selection included proportions of sagebrush (7.1 ha), cover class III (7.1 ha), cover class II (7.1 ha), cover class I (202.6 ha), bare ground (7.1 ha), perennial herbaceous (7.1 ha), woody wetlands (202.6 ha), and distance to cover class I (Table 2.6). Both reproductive groups selected habitats with lower proportions of sagebrush compared to available habitats (Figure 2.2). Both brooding and non-brooding hens selected habitats with lower proportions of cover class III. Brooding hens selected habitats with lower proportions of cover class II juniper than available habitats while non-brooding hens did not show a selection pattern. Brooding hens were 2 times more likely to avoid cover class II juniper than non-brooding hens (odds = 0.42, 85% CI: 0.18–0.77 and odds = 0.84, 85% CI: 0.57–1.16, respectively; Figure 2.2). Both reproductive groups selected habitats with greater proportions of cover class I than available habitats at the 202.6-ha scale (Figure 2.2). Both reproductive groups selected habitats with greater proportions of woody wetlands at the 202.6-ha scale, lower proportions of bare ground and perennial herbaceous at the 7.1-ha scale, and further from cover class I than available habitats.

During the late-season period, the best predictors of habitat selection included proportion of sagebrush (7.1 ha), cover class III and II (7.1 ha), cover class I (202.6 ha), bare ground (7.1 ha), perennial herbaceous plants (7.1 ha), woody wetlands (202.6 ha), and edge density of herbaceous wetlands (7.1 ha; Table 2.6). Non-brooding hens selected habitats with lower proportions of sagebrush at the 7.1-ha scale while brooding hens did not show a selection pattern. Both brooding and non-brooding hens selected habitats with lower proportions of cover class III at the 7.1-ha scale compared to available habitats (Figure 2.2). Non-brooding hens selected habitats with lower proportions of cover class II compared to available habitats at the 7.1-ha scale whereas brooding hens did not show a selection pattern (Figure 2.2). Both reproductive groups selected habitats with greater proportions of cover class I than available habitats at the 202.6-ha scale. Both reproductive groups selected habitats with lower proportions of bare ground and perennial herbaceous plants at the 7.1-ha scale, greater proportions of woody wetlands at the 202.6-ha scale, and greater edge density of herbaceous wetlands at the 7.1-ha scale compared to available habitats (Figure 2.2). All modeling results from steps 1 and 2 of model selection at the macro-scale are in Appendix A: Tables A.9–A.12.

Discussion

The patterns in habitat selection I report are reflective of current reproductive status and not previous reproductive status (i.e., reproductive status was not an outcome of habitat selection decisions because I re-classified brooding hens as non-brooding when they lost their brood, therefore patterns of selection for non-brooding hens are associated with their broodless state). Therefore my study suggests that habitat selection at multiple spatial scales can be influenced by female reproductive status among sage-grouse that occupy landscapes with juniper. Smith et al. (2018) reported differences in habitat selection between brooding and non-brooding hens at multiple spatial scales, and Kirol et al. (2015) suggested differences based on reproductive status at broad spatial scales. The availability of sage-grouse habitat is likely reduced by juniper expansion and may influence the likelihood that habitat is partitioned between reproductive groups. My work is the first to evaluate habitat selection patterns between reproductive groups in landscapes undergoing juniper expansion.

Micro-scale Habitat Selection

At a fine spatial scale, selection of habitats with taller vegetation by brooding hens may be driven by a need for greater concealment. Chicks often have a higher risk of predation than adults, possibly in part because they have a broader suite of potential predators (Conover and Roberts 2017, McIntire et al. 2020), and brooding hens likely select habitats that provide concealment cover to promote survival of their young (Gregg and Crawford 2009, Hagen et al. 2007, Dinkins et al. 2014b, Gibson et al. 2017). I observed brooding hens consistently select habitats with greater cover throughout the breeding season. During the early-season period, the majority of chicks are young and have relatively limited mobility because they are poor flyers compared to adults (Schroeder et al. 1999). During the late-season period, as herbaceous plants begin to senesce in upland habitats, hens move their broods in response to changing forage conditions to higher elevations and/or wetland habitats to improve access to succulent forbs, but still require concealment cover for broods (Dalke et al. 1963, Gregg et al. 1993, Atamian et al. 2010, Pratt et al. 2017, this study). At my study area, large, non-sagebrush shrubs (e.g., willows, serviceberry, and snowberry) generally occur in wetter locations and at higher elevations and likely provide greater concealment cover for chicks because these species tend to grow larger than sagebrush (NRCS 2019b). Non-brooding hens may be able to select habitats with less concealment cover because of their reproductive status. Non-brooding hens are likely more mobile without chicks, allowing them to respond more quickly to potential predators, and they may use alternate predator avoidance strategies, such as grouping behavior, to decrease mortality risk (Dinkins et al. 2014a). During my study, I observed > 1 adult at 18.9% of locations used by non-brooding hens as opposed to 5.9% of locations used by brooding hens. Although these observations are anecdotal, the pattern suggests that grouping behavior may allow non-brooding hens to use areas with relatively less cover.

Hens may not have exhibited strong responses towards juniper at fine spatial scales because they prioritized selection for other habitat characteristics (e.g., taller grass and shrubs). Previous studies have observed influence on selection patterns from juniper at greater spatial extents (Coates et al. 2017, Severson et al. 2018a, Ricca et al. 2018). Additionally, juniper may be a more important factor on selection of seasonal or annual home range (i.e., 3rd order selection) than selection within the home range (i.e., 4th order selection; Johnson et al. 1980), as was observed in this study.

Macro-scale Habitat Selection

At broader spatial scales, both reproductive groups selected habitats with relatively less sagebrush, perennial herbaceous, and bare ground. Selection for less sagebrush and perennial herbaceous was an unexpected result. Sagebrush and herbaceous cover could be highly available throughout my study area and sage-grouse may need to select small amounts of these cover types to maintain biological functions (see Johnson et al. 1980). Additionally, the Sage-grouse Habitat Assessment Framework (Stiver et al. 2015) suggests 10–25% canopy cover of sagebrush is suitable habitat for early and late brood-rearing. During the early-season period, hens may choose habitats with less sagebrush cover because these areas can provide more of the preferred conditions I observed at finer spatial scales (e.g., taller sagebrush) or have a greater abundance of forbs compared to available habitats (i.e., sagebrush cover and herbaceous cover are often inversely related; Anderson and Inouye 2001, Olson and Whitson 2002). My evaluation of vegetation communities at broad scales did not allow for estimation of forb cover exclusively, so I could not evaluate the relationship between selection patterns and forb abundance. Furthermore, areas with lower proportions of sagebrush could provide habitat favored at broader spatial extents, such as wetlands dominated by woody vegetation. During the late-season period, hens in my study area tended to move to wetter areas and higher elevations. Because these habitats have greater water availability than either upland habitats (Whitford et al. 1995) or lower elevations (NRCS 2019a), there is potentially greater diversity and cover of non-sagebrush shrubs relative to sagebrush (Knapp et al. 2002, McAdoo et al. 2013, Wenninger and Inouye 2008). Thus, habitats selected by hens during the late-season period may have less sagebrush cover because there is greater diversity and cover of non-sagebrush shrubs. Cover of non-sagebrush shrubs increased with elevation at my study area, and sagebrush cover began to decline when cover of non-sagebrush shrubs was ~5% (results not shown). Similarly, hens may select areas with less perennial herbaceous and bare ground cover because they favored woody wetlands and smaller, patchy herbaceous wetlands (i.e., wetlands with greater edge densities), and the surrounding area around these wetlands could proportionally have more sagebrush cover than herbaceous and bare ground cover.

Both reproductive groups showed selection for wetland habitats, but non-brooding hens had a slightly stronger selection for woody wetlands than brooding hens. Non-brooding hens may be less constrained by food availability than hens with chicks; if non-brooding hens select habitat primarily to reduce predation risk then wetlands with more woody vegetation could provide more cover. However, the small difference in the strength of selection for woody wetlands could suggest there is not a biological difference between the two reproductive groups. I also observed both reproductive groups selecting herbaceous wetlands with greater edge densities. Broods are more likely to be successful if hens select herbaceous wetlands with greater edge densities because these areas may provide an optimum balance of food sources (i.e., forbs and insects) and concealment cover from predators; non-brooding hens likely benefit from these characteristics as well (Forbes et al. 2005, Casazza et al. 2011).

I observed avoidance of relatively high juniper cover (> 20%) similar to that reported by others (Coates et al. 2017, Ricca et al. 2018, Severson et al. 2017a, Westover et al. 2016), but I also observed differences in selection for cover class II between brooding and non-brooding hens, and selection for cover class I by both reproductive groups. Both reproductive groups generally avoided cover class II and III, possibly because resources that support demographic processes are less available in these areas. As juniper expansion transitions to cover class II and III, important food and cover resources in the understory are significantly reduced. However, during the early-season period habitat selection among non-brooding hens was not influenced by cover class II, possibly because there was variation in behavior among these hens during this period. Early in the breeding season, hens with failed nests may remain near leks and attempt to re-nest or undergo long-distance movements to higher elevations and wetland habitats (Connelly et al. 2000, 2011). Because juniper cover tends to increase in elevation at my study area, the variation in behavior could cause hens that have moved to higher elevation to use proportionally more cover class II than hens that attempt to re-nest and remain at low elevations. In contrast, habitat selection among brooding hens was not influenced by cover class II during the late-season period, whereas non-brooding hens showed avoidance during this period. Brooding hens may prioritize the selection for taller, non-sagebrush shrubs and wetland habitats and may cause hens with chicks to show a lack of response towards cover class II. Both reproductive groups selected cover class I, possibly because food resources and concealment cover are not yet reduced to levels that result in habitat unsuitable for sage-grouse (Miller et al. 2000, Coultrap et al. 2008, Stiver et al. 2015).   Although there is risk of higher mortality (Coates et al. 2017), brooding hens may have little choice but to select for cover class I because of limited mobility due to dependent chicks and selection being driven by taller vegetation structures at fine spatial scales (e.g., taller grass and shrubs). My results also suggest that non-brooding hens have a stronger selection for cover class I than brooding hens, however, this difference is small between the two reproductive groups. Non-brooding hens may show a greater preference for cover class I because adults with no dependent young may be more able to survive in areas with low levels of juniper than chicks. Younger age classes of sage-grouse can have higher rates of mortality than adults when encountering areas with juniper (Prockazka et al. 2017), and brooding hens may be less likely to select cover class I than non-brooding hens because these areas may pose a greater risk for chicks.

Although I report differences in selection between brooding and non-brooding hens, I acknowledge aspects of my approach may influence my interpretation. First, my sample size for both reproductive groups is relatively small (n =11 brooding hens and n = 21 non-brooding hens) and I don’t know to what extent my sample represents overall study populations. However, I did have enough information to detect differences in habitat selection between reproductive groups, and therefore view my sample size as acceptable. Because of relatively small samples, I was unable to test for differences in selection between years. The two years of my study varied in precipitation and temperature during the lekking season and this variation may have influenced plant phenology, growth, and food availability during the brood-rearing season (NRCS 2019a). These differences could affect selection patterns of sage-grouse between years (Gregg et al. 2008), and future studies should attempt to incorporate annual variation into evaluations of habitat partitioning. Finally, my analytical approach included the evaluation of patterns of habitat selection within two separate frameworks: I used multinomial models with data pooled from both reproductive groups to identify primary relationships of reproductive state with specific habitat variables, and binomial models for making inferences on selection. This approach likely affected the estimated strength of relationships between reproductive status and habitat selection. Although alternative approaches are available, I considered mine to be conservative because multinomial models allowed all data to inform overall patterns of selection in relation to ecological conditions, and binomial models allowed me to incorporate random effects and account for the non-independent nature of multiple observations made on the same individuals.

Management Implications

Managers tasked with conserving sage-grouse populations aim to employ strategies that maximize the availability of preferred habitat. However, managing for preferred habitat should be weighed against the demographic outcomes for individuals associated with those preferred habitats. My observation of selection for low levels of juniper cover taken together with similar patterns reported previously that also demonstrated survival costs associated with these selection patterns suggest that early-phase juniper expansion could serve as an ecological trap, and that removal efforts would likely benefit grouse populations in areas of juniper expansion (Coates et al. 2017). Juniper in cover class II and III are largely avoided throughout the breeding season, so removal of these classes would likely benefit both reproductive groups. However, cost of restoration (Farzan et al. 2015, Boyd et al. 2017) and risk of invasion from annual plants at low elevations (Bates et al. 2005, Coultrap et al. 2008) associated with treating cover class III largely precludes treatment from occurring in areas with heavy juniper cover. Given the overall avoidance of cover class II and III and selection for wetland habitats, removal strategies that reduce juniper cover around herbaceous wetlands with high edge ratios and woody wetlands could be beneficial because these areas are preferred by both brooding and non-brooding hens. Additionally, reduction of juniper cover near mesic habitats with tall, non-sagebrush shrubs, such as willow and serviceberry, could increase the availability of this habitat type for brooding hens.

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Tables

Table 2.1. Proportional distribution of cover classes from Falkowski et al. (2017) within a 10-km radius plot centered at each lek in Owyhee County, Idaho during 2017–18.

	Cover Class					
Lek #	0–1%	1–4%	4–10%	10–20%	20–50%	Total 1–50%
2O196	0.740	0.072	0.070	0.089	0.029	0.260
2O197	0.909	0.048	0.028	0.013	0.002	0.091
2O523	0.905	0.069	0.023	0.002	0.000	0.095
2O619	0.405	0.167	0.169	0.197	0.063	0.595
2O642	0.685	0.101	0.085	0.094	0.035	0.315

Table 2.2. Results from accuracy assessment using a commission-omission analysis on the final spatial layer representing western juniper (*Juniperus occidentalis*) cover in Owyhee County, Idaho 2017-18. User's Accuracy = errors of commission; Producer's Accuracy = errors of omission.

	Conifer	Non-conifer	Total	User's Accuracy
Conifer Random	34	16	50	68.00%
Non-conifer Random	0	50	50	100.00%
Total	34	66	100	
Producer's Accuracy	100.00%	75.76%		84.00%

Table 2.3. Percent cover of forest types from LANDFIRE (LandFire 2013) spatial layers within Minimum Convex Polygons bounded by use locations of greater sage-grouse (*Centrocercus urophasianus*) hens from 30 April–26 July in Owyhee County, Idaho during 2017–18.

Class name	Conifer Type	Area (ha)	% Forest Type
Columbia Plateau Western Juniper Woodland and Savanna	Juniper	5177.8	90.372
Great Basin Pinyon-Juniper Woodland	Juniper	270.8	4.727
Northern Rocky Mountain Dry-Mesic Montane Mixed Conifer Forest	Conifer	124.6	2.174
Northern Rocky Mountain Mesic Montane Mixed Conifer Forest	Conifer	0.4	0.006
Rocky Mountain Lodgepole Pine Forest	Pine	0.5	0.008
Northern Rocky Mountain Ponderosa Pine Woodland and Savanna	Pine	40.5	0.707
Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland	Spruce-fir	38.1	0.664
Rocky Mountain Subalpine Mesic-Wet Spruce-Fir Forest and Woodland	Spruce-fir	0.1	0.002
Northern Rocky Mountain Conifer Swamp	Conifer	2.4	0.042
Northern Rocky Mountain Foothill Conifer Wooded Steppe	Conifer	7.1	0.124
Middle Rocky Mountain Montane Douglas-fir Forest and Woodland	Douglas-fir	10.0	0.017
Dry-mesic Montane Douglas-fir Forest	Douglas-fir	6.1	0.107
Abies grandis Forest	Spruce	59.0	1.030

Table 2.3. *Continued…*

Class name	Conifer Type	Area (ha)	% Forest Type
Subalpine Douglas-fir Forest	Douglas-fir	0.1	0.002
Western Cool Temperate Developed Ruderal Evergreen Forest	Conifer	0.1	0.002
	Total	5729.4	100.0000

Table 2.4. Summary of habitat surveys at the micro-scale (0.03 ha) conducted at greater sage-grouse (*Centrocercus urophasianus*) use and available locations in Owyhee County, Idaho during 2017–18.

Breeding Period[a]	Year	Reproductive Status[b]	# of Hens	# of Habitat Surveys at Use Locations	# of Habitat Surveys at Available Locations
Early-Season	2017	Brood	1	1	1
		Non-brood	6	10	10
	2018	Brood	10	19	18
		Non-brood	8	11	11
Late-Season	2017	Brood	1	6	6
		Non-brood	9	20	20
	2018	Brood	8	18	18
		Non-brood	5	6	6

[a] Early-season was defined as 30 April–13 June; late-season was defined as 14 June–26 July.
[b] Brood are hens with chicks; non-brood are hens without chicks.
[c] Unique individuals = 24.

Table 2.5. Summary of habitat surveys at macro-scales (7.1, 15.0, 94.7, 202.6 ha) conducted at greater sage-grouse (*Centrocercus urophasianus*) use and available locations in Owyhee County, Idaho during 2017–18.

Period[a]	Year	Reproductive Status[b]	# of Hens	# of Habitat Surveys at Use Locations	# of Habitat Surveys at Available Locations
Early-Season	2017	Brood	2	4	20
		Non-brood	9	60	300
	2018	Brood	10	60	300
		Non-brood	11	57	285
Late-Season	2017	Brood	1	11	55
		Non-brood	10	62	310
	2018	Brood	8	61	305
		Non-brood	12	56	280

[a] Early-season was defined as 30 April–13 June; Late-season was defined as 14 June–26 July.
[b] Brood are hens with chicks; non-brood are hens without chicks.
[c] Unique individuals = 28.

Table 2.6. Top four multinomial models evaluating habitat selection at the micro- (0.03 ha) and macro-scales (7.1, 15.0, 94.7, 202.6 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens in Owyhee County, Idaho 2017–18. Selection for juniper (*Juniperus occidentalis*) was evaluated as transitional phases (cover class I = > 0–10% juniper cover; cover class II = > 10–20% juniper cover; cover class III = > 20% juniper cover). K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights. The full list of models is presented in Appendix A.

			Model Fit Statistics			
Scale	Period[a]	Model[b]	K	AIC_c	ΔAIC_c	ω_i
Micro-scale	Early-season	%SageCC + HPGrass	6	170.990	0.000	0.147
		%SageCC + HPGrass + Hxeric	8	171.380	0.391	0.121
		%SageCC + HPGrass + Hsage	8	171.784	0.795	0.099
		%SageCC + HPGrass + Stm10mD	8	172.171	1.181	0.082
	Late-season	%SageCC + Hother+ %Bgnd + %Aforb	10	197.871	0.000	0.272
		%SageCC + Hother + %Bgnd + HRgrass	10	198.856	0.985	0.166
		%SageCC + Hother + %Bgnd	8	199.882	2.011	0.100
		%SageCC + Hother + HRgrass + %Aforb	10	201.210	3.338	0.051
Macro-scale	Early-season	Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + Rip202	18	1050.444	0.000	0.906
		Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + CCIDis + Rip202	18	1057.187	6.742	0.031

Table 2.6. *Continued…*

			Model Fit Statistics			
Scale	Period[a]	Model[b]	K	AIC_c	ΔAIC_c	ω_i
		Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Per7 + Rip202	18	1058.454	8.010	0.017
		Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Per7 + Rip202	18	1058.514	8.070	0.016
	Late-season	Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + WEdge7	18	941.377	0.000	0.991
		Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + REdge15	18	953.210	11.833	0.003
		Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + RipDis	18	953.333	11.956	0.003
		Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + Wet202	18	953.387	12.011	0.002

[a] Early-season was 30 April–13 June; Late-season was 14 June–26 July.

[b] %SageCC = mean % cover of sagebrush (*Artemisia* spp.) eestimated along two 20-m perpendicular transects; HPgrass = mean height (cm) of perennial grass; Hxeric = mean height (cm) of xeric shrub; Hsage = mean height (cm) of sagebrush; Stm10mD = stem density of trees; %Aforb = mean % cover of annual forb estimated within a 20 cm x 50 cm Daubenmire frame; Hother = mean height (cm) of non-sagebrush shrubs; HRgrass = mean height (cm) of residual grass; %Bgnd = mean % cover of bare ground estimated within a 20 cm x 50 cm Daubenmire frame; Sage7 = proportion of sagebrush (*Artemisia* spp.) within 7.1 ha;

CCI202 = proportion of cover class I within 202.6 ha; CCII7 = proportion of cover class II within 7.1 ha; CCIII7 = proportion of cover class III within 7.1 ha; CCIDis = distance (m) to nearest cover class I; Bgnd7 = proportion of bare ground within 7.1 ha; Per7 = proportion of perennial herbaceous plants within 7.1 ha; Rip202 = proportion of woody wetlands within 202.6 ha; Wet7 = proportion of herbaceous wetlands within 7.1 ha; Wet202 = proportion of herbaceous wetlands within 202.6 ha; Ann7 = proportion of annual herbaceous plants within 7.1 ha; Nsage7 = proportion of non-sagebrush shrubs within 7.1 ha; WEdge7 = edge density (perimeter (m)/area (m^2)) of herbaceous wetlands within 7.1 ha; REdge15 = edge density of woody wetlands within 15.0 ha; RipDis = distance (m) to nearest woody wetlands.

Figures

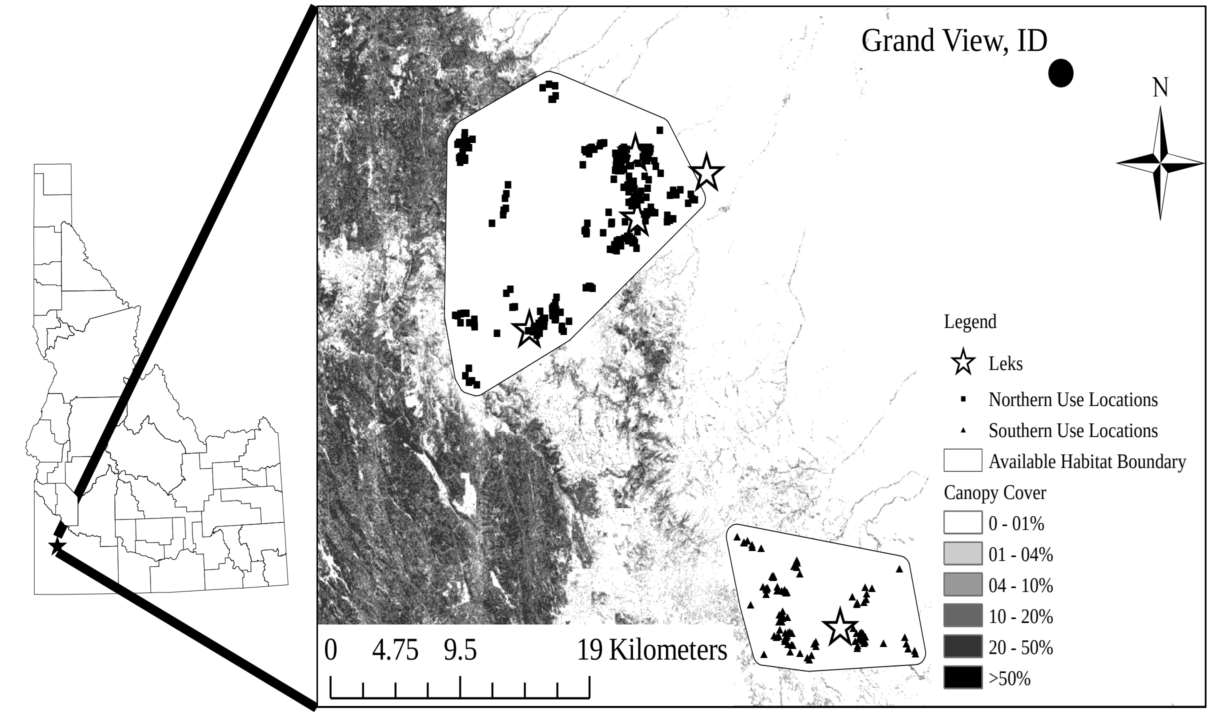

Figure 2.1. My study area was located in Owyhee County, southwestern Idaho. Leks at which captures (n = 39 greater sage-grouse *Centrocercus urophasianus* hens) took place during 2017–18 occurred in areas representing a gradient of tree cover from Falkowski et al. (2017). I categorized hens into two subpopulations (Northern and Southern).

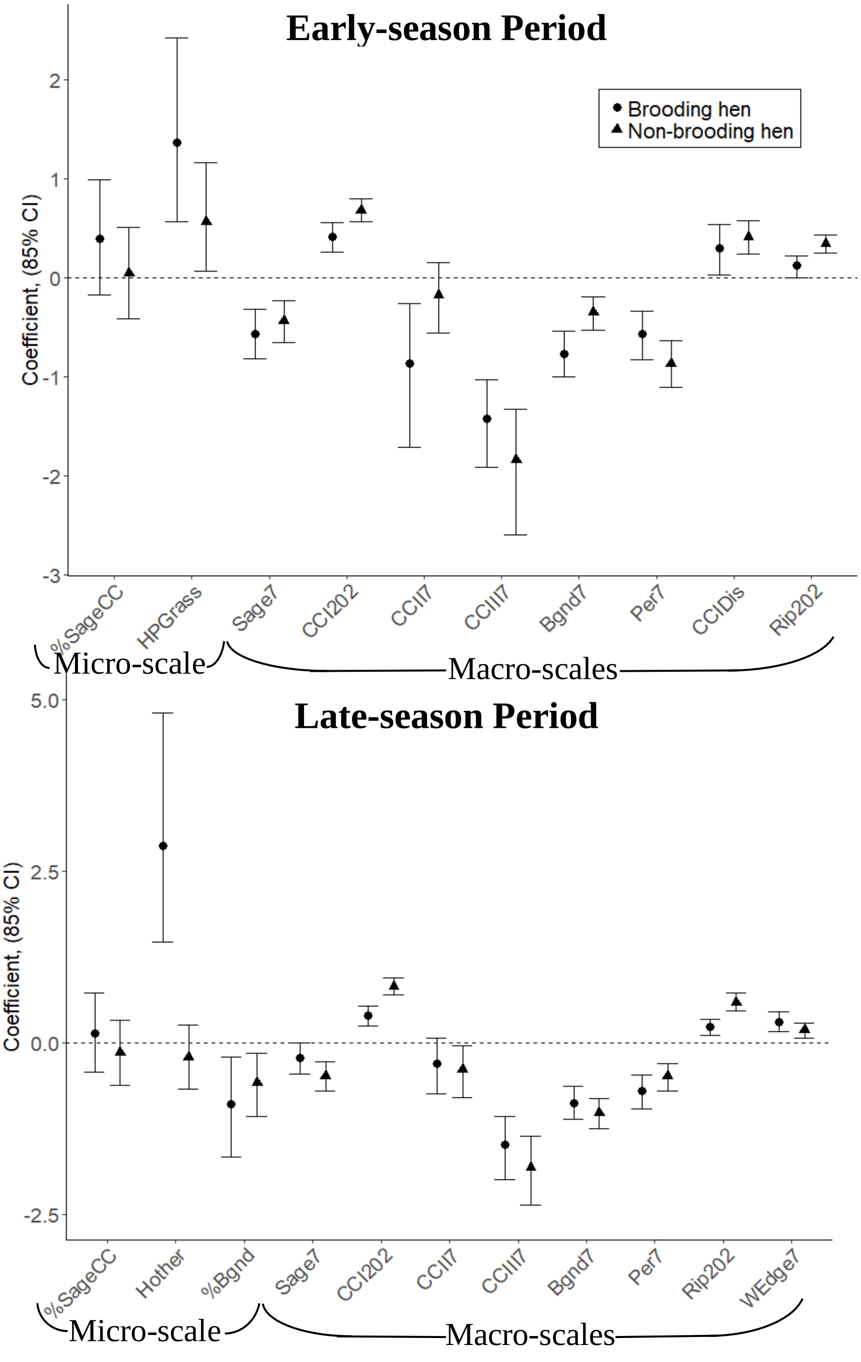

Figure 2.2. Parameter coefficients from best-supported generalized linear mixed models comparing habitat selection between greater sage-grouse (*Centrocercus urophasianus*) hens (n = 28 unique hens) with and without broods in Owyhee County, Idaho 2017-18 during the early-season period (30 April–13 June) and the late-season period (14 June–26 July). The following variables were estimated at the micro-scale (0.03 ha): percent cover of sagebrush (*Artemisia* spp.; %SageCC), % cover of bare ground (%Bgnd), non-sagebrush shrub height (cm; Hother), perennial grass height (cm; HPGrass). The following variables were measured at macro-scales (7.1, 15.0, 94.7, and 202.6 ha): proportion of sagebrush within 7.1 ha

(Sage7), proportion of cover class I (> 0–10% juniper (*Juniperus occidentalis*) cover) within 202.6 ha (CCI202), proportion of cover class II (> 10–20% juniper cover) within 7.1 ha (CCII7), proportion of cover class III (> 20% juniper cover) within 7.1 ha (CCIII7), proportion of bare ground within 7.1 ha (Bgnd7), proportion of perennial herbaceous plants within 7.1 ha (Per7), proportion of woody wetlands within 202.6 ha (Rip202), edge density (perimeter (m)/area (m^2)) of herbaceous wetlands within 7.1 ha (WEdge7), distance (m) to nearest cover class I (CCIDis). Error bars represent 85% confidence intervals (CI > 0 = selection, CI < 0 = avoidance, and CI that include 0 = neither selection nor avoidance for variable).

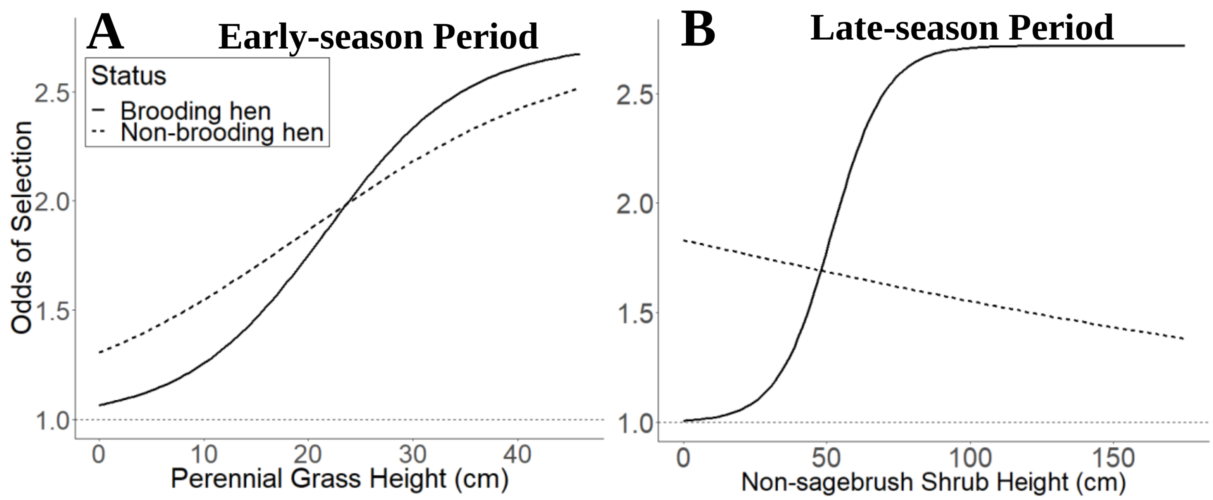

Figure 2.3. Relationships between selection and habitat variables from best-supported generalized linear-mixed models evaluating relationships at the micro-scale (0.03 ha) between greater sage-grouse (*Centrocercus urophasianus*; n = 24 unique hens) with and without broods in Owyhee County, Idaho 2017-18. A) Odds of selection for taller perennial grass (cm); B) Odds of selection for taller non-sagebrush shrubs (cm).

Chapter 3: Ecological Correlates of Fecal Corticosterone Metabolites in Female Greater Sage-Grouse (*Centrococercus urophasianus*) in a Landscape with Juniper

Abstract

The expansion of western juniper (*Juniperus occidentalis*; hereafter, juniper) woodlands into sagebrush steppe may cause challenging conditions for greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse). Percent cover and species richness of shrubs and herbaceous plants may decline with increasing cover of juniper, possibly affecting the availability of food and concealment cover for sage-grouse. Additionally, juniper trees may create suitable habitat for avian predators, potentially increasing the risk of predation, real or perceived, for sage-grouse. In several avian species, habitat characteristics can influence concentrations of stress hormones, and increases in hormone concentrations may affect factors related to survival and reproductive success. In sage-grouse, elevated levels of anthropogenic noise at breeding grounds (i.e., leks) can increase concentrations of stress hormones in males, and hormone concentrations in individuals using landscapes grazed by cattle can be higher than those using areas that are not grazed. Hormone concentrations in sage-grouse may be positively associated with juniper cover through decreased resource availability or increased pressure from predators. I evaluated relationships between vegetation cover (hereafter, ecological variables) and corticosterone (stress hormone) metabolites in feces (hereafter, $FCORT_m$) of sage-grouse. I collected fecal samples at nighttime roost locations of radio-collared hens during the lekking (4 March–8 May) and brood-rearing period (24 May–26 July) in Owyhee County, Idaho 2017–18. Corticosterone metabolites in fecal samples were estimated using enzyme-immunoassay (EIA). I used

remotely-sensed layers to estimate ecological variables within multiple spatial extents centered at leks and within separate, minimum convex polygons (MCP) that surrounded use locations of each hen. I used values from ecological variables estimated within leks and MCPs to evaluate relationships on $FCORT_m$ during the lekking and brood-rearing period, respectively. I used linear mixed models to account for variation in $FCORT_m$ among leks, individuals, and year. Prior to evaluating relationships with ecological variables, I accounted for factors previously shown to influence $FCORT_m$ in other vertebrate species, such as age, temperature, and sample mass. I collected 37 fecal samples from 34 hens during the lekking period and 36 fecal samples from 22 hens during the brood-rearing period. During the lekking period, $FCORT_m$ had a negative relationship with dry mass of the fecal sample and there was no relationship with ecological variables. During the brood-rearing period, $FCORT_m$ had a positive relationship with total area of MCP but a negative relationship with the number of days of reproductive activity, maximum daily temperature (°F), and proportion of cover class I (> 0–10% juniper cover) within MCP. I may not have observed relationships between ecological variables and $FCORT_m$ during the lekking period because hens arrive on breeding grounds at different times and could vary temporally and spatially in their use of habitat surrounding each lek. During the brood-rearing period, $FCORT_m$ may decrease with greater proportions of cover class I because of density dependent factors and high productivity of shrubs and herbaceous plants in areas with young stands of juniper. Because interpretation of relationships between stress and ecological factors can be influenced by sampling and extraction procedures, my results lay the groundwork for additional studies that employ the same laboratory methods to evaluate $FCORT_m$ in sage-grouse.

Introduction

Conifer expansion into sagebrush steppe ecosystems has gained attention from land managers and conservationists in recent decades in part because of negative impacts on sagebrush-associated wildlife (Holmes et al. 2015, Severson et al. 2017, Woods et al. 2013). Western juniper (*Juniperus occidentalis*; hereafter, juniper), the most abundant species of conifer expanding into sagebrush steppe, occupies an estimated 3.6 million ha across Oregon, California, Nevada, Washington, and Idaho (Miller et al. 2005). In sagebrush ecosystems, juniper expansion can reduce cover and species richness of shrubs and herbaceous plants, thereby affecting the availability of food and cover for herbivores (Bates et al. 2000, Bunting et al. 1999, Miller et al. 2000). Juniper expansion can thus add new challenges to conservation efforts for sagebrush-associated wildlife species, especially those with declining populations.

One sagebrush-obligate species impacted by juniper expansion is the greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse). Sage-grouse have experienced population declines and range contractions since the mid-20th century (Connelly et al. 2000, Schroeder et al. 2004) and loss and fragmentation of sagebrush have been important drivers throughout their geographic range (Braun 1998, Crawford et al. 2004). Juniper expansion has been identified as a major threat to sage-grouse in portions of the Great Basin (Davies et al. 2011, Baruch-Mordo et al. 2013, Boyd et al. 2017). Sage-grouse generally avoid dense stands of juniper that have reduced or depauperate shrub and herbaceous understories (i.e., Phases II and III, Miller et al. 2005) across multiple life stages (Atamian et al. 2010, Casazza et al. 2011, Coates et al. 2017, Doherty et al. 2008). Yet, sage-grouse can demonstrate marked variation in selection among individuals when landscape cover of scattered and dispersed juniper is sub-dominant to shrubs (i.e., Phase I; Miller et al. 2005, Coates et al. 2017). Importantly, as little as 2–4% cover of juniper can negatively influence demographic processes of sage-grouse (Baruch-mordo et al. 2013, Coates et al. 2017, Severson et al. 2017). Although demographic patterns of sage-grouse occupying juniper-dominated landscapes are becoming well-documented, specific mechanisms responsible for those patterns are not fully understood. Juniper trees may create suitable habitat for avian predators (Andersson et al. 2009, Coates et al. 2014), potentially increasing the risk of predation, real or perceived, for sage-grouse. Encountering juniper can increase movement rates and subsequent detection by predators (Prochazka et al. 2017), and ecological cues that identify juniper encroached sagebrush as risky habitat can become decoupled and create ecological traps (Coates et al. 2017). Additionally, because juniper expansion alters characteristics of sagebrush and herbaceous plants (Bunting et al. 1999, Miller et al. 2000), reductions in resource availability for sage-grouse may result from increased juniper cover.

If sage-grouse experience challenging conditions in landscapes with juniper, such as increased predation risk or decreased resource availability, then physiological condition of individuals may also be affected. Physiological condition can be assessed using various metrics, including morphometric (e.g., body condition indices) and physiological measurements (e.g., hormone levels or plasma-lipid metabolites; Labocha and Hayes 2012), and several metrics are correlated with demographic performance in birds (Bety et al. 2003, Hayward and Wingfield 2004, Strauss et al. 2005, Milenkaya et al. 2015). For example, elevated concentrations of stress hormones may lower winter survival (Koren et al. 2012), suppress growth and development of chicks (Hayward et al. 2006, Wada and Bruener 2008), lower the number of fledglings (Saino et al. 2005, Bonier et al. 2009), and suppress immune responses, potentially increasing infection rates of diseases (Gao et al. 2017). Concentrations of stress hormones can be influenced by the presence of predators (Boonstra et al. 1998, Saino et al. 2005), or simply predatory cues (Clinchy et al. 2013), through tradeoffs between foraging and predator evasion (Clinchy et al. 2004), and habitat availability (Janin et al. 2011). More specifically, habitat characteristics such as anthropogenic noise (Blickely et al. 2012) and cattle presence (Jankowski et al. 2014) can increase concentrations of stress hormones in sage-grouse. Therefore, stress hormones in sage-grouse could be an indicator of habitat availability or quality associated with juniper expansion.

The objective of my study was to provide insight into the relationship between habitat characteristics used in landscapes with juniper expansion and concentrations of stress hormones in female sage-grouse. I used corticosterone metabolites (ng/g) in feces (hereafter, $FCORT_m$) from radio-marked hens to measure chronic stress levels, and evaluated relationships between habitat characteristics used by hens and $FCORT_m$ during two periods within the breeding season: 1) when hens were captured but before initiating nests (March–May), and 2) after nests hatched and hens were rearing chicks (May–July). I account for factors intrinsic to individual birds (e.g., age), extrinsic but not directly affected by management (e.g., temperature), and sampling conditions (e.g., sample mass) that might influence stress levels (hereafter, nuisance variables). Further, I evaluate relationships between $FCORT_m$ and vegetation characteristics because I was particularly interested in the potential for managing sage-grouse habitat via juniper removal (hereafter, ecological variables; Millspaugh and Washburn 2004, Baker et al. 2013). Of the ecological variables I considered, I was primarily interested in whether juniper cover directly influences $FCORT_m$.

Methods and Materials

Study Site

I conducted my study in southwestern Idaho where juniper is considered a primary threat to local sage-grouse populations (Owyhee 2013; Figure 3.1). The majority of land in my study area was managed by the Bureau of Land Management (BLM) interspersed with private and state-owned sections. Land use consisted of cattle grazing, hunting, camping, and localized off-road vehicle recreation. Elevation at my study area ranged from 1,200–2,400 m, and precipitation, temperature, and associated plant communities varied along this elevational gradient. Mean annual precipitation from ~1,200 m to ~1,800 m during my study was 34–47 cm; average high temperature in January and July at ~1,200 m was 5°C and 36°C and at ~1,800 m was 2°C and 29°C, respectively (NRCS 2019).

My study area comprised two ecoregions: Northern Basin and Range and Snake River Plains (McGrath et al. 2002). Big sagebrush (*Artemisia tridentata*) and low sagebrush (*A. arbuscula*) were the dominant shrub species throughout my study area. In the northern end, alkaline foothills, canyons, and badlands were found at the lowest elevations, and sagebrush communities included shadscale (*Atriplex confertifolia*), bitterbrush (*Purshia tridentata*), cheatgrass (*Bromus tectorum*), and Sandberg bluegrass (*Poa secunda*; McGrath et al. 2002). Mid-elevations were classified as semiarid uplands, where juniper, snowberry (*Symphoricarpos* spp.), and serviceberry (*Amelanchier* spp.) were more prevalent (McGrath et al. 2002). Juniper increased in density with elevation until forest communities transitioned to predominantly Douglas-fir (*Pseudotsuga menziesii*; McGrath et al. 2002). The southern end of my study area comprised less juniper and cheatgrass (McGrath et al. 2002). Large expanses of sagebrush and grasslands were interspersed with serviceberry and curl-leaf mountain mahogany (*Cercocarpus ledifolius*; hereafter, mahogany). Idaho fescue (*Festuca idahoensis*), bluebunch wheatgrass (*Pseudoroegneria spicata*), and other perennial bunchgrasses were more common at mid–high elevations, whereas invasive annual grasses were more common at low elevations. Willow (*Salix* spp.) and balsam poplar (*Populus balsamifera*) occurred within wetland habitats.

Lek Selection

To evaluate relationships between $FCORT_m$ and juniper cover, I aimed to sample sage-grouse that experience a gradient of juniper cover throughout the breeding season. To select leks from which to capture sage-grouse, I used a raster layer from Falkowski et al. (2017) in ArcGIS 10.5.1 (GIS, Overwatch Systems, Sterling, VA) to identify leks in my study area that varied in tree canopy cover (Figure 3.1). I estimated tree canopy cover within a 10-km buffer around each lek because this scale is expected to include a majority of the nesting habitat used by hens at each lek (Schroeder et al. 1999, Wakkinen et al. 1992, Coates et al. 2013). I then identified five leks for which canopy cover of trees was > 1% within the 10-km buffer (range = 9–60% of area with > 1% canopy cover; Table 3.1).

Sage-grouse capture and monitoring

I captured hens March–May in 2017–18 at roost locations during nighttime hours (2000–0500) using spotlighting and netting techniques (Wakkinen et al. 1992) and by rocket-netting (Giesen et al. 1982) at leks during morning hours (0700–1000 MDT). All hens received a numbered aluminum leg band (National Band and Tag, Newport, KY, size 14) for unique identification and a 22-gram necklace-style Very High Frequency (VHF) radio-transmitter (model A4060; Advanced Telemetry Systems, Isanti, MN). I measured mass using an electronic scale (±1.0 g; model EP22405; Costway, Fontana, CA). I measured left- and right-wing chord length (±0.1 cm) by flattening primary feathers against a measurement board and recording distance from the edge of the carpal joint to the tip of the longest feather. I measured left and right tarsus length (±0.01 mm) using digital calipers (model 147; General Tools and Instruments; Secaucus, NJ) from the outside edge of the intertarsal joint to the base of the toes (USGS 2016). I repeated measurements twice for wing chords and three times for tarsus on sage-grouse captured via spotlighting. To reduce handling time for sage-grouse captured via rocket-netting, I obtained a single measurement for left- and right-wing chords and tarsus. I monitored hens via radio-telemetry following capture through the end of July in each year. I acquired use locations beginning 1 April 2017 and 1 March 2018 by homing in on collar signals with a three element yagi antenna and a receiver (model R2000; Advanced Telemetry Systems, Isanti, MN). I circled hens ~30–50 m away and marked the use location by projecting a point from the observer's location with an estimated bearing and distance in a Global Positioning System (GPS). If a hen flushed, then the area on the ground from which the hen flushed was marked as the use location. All sage-grouse were captured, marked, and monitored in accordance with approved protocols (Idaho Department of Fish and Game permit #161213 and #180205 and University of Idaho Institutional Animal Care and Use Committee protocol 2016-58).

I monitored hens on nests via telemetry three times per week; I monitored a subset of nests with continuously recording cameras (model SSC-24C36, Advanced Security, Swansea, IL, USA) attached to a digital video recorder (DVR; model MDVR14, Super-Circuits, Austin, TX, USA; model SSC-773V2, Advanced Security, Swansea, IL, USA). I identified the first day of incubation as the median date between the last location the hen was not on the nest and the first date the hen was on the nest. I visually inspected nests when a hen was absent for two consecutive tracking events. I considered nests successful when ≥ 1 egg met criteria for hatched eggs (Gregg et al. 1994). I identified the hatch date for nests without cameras as the median date between the last date a hen was observed incubating and the first date the hen was observed absent from the nest; for nests with cameras, hatch dates were determined from video footage. I attempted to locate all hens twice weekly during daytime hours following completion of nesting attempts. For hens with successful nests, I also conducted nighttime checks (2100-0500) every 10 days post-hatch and obtained visuals on chicks via spotlight and binoculars to confirm brood status (present or absent). I conducted nighttime checks until broods were considered successful (50 days post-hatch) or until there were no chicks observed with the hen for two consecutive nighttime locations (i.e. failed brood; Casazza et al. 2011, Gregg and Crawford 2009, Schreiber et al. 2016). I classified hens with chicks present during nighttime checks as brooding hens; I classified hens that did not have a successful nest as non-brooding hens. I reclassified brooding hens that lost all chicks as non-brooding on the median date between the last date I observed chicks and the first date I did not observe chicks (Smith et al. 2018).

Fecal collection

To evaluate $FCORT_m$, I collected fecal pellets from hens during nighttime hours (2100–0500) immediately following locating roost sites. In general, sage-grouse are not mobile during nighttime hours and will deposit several fecal pellets where they are roosting for the night (i.e., roost pile). Corticosterone metabolites in fecal pellets deposited prior to a stressful event provide a baseline measurement of circulating corticosterone that is not influenced by disturbance from an observer (i.e., capturing, flushing, etc.; Sheriff et al. 2010). Fecal corticosterone metabolites can peak 1–2 times in response to a stressful event (such as capture) but generally return to baseline levels within 24–48 hours in sage-grouse, other grouse species, greylag geese (*Anser anser*), and barred (*Strix varia*) and great horned owls (*Bubo virginianus*; Baltic et al. 2005, Möstl et al. 2005, Thiel et al. 2005, Wasser and Hunt 2005, Jankowski et al. 2009). I did not use corticosterone metabolites in blood plasma to measure stress levels because changes in baseline concentrations of plasma corticosterone can occur within three minutes of disturbance for some bird species, and my capture techniques prevented me from reliably collecting blood within such a short period (Romero and Romero 2002, Romero and Reed 2005). I collected fecal pellets from hens at the initial capture site and from use locations during the early (~20 days post-hatch) and late (~50 days post-hatch) brood-rearing period. In 2018, I did not recapture hens collared in 2017 but collected fecal samples from these hens in March when the majority of captures occurred. Given the potential for elevating $FCORT_m$ above normal levels up to 48 hours following capture, I waited 4–5 days to collect fecal samples from hens captured via rocket-netting (Baltic et al. 2005, Thiel et al. 2005). I collected fecal samples from hens with failed nests based on the predicted hatch date of the last nesting attempt (predicted hatch date = first date of incubation + 26.4 days, USGS 2018). In each year, a single hen did not attempt to nest; I collected fecal samples from each of these hens in June when the majority of collection attempts occurred for other hens. All fecal samples were stored in a freezer at -20°C until laboratory analysis.

I used two different approaches to collect fecal samples from hens with and without broods. To avoid disturbing broods to collect fecal samples, I located a target hen during nighttime hours and projected a GPS point, and then returned to the roost location around sunrise to collect a fecal sample. Brooding hens primarily roosted without other adults present and body size (and pellet size) differs between chicks and hens up to at least 50-days post-hatch (Johnson and Boyce 1990), so it is unlikely I collected fecal samples from a non-target individual. Non-brooding hens often roost together; in this case, I first circled the group to identify and target the radio-collared hen, then flushed the group and collected a sample at the roost location of the target hen. If I was unable to find a sample or single out the target hen, I waited ≥ 5 days before I again attempted to collect from the same individual. I attempted to collect a sample up to three and two times from the same individual in 2017 and 2018, respectively.

Fecal Corticosterone Analysis

Fecal corticosterone metabolites were extracted with the assistance of Dr. Cassandra Nuñez from The University of Tennessee using methods modified from Kozlowski et al. (2018). The uric acid from fecal samples was removed, then samples were thawed at 4°C overnight and homogenized before vortexing 0.5 g of wet fecal matter into 5.0 ml of a 50/50% methanol/extraction buffer solution. The extraction buffer contained 0.15M NaCl, 0.04M $NaH_2PO_4AH_2O$, and 0.06M Na_2HPO_4 in deionized water, with 0.1% RIA grade bovine serum albumin and 0.1% sodium azide and was brought to pH 7.0 by addition of either NaOH or HCl. Extraction buffer was kept at 4°C and allowed to come to room temperature before use.

After vortexing, samples were shaken for approximately 16 hours at 250 RPM. Fecal matter was allowed to settle for 1 hour, the solution decanted, and samples centrifuged on a Beckman Coulter Allegra 6R centrifuge (rotor type GH 3.8) for 1 hour at 3750 RPM, after which the supernatant was removed and stored at -80°C until assay. The remaining fecal material was dried at 100°C overnight and dry fecal weight was estimated to the nearest 0.001 g to calculate corticosterone levels (ng/g/feces) after assay.

To validate the assay for use in female sage-grouse, a collection of five samples taken from random females was homogenized to make a sample pool. The sample pool was extracted as outlined above, assayed to determine parallelism with the Enzyme Immunoassay (EIA) standard curve, and included one pooled sample in each assay to calculate inter-assay variation.

Corticosterone levels were analyzed using the ARBOR ASSAYS Corticosterone EIA kit (K014-H5, ARBOR ASSAYS, Ann Arbor, MI 48108), following the manufacturer's instructions. All samples were diluted 1:10 in assay buffer and split each diluted sample into duplicate wells. Reruns were performed for any duplicates with a coefficient of variation (CV) greater than 15% (%CV = (standard deviation/mean) × 100). The assay was validated as in Brown et al. (2003). A serial dilution of the fecal pool showed parallelism to the corticosterone standard curve (Linear Model; log (concentration) × Sample type (standard or pool): estimate = -0.007, SE = 0.02, t = -0.32, P = 0.75). Intra- and inter-assay CVs were 5.18 ± 0.36% (mean ± SE) and 12.54%, respectively (n = 4). Mean assay recovery ((observed/expected) × 100) was 97.42 $\pm$ 4.14 pg/mL.

Ecological Variables

To describe ecological variables at locations used by hens, I used remotely-sensed GIS layers to estimate the proportion of landcover types within multiple spatial extents centered on leks and within minimum convex polygons (MCP) created with use locations. For leks, I estimated four spatial scales using the minimum (0.5 km), mean (3.3 km), and maximum (8.0 km) distance between the lek at which hens were captured and nest sites, and the distance thought to include the majority of nesting habitat (10.0 km), which resulted in spatial extents of 0.63-km^2, 33.21-km^2, 198.50-km^2, and 314.15-km^2, respectively (hereafter, lek-scales; Schroeder et al. 1999, Wakkinen et al. 1992, Coates et al. 2013). Because sage-grouse migration from winter to breeding range occurs from mid-February–mid-March and 90% of space use during winter can occur within 7.5 km of leks, I assumed hens were using habitat within at least one of my lek-scales prior to capture (Connelly et al. 2011, Coates et al. 2013). To describe habitat used during the brood-rearing period, I first created two MCPs from use locations for each hen. Minimum Convex Polygons describing each brood-rearing period included all locations obtained for that hen for the respective year until the date each fecal sample was collected.

I created ecological variables using spatial layers from the 2016 National Land Cover Data (NLCD) fractional components, woody wetlands, and emergent herbaceous wetlands (Xian et al. 2015, Yang et al. 2018; see Table 3.2 and 3.3 for descriptions of variables). Available layers of tree cover were either too coarse in spatial scale or represented cover of all trees and not just juniper (i.e., 30 m x 30 m resolution; Landfire 2013, Falkowski et al. 2017), so with the assistance from the U. S. Geological Survey, I created a layer using Feature Analyst™ (Overwatch Systems, Sterling, VA) that represented percent juniper cover as a continuous variable from 2011 National Agricultural Imagery Program (NAIP) satellite imagery of my study area. In addition to testing relationships between $FCORT_m$ and a continuous gradient of juniper, I also wanted to evaluate effects on stress from juniper cover in transitional phases used in Coates et al. 2017 (i.e., cover class I = > 0–10% juniper cover, cover class II = > 10–20% juniper cover, and cover class III = > 20% juniper cover). I refined my tree layer to represent juniper and excluded other tree species in my study area. My final tree layer was a raster with 30 m x 30 m resolution where pixel values represented the percent cover of juniper (See “METHODS” section of chapter 2 for further details on creating final juniper layer).

Nuisance Variables

I considered additional variables that may also influence $FCORT_m$ but are not likely to be directly influenced by habitat management (Tables 3.2 and 3.3). I accounted for factors previously demonstrated to influence stress levels in other free-ranging vertebrates (Tempel and Gutiérrez 2004, Harms et al. 2010, Baker et al. 2013, Santos et al. 2018, Shipley et al. 2019) including variables that addressed environmental and sampling conditions, and physiological parameters (Tables 3.2 and 3.3).

Statistical analysis

I aimed to collect multiple fecal samples from the same individual, but this was not always possible because hens died or moved out of the study area and could not be relocated. Thus, my sample does not reflect a true cohort of the same individuals through time, although in some cases (n = 11 hens) I was able to collect repeated samples from the same hen during the brood-rearing period within the same year. I separated fecal samples into two time periods because sage-grouse use different habitat types prior to nesting and during brood-rearing (Crawford et al. 2004, Dzialek et al. 2011), and ecological and physiological factors that might influence stress could vary between these time periods. The time periods I used included the lekking period (4 March–8 May) and the brood-rearing period (24 May–26 July; samples collected during early and late periods). I excluded fecal samples from my analyses if CV between duplicates remained > 15.0% after reruns (C. Nuñez, personal communication).

I natural-log transformed $FCORT_m$ to include outliers from my analysis (Zuur et al. 2009), and this transformation has been used in other grouse studies investigating influences on fecal corticosterone (Blickley et al. 2012, Shipley et al. 2019). I then visualized $FCORT_m$ against all predictor variables in a scatterplot matrix to evaluate potential nonlinear responses (Zuur et al. 2009). I then z-standardized all continuous predictor variables to make comparisons among variables on different scales (Marquardt 1980). To evaluate patterns of $FCORT_m$ in hens for each season, I used linear mixed-effects models (LMM) from the lme4 package in R (Bates et al. 2015). Linear mixed-effects models can be used for responses with repeated measurements from the same hens and are appropriate when there is lack of independence among observations (Zuur et al. 2009). I used lek nested within year as a random effect term for the lekking period and individual and year for the brood-rearing period.

Throughout all stages of modeling, I removed predictor variables if 85% confidence intervals included zero (Arnold 2010). I also considered models competitive with each other if the difference in AIC_c from the top model (ΔAIC_c) was ≤ 2 (Burnham and Anderson

2004). I used Pearson correlation index (r) to determine correlations among predictor variables and did not include variables in the same model if $r \geq |0.6|$. Finally, I considered interactions among predictor variables, as well as quadratic forms of predictor variables, and carried them forward into subsequent stages if they had greater support ($\Delta AIC_c \geq 2$) than additive or linear forms, respectively.

I used a multi-stage approach to create candidate models that best explain $FCORT_m$. My modeling approach was an attempt to minimize the number of candidate models because I had a relatively large number of predictor variables (n = 39 for lekking and 28 for brood-rearing periods) to consider relative to my sample size. First, I determined the best among nuisance variables that represented environmental and sampling conditions by creating a set of models with each variable as a single-term model. I ranked these models using AIC_c and considered variables the best predictors of $FCORT_m$ if AIC_c was lower than the intercept-only model. I then determined the best combination of nuisance variables by creating models using predictors with the most support as a single-term model. At this stage, I used up to two variables per model and carried forward models with $\Delta AIC_c < 2$ into subsequent stages. Second, I separately determined the best predictors among ecological variables using single-term models only. Third, I combined the best predictors of ecological variables with best-supported nuisance variables to create a new set of candidate models. I included up to four predictor variables per model during this stage. If a nuisance and ecological variable were highly correlated, I excluded the nuisance variable from the model because my primary interest was to identify relationships between stress and ecological factors that can potentially be affected by habitat management. I report all final models in Table 3.4.

Lekking Period

I used values of $FCORT_m$ from each hen at the time of capture as the response variable to evaluate effects of habitat characteristics associated with lek location. To determine the best spatial scale for ecological variables, I created separate sets of each variable at the four lek-scales and considered the variable with the lowest AIC_c as the best predictor of $FCORT_m$ (Table A.13). After determining the best combination of ecological and nuisance variables that described $FCORT_m$ during the lekking season, I investigated whether body condition improved model fit (Table 3.2). Measures in body condition and stress hormones can be correlated in other free-ranging vertebrates and I hypothesized that interactions between body condition and habitat could have an effect on $FCORT_m$ (Boonstra et al. 1998, Harms et al. 2010, Raja-aho et al. 2010). I estimated body condition scores using residuals from a generalized linear model that regressed mass on wing chord length and capture date (Table A.15).

Brood-rearing Period

I used fecal samples collected during early and late brood-rearing periods to evaluate effects of habitat associated with home range areas on $FCORT_m$. Because fecal corticosterone is reflective of chronic stress, I assumed concentrations were influenced by cumulative habitat use over time (Palme 2005, Sheriff et al. 2010). Therefore, I used values of ecological variables estimated within MCPs and from use locations (Table 3.3). I was unable to evaluate whether body condition influenced $FCORT_m$ during the brood-rearing period because I did not recapture hens after the lekking season. I averaged values of distance to wetlands, distance to cover class I, II, and III, and elevation at use locations for each fecal sample collected. I used the cumulative number of days a hen laid eggs (3 days to lay 2 eggs; Schroeder et al. 1999), incubated eggs, and raised chicks to estimate reproductive effort prior to collecting a fecal sample (Table 3.3). Because predators can carry eggs from nests and cause an inaccurate count in the number of eggs a hen laid, I used the minimum clutch size (n = 4) from my sample of successful nests as the clutch size for depredated nests that had < 4 eggs recovered (n = 2). I assumed all hens laid ≥ 4 eggs before incubating nests.

Results

I captured 35 hens during the lekking period in 2017–18. I collected 37 fecal samples from 34 hens during the lekking period and 36 fecal samples from 22 hens during the brood-rearing period. I was unable to collect multiple fecal samples from all hens because hens either were killed by predators (n = 5 hens), moved out of study area (n = 4 hens), or were unable to be targeted for sample collection (n = 4 hens). I removed one fecal sample from the analysis for the lekking period because CV > 15.0% and one fecal sample from the brood-rearing period because collection occurred during daytime hours and not at a nighttime roost location.

Lekking Period

Mean $FCORT_m$ during the lekking season was 309.47 (± 143.23 ng/g standard deviation; n = 36 fecal samples). My final model that best-described $FCORT_m$ included sample mass as the only predictor variable (Table 3.4). I identified no ecological-related variables associated with $FCORT_m$ (Table C.2). Body condition score lowered AIC_c by 1.02 when added to sample mass, but did not meet my criteria to be considered in the final model (Table 3.4). Fecal corticosterone concentrations generally had a negative relationship with sample mass (β = -0.171, 85% CI = -0.268, -0.079), where larger samples had lower concentrations. However, this relationship was quadratic and $FCORT_m$ increased slightly when mass was between 0 g and ~0.11 g (Figure 3.2). Preliminary results of model selection can be found in Appendix A :Tables A.13–A.15.

Brood-rearing Period

Mean $FCORT_m$ during the brood-rearing season was 179.82 (± 118.63 ng/g standard deviation; *n* = 35 fecal samples) and was associated with total area of MCP, proportion of cover class I juniper within MCP, mean maximum temperature, and reproductive effort (Table 3.4). Adding cover class I to area of MCP and temperature was competitive (ΔAIC_c = 1.317) but increased AIC_c, thus I did not consider it a final model (Table 3.4). The linear and quadratic forms of reproductive effort were within 2 AIC_c of each other, but I used the quadratic form for my final model because the linear form had AIC_c greater than the null model (Table D.1). Fecal corticosterone concentrations increased with total area of MCP (β = 0.127, 85% CI = 0.040, 0.216), and decreased with increasing temperature (β = -0.181, 85% CI = -0.301, -0.066) and proportion of cover class I juniper within MCP (β = -0.197, 85% CI = -0.313, -0.081; Figure 3.3). Fecal corticosterone concentrations generally had a negative relationship with reproductive effort (β = -0.093, 85% CI = -0.170, -0.017), however, this relationship was quadratic and concentrations increased slightly between 0 days and ~26 days (Figure 3.3B). Preliminary results of model selection can be found in Appendix A: Tables A.16 and A.17.

Discussion

My study suggests that $FCORT_m$ in female sage-grouse can be associated with ecological conditions, but juniper cover did not have the positive association with corticosterone I expected. I evaluated $FCORT_m$ because it can indicate chronic stress caused by persistent conditions (e.g., low habitat availability or quality) or a series of acute events (e.g., repeated encounters with predators; Baker et al. 2013). Juniper expansion may reduce habitat availability or increase predation risk for sage-grouse, thereby reducing habitat quality; however, any reduced habitat quality caused by juniper was not directly reflected by $FCORT_m$ values I observed.

During the lekking period, the primary driver of variation in $FCORT_m$ was mass of the dried fecal sample, a pattern that may have resulted from the protocol used to extract corticosterone from samples (Kozlowski et al. 2018). Although sample mass was standardized prior to extracting corticosterone by measuring out 0.5 g of a homogenized sample, samples were not dried prior to separating out this standard amount. Moisture content seems to have varied among fecal samples at the time of collection, resulting in variable dry mass after moisture was removed from each 0.5-g sample (mean = 0.11 ± 0.03 SD). Moisture content in sage-grouse feces may be influenced by variation of nutrient concentrations within individual diets, as seen in domesticated chickens (*Gallus gallus domesticus*; Hoeven-Hangoor et al. 2014), or from variation in precipitation and temperature patterns. Other studies have reported negative relationships between dry sample mass and $FCORT_m$ (Millspaugh and Washburn 2004, Tempel and Guitérrez 2004), however, these studies freeze dried samples before extraction. My dry sample mass reflects weight of samples that were dried after extracting corticosterone for the purpose of obtaining concentration estimates. Fecal samples that have not been dried can be used to estimate $FCORT_m$ levels (Möstl et al. 2005, Sheriff et al. 2011). Future analyses investigating influences on $FCORT_m$ should control for potential variation in moisture among fecal pellets by first freeze-drying samples and then standardizing the amount of material used for extraction.

I was unable to collect data on specific habitat use for most hens prior to collecting fecal samples during the lekking period and it may have influenced the lack of association between $FCORT_m$ and ecological variables. I assumed habitat use during late winter included habitat around leks, and this may be true for a portion of hens in my sample but unlikely for all. Timing of migration and distances travelled between winter and breeding range are highly variable among sage-grouse populations and individuals (Connelly et al. 2011, Reinhart et al. 2013, Pratt et al. 2017), and likely resulted in variation among arrival dates of hens using habitat around leks prior to collecting samples.

I did not identify conditions that clearly affected $FCORT_m$ values during the brood-rearing period. Accounting for individual and year (assigned as random effect terms in statistical models) explained a large amount of variability in $FCORT_m$ values relative to the other factors I evaluated as fixed effects in statistical models (Table 3.4). However, the patterns I observed in $FCORT_m$ values do have some biological support, which I explore below.

During the brood-rearing period, $FCORT_m$ was associated with total area of MCP, as it appeared in all competitive models in the final candidate set. Because increases in MCP area could be associated with migratory movements among sage-grouse (see Connelly et al. 2011), larger areas occupied by an individual may increase stress through increased exposure to predators or energy expenditure (Lima and Dill 1990, Jimeno et al. 2018). Alternatively, $FCORT_m$ may reflect poor habitat quality (Kitaysky et al. 1999, Janin et al. 2011) which could in turn influence the likelihood of undertaking larger movements, possibly in search of better habitat. Corticosterone metabolites can increase before and during migration in avian species, and it is possible I captured these increases in my $FCORT_m$ sampling because hens would have undertaken migratory movements during brood-rearing (Landys-Ciannelli et al. 2001, Eikenaar et al. 2015). Moreover, because corticosterone can mobilize glucose into the bloodstream to maintain tissue and organ functions, corticosterone would be expected to increase before or during activities that require high amounts of energy, such as migration or quicker movements (Koolhass et al. 2011, Eikenarr et al. 2015, Jimeno et al. 2018).

I observed relatively less support for effects of temperature and reproductive effort on $FCORT_m$. Warmer temperatures can initiate plant green-up and growth, possibly increasing the availability of food or concealment cover for sage-grouse. Furthermore, warmer temperatures could affect habitat selection, where individuals move to higher elevations and near wetland habitats that could provide better habitat (i.e., more food availability; Connelly et al. 2000, Pratt et al. 2017) at a finer scale than I measured, thereby decreasing $FCORT_m$. In addition, $FCORT_m$ and reproductive effort could have had an overall negative relationship because of differences in habitat selection between brooding and non-brooding hens. Habitat selection is associated with nest and chick survival in sage-grouse, and factors that cause nest or brood failure (primarily predators and weather) could also be associated with stress levels in adult sage-grouse (Coates et al. 2008, Gregg and Crawford 2009, Webb et al. 2012, Gibson et al. 2017). Hens with more days of reproductive activity may occupy better habitat than hens that lost nests or broods; if this is the case, it would suggest that $FCORT_m$ serves as a reasonable indicator of habitat quality. Alternatively, my sampling protocol may have influenced these patterns to some degree because I generally collected fecal samples for non-brooding hens 2–4 hours after sunset and for brooding hens at dawn. This sampling schedule could have contributed to a negative relationship if time of day predictably affects $FCORT_m$ levels for sage-grouse, as seen in some avian species (Carere et al. 2003, Goymann and Trappschuh 2011, Scheiber et al. 2017). However, $FCORT_m$ may not exhibit significant differences between nighttime and morning hours, as seen in European stonechats (*Saxicola torquata rubicola*; Goymann and Trappschuh 2011), and may not have a predictable pattern over a 24-hour period in sage-grouse (see Jachowski et al. 2015).

I observed moderate support for a negative association between $FCORT_m$ and Cover class I juniper and there are two possible explanations for this pattern: density-dependence and better understory conditions. Hens can form groups following the nesting season and high concentrations of males and females can occur at wetlands or at high-elevation habitats during mid–late summer (Connelly et al. 2000, Crawford et al. 2004). Because most individuals avoid juniper and can have higher mortality rates when occupying these areas, sage-grouse densities could be lower in Cover class I during the brood-rearing period (Coates et al. 2017). Density-dependent stress levels have been observed for other vertebrate species and may be because per-capita resources are scarcer, causing interspecific competition or more social interactions (Baker et al. 2013, Santos et al. 2018). Cover class I juniper could provide more resources in the understory per capita if sage-grouse densities are lower in areas with a higher proportion of Cover class I. Additionally, young stands of juniper tend to establish in areas with high productivity of shrubs and herbaceous plants (Miller et al. 2005), and these areas could have more resources in the understory for sage-grouse than areas with no juniper. Miller et al. (2000) found the highest densities of juniper were in areas with the highest plant productivity and diversity in southwestern Oregon and northwestern California. Therefore, sage-grouse that occupy areas with Cover class I juniper could have lower $FCORT_m$ levels because there are abundant resources in the understory.

Because interpretation of relationships between stress and ecological conditions can be influenced by sampling and extraction procedures, my results lay the groundwork for additional studies that employ the same laboratory methods to evaluate $FCORT_m$ in sage-grouse. Differences in $FCORT_m$ can result from different assay methods (radioimmunoassay (RIA) vs. EIA), the cross-reactivity in antibodies used in the assay, and/or preparation of samples (Wasser et al. 2000, Millspaugh and Washburn 2004, Glucs et al. 2018). Glucs et al. (2018) found RIA used to evaluate corticosterone levels in California condors (*Gymnogyps californianus*) to be more accurate and generally estimated corticosterone concentrations higher than EIA conducted on the same sample. However, the enzyme immunoassay used in my study has been used to evaluate $FCORT_m$ for other species of Galliformes (e.g., domesticated chickens) and is regarded as an acceptable method of estimating $FCORT_m$ (Alm et al. 2014). I suggest future studies investigate direct comparisons in $FCORT_m$ of sage-grouse between RIA and EIA to evaluate the relationship between the two assay methods.

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Tables

Table 3.1. Proportional distribution of tree cover classes from Falkowski et al. (2017) within plots (10-km radius) centered at each lek sampled in Owyhee County, Idaho during 2017–18.

	Cover Class					
Lek #	0–1%	1–4%	4–10%	10–20%	20–50%	Total 1–50%
2O196	0.740	0.072	0.070	0.089	0.029	0.260
2O197	0.909	0.048	0.028	0.013	0.002	0.091
2O523	0.905	0.069	0.023	0.002	0.000	0.095
2O619	0.405	0.167	0.169	0.197	0.063	0.595
2O642	0.685	0.101	0.085	0.094	0.035	0.315

Table 3.2. Variables used to evaluate fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*) hens during the 2017–18 lekking period (4 March–8 May) in Owyhee County, Idaho.

Variable Type	Variable Group	Variable Name	Description
Nuisance	Environmental Conditions[a]	ElevC	Elevation (m) of collection site
		Precip	Percent accumulation of precipitation over the 30 days prior to fecal sample collection compared to the 30-year normal amount (1981–2010)
		MaxTemp	Average maximum temperature (°F) over the 30 days prior to collection of fecal sample
		MinTemp	Average maximum temperature (°F) over the 30 days prior to collection of fecal sample
		LekCount	Maximum number of hens and males on leks from survey conducted within the fewest days of collecting a fecal sample
	Sampling Conditions	CollectDate	Number of days between January 1 and date when fecal samples were collected within each year (collection date)
		Age	Yearling or Adult
		Samplewt	Mass (g) of dried fecal sample
	Physiological Parameter	BCScore	Residuals (body condition scores) from a generalized linear model that regressed mass (g) against mean length of wing chord (cm) and capture date

Table 3.2. *Continued…*

Variable Type	Variable Group	Variable Name	Description[a]
Ecological[b]	Herbaceous	Ann0.63	Proportion of annual herbaceous plants within 0.63 km^2
		Ann33	Proportion of annual herbaceous plants within 33.21 km^2
		Ann198	Proportion of annual herbaceous plants within 198.50 km^2
		Ann314	Proportion of annual herbaceous plants within 314.15 km^2
		Per0.63	Proportion of perennial herbaceous plants within 0.63 km^2
		Per33	Proportion of perennial herbaceous plants within 33.21 km^2
		Per198	Proportion of perennial herbaceous plants within 198.50 km^2
		Per314	Proportion of perennial herbaceous plants within 314.15 km^2
	Shrub	Bsage0.63	Proportion of big sagebrush (*Artemisia tridentata*) within 0.63 km^2
		Bsage33	Proportion of big sagebrush within 33.21 km^2
		Bsage198	Proportion of big sagebrush within 198.50 km^2
		Bsage314	Proportion of big sagebrush within 314.15 km^2
		Nsage0.63	Proportion of non-sagebrush shrubs within 0.63 km^2
		Nsage33	Proportion of non-sagebrush shrubs within 33.21 km^2
		Nsage198	Proportion of non-sagebrush shrubs within 198.50 km^2

Table 3.2. *Continued…*

Variable Type	Variable Group	Variable Name	Description[a]
		Nsage314	Proportion of non-sagebrush shrubs within 314.15 km^2
	Juniper	Juni0.63	Proportion of western juniper (*Juniperus occidentalis*) within 0.63 km^2
		Juni33	Proportion of western juniper within 33.21 km^2
		Juni198	Proportion of western juniper within 198.50 km^2
		Juni314	Proportion of western juniper within 314.15 km^2
		CCI0.63	Proportion of cover class I (> 0–10% western juniper cover) within 0.63 km^2
		CCI33	Proportion of cover class I within 33.21 km^2
		CCI198	Proportion of cover class I within 198.50 km^2
		CCI314	Proportion of cover class I within 314.15 km^2
		CCII33	Proportion of cover class II (>10–20% western juniper cover) within 33.21 km^2
		CCII198	Proportion of cover class II within 198.50 km^2
		CCII314	Proportion of cover class II within 314.15 km^2
		CCIII33	Proportion of cover class III (>20% western juniper cover) within 33.21 km^2
			Proportion of cover class III within 198.50 km^2

Table 3.2. *Continued…*

Variable Type	Variable Group	Variable Name	Description[a]
		CCIII198	
		CCIII314	Proportion of cover class III within 314.15 km^2

[a] Elevation was estimated using the elevatr package in R (Hollister and Shah 2017). Precipitation and temperature data were from three weather stations: Name (Station ID) = Orchard Range Site (674), Reynolds Creek (2029), and Mud Flat (654) (NRCS 2019). Lek surveys were conducted up to 4 times per lek each year by Idaho Fish and Game and Bureau of Land Management.

[b] Area (m^2) of herbaceous, sagebrush, and non-sagebrush cover were estimated using 2016 National Land Cover Database fractional layers. Area of juniper was estimated from a spatial layer that classified conifers throughout my study area. There was no cover class II or III within 0.63 km of all leks in study area.

Table 3.3. Variables used to evaluate greater sage-grouse (*Centrocercus urophasianus*) fecal corticosterone metabolites (ng/g) during the 2017–18 brood-rearing period (24 May–26 July) in Owyhee County, Idaho.

Variable Type	Variable Group	Variable Name	Description
Nuisance	Environmental Factor[a]	ElevU	Mean elevation (m) of use locations
		Precip	Percent precipitation accumulated over the 30 days prior to collection of fecal samples compared to the 30-year normal amount (1981–2010)
		MaxTemp	Mean maximum temperature (°F) over the 30 days prior to collection of fecal samples
		MinTemp	Mean minimum temperature (°F) over the 30 days prior to collection of fecal samples
	Sampling Conditions	CollectDate	Number of days between January 1 and date when fecal samples were collected within each year (collection date)
		MCPArea	Area (km^2) of MCP
		DailyDis	Mean distance (m) of daily movement
		RepEffort[b]	Cumulative days hens were laying eggs, on nest(s), and rearing chicks
		Age	Yearling or Adult
		Samplewt	Mass (g) of dried fecal sample

Table 3.3. *Continued…*

Variable Type	Variable Group	Variable Name	Description[a]
Ecological[c]	Herbaceous	AnnMCP	Proportion of annual herbaceous plants within MCP[c] surrounding use locations
		PerMCP	Proportion of perennial herbaceous plants within MCP
	Shrub	BsageMCP	Proportion of big sagebrush (*Artemisia tridentata*) within MCP
		NsageMCP	Proportion of non-sagebrush shrubs within MCP
	Juniper	JuniMCP	Proportion of western juniper (*Juniperus occidentalis*) within MCP
		CCIMCP	Proportion of cover class I (> 0–10% western juniper cover) within MCP
		CCIIMCP	Proportion of cover class II (>10–20% western juniper cover) within MCP
		CCIIIMCP	Proportion of cover class III (>20% western juniper cover) within MCP
		CCITime[c]	Proportion of use locations within cover class I
	Wetland	RipMCP	Proportion of woody wetlands within MCP
		WetMCP	Proportion of herbaceous wetlands within MCP
		REdgeMCP	Edge density (perimeter (m)/area (m^2) of woody wetlands within MCP

Table 3.3. *Continued…*

Variable Type	Variable Group	Variable Name	Description[a]
		WEdgeMCP	Edge density of herbaceous wetlands within MCP
	Distance	CCIDis	Mean distance (m) to nearest cover class I
		CCIIDis	Mean distance (m) to nearest cover class II
		CCIIIDis	Mean distance (m) to nearest cover class III
		RipDis	Mean distance (m) to nearest woody wetlands
		WetDis	Mean distance (m) to nearest herbaceous wetlands

[a] Elevation was estimated using the elevatr package in R (Hollister and Shah 2017). Precipitation and temperature data were from three weather stations: Name (Station ID) = Orchard Range Site (674), Reynolds Creek (2029), and Mud Flat (654) (NRCS 2019).
[b] Laying rate of 2 eggs/3 days was used to calculate number of days laying (Schroeder et al. 1999).
[c] Area of herbaceous, sagebrush, and non-sagebrush cover were estimated using 2016 National Land Cover Database (NLCD) fractional layers. Area of juniper was estimated from a spatial layer that classified conifers throughout my study area. Area of woody (> 20% cover shrubs and trees) and herbaceous wetlands (> 80% perennial herbaceous cover) were estimated using 2016 NLCD land cover spatial layers. I used the Intersect tool in ArcGIS 10.5.1 (GIS) to estimate perimeter, the Near tool to estimate distance, and the Minimum Bounding Polygon tool to create MCP surrounding all use locations of each hen.

Table 3.4. All final linear mixed-effects models with nuisance and ecological variables predicting fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; n = 33 hens) during the 2017–18 lekking (4 March–8 May) and brood-rearing (24 May–26 July) periods in Owyhee County, Idaho. K = number of parameters; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights; mR^2 = marginal R-squared value; cR^2 = conditional R-squared value.

		Model Fit Statistics					
Season	Model[a]	K	AIC_c	ΔAIC_c	ω_i	mR^2	cR^2
Lekking[b]	Samplewt^2 + BCScore	7	41.553	0.000	0.560	0.32	0.62
	Samplewt^2	6	42.579	1.025	0.336	0.35	0.49
	Samplewt^2 + BCScore^2	8	44.920	3.367	0.104	0.36	0.56
Brood-rearing[c]	MCPArea + RepEffort^2 + CCIMCP	8	51.524	0.000	0.345	0.23	0.72
	MCPArea + MaxTemp	6	52.404	0.880	0.222	0.17	0.63
	MCPArea + MaxTemp + CCIMCP	7	52.842	1.317	0.179	0.19	0.72
	MCPArea + RepEffort^2	7	53.693	2.169	0.117	0.21	0.53
	MCPArea*CCIMCP + RepEffort^2	9	55.143	3.618	0.056	0.23	0.72
	MCPArea*CCIMCP + MaxTemp	8	56.038	4.513	0.036	0.18	0.72
	MCPArea + MaxTemp*CCIMCP	8	56.217	4.693	0.033	0.19	0.73
	MCPArea +CCIMCP* RepEffort^2	10	58.204	6.680	0.012	0.24	0.71

[a] Samplewt^2 = quadratic form of mass (g) of dried fecal sample; BCScore = residuals (body condition score) from linear regression with mean length of wing chord (cm) and capture date

predicting mass (g); BCScore^2 = quadratic form of BCScore; Per0.63 = proportion of perennial herbaceous plants within 0.63 km^2; Bsage33 = proportion of big sagebrush (*Artemisia tridentata* spp.) within 33.21 km^2 of leks; MCPArea = area (km^2) of minimum convex polygon (MCP) surrounding use locations; RepEffort^2 = quadratic form of cumulative days laying eggs, incubating nest(s), and rearing chicks; MaxTemp = mean maximum temperature (°F) from the past 30 days; CCIMCP = proportion of cover class I (> 0–10% western juniper (*Juniperus occidentalis*) cover) within MCP.

[b] Lek nested within year used as random effect term.

[c] Individual and year used as random effect terms.

Figures

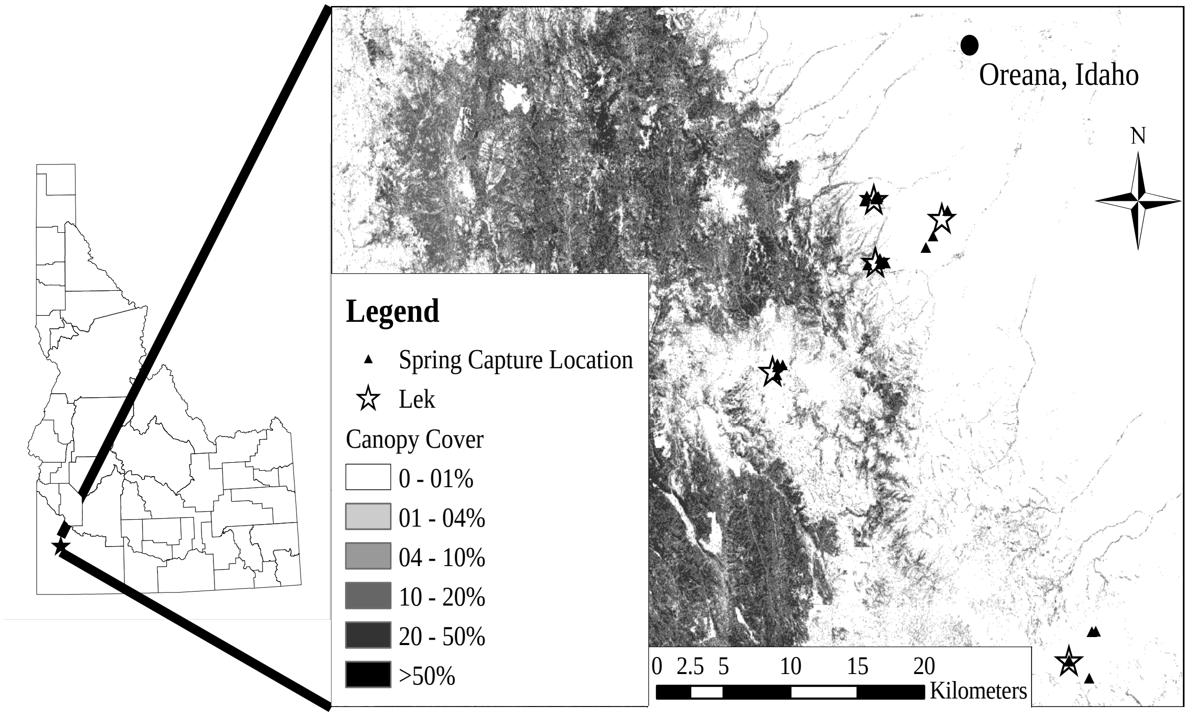

Figure 3.1. My study took place in Owyhee County, southwestern Idaho. Greater sage-grouse (*Centrocercus urophasianus)* leks at which captures (*n* = 35 hens) took place during 2017–18 occurred in areas with a gradient of juniper cover (Falkowski et al. 2017).

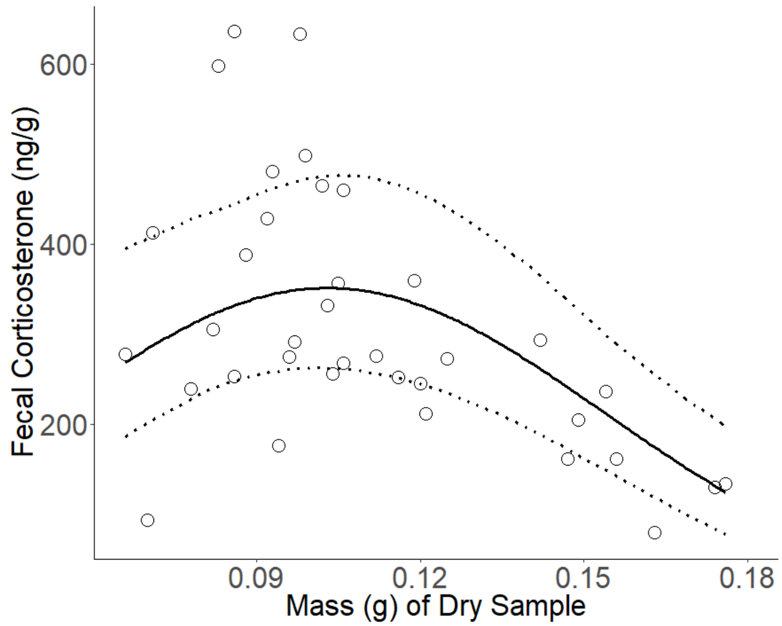

Figure 3.2. Observed and predicted fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; n = 33 hens) during the 2017–18 lekking (4 March–8 May) season in Owyhee County, Idaho. Eighty-five % confidence intervals are represented by dotted lines. Predictions and confidence intervals were back transformed to be displayed with observed values of fecal corticosterone metabolites.

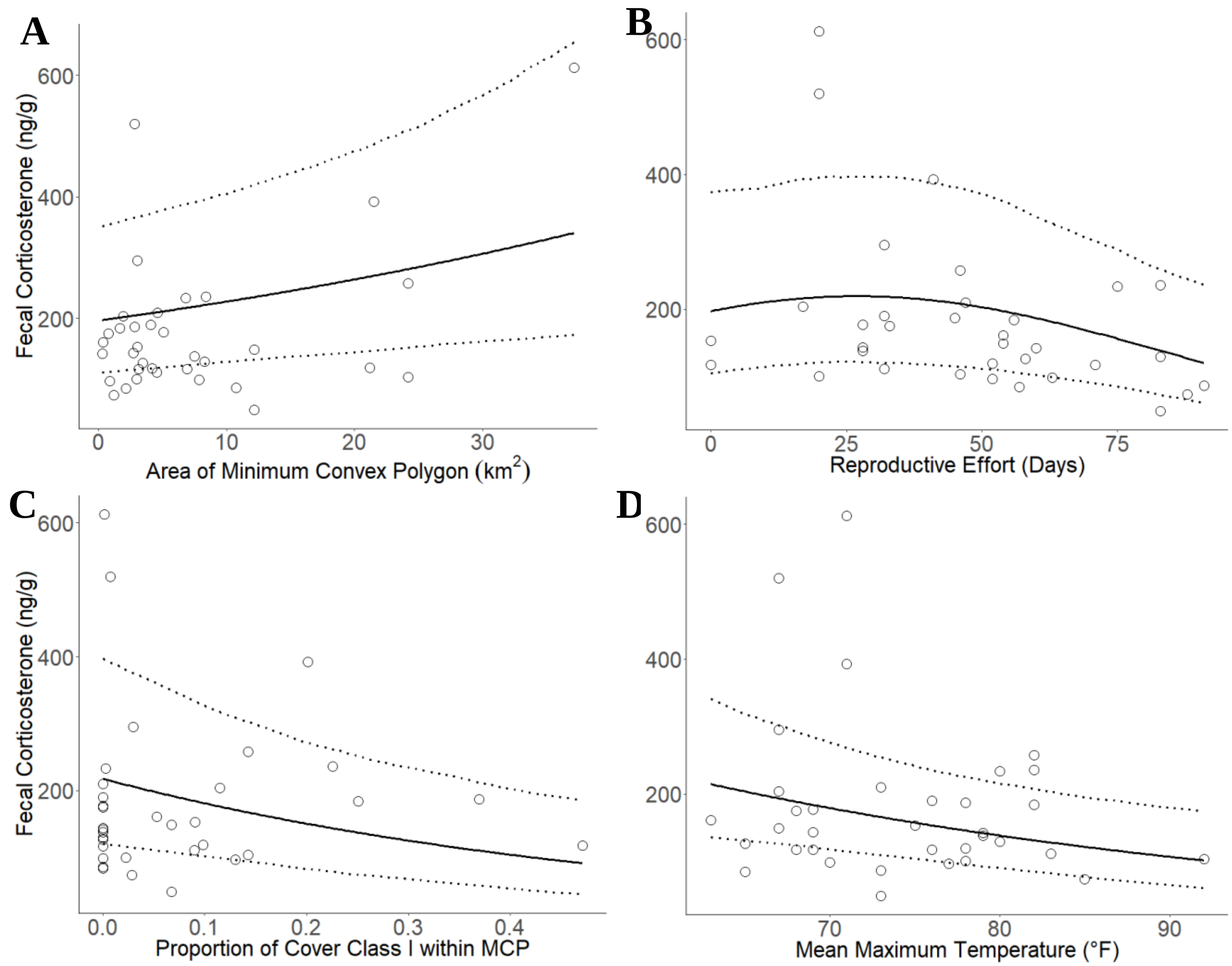

Figure 3.3. Observed and predicted fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; *n* = 22 hens) during the 2017–18 brood-rearing season (24 May–26 July) in Owyhee County, Idaho. Eighty-five % confidence intervals are represented by dotted lines. For each plot, predictions and confidence intervals were back transformed to be displayed with observed values of fecal corticosterone metabolites and covariates in the model not being displayed were set at the respective median value. A)

minimum convex polygon (MCP) surrounded all use locations from first location for the year of each hen to when a sample was collected; predictions estimated from model with lowest AIC_c (Table 3.4); B) cumulative days a hen was laying eggs, incubating nest(s), and rearing chicks; C) proportion of cover class I (> 0–10% western juniper (*Juniperus occidentalis*) cover) within MCP; D) mean maximum temperature over the 30 days prior to collecting fecal sample.

Chapter 4: Conclusion

My research is the first to investigate whether reproductive status of female sage-grouse influences habitat selection in landscapes undergoing juniper expansion and if stress levels among hens are correlated with juniper. I observed differences in habitat selection between hens with and without chicks at fine spatial scales; hens with chicks were more likely to select habitats with greater concealment cover, such as taller, non-sagebrush shrubs. At broad spatial extents, reproductive status generally did not influence selection patterns for any cover class of juniper expansion (cover class I = > 0–10% juniper cover, cover class II = > 10–20% juniper cover, cover class III = > 20% juniper cover) or wetland habitats, but hens without chicks had slightly stronger selection for cover class I and wetlands dominated by woody vegetation. Additionally, I found support that stress levels of hens decreased with the proportion of cover class I within an individual's home range, which was opposite of my predictions. My results contribute to a better understanding of interactions between life history characteristics, physiological condition, and habitat. This understanding will aid efforts for juniper removal in targetting specific habitats that will benefit a larger proportion of the sage-grouse population.

Previous studies have reported that survival rates of adult hens and nests had a positive response to juniper removal (Severson et al. 2017a, b, Olson 2019). In the same manner, survival rates of hens and chicks during the brood-rearing period could improve following removal of juniper near wetlands and mesic habitats with tall shrubs. Given the overall avoidance of cover classes II and III and selection for wetland habitats and taller, non-sagebrush shrubs, juniper removal targetting herbaceous wetlands with high edge ratios, woody wetlands, and mesic areas with taller shrubs could be beneficial because these areas are preferred by hens. Mesic areas often provide a greater abundance and diversity of food sources (i.e., forbs and insects) for sage-grouse because site productivity is greater than surrounding uplands (Whitford et al. 1995, Knapp et al. 2002, Wenninger and Inouye 2008, McAdoo et al. 2013, Dahlgren et al. 2015). Broods are more likely to be successful if hens select herbaceous wetlands with greater edge densities because these areas may provide an optimum balance of food sources and concealment cover from predators (Casazza et al. 2011); it is likely that non-brooding hens benefit from these characteristics as well. Furthermore, it is possible that chicks could benefit from using habitats with taller shrubs (e.g., willow (*Salix* spp.), serviceberry, (*Amelanchier* spp.), snowberry (*Symphoricarpos* spp.), etc.) as these shrubs may increase concealment cover and thereby provide more protection from predators. However, these taller shrubs may also provide structural resources for avian predators, and an understanding of the demographic outcomes for hens and chicks using habitats with taller shrubs would elucidate whether this is a habitat feature that should be targeted for management. Future investigations should evaluate trends between habitat selection and demographic rates to assess the quality of preferred habitat.

My observation of hens selecting for cover class I taken together with similar patterns reported previously that also demonstrated survival costs associated with these selection patterns suggest that juniper expansion in the early-stages could serve as an ecological trap (Coates et al. 2017, Severson et al. 2017a, b). Thus, removal efforts would likely benefit sage-grouse populations in areas of juniper expansion. Although my results suggest lower stress levels among hens that use more cover class I, perhaps affected by density-dependent factors or higher plant productivity in areas with young stands of juniper, this benefit to individuals probably does not outweigh the potential cost to survival (Coates et al. 2017).

Because population growth of sage-grouse can increase following juniper removal (Severson et al. 2017a, Olson 2019), and because the conditions that favor juniper establishment persist on the landscape resulting in expected infill of juniper in cover class I and an eventual transition to juniper cover classes that are actively avoided by sage-grouse, reducing the amount of cover class I would aid in conservation of sage-grouse.

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Appendix A Preliminary model results

Habitat selection at the micro-scale.

Results from habitat selection at the micro-scale (0.03 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens in Owyhee County, Idaho 2017–18. Table A.1 describes all habitat variables considered in my analyses; Table A.2 summarizes mean and standard errors of habitat variables; Tables A.3 and A.4 are modeling results from step 1 of model selection; and Tables A.5 and A.6 are modeling results from step 2 of model selection.

Table A.1. Variables used in multinomial and generalized linear mixed models (GLMM) to evaluate greater sage-grouse (*Centrocercus urophasianus*) habitat selection at the micro-scale (0.03 ha) in Owyhee County, Idaho during 2017–18.

Variable Name	Description
Estimates from Daubenmire frames	
%Pgrass[b]	Mean % canopy cover of perennial grass
%Agrass	Mean % canopy cover of annual grass
%Pforb[a]	Mean % canopy cover of perennial forb
%Aforb[b]	Mean % canopy cover of annual forb
%Rcover	Mean % canopy cover of standing dead grass and forb
%Litter	Mean % cover of litter
%Bgnd[b]	Mean % cover of bare ground
%Rock	Mean % cover of rock
Estimated plant heights (cm)	
Hsage[a,b]	Mean height (cm) of sagebrush (*Artemisia* spp.)
Hother[b]	Mean height (cm) of non-sagebrush shrubs
Hmesic	Mean height (cm) of non-sagebrush shrubs in mesic habitats
Hxeric[a,b]	Mean height (cm) of non-sagebrush shrubs in xeric habitats
HPgrass[a,b]	Mean height (cm) of perennial grass
Hshrub[b]	Mean height (cm) of all shrubs
HPforb[a]	Mean height (cm) of perennial forb
HRgrass[b]	Mean height (cm) of dead standing grass

Table A.1. *Continued…*

Variable Name	Description
Species richness	
ShrubR[a]	Mean richness of shrub species
PgrassR	Mean richness of perennial grass species
PforbR[b]	Mean richness of perennial forb species
TotalR	Mean richness of shrub, grass, and forb species
Visual obstruction	
%Vis0	Mean % visibility estimated by viewing Jone's cover board at 0° angle
%Vis45	Mean % visibility estimated by viewing Jone's cover board at 45° angle
%Vis90	Mean % visibility estimated by viewing Jone's cover board at 90° angle
%VisTotal[a]	Mean % visibility from all estimates of Jone's cover board
Canopy cover	
%TotalCC	Mean % canopy cover of all shrubs along two perpendicular 20-m transects
%SageCC[a,b]	Mean % canopy cover of all sagebrush along two perpendicular 20-m transects
%LSageCC	Mean % canopy cover of low sagebrush (*A. arbuscula*) along two perpendicular 20-m transects
%BSageCC	Mean % canopy cover of big sagebrush (*A. tridentata*) along two perpendicular 20-m transects
%NSageCC[b]	Mean % canopy cover of non-sagebrush shrubs along two perpendicular 20-m transects

Table A.1. *Continued…*

Variable Name	Description
Tree variables	
Stm10mD[a]	Stem density of trees within 0.03 ha plot
10mWtDBH	Weighted mean Diameter at Breast Height (DBH; cm) of trees within 0.03 ha plot (weight = number of trees within height class)

[a] Variables used in final multinomial models during the early-season period (30 April–13 June).
[b] Variables used in final multinomial models during the late-season period (14 June–26 July).

Table A.2. Mean estimates of micro-scale habitat variables at use and available locations of greater sage-grouse (*Centrocercus urophasianus*) hens in Owyhee County, Idaho during 2017-18. Standard error (SE) in parentheses. Early-season period and late-season period were 30 April–13 June and 14 June–26 July, respectively. "Brood" are hens with chicks and "non-brood" are hens without chicks; "Available" are randomly chosen locations 50–850 m from use locations.

	Early-season period				Late-season period			
Variable	Brood Use	Brood Available	Non-brood Use	Non-brood Available	Brood Use	Brood Available	Non-brood Use	Non-brood Available
% canopy cover of perennial grass[a]	18.29 (3.38)	15.91 (3.2)	15.49 (2.75)	15.51 (3.32)	20.67 (3.49)	11.49 (1.86)	12.11 (2.24)	11.55 (3.35)
% canopy cover of annual grass[a]	11.99 (4.43)	8.36 (3.06)	11.48 (2.48)	9.45 (2.21)	3.12 (0.07)	3.42 (0.31)	3.3 (0.28)	3.19 (0.13)
% canopy cover of perennial forb[a]	5.43 (0.74)	6.9 (1.26)	7.66 (0.99)	7.81 (1.31)	11.01 (2.16)	5.95 (0.63)	10.92 (2.00)	10.33 (1.79)
% canopy cover of annual forb[a]	3.43 (0.26)	3.65 (0.42)	3.86 (0.37)	4.2 (0.51)	3.69 (0.24)	3.23 (0.11)	3.7 (0.36)	3.07 (0.04)
% canopy cover of residual grass and forb[a]	13.98 (2.68)	17.9 (3.87)	13.04 (2.2)	14.51 (2.62)	26.94 (3.84)	23.13 (3.2)	27.25 (4.28)	30.92 (4.81)
% cover of litter[a]	15.58 (2.06)	14.54 (2.58)	16.18 (2.31)	16.14 (2.18)	20.77 (3.61)	17.47 (2.8)	18.99 (2.57)	15.2 (1.93)
% cover of bare ground[a]	33.12 (3.73)	30.87 (3.68)	31.73 (3.15)	38.25 (3.87)	26.04 (2.72)	41.78 (3.61)	26.88 (2.53)	35.55 (3.76)
% cover of rock[a]	11.07 (4.14)	15.24 (4.61)	11.46 (2.47)	7.72 (1.81)	5.6 (1.17)	9.71 (3.7)	12.19 (2.89)	7.29 (1.50)

Table A.2. *Continued…*

Variable	Early-season period: Brood Use	Early-season period: Brood Available	Early-season period: Non-brood Use	Early-season period: Non-brood Available	Late-season period: Brood Use	Late-season period: Brood Available	Late-season period: Non-brood Use	Late-season period: Non-brood Available
Sagebrush (*Artemisia* spp.) height (cm)	41.02 (3.27)	36.81 (2.75)	47.2 (4.36)	42.64 (3.9)	55.49 (3.7)	44.96 (4.18)	48.24 (4.04)	43.07 (4.36)
Non-sagebrush shrub height (cm)	37.61 (3.18)	32.89 (2.84)	36.95 (3.94)	36.89 (4.39)	64.85 (6.35)	37.72 (2.57)	41.48 (3.86)	42.97 (6.35)
Mesic shrub height (cm)	5.56 (3.83)	0.00 (0.00)	2.21 (2.21)	7.36 (5.40)	37.37 (10.63)	15.74 (5.66)	11.71 (4.45)	15.50 (7.83)
Xeric shrub height (cm)	31.27 (4.37)	25.87 (4.86)	37.42 (5.08)	25.35 (4.32)	45.88 (7.31)	32.27 (3.46)	33.06 (5.04)	28.08 (5.69)
All shrub height (cm)	38.62 (2.42)	34.45 (2.51)	43.56 (2.98)	42.54 (4.12)	62.59 (4.74)	42.43 (2.87)	46.14 (3.57)	48.11 (5.37)
Perennial grass height (cm)	15.31 (1.36)	11.05 (1.04)	18.57 (1.88)	15.25 (0.92)	18.77 (1.30)	13.91 (0.81)	18.29 (2.77)	16.23 (1.50)
Perennial forb height (cm)	9.48 (1.27)	7.95 (1.1)	11.72 (1.73)	8.48 (1.3)	16.9 (1.59)	13.18 (1.66)	16.07 (1.95)	15.29 (1.98)
Residual grass height (cm)	8.53 (0.67)	7.68 (0.94)	9.65 (1)	8.62 (0.89)	13.73 (1.60)	11.39 (1.69)	9.61 (1.19)	9.53 (1.21)

Table A.2. *Continued…*

Variable	Early-season period: Brood Use	Brood Available	Non-brood Use	Non-brood Available	Late-season period: Brood Use	Brood Available	Non-brood Use	Non-brood Available
Shrub species richness	4.45	3.68	3.9	3.71	4.58	4.50	3.42	2.88
	(0.36)	(0.28)	(0.32)	(0.35)	(0.35)	(0.36)	(0.27)	(0.25)
Perennial grass species richness	2.1	2.11	2.19	1.95	2.58	2.33	2.42	2.46
	(0.18)	(0.23)	(0.18)	(0.18)	(0.22)	(0.23)	(0.26)	(0.22)
Perennial forb species richness	4.95	4.84	4.19	4.1	4.08	3.96	3.69	2.92
	(0.37)	(0.49)	(0.31)	(0.34)	(0.28)	(0.30)	(0.32)	(0.25)
Total species richness	11.5	10.63	10.29	9.76	11.25	10.79	9.54	8.27
	(0.62)	(0.71)	(0.57)	(0.64)	(0.70)	(0.70)	(0.68)	(0.49)
% visibility at 0°[b]	44.9	49.34	33.57	40.00	26.06	38.42	35.89	30.3
	(6.02)	(6.39)	(4.84)	(5.8)	(4.42)	(5.30)	(5.16)	(4.47)
% visibility at 45°[b]	88.71	89.9	84.14	84.76	75.74	83.76	79.03	78.26
	(1.43)	(1.83)	(2.47)	(2.53)	(3.46)	(2.00)	(3.92)	(4.17)
% visibility at 90°[b]	93.80	93.4	89.73	90.43	85.63	88.72	86.68	89.15
	(1.39)	(1.59)	(1.75)	(2.07)	(3.32)	(2.06)	(2.92)	(3.43)
% total visibility[b]	70.66	73.02	63.28	66.39	55.86	65.04	61.63	59.24
	(3.03)	(3.30)	(3.01)	(3.42)	(3.36)	(3.09)	(3.92)	(3.77)
% canopy cover of all shrubs[c]	18.65	15.3	19.11	19.34	27.24	24.21	20.72	22.67
	(1.93)	(2.45)	(2.06)	(2.14)	(3.64)	(2.46)	(2.86)	(2.78)

Table A.2. *Continued…*

Variable	Early-season period Brood Use	Brood Available	Non-brood Use	Non-brood Available	Late-season period Brood Use	Brood Available	Non-brood Use	Non-brood Available
% canopy cover of all sagebrush[c]	11.36 (1.86)	10.31 (1.95)	14.38 (1.82)	14.25 (2.13)	12.53 (2.43)	14.89 (2.12)	13.14 (2.04)	14.30 (1.84)
% canopy cover of non-sagebrush shrubs[c]	7.29 (1.44)	4.99 (1.07)	4.73 (1.05)	5.09 (1.59)	14.71 (3.21)	9.31 (1.14)	7.58 (2.32)	8.37 (2.25)
% canopy cover of big sagebrush (*A. tridentata*)[c]	7.12 (1.61)	7.20 (1.78)	10.83 (1.97)	9.19 (2.03)	11.39 (2.34)	12.72 (2.10)	10.64 (2.20)	11.04 (1.91)
% canopy cover of low sagebrush (*A. arbuscula*)[c]	4.24 (1.43)	2.96 (1.51)	3.55 (1.56)	5.07 (2.06)	0.91 (0.60)	2.18 (1.45)	2.50 (1.11)	3.25 (1.40)
Stem density	0.3 (0.15)	0.32 (0.13)	0.81 (0.33)	0.33 (0.17)	0.79 (0.39)	0.46 (0.22)	0.31 (0.15)	0.23 (0.13)
Mean diameter at breast height (cm)[d]	2.65 (1.31)	0.95 (0.58)	3.94 (2.18)	2.12 (1.64)	1.99 (0.90)	0.89 (0.56)	1.35 (0.81)	0.60 (0.41)

[a] Estimated with a 20 cm x 50 cm Daubenmire frame.
[b] Estimated with 25 cm x 25 cm Jones cover board.
[c] Estimated along two 20-m long transects.
[d] Estimated with metric Biltmore stick. Weighted by number of trees in each height class (Class I = 0–1 m, Class II = 1–2 m, Class III = 2–3 m, and Class IV = 3+ m).

Table A.3. All multinomial models from step 1 of model selection evaluating habitat selection at the micro-scale (0.03 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens during the early-season period (30 April–13 June) in Owyhee County, Idaho 2017–18. K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Perennial grass height (cm)	4	168.126	0.000	0.551
Xeric shrub height (cm)	4	173.085	4.959	0.046
Perennial forb height (cm)	4	173.442	5.316	0.039
Stem density	4	174.008	5.882	0.029
Shrub species richness	4	174.135	6.008	0.027
% total visibility[a]	4	174.242	6.116	0.026
% canopy cover of perennial forb[b]	4	174.422	6.296	0.024
Total species richness[e]	4	174.679	6.553	0.021
% visibility at 0° angle[a,e]	4	174.715	6.589	0.020
% visibility at 90° angle[a,f]	4	174.758	6.632	0.020
Sagebrush (*Artemesia* spp.) height (cm)	4	174.885	6.759	0.019
% visibility at 45° angle[a,f]	4	175.250	7.123	0.016
% canopy cover of non-sagebrush shrubs[c,f]	4	175.313	7.187	0.015
% canopy cover of big sagebrush (*A. tridentata*)[c,f]	4	175.444	7.318	0.014
Perennial forb species richness[f]	4	175.551	7.425	0.013
Residual grass height (cm)[f]	4	175.751	7.625	0.012
Shrub height (cm)[f]	4	175.819	7.693	0.012
Diameter at breast height (cm)[d,f]	4	176.037	7.911	0.011

Table A.3. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
% canopy cover of annual forb[b,f]	4	176.244	8.118	0.010
% canopy cover of sagebrush[c]	4	176.318	8.192	0.009
% canopy cover of residual grass and forb[b]	4	176.677	8.551	0.008
% canopy cover of annual grass[b]	4	176.761	8.635	0.007
Perennial grass species richness	4	177.069	8.943	0.006
% canopy cover of perennial grass[b]	4	177.084	8.958	0.006
% cover of bare ground[b]	4	177.112	8.986	0.006
% canopy cover of all shrubs[c]	4	177.117	8.991	0.006
Mesic shrub height (cm)	4	177.149	9.023	0.006
Non-sagebrush shrub height (cm)	4	177.201	9.075	0.006
% canopy cover of low sagebrush (*A. arbuscula*)[c]	4	177.514	9.388	0.005
% cover of litter[b]	4	177.530	9.404	0.005
% cover of rock[b]	4	177.610	9.484	0.005

[a] Estimated with 25 cm x 25 cm Jones cover board.
[b] Estimated with a 20 cm x 50 cm Daubenmire frame.
[c] Estimated along two 20-m long transects.
[d] Estimated with metric Biltmore stick. Weighted by number of trees in each height class (Class I = 0–1 m, Class II = 1–2 m, Class III = 2–3 m, and Class IV = 3+ m).
[e] Variable highly correlated with variables with lower AIC_c and removed from future analysis.
[f] Eighty-five percent confidence intervals included zero and variable removed from future analysis.

Table A.4. All multinomial models from step 1 of model selection to evaluate habitat selection at the micro-scale (0.03 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens during the late-season period (14 June–26 July) in Owyhee County, Idaho 2017–18. K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Non-sagebrush shrub height (cm)	4	202.035	0.000	0.504
% cover of bare ground[a]	4	202.847	0.812	0.336
Shrub height (cm)[e]	4	206.237	4.201	0.062
% canopy cover of annual forb[a]	4	208.645	6.610	0.019
Shrub species richness	4	209.329	7.294	0.013
% canopy cover of perennial grass[a]	4	209.850	7.815	0.010
Mesic shrub height (cm)[e]	4	209.939	7.904	0.010
Xeric shrub height (cm)	4	211.124	9.089	0.005
Sagebrush (*Artemisia* spp.) height (cm)	4	211.127	9.091	0.005
% canopy cover of non-sagebrush shrubs[b]	4	211.357	9.322	0.005
Total species richness[e]	4	211.414	9.378	0.005
Residual grass height (cm)	4	211.827	9.791	0.004
% cover of rock[a,f]	4	212.215	10.180	0.003
Perennial grass height (cm)	4	212.508	10.472	0.003
Perennial forb species richness	4	213.068	11.033	0.002
% visibility at 0° angle[c,f]	4	213.737	11.702	0.001
% canopy cover of all shrubs[b,f]	4	213.803	11.768	0.001
% canopy cover of perennial forb[a,f]	4	213.817	11.782	0.001

Table A.4. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Stem density of trees[f]	4	213.898	11.862	0.001
% canopy cover of low sagebrush (*A. arbuscula*)[b,f]	4	214.097	12.062	0.001
Diameter of Breast Height of trees (cm)[d,f]	4	214.124	12.089	0.001
Total % visibility[c,f]	4	214.217	12.182	0.001
% cover of litter[a,f]	4	214.391	12.356	0.001
Perennial forb height (cm)[f]	4	214.699	12.664	0.001
% visibility at 45° angle[c,f]	4	214.932	12.896	0.001
% visibility at 90° angle[c,f]	4	215.347	13.311	0.001
% canopy cover of sagebrush[b]	4	215.649	13.614	0.001
% canopy cover of annual grass[a]	4	215.854	13.819	0.001
Perennial grass species richness	4	216.055	14.020	0.000
% canopy cover of big sagebrush (*A. tridentata*)[b]	4	216.282	14.247	0.000
% canopy cover of residual grass and forb[a]	4	213.898	11.862	0.000

[a] Estimated with a 20 cm x 50 cm Daubenmire frame.
[b] Estimated along two 20-m long transects.
[c] Estimated with 25 cm x 25 cm Jones cover board.
[d] Estimated with metric Biltmore stick. Weighted by number of trees in each height class (Class I = 0–1 m, Class II = 1–2 m, Class III = 2–3 m, and Class IV = 3+ m).
[e] Variable highly correlated with variable with lower AIC_c and removed from future analysis.
[f] Eighty-five percent confidence intervals included zero and variables removed from future analysis.

Table A.5. All multinomial models from step 2 of model selection evaluating habitat selection at the micro-scale (0.03 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens during the early-season period (30 April–13 June) in Owyhee County, Idaho 2017–18. K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + HPgrass	6	170.99	0.000	0.109
%SageCC + HPgrass + Hxeric	8	171.38	0.391	0.09
%SageCC + HPgrass + Hsage	8	171.784	0.795	0.074
%SageCC + HPgrass + %Pforb	8	172.024	1.034	0.065
%SageCC + HPgrass + Stm10mD	8	172.171	1.181	0.061
%SageCC + HPgrass + Hxeric + %Pforb	10	172.719	1.73	0.046
%SageCC + HPgrass + ShrubR	8	172.724	1.734	0.046
%SageCC + HPgrass + Hxeric + ShrubR	10	172.826	1.837	0.044
%SageCC + HPgrass + Hsage + %Pforb	10	172.946	1.956	0.041
%SageCC + HPgrass + Hsage + ShrubR	10	173.431	2.441	0.032
%SageCC + HPgrass + Stm10mD + %Pforb	10	173.433	2.443	0.032
%SageCC + HPforb + HPgrass	8	173.987	2.998	0.024
%SageCC + HPgrass + ShrubR + Stm10mD	10	174.137	3.148	0.023
%SageCC + HPgrass + Hxeric + Stm10mD	10	174.379	3.389	0.02
%SageCC + HPgrass + Hsage + Stm10mD	10	174.74	3.75	0.017
%SageCC + HPgrass + %VisTotal	8	174.762	3.773	0.017
%SageCC + HPgrass + ShrubR + %Pforb	10	174.823	3.834	0.016
%SageCC + HPgrass + Hsage + Hxeric	10	174.84	3.851	0.016
%SageCC + HPforb + HPgrass + %Pforb	10	174.989	3.999	0.015
%SageCC + HPgrass + Stm10mD + %VisTotal	10	175.319	4.329	0.013

Table A.5. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + Hxeric	6	175.437	4.448	0.012
%SageCC + HPforb + HPgrass + Stm10mD	10	175.817	4.828	0.01
%SageCC + HPgrass + Hxeric + %VisTotal	10	175.915	4.925	0.009
%SageCC + HPforb + HPgrass + ShrubR	10	175.971	4.982	0.009
%SageCC + HPgrass + ShrubR + %VisTotal	10	176.091	5.101	0.009
%SageCC + HPforb + HPgrass + Hxeric	10	176.114	5.124	0.008
%SageCC + Hxeric + ShrubR	8	176.167	5.178	0.008
%SageCC + HPforb + HPgrass + Hsage	10	176.235	5.246	0.008
%SageCC + HPgrass + %Pforb + %VisTotal	10	176.28	5.291	0.008
%SageCC[b]	4	176.318	5.329	0.008
%SageCC + HPgrass + Hsage + %VisTotal	10	176.692	5.703	0.006
%SageCC + HPforb	6	176.857	5.868	0.006
%SageCC + Hxeric + %Pforb	8	177.066	6.076	0.005
%SageCC + Stm10mD	6	177.134	6.144	0.005
%SageCC + Hsage	6	177.198	6.209	0.005
%SageCC + Hxeric + Stm10mD	8	177.386	6.397	0.004
%SageCC + ShrubR	6	177.435	6.445	0.004
%SageCC + %Pforb	6	177.776	6.786	0.004
%SageCC + Stm10mD + %VisTotal	8	178.076	7.086	0.003
%SageCC + HPforb + Stm10mD	8	178.163	7.173	0.003
%SageCC + ShrubR + Stm10mD	8	178.208	7.218	0.003

Table A.5. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + Hsage + ShrubR	8	178.323	7.334	0.003
%SageCC + HPforb + %Pforb	8	178.355	7.365	0.003
%SageCC + Hsage + %Pforb	8	178.383	7.394	0.003
%SageCC + HPforb + ShrubR	8	178.468	7.478	0.003
%SageCC + HPforb + HPgrass + %VisTotal	10	178.515	7.526	0.003
%SageCC + Stm10mD + %Pforb	8	178.573	7.584	0.002
%SageCC + %VisTotal	6	178.681	7.691	0.002
%SageCC + HPforb + Hxeric	8	178.705	7.716	0.002
%SageCC + Hsage + Hxeric	8	178.855	7.866	0.002
%SageCC + Hxeric + Stm10mD + %Pforb	10	179.006	8.016	0.002
%SageCC + Hxeric + ShrubR + %Pforb	10	179.139	8.149	0.002
%SageCC + ShrubR + Stm10mD + %VisTotal	10	179.36	8.37	0.002
%SageCC + Hxeric + %VisTotal	8	179.4	8.41	0.002
%SageCC + ShrubR + %VisTotal	8	179.442	8.452	0.002
%SageCC + Hxeric + ShrubR + Stm10mD	10	179.46	8.47	0.002
%SageCC + Hsage + Hxeric + ShrubR	10	179.464	8.475	0.002
%SageCC + HPforb + Hsage	8	179.5	8.51	0.002
%SageCC + Hxeric + ShrubR + %VisTotal	10	179.531	8.542	0.002
%SageCC + ShrubR + %Pforb	8	179.681	8.692	0.001
%SageCC + HPforb + ShrubR + Stm10mD	10	179.718	8.729	0.001
%SageCC + Hsage + Stm10mD	8	179.791	8.801	0.001
%SageCC + HPforb + Hxeric + ShrubR	10	179.851	8.862	0.001

Table A.5. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + HPforb + Stm10mD + %Pforb	10	179.889	8.899	0.001
%SageCC + Hsage + Hxeric + %Pforb	10	180.191	9.201	0.001
%SageCC + Stm10mD + %Pforb + %VisTotal	10	180.29	9.3	0.001
%SageCC + Hsage + ShrubR + %Pforb	10	180.318	9.328	0.001
%SageCC + ShrubR + Stm10mD + %Pforb	10	180.413	9.424	0.001
%SageCC + Hxeric + Stm10mD + %VisTotal	10	180.467	9.477	0.001
%SageCC + HPforb + Hxeric + %Pforb	10	180.487	9.497	0.001
%SageCC + %Pforb + %VisTotal	8	180.734	9.745	0.001
%SageCC + HPforb + Hsage + %Pforb	10	180.754	9.764	0.001
%SageCC + HPforb + %VisTotal	8	180.759	9.77	0.001
%SageCC + HPforb + ShrubR + %Pforb	10	180.915	9.926	0.001
%SageCC + HPforb + Hxeric + Stm10mD	10	180.923	9.934	0.001
%SageCC + HPforb + Hsage + ShrubR	10	180.981	9.992	0.001
%SageCC + HPforb + Stm10mD + %VisTotal	10	181.075	10.086	0.001
%SageCC + Hsage + Stm10mD + %Pforb	10	181.112	10.123	0.001
%SageCC + Hsage + %VisTotal	8	181.259	10.27	0.001
%SageCC + Hsage + ShrubR + Stm10mD	10	181.314	10.324	0.001
%SageCC + Hxeric + %Pforb + %VisTotal	10	181.615	10.625	0.001
%SageCC + HPforb + ShrubR + %VisTotal	10	181.69	10.701	0.001
%SageCC + Hsage + Hxeric + Stm10mD	10	181.851	10.862	0.000
%SageCC + Hsage + ShrubR + %VisTotal	10	182.021	11.032	0.000
%SageCC + HPforb + Hsage + Stm10mD	10	182.173	11.183	0.000

Table A.5. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + ShrubR + %Pforb + %VisTotal	10	182.65	11.66	0.000
%SageCC + Hsage + Stm10mD + %VisTotal	10	182.686	11.697	0.000
%SageCC + HPforb + %Pforb + %VisTotal	10	182.704	11.715	0.000
%SageCC + HPforb + Hsage + Hxeric	10	182.734	11.744	0.000
%SageCC + Hsage + %Pforb + %VisTotal	10	183.096	12.107	0.000
%SageCC + HPforb + Hxeric + %VisTotal	10	183.223	12.233	0.000
%SageCC + Hsage + Hxeric + %VisTotal	10	183.515	12.526	0.000
%SageCC + HPforb + Hsage + %VisTotal	10	184.237	13.248	0.000

[a] %SageCC = mean % canopy cover of sagebrush (*Artemisia* spp.; estimated along two 20-m perpendicular transects); HPgrass = mean perennial grass height (cm); Hxeric = mean height of xeric shrub; %VisTotal = mean % visibility from all angles (estimated with 25 cm x 25 cm Jone’s cover board); HPforb = mean perennial forb height (cm); Stm10mD = stem density of trees (estimated with metric Biltmore stick); ShrubR = shrub species richness; Hsage = mean sagebrush height (cm); %Pforb = mean % canopy cover of perennial forbs.
[b] Null model.

Table A.6. All multinomial models from step 2 of model selection evaluating habitat selection at the micro-scale (0.03 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens during the late-season period (14 June–26 July) in Owyhee County, Idaho 2017–18. K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + Hother + %Aforb + %Bgnd	10	197.871	0.000	0.234
%SageCC + Hother + HRgrass + %Bgnd	10	198.856	0.985	0.143
%SageCC + Hother + %Bgnd	8	199.882	2.011	0.086
%SageCC + Hother + ShrubR + %Bgnd	10	201.049	3.178	0.048
%SageCC + Hother + HRgrass + %Aforb	10	201.210	3.338	0.044
%SageCC + HRgrass + ShrubR + %Bgnd	10	201.686	3.815	0.035
%SageCC + ShrubR + %Aforb + %Bgnd	10	201.886	4.015	0.031
%SageCC + Hother + Hxeric + %Bgnd	10	202.256	4.385	0.026
%SageCC + Hother + Hsage + %Bgnd	10	202.433	4.561	0.024
%SageCC + Hother + %Aforb	8	202.716	4.845	0.021
%SageCC + Hother + PforbR + %Bgnd	10	202.983	5.112	0.018
%SageCC + ShrubR + %Bgnd	8	203.365	5.494	0.015
%SageCC + Hother + %Bgnd + %Pgrass	10	203.589	5.718	0.013
%SageCC + Hother + HPgrass + %Bgnd	10	203.750	5.879	0.012
%SageCC + Hother + %Bgnd + %NsageCC	10	203.846	5.975	0.012
%SageCC + Hother + ShrubR + %Aforb	10	203.942	6.070	0.011
%SageCC + HRgrass + %Bgnd + %NsageCC	10	204.196	6.325	0.010
%SageCC + HRgrass + %Bgnd + %Pgrass	10	204.270	6.399	0.010
%SageCC + HRgrass + %Aforb + %Bgnd	10	204.300	6.429	0.009
%SageCC + %Aforb + %Bgnd + %NsageCC	10	204.477	6.606	0.009

Table A.6. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + Hother + HRgrass	8	204.521	6.650	0.008
%SageCC + Hxeric + %Aforb + %Bgnd	10	204.680	6.809	0.008
%SageCC + %Aforb + %Bgnd	8	204.818	6.947	0.007
%SageCC + Hother + HRgrass + ShrubR	10	205.049	7.178	0.006
%SageCC + Hxeric + %Bgnd + %Pgrass	10	205.116	7.245	0.006
%SageCC + %Bgnd + %NsageCC + %Pgrass	10	205.165	7.294	0.006
%SageCC + ShrubR + %Bgnd + %Pgrass	10	205.196	7.324	0.006
%SageCC + Hxeric + %Bgnd + %NsageCC	10	205.257	7.386	0.006
%SageCC + Hsage + ShrubR + %Bgnd	10	205.424	7.553	0.005
%SageCC + Hother	6	205.548	7.677	0.005
%SageCC + %Aforb + %Bgnd + %Pgrass	10	205.681	7.810	0.005
%SageCC + ShrubR + %Bgnd + %NsageCC	10	205.685	7.814	0.005
%SageCC + Hxeric + %Bgnd	8	205.774	7.902	0.005
%SageCC + Hother + HPgrass + %Aforb	10	205.833	7.961	0.004
%SageCC + Hsage + %Aforb + %Bgnd	10	206.070	8.199	0.004
%SageCC + Hxeric + ShrubR + %Bgnd	10	206.118	8.247	0.004
%SageCC + Hother + Hsage + %Aforb	10	206.124	8.253	0.004
%SageCC + HRgrass + %Bgnd	8	206.525	8.654	0.003
%SageCC + HRgrass + %NsageCC + %Pgrass	10	206.531	8.660	0.003
%SageCC + Hother + ShrubR	8	206.548	8.677	0.003
%SageCC + Hother + %Aforb + %Pgrass	10	206.587	8.716	0.003

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + Hother + %Aforb + %NsageCC	10	206.618	8.747	0.003
%SageCC + %Bgnd + %NsageCC	8	206.620	8.748	0.003
%SageCC + Hother + HRgrass + PforbR	10	206.679	8.808	0.003
%SageCC + HPgrass + ShrubR + %Bgnd	10	206.735	8.864	0.003
%SageCC + Hother + Hxeric + %Aforb	10	206.816	8.945	0.003
%SageCC + %Bgnd	6	206.818	8.947	0.003
%SageCC + Hsage + %Bgnd + %Pgrass	10	206.820	8.949	0.003
%SageCC + %Bgnd + %Pgrass	8	206.821	8.950	0.003
%SageCC + Hother + PforbR + %Aforb	10	206.838	8.967	0.003
%SageCC + HRgrass + PforbR + %Bgnd	10	206.911	9.040	0.003
%SageCC + HRgrass + Hxeric + %Bgnd	10	207.005	9.134	0.002
%SageCC + Hother + HRgrass + %Pgrass	10	207.095	9.223	0.002
%SageCC + Hother + HRgrass + %NsageCC	10	207.205	9.334	0.002
%SageCC + Hother + HPgrass + HRgrass	10	207.239	9.368	0.002
%SageCC + Hsage + %Bgnd	8	207.251	9.380	0.002
%SageCC + PforbR + ShrubR + %Bgnd	10	207.404	9.533	0.002
%SageCC + Hother + HRgrass + Hsage	10	207.684	9.812	0.002
%SageCC + PforbR + %Aforb + %Bgnd	10	207.685	9.814	0.002
%SageCC + Hsage + %Bgnd + %NsageCC	10	207.715	9.844	0.002
%SageCC + Hother + Hsage	8	207.930	10.059	0.002
%SageCC + Hother + HPgrass	8	207.996	10.125	0.001
%SageCC + Hxeric + PforbR + %Bgnd	10	208.048	10.177	0.001

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + PforbR + %Bgnd	8	208.460	10.589	0.001
%SageCC + HPgrass + %Aforb + %Bgnd	10	208.572	10.700	0.001
%SageCC + Hother + PforbR	8	208.678	10.806	0.001
%SageCC + Hother + %Pgrass	8	208.784	10.912	0.001
%SageCC + Hother + HRgrass + Hxeric	10	208.792	10.921	0.001
%SageCC + HRgrass + Hsage + %Bgnd	10	208.815	10.944	0.001
%SageCC + PforbR + %Bgnd + %NsageCC	10	208.853	10.982	0.001
%SageCC + Hother + Hxeric	8	208.978	11.106	0.001
%SageCC + HPgrass + Hxeric + %Bgnd	10	209.024	11.153	0.001
%SageCC + Hother + HPgrass + ShrubR	10	209.153	11.281	0.001
%SageCC + Hother + Hsage + ShrubR	10	209.179	11.308	0.001
%SageCC + Hother + %NsageCC	8	209.269	11.398	0.001
%SageCC + Hsage + PforbR + %Bgnd	10	209.314	11.443	0.001
%SageCC + Hsage + Hxeric + %Bgnd	10	209.424	11.553	0.001
%SageCC + HRgrass + ShrubR + %Aforb	10	209.729	11.858	0.001
%SageCC + Hxeric + %NsageCC + %Pgrass	10	209.737	11.866	0.001
%SageCC + HPgrass + %Bgnd	8	210.016	12.144	0.001
%SageCC + Hother + PforbR + ShrubR	10	210.051	12.179	0.001
%SageCC + HPgrass + HRgrass + %Bgnd	10	210.120	12.249	0.001
%SageCC + HRgrass + ShrubR + %Pgrass	10	210.197	12.326	0.000
%SageCC + HPgrass + %Bgnd + %NsageCC	10	210.214	12.343	0.000
%SageCC + Hother + ShrubR + %Pgrass	10	210.444	12.573	0.000

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + PforbR + %Bgnd + %Pgrass	10	210.469	12.598	0.000
%SageCC + HRgrass + %Aforb + %Pgrass	10	210.508	12.636	0.000
%SageCC + HPgrass + %Bgnd + %Pgrass	10	210.534	12.663	0.000
%SageCC + Hother + Hxeric + ShrubR	10	210.541	12.670	0.000
%SageCC + ShrubR + %Aforb	8	210.566	12.694	0.000
%SageCC + %Aforb + %NsageCC + %Pgrass	10	210.732	12.861	0.000
%SageCC + HRgrass + %Aforb + %NsageCC	10	210.746	12.874	0.000
%SageCC + Hother + HPgrass + Hsage	10	210.807	12.936	0.000
%SageCC + Hother + ShrubR + %NsageCC	10	210.820	12.949	0.000
%SageCC + Hother + Hsage + %Pgrass	10	211.051	13.180	0.000
%SageCC + HPgrass + Hsage + %Bgnd	10	211.173	13.302	0.000
%SageCC + Hother + Hsage + PforbR	10	211.209	13.338	0.000
%SageCC + Hother + HPgrass + %NsageCC	10	211.229	13.358	0.000
%SageCC + Hother + HPgrass + Hxeric	10	211.255	13.384	0.000
%SageCC + Hsage + %NsageCC + %Pgrass	10	211.330	13.459	0.000
%SageCC + ShrubR + %Aforb + %Pgrass	10	211.496	13.625	0.000
%SageCC + Hother + HPgrass + PforbR	10	211.525	13.654	0.000
%SageCC + Hother + HPgrass + %Pgrass	10	211.535	13.664	0.000
%SageCC + Hxeric + %Aforb + %Pgrass	10	211.561	13.690	0.000
%SageCC + Hsage + ShrubR + %Aforb	10	211.764	13.893	0.000
%SageCC + Hother + Hsage + %NsageCC	10	211.785	13.914	0.000
%SageCC + HRgrass + %Pgrass	8	211.897	14.026	0.000

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + Hother + Hxeric + %Pgrass	10	211.995	14.124	0.000
%SageCC + HRgrass + Hxeric + %Pgrass	10	211.999	14.128	0.000
%SageCC + Hother + %NsageCC + %Pgrass	10	212.026	14.155	0.000
%SageCC + Hsage + %Aforb + %Pgrass	10	212.059	14.188	0.000
%SageCC + HPgrass + ShrubR + %Aforb	10	212.107	14.236	0.000
%SageCC + HPgrass + PforbR + %Bgnd	10	212.152	14.281	0.000
%SageCC + %NsageCC + %Pgrass	8	212.190	14.318	0.000
%SageCC + Hother + Hxeric + PforbR	10	212.220	14.348	0.000
%SageCC + HRgrass + ShrubR	8	212.221	14.350	0.000
%SageCC + Hother + Hsage + Hxeric	10	212.334	14.463	0.000
%SageCC + %Aforb + %Pgrass	8	212.456	14.585	0.000
%SageCC + Hxeric + %Pgrass	8	212.468	14.597	0.000
%SageCC + Hother + Hxeric + %NsageCC	10	212.486	14.615	0.000
%SageCC + Hother + PforbR + %NsageCC	10	212.540	14.669	0.000
%SageCC + Hxeric + %Aforb + %NsageCC	10	212.548	14.677	0.000
%SageCC + ShrubR + %Aforb + %NsageCC	10	212.676	14.805	0.000
%SageCC + %Aforb + %NsageCC	8	212.700	14.828	0.000
%SageCC + Hsage + %Pgrass	8	212.722	14.851	0.000
%SageCC + Hother + PforbR + %Pgrass	10	212.818	14.947	0.000
%SageCC + HRgrass + ShrubR + %NsageCC	10	212.843	14.972	0.000
%SageCC + ShrubR	6	212.890	15.019	0.000
%SageCC + Hsage + ShrubR + %Pgrass	10	212.900	15.029	0.000

Table A.6. *Continued…*

Model	Model Fit Statistics			
	K	AIC_c	ΔAIC_c	ω_i
%SageCC + %Aforb	6	212.930	15.058	0.000
%SageCC + ShrubR + %Pgrass	8	212.934	15.063	0.000
%SageCC + HRgrass + %Aforb	8	213.052	15.180	0.000
%SageCC + Hxeric + %Aforb	8	213.109	15.238	0.000
%SageCC + HRgrass + Hsage + %Pgrass	10	213.190	15.319	0.000
%SageCC + Hsage + ShrubR	8	213.197	15.326	0.000
%SageCC + Hsage + %Aforb	8	213.249	15.378	0.000
%SageCC + ShrubR + %NsageCC + %Pgrass	10	213.544	15.673	0.000
%SageCC + Hxeric + ShrubR + %Aforb	10	213.549	15.677	0.000
%SageCC + HRgrass + %NsageCC	8	213.556	15.685	0.000
%SageCC + Hsage + %Aforb + %NsageCC	10	213.683	15.812	0.000
%SageCC + HPgrass + ShrubR	8	213.820	15.949	0.000
%SageCC + HPgrass + HRgrass + ShrubR	10	213.930	16.059	0.000
%SageCC + HPgrass + %NsageCC + %Pgrass	10	213.978	16.107	0.000
%SageCC + %Pgrass	6	213.984	16.113	0.000
%SageCC + HRgrass + PforbR + %NsageCC	10	214.161	16.290	0.000
%SageCC + HRgrass + Hsage + ShrubR	10	214.239	16.367	0.000
%SageCC + Hxeric + ShrubR + %Pgrass	10	214.329	16.458	0.000
%SageCC + HPgrass + %Aforb	8	214.428	16.557	0.000
%SageCC + Hxeric + %NsageCC	8	214.487	16.615	0.000
%SageCC + HPgrass + HRgrass + %Pgrass	10	214.505	16.634	0.000
%SageCC + HPgrass + Hxeric + %Pgrass	10	214.505	16.634	0.000

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + HPgrass + %Aforb + %Pgrass	10	214.574	16.703	0.000
%SageCC + HRgrass + PforbR + %Aforb	10	214.587	16.715	0.000
%SageCC + HPgrass + %Aforb + %NsageCC	10	214.617	16.745	0.000
%SageCC + HRgrass + Hxeric + %NsageCC	10	214.627	16.756	0.000
%SageCC + HPgrass + Hxeric + %Aforb	10	214.723	16.852	0.000
%SageCC + HRgrass + Hxeric + %Aforb	10	214.733	16.861	0.000
%SageCC + PforbR + ShrubR + %Aforb	10	214.765	16.894	0.000
%SageCC + HPgrass + ShrubR + %Pgrass	10	214.780	16.909	0.000
%SageCC + HPgrass + HRgrass + %Aforb	10	214.843	16.972	0.000
%SageCC + ShrubR + %NsageCC	8	214.845	16.974	0.000
%SageCC + Hsage	6	214.934	17.062	0.000
%SageCC + HPgrass + HRgrass + %NsageCC	10	214.969	17.098	0.000
%SageCC + Hxeric	6	215.110	17.239	0.000
%SageCC + Hsage + Hxeric + %Pgrass	10	215.124	17.252	0.000
%SageCC + HRgrass + Hsage + %NsageCC	10	215.147	17.276	0.000
%SageCC + HRgrass + Hsage + %Aforb	10	215.150	17.279	0.000
%SageCC + HPgrass + Hsage + ShrubR	10	215.192	17.321	0.000
%SageCC + Hsage + %NsageCC	8	215.308	17.436	0.000
%SageCC + %NsageCC	6	215.343	17.471	0.000
%SageCC + Hxeric + ShrubR	8	215.350	17.478	0.000
%SageCC + HRgrass + PforbR + ShrubR	10	215.422	17.551	0.000
%SageCC + PforbR + %Aforb	8	215.436	17.565	0.000

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + HRgrass + Hxeric + ShrubR	10	215.487	17.616	0.000
%SageCC + Hsage + ShrubR + %NsageCC	10	215.497	17.626	0.000
%SageCC + HPgrass + Hsage + %Pgrass	10	215.514	17.643	0.000
%SageCC[b]	4	215.533	17.662	0.000
%SageCC + HPgrass + Hsage + %Aforb	10	215.592	17.721	0.000
%SageCC + HRgrass + PforbR + %Pgrass	10	215.642	17.771	0.000
%SageCC + HPgrass + Hxeric + %NsageCC	10	215.660	17.789	0.000
%SageCC + PforbR + %Aforb + %NsageCC	10	215.783	17.912	0.000
%SageCC + HRgrass	6	215.784	17.913	0.000
%SageCC + HPgrass + %Pgrass	8	215.874	18.003	0.000
%SageCC + Hxeric + PforbR + %Aforb	10	215.890	18.019	0.000
%SageCC + HRgrass + PforbR	8	215.942	18.070	0.000
%SageCC + HPgrass + Hxeric	8	216.021	18.150	0.000
%SageCC + Hsage + PforbR + %Aforb	10	216.080	18.209	0.000
%SageCC + HPgrass + ShrubR + %NsageCC	10	216.098	18.227	0.000
%SageCC + PforbR + ShrubR	8	216.120	18.249	0.000
%SageCC + PforbR + %NsageCC + %Pgrass	10	216.187	18.316	0.000
%SageCC + HPgrass + Hxeric + ShrubR	10	216.328	18.456	0.000
%SageCC + PforbR + ShrubR + %Pgrass	10	216.353	18.482	0.000
%SageCC + Hsage + Hxeric + %Aforb	10	216.374	18.502	0.000
%SageCC + HPgrass	6	216.415	18.544	0.000
%SageCC + Hsage + PforbR + ShrubR	10	216.525	18.653	0.000

Table A.6. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
%SageCC + HPgrass + %NsageCC	8	216.552	18.681	0.000
%SageCC + Hxeric + PforbR + %Pgrass	10	216.624	18.753	0.000
%SageCC + Hxeric + PforbR + %NsageCC	10	216.701	18.830	0.000
%SageCC + PforbR + %Aforb + %Pgrass	10	216.711	18.840	0.000
%SageCC + Hsage + PforbR	8	216.717	18.845	0.000
%SageCC + HRgrass + Hxeric	8	216.789	18.918	0.000
%SageCC + Hxeric + PforbR	8	216.815	18.944	0.000
%SageCC + HPgrass + Hsage	8	216.833	18.962	0.000
%SageCC + PforbR	6	216.852	18.981	0.000
%SageCC + HRgrass + Hsage	8	216.855	18.984	0.000
%SageCC + Hxeric + ShrubR + %NsageCC	10	216.905	19.034	0.000
%SageCC + Hsage + PforbR + %Pgrass	10	216.927	19.056	0.000
%SageCC + HPgrass + HRgrass	8	217.028	19.157	0.000
%SageCC + PforbR + %NsageCC	8	217.152	19.281	0.000
%SageCC + HPgrass + Hsage + %NsageCC	10	217.197	19.325	0.000
%SageCC + HPgrass + PforbR + %Aforb	10	217.473	19.602	0.000
%SageCC + Hsage + PforbR + %NsageCC	10	217.533	19.662	0.000
%SageCC + HRgrass + Hxeric + PforbR	10	217.606	19.735	0.000
%SageCC + Hsage + Hxeric + ShrubR	10	217.610	19.739	0.000
%SageCC + Hsage + Hxeric + %NsageCC	10	217.653	19.782	0.000
%SageCC + Hsage + Hxeric	8	217.727	19.856	0.000
%SageCC + HPgrass + PforbR + ShrubR	10	217.743	19.871	0.000

Table A.6. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
%SageCC + PforbR + %Pgrass	8	217.766	19.895	0.000
%SageCC + HRgrass + Hsage + PforbR	10	217.966	20.095	0.000
%SageCC + Hxeric + PforbR + ShrubR	10	218.072	20.201	0.000
%SageCC + HPgrass + HRgrass + PforbR	10	218.128	20.257	0.000
%SageCC + HPgrass + HRgrass + Hxeric	10	218.219	20.348	0.000
%SageCC + PforbR + ShrubR + %NsageCC	10	218.236	20.365	0.000
%SageCC + HPgrass + PforbR	8	218.489	20.618	0.000
%SageCC + HPgrass + Hxeric + PforbR	10	218.507	20.636	0.000
%SageCC + HPgrass + PforbR + %NsageCC	10	218.946	21.074	0.000
%SageCC + HPgrass + HRgrass + Hsage	10	219.083	21.212	0.000
%SageCC + HPgrass + Hsage + PforbR	10	219.264	21.393	0.000
%SageCC + HPgrass + Hsage + Hxeric	10	219.506	21.635	0.000
%SageCC + Hsage + Hxeric + PforbR	10	219.827	21.955	0.000
%SageCC + HPgrass + PforbR + %Pgrass	10	220.004	22.133	0.000
%SageCC + HRgrass + Hsage + Hxeric	10	220.097	22.226	0.000

[a] %SageCC = mean % canopy cover of sagebrush (*Artemisia* spp.; estimated along two 20-m perpendicular transects); Hother = mean non-sagebrush shrub height (cm); Hxeric = mean xeric shrub height; HPgrass = mean perennial grass height (cm); %Bgnd = mean % cover of bare ground (estimated with 20 cm x 50 cm Daubenmire frame); %Pgrass = mean % canopy cover of perennial grass (estimated with 20 cm x 50 cm Daubenmire frame); %Aforb = mean % canopy cover of annual forb (estimated with 20 cm x 50 cm Daubenmire frame); HRgrass = mean residual grass height (cm); Hsage = mean sagebrush height (cm); ShrubR = shrub species richness; PforbR = perennial forb species richness; HPgrass = mean perennial grass height (cm).

b Null model.

Habitat selection at the macro-scale.

Results from step 1 and 2 from analyses of habitat selection at macro-scales (7.1, 15.0, 94.7, and 202.6 ha) for greater sage-grouse (*Centrocercus urophasianus*) hens in Owyhee County, Idaho 2017–18. Table A.7 describes all habitat variables considered; Table A.8 summarizes mean and standard error of all habitat variables; Tables A.9 and A.10 are modeling results from step 1 of model selection; and Tables A.11 and A.12 are modeling results from step 2 of model selection.

Table A.7. Variables used in multinomial and generalized linear mixed-models to evaluate greater sage-grouse (*Centrocercus urophasianus*) habitat selection at the macro- (7.1, 15.0, 94.7, and 202.6 ha) scale in Owyhee County, Idaho during 2017–18. Proportion of big sagebrush (*Artemisia* spp.), herbaceous plants, litter, bare ground, and wetland were estimated using 2016 National Land cover Data fractional components, woody wetlands, and emergent herbaceous wetlands spatial layers. Proportion of western juniper (*Juniperus occidentalis*) was estimated using a spatial layer that classified all conifer canopy cover.

Variable Name	Description
Sage7[a,b]	Proportion of all sagebrush shrublands within 7.1 ha
Sage15	Proportion of all sagebrush shrublands within 15.0 ha
Sage94	Proportion of all sagebrush shrublands within 94.7 ha
Sage202	Proportion of all sagebrush shrublands within 202.6 ha
BSage7	Proportion of big sagebrush (*A. tridentata*) shrublands within 7.1 ha
BSage15	Proportion of big sagebrush shrublands within 15.0 ha
BSage94	Proportion of big sagebrush shrublands within 94.7 ha
BSage202	Proportion of big sagebrush shrublands within 202.6 ha
NSage7[a,c]	Proportion of non-sagebrush shrublands within 7.1 ha
NSage15[b,c]	Proportion of non-sagebrush shrublands within 15.0 ha
NSage94[c]	Proportion of non-sagebrush shrublands within 94.7 ha
NSage202[c]	Proportion of non-sagebrush shrublands within 202.6 ha
Ann7[a]	Proportion of annual herbaceous plants within 7.1 ha
Ann15[b]	Proportion of annual herbaceous plants within 15.0 ha
Ann94	Proportion of annual herbaceous plants within 94.7 ha
Ann202	Proportion of annual herbaceous plants within 202.6 ha
Per7[a,b,d]	Proportion of perennial herbaceous plants within 7.1 ha
Per15[d]	Proportion of perennial herbaceous plants within 15.0 ha

Table A.7. *Continued…*

Variable Name	Description
Per94[d]	Proportion of perennial herbaceous plants within 94.7 ha
Per202[d]	Proportion of perennial herbaceous plants within 202.6 ha
Bgnd7[a,b]	Proportion of bare ground within 7.1 ha
Bgnd15	Proportion of bare ground within 15.0 ha
Bgnd94	Proportion of bare ground within 94.7 ha
Bgnd202	Proportion of bare ground within 202.6 ha
Lit7	Proportion of litter within 7.1 ha
Lit15	Proportion of litter within 15.0 ha
Lit94	Proportion of litter within 94.7 ha
Lit202	Proportion of litter within 202.6 ha
CCI7	Proportion of cover class I juniper (> 0–10% cover) within 7.1 ha
CCI15	Proportion of cover class I juniper within 15.0 ha
CCI94	Proportion of cover class I juniper within 94.7 ha
CCI202[a,b]	Proportion of cover class I juniper within 202.6 ha
CCII7[a,b]	Proportion of cover class II juniper (> 10–20% cover) within 7.1 ha
CCII15	Proportion of cover class II juniper within 15.0 ha
CCII94	Proportion of cover class II juniper within 94.7 ha
CCII202	Proportion of cover class II juniper within 202.6 ha
CCIII7[a,b]	Proportion of cover class III juniper (> 20% cover) within 7.1 ha
CCIII15	Proportion of cover class III juniper within 15.0 ha

Table A.7. *Continued…*

Variable Name	Description
CCIII94	Proportion of cover class III juniper within 94.7 ha
CCIII202	Proportion of cover class III juniper within 202.6 ha
Rip7	Proportion of woody wetlands within 7.1 ha
Rip15	Proportion of woody wetlands within 15.0 ha
Rip94	Proportion of woody wetlands within 94.7 ha
Rip202[a,b]	Proportion of woody wetlands within 202.6 ha
Wet7	Proportion of herbaceous wetlands within 7.1 ha
Wet15	Proportion of herbaceous wetlands within 15.0 ha
Wet94	Proportion of herbaceous wetlands within 94.7 ha
Wet202[a,b]	Proportion of herbaceous wetlands within 202.6 ha
REdge7	Edge density (perimeter (m)/area (m^2)) of woody wetlands within 7.1 ha
REdge15[b]	Edge density of woody wetlands within 15.0 ha
REdge94	Edge density of woody wetlands within 94.7 ha
REdge202	Edge density of woody wetlands within 202.6 ha
WEdge7[b]	Edge density of herbaceous wetlands within 7.1 ha
WEdge15	Edge density of herbaceous wetlands within 15.0 ha
WEdge94	Edge density of herbaceous wetlands within 94.7 ha
WEdge202	Edge density of herbaceous wetlands within 202.6 ha
CCIDis[a,b]	Distance (m) to the nearest cover class I juniper
CCIIDis	Distance (m) to the nearest cover class II juniper
CCIIIDis	Distance (m) to the nearest cover class III juniper

Table A.7. *Continued…*

Variable Name	Description
RipDis[a,b]	Distance (m) to the nearest woody wetlands
WetDis	Distance (m) to the nearest wet meadow
Elev[a,b]	Elevation (m)

[a] Variables used in final multinomial models during the early-season period (30 April–13 June).
[b] Variables used in final multinomial models during the late-season period (14 June–26 July).
[c] Created using the difference in proportions between percent shrub and percent sagebrush fractional components.
[d] Created using the difference in proportions between percent herbaceous and percent annual herbaceous fractional components.

Table A.8. Mean estimates of macro-scale (7.1, 15.0, 94.7, and 202.6 ha) habitat variables at use and available locations of greater sage-grouse (*Centrocercus urophasianus*) hens in Owyhee County, Idaho during 2017-18. Standard error in parentheses. Early-season period and late-season period were from 30 April–13 June and 14 June–26 July, respectively. "Brooding hen" are locations used by hens with chicks and "non-brooding hen" are locations used by hens without chicks. "Available" are randomly chosen locations within two minimum convex polygons around use locations. Proportion of sagebrush (*Artemisia* spp.), herbaceous plants, litter, bare ground, and wetland was estimated using 2016 National Land cover Data fractional components, woody wetlands, and emergent herbaceous wetlands spatial layers. Proportion of western juniper (*Juniperus occidentalis*) was estimated using a spatial layer that classified all conifer canopy cover: cover class I = > 0–10% juniper cover; cover class II = > 10–20% juniper cover; cover class III = > 20% juniper cover; edge density = perimeter (m)/area (m^2).

	Early-season Period		Late-season Period		
Variable	Brooding hen	Non-brooding hen	Brooding hen	Non-brooding hen	Available
Proportion of all sagebrush within 7.1 ha	0.09 (0.01)	0.11 (0.00)	0.1 (0.01)	0.09 (0.01)	0.14 (0.00)
Proportion of all sagebrush within 15.0 ha	0.08 (0.01)	0.09 (0.00)	0.08 (0.01)	0.08 (0.01)	0.12 (0.00)
Proportion of all sagebrush within 94.7 ha	0.04 (0.01)	0.05 (0.00)	0.04 (0.01)	0.04 (0.00)	0.06 (0.00)
Proportion of all sagebrush within 202.6 ha	0.04 (0.01)	0.03 (0.00)	0.03 (0.01)	0.03 (0.00)	0.05 (0.00)
Proportion of big sagebrush (*A. tridentata*) within 7.1 ha	0.07 (0.01)	0.08 (0.00)	0.07 (0.01)	0.07 (0.00)	0.1 (0.00)
Proportion of big sagebrush within 15.0 ha	0.06 (0.01)	0.06 (0.00)	0.06 (0.01)	0.06 (0.00)	0.09 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period Brooding hen	Early-season Period Non-brooding hen	Late-season Period Brooding hen	Late-season Period Non-brooding hen	Available
Proportion of big sagebrush within 94.7 ha	0.03 (0.00)	0.03 (0.00)	0.03 (0.00)	0.03 (0.00)	0.04 (0.00)
Proportion of big sagebrush within 202.6 ha	0.03 (0.01)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)	0.04 (0.00)
Proportion of non-sagebrush shrubs within 7.1 ha[a]	0.02 (0.00)	0.03 (0.00)	0.04 (0.00)	0.04 (0.00)	0.06 (0.00)
Proportion of non-sagebrush shrubs within 15.0 ha[a]	0.02 (0.00)	0.02 (0.00)	0.03 (0.00)	0.03 (0.00)	0.05 (0.00)
Proportion of non-sagebrush shrubs within 94.7 ha[a]	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.04 (0.00)
Proportion of non-sagebrush shrubs within 202.6 ha[a]	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.02 (0.00)
Proportion of annual herbaceous plants within 7.1 ha	0.05 (0.01)	0.07 (0.00)	0.05 (0.00)	0.06 (0.00)	0.06 (0.00)
Proportion of annual herbaceous plants within 15.0 ha	0.04 (0.00)	0.06 (0.00)	0.04 (0.00)	0.05 (0.00)	0.06 (0.00)
	0.02 (0.00)	0.03 (0.00)	0.02 (0.00)	0.02 (0.00)	0.03 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period: Brooding hen	Early-season Period: Non-brooding hen	Late-season Period: Brooding hen	Late-season Period: Non-brooding hen	Available
Proportion of annual herbaceous plants within 94.7 ha					
Proportion of annual herbaceous plants within 202.6 ha	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)
Proportion of perennial herbaceous plants within 7.1 ha[b]	0.12 (0.01)	0.13 (0.00)	0.13 (0.01)	0.13 (0.01)	0.18 (0.00)
Proportion of perennial herbaceous plants within 15.0 ha[b]	0.1 (0.01)	0.11 (0.01)	0.1 (0.01)	0.1 (0.01)	0.15 (0.00)
Proportion of perennial herbaceous plants within 94.7 ha[b]	0.05 (0.01)	0.06 (0.01)	0.05 (0.01)	0.05 (0.01)	0.07 (0.00)
Proportion of perennial herbaceous plants within 202.6 ha[b]	0.04 (0.01)	0.04 (0.00)	0.04 (0.01)	0.04 (0.01)	0.06 (0.00)
Proportion of bare ground within 7.1 ha	0.23 (0.02)	0.29 (0.01)	0.2 (0.01)	0.21 (0.01)	0.31 (0.00)
Proportion of bare ground within 15.0 ha	0.19 (0.02)	0.24 (0.01)	0.17 (0.01)	0.17 (0.01)	0.27 (0.00)
Proportion of bare ground within 94.7 ha	0.1 (0.01)	0.13 (0.01)	0.08 (0.01)	0.09 (0.01)	0.13 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period Brooding hen	Early-season Period Non-brooding hen	Late-season Period Brooding hen	Late-season Period Non-brooding hen	Available
Proportion of bare ground within 202.6 ha	0.08 (0.01)	0.09 (0.01)	0.06 (0.01)	0.06 (0.01)	0.11 (0.00)
Proportion of litter within 7.1 ha	0.14 (0.01)	0.16 (0.01)	0.14 (0.01)	0.15 (0.01)	0.20 (0.00)
Proportion of litter within 15.0 ha	0.12 (0.01)	0.14 (0.01)	0.11 (0.01)	0.12 (0.01)	0.17 (0.00)
Proportion of litter within 94.7 ha	0.06 (0.01)	0.07 (0.01)	0.06 (0.01)	0.06 (0.01)	0.08 (0.00)
Proportion of litter within 202.6 ha	0.05 (0.01)	0.05 (0.01)	0.04 (0.01)	0.04 (0.01)	0.07 (0.00)
Proportion of cover class I juniper within 7.1 ha	0.09 (0.02)	0.15 (0.02)	0.07 (0.01)	0.19 (0.02)	0.11 (0.00)
Proportion of cover class I juniper within 15.0 ha	0.08 (0.02)	0.16 (0.02)	0.07 (0.01)	0.19 (0.02)	0.09 (0.00)
Proportion of cover class I juniper within 94.7 ha	0.08 (0.01)	0.15 (0.02)	0.09 (0.01)	0.17 (0.02)	0.05 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period Brooding hen	Non-brooding hen	Late-season Period Brooding hen	Non-brooding hen	Available
Proportion of cover class I juniper within 202.6 ha	0.09 (0.01)	0.14 (0.02)	0.09 (0.01)	0.17 (0.01)	0.04 (0.00)
Proportion of cover class II juniper within 7.1 ha	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.02 (0.00)	0.05 (0.00)
Proportion of cover class II juniper within 15.0 ha	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)	0.02 (0.00)	0.04 (0.00)
Proportion of cover class II juniper within 94.7 ha	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)	0.03 (0.00)	0.02 (0.00)
Proportion of cover class II juniper within 202.6 ha	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)	0.03 (0.00)	0.02 (0.00)
Proportion of cover class III juniper within 7.1 ha	0.03 (0.02)	0.01 (0.01)	0.03 (0.01)	0.02 (0.01)	0.18 (0.00)
Proportion of cover class III juniper within 15.0 ha	0.04 (0.02)	0.01 (0.01)	0.04 (0.01)	0.02 (0.01)	0.15 (0.01)
Proportion of cover class III juniper within 94.7 ha	0.05 (0.02)	0.02 (0.00)	0.05 (0.01)	0.04 (0.01)	0.07 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period Brooding hen	Early-season Period Non-brooding hen	Late-season Period Brooding hen	Late-season Period Non-brooding hen	Available
Proportion of cover class III juniper within 202.6 ha	0.05 (0.02)	0.02 (0.01)	0.05 (0.02)	0.04 (0.01)	0.06 (0.00)
Distance (m) to nearest cover class I juniper	1667.29 (377.26)	2338.49 (292.76)	1130.08 (198.43)	1121.23 (208.62)	1644.81 (65.44)
Distance (m) to nearest cover class II juniper	2577.73 (442.43)	3268.81 (355.02)	1914.47 (271.38)	1646.73 (274.08)	2212.28 (79.60)
Distance (m) to nearest cover class III juniper	3366.74 (558.18)	4070.65 (442.89)	2190.52 (302.22)	1992.08 (304.01)	2862.47 (101.55)
Distance (m) to nearest woody wetlands	3626.66 (317.73)	4258.06 (206.53)	2726.5 (298.79)	3683.99 (242.24)	3363.63 (56.10)
Distance (m) to nearest herbaceous wetlands	3438.77 (288.49)	3955.49 (194.3)	2840.35 (276.21)	3276.00 (227.67)	3372.80 (55.18)
Proportion of woody wetlands within 7.1 ha	0 (0.00)	0.01 (0.00)	0.06 (0.02)	0.02 (0.01)	0.00 (0.00)
Proportion of woody wetlands within 15.0 ha	0 (0.00)	0.01 (0.00)	0.04 (0.01)	0.02 (0.01)	0 .00 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period Brooding hen	Early-season Period Non-brooding hen	Late-season Period Brooding hen	Late-season Period Non-brooding hen	Available
Proportion of woody wetlands within 94.7 ha	0 (0.00)	0.01 (0.00)	0.02 (0.00)	0.02 (0.01)	0 .00 (0.00)
Proportion of woody wetlands within 202.6 ha	0 (0.00)	0.01 (0.00)	0.01 (0.00)	0.02 (0.00)	0.00 (0.00)
Edge density of woody wetlands within 7.1 ha	0 (0.00)	0 (0.00)	0.02 (0.00)	0.01 (0.00)	0.00 (0.00)
Edge density of woody wetlands within 15.0 ha	0 (0.00)	0 (0.00)	0.02 (0.01)	0.01 (0.00)	0.00 (0.00)
Edge density of woody wetlands within 94.7 ha	0.01 (0.00)	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)	0.01 (0.00)
Edge density of woody wetlands within 202.6 ha	0.02 (0.01)	0.01 (0.00)	0.03 (0.00)	0.02 (0.00)	0.02 (0.00)
Proportion of herbaceous wetlands within 7.1 ha	0 (0.00)	0 (0.00)	0.03 (0.01)	0.00 (0.00)	0.00 (0.00)
Proportion of herbaceous wetlands within 15.0 ha	0 (0.00)	0 (0.00)	0.02 (0.01)	0 (0.00)	0.00 (0.00)

Table A.8. *Continued…*

Variable	Early-season Period Brooding hen	Non-brooding hen	Late-season Period Brooding hen	Non-brooding hen	Available
Proportion of herbaceous wetlands within 94.7 ha	0 (0.00)	0 (0.00)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)
Proportion of herbaceous wetlands within 202.6 ha	0.01 (0.00)	0 (0.00)	0.01 (0.00)	0.01 (0.00)	0.00 (0.00)
Edge density of herbaceous wetlands within 7.1 ha	0 (0.00)	0 (0.00)	0.03 (0.01)	0.01 (0.00)	0.00 (0.00)
Edge density of herbaceous wetlands within 15.0 ha	0.01 (0.00)	0 (0.00)	0.03 (0.01)	0.01 (0.00)	0.00 (0.00)
Edge density of herbaceous wetlands within 94.7 ha	0.01 (0.00)	0.01 (0.00)	0.02 (0.00)	0.02 (0.00)	0.01 (0.00)
Edge density of herbaceous wetlands within 202.6 ha	0.02 (0.01)	0.01 (0.00)	0.03 (0.00)	0.03 (0.00)	0.01 (0.00)
Elevation (m)	1593.66 (33.95)	1481.84 (24.74)	1625.8 (31.63)	1595.24 (30.02)	1653.99 (5.43)

[a] Created using the difference in proportions between percent shrub and percent sagebrush fractional components.
[b] Created using the difference in proportions between percent herbaceous and percent annual herbaceous fractional components.

Table A.9. All multinomial models from step 1 of model selection to evaluate habitat selection for greater sage-grouse (*Centrocercus urophasianus*) hens during the early-season period (30 April–13 June) at macro-scales (7.1, 15.0, 94.7, and 202.6 ha) in Owyhee County, Idaho 2017–18. Proportion of sagebrush (*Artemisia* spp.), herbaceous plants, litter, bare ground, and wetland was estimated using 2016 National Land Cover Data fractional components, woody wetlands, and emergent herbaceous wetlands spatial layers. Proportion of western juniper (*Juniperus occidentalis*) was estimated using a spatial layer that classified all conifer canopy cover: cover class I = > 0–10% juniper cover; cover class II = > 10–20% juniper cover; cover class III = > 20% juniper cover; edge density = perimeter (m)/area (m^2); K = number of parameters multiplied by number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

			Model Fit Statistics		
Model set	Model	K	AIC_c	ΔAIC_c	ω_i
1	Proportion of all sagebrush within 7.1 ha	4	1360.891	0.000	1.000
	Proportion of all sagebrush within 15.0 ha	4	1381.204	20.313	0.000
	Proportion of all sagebrush within 202.6 ha	4	1451.642	90.751	0.000
	Proportion of all sagebrush within 94.7 ha	4	1452.701	91.810	0.000
	Null	2	1460.715	99.824	0.000
2	Proportion of big sagebrush (*A. tridentata*) within 7.1 ha[c]	4	1338.662	0.000	1.000
	Proportion of big sagebrush within 15.0 ha	4	1363.831	25.169	0.000
	Proportion of big sagebrush within 202.6 ha	4	1448.675	110.013	0.000
	Proportion of big sagebrush within 94.7 ha	4	1449.140	110.479	0.000

Table A.9. *Continued...*

Model set	Model	Model Fit Statistics			
		K	AIC_c	ΔAIC_c	ω_i
	Null	2	1460.715	122.053	0.000
3[a]	Proportion of non-sagebrush shrubs within 7.1 ha	4	1338.916	0.000	0.839
	Proportion of non-sagebrush shrubs within 15.0 ha	4	1342.224	3.308	0.161
	Proportion of non-sagebrush shrubs within 94.7 ha	4	1421.976	83.060	0.000
	Proportion of non-sagebrush shrubs within 202.6 ha	4	1426.817	87.901	0.000
	Null	2	1460.715	121.799	0.000
4	Proportion of annual herbaceous plants within 7.1 ha	4	1453.933	0.000	0.540
	Proportion of annual herbaceous plants within 15.0 ha	4	1454.681	0.748	0.371
	Proportion of annual herbaceous plants within 202.6 ha	4	1458.964	5.032	0.044
	Proportion of annual herbaceous plants within 94.7 ha	4	1459.913	5.980	0.027
	Null	2	1460.715	6.782	0.018
5[b]	Proportion of perennial herbaceous plants within 7.1 ha	4	1300.400	0.000	1.000
	Proportion of perennial herbaceous plants within 15.0 ha	4	1348.996	48.596	0.000

Table A.9. *Continued...*

Model set	Model	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Proportion of perennial herbaceous plants within 202.6 ha	4	1445.643	145.243	0.000
	Proportion of perennial herbaceous plants within 94.7 ha	4	1449.207	148.807	0.000
	Null	2	1460.715	160.314	0.000
6	Proportion of bare ground within 7.1 ha	4	1423.680	0.000	0.868
	Proportion of bare ground within 15.0 ha	4	1427.446	3.766	0.132
	Proportion of bare ground within 202.6 ha	4	1457.409	33.729	0.000
	Proportion of bare ground within 94.7 ha	4	1458.866	35.186	0.000
	Null	2	1460.715	37.035	0.000
7	Proportion of litter within 7.1 ha[c]	4	1340.031	0.000	1.000
	Proportion of litter within 15.0 ha	4	1377.300	37.269	0.000
	Proportion of litter within 202.6 ha	4	1451.775	111.744	0.000
	Proportion of litter within 94.7 ha	4	1454.686	114.654	0.000
	Null	2	1460.715	120.683	0.000

Table A.9. *Continued...*

		Model Fit Statistics			
Model set	Model	K	AIC_c	ΔAIC_c	ω_i
8	Proportion of cover class I juniper within 202.6 ha	4	1357.128	0.000	1.000
	Proportion of cover class I juniper within 94.7 ha	4	1386.085	28.956	0.000
	Proportion of cover class I juniper within 15.0 ha	4	1445.060	87.932	0.000
	Proportion of cover class I juniper within 7.1 ha	4	1456.485	99.357	0.000
	Null	2	1460.715	103.587	0.000
9	Proportion of cover class II juniper within 7.1 ha	4	1413.201	0.000	0.997
	Proportion of cover class II juniper within 15.0 ha	4	1424.951	11.750	0.003
	Proportion of cover class II juniper within 202.6 ha	4	1458.513	45.312	0.000
	Null	2	1460.715	47.514	0.000
	Proportion of cover class II juniper within 94.7 ha	4	1461.205	48.003	0.000
10	Proportion of cover class III juniper within 7.1 ha	4	1389.615	0.000	0.969
	Proportion of cover class III juniper within 15.0 ha	4	1396.511	6.896	0.031
	Proportion of cover class III juniper within 94.7 ha	4	1446.176	56.561	0.000

Table A.9. *Continued...*

		Model Fit Statistics			
Model set	Model	K	AIC_c	ΔAIC_c	ω_i
	Proportion of cover class III juniper within 202.6 ha	4	1452.368	62.753	0.000
	Null	2	1460.715	71.100	0.000
11	Proportion of woody wetlands within 202.6 ha	4	1428.318	0.000	0.993
	Proportion of woody wetlands within 94.7 ha	4	1438.222	9.903	0.007
	Null	2	1460.715	32.397	0.000
	Proportion of woody wetlands within 15.0 ha	4	1460.810	32.491	0.000
	Proportion of woody wetlands within 7.1 ha	4	1463.653	35.335	0.000
12	Null	2	3597.649	0.000	1.000
	Edge density of woody wetlands within 202.6 ha	4	3634.511	36.862	0.000
	Edge density of woody wetlands within 94.7 ha	4	3641.731	44.082	0.000
	Edge density of woody wetlands within 7.1 ha	4	3642.626	44.977	0.000
	Edge density of woody wetlands within 15.0 ha	4	3644.852	47.203	0.000
13	Proportion of herbaceous wetlands within 202.6 ha	4	1458.158	0.000	0.425

Table A.9. *Continued...*

Model set	Model	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Proportion of herbaceous wetlands within 94.7 ha	4	1459.496	1.338	0.218
	Proportion of herbaceous wetlands within 7.1 ha	4	1459.986	1.827	0.171
	Null	2	1460.715	2.556	0.118
	Proportion of herbaceous wetlands within 15.0 ha	4	1461.840	3.681	0.068
14	Null	2	1460.715	0.000	0.514
	Edge density of herbaceous wetlands within 7.1 ha	4	1462.711	1.996	0.189
	Edge density of herbaceous wetlands within 15.0 ha	4	3640.597	36.534	0.000
	Edge density of herbaceous wetlands within 202.6 ha	4	1464.097	3.382	0.095
	Edge density of herbaceous wetlands within 94.7 ha	4	1464.556	3.841	0.075
15	Elevation (m)	4	1410.021	0.000	1.000
	Distance (m) to nearest woody wetlands	4	1450.628	40.606	0.000
	Distance (m) to nearest cover class II juniper[d]	4	1454.467	44.446	0.000
	Distance (m) to nearest cover class III juniper[d]	4	1456.179	46.158	0.000

Table A.9. *Continued...*

Model set	Model	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Distance (m) to nearest cover class I juniper	4	1458.286	48.265	0.000
	Distance (m) to nearest herbaceous wetlands[e]	4	1458.923	48.902	0.000
	Null	2	1460.715	50.693	0.000

[a] Created using the difference in proportions between percent shrub and percent sagebrush fractional components.
[b] Created using the difference in proportions between percent herbaceous and percent annual herbaceous fractional components.
[c] Highly correlated with proportion of all sagebrush within 7.1 ha and removed from future analyses.
[d] Highly correlated with distance to nearest cover class I juniper and removed from future analyses.
[e] Highly correlated with distance to nearest woody wetlands and removed from future analyses.

Table A.10. All multinomial models from step 1 of model selection to evaluate habitat selection for greater sage-grouse (*Centrocercus urophasianus*) hens during the late-season period (14 June–26 July) at the macro-scale (7.1, 15.0, 94.7, and 202.6 ha) in Owyhee County, Idaho 2017–18. Proportion of sagebrush (*Artemisia* spp.), herbaceous plants, litter, bare ground, and wetland variables was estimated using 2016 National Land Cover Data fractional components, woody wetlands, and emergent herbaceous wetlands spatial layers. Proportion of western juniper (*Juniperus occidentalis*) was estimated using a spatial layer that classified all conifer canopy cover: cover class I = > 0–10% juniper cover; cover class II = > 10–20% juniper cover; cover class III = > 20% juniper cover; edge density = perimeter (m)/area (m^2); K = number of parameters multiplied by number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

		Model Fit Statistics			
Model Set	Model	K	AIC_c	ΔAIC_c	ω_i
1	Proportion of all sagebrush within 7.1 ha	4	1394.124	0.000	0.998
	Proportion of all sagebrush within 15.0 ha	4	1406.765	12.641	0.002
	Proportion of all sagebrush within 94.7 ha	4	1497.437	103.314	0.000
	Proportion of all sagebrush within 202.6 ha	4	1497.902	103.779	0.000
	Null	2	1520.856	126.733	0.000
2	Proportion of big sagebrush (*A. tridentata*) within 7.1 ha[c]	4	1389.578	0.000	0.998
	Proportion of big sagebrush within 15.0 ha	4	1401.564	11.986	0.002
	Proportion of big sagebrush within 94.7 ha	4	1496.360	106.783	0.000

Table A.10. *Continued…*

Model Set	Model	Model Fit Statistics K	AIC$_c$	ΔAIC$_c$	ω_i
2	Proportion of big sagebrush (*A. tridentata*) within 7.1 ha[c]	4	1389.578	0.000	0.998
	Proportion of big sagebrush within 15.0 ha	4	1401.564	11.986	0.002
	Proportion of big sagebrush within 94.7 ha	4	1496.360	106.783	0.000
	Proportion of big sagebrush within 202.6 ha	4	1497.538	107.960	0.000
	Null	2	1520.856	131.279	0.000
3[a]	Proportion of non-sagebrush shrubs within 15.0 ha	4	1472.176	0.000	1.000
	Proportion of non-sagebrush shrubs within 7.1 ha	4	1489.096	16.920	0.000
	Proportion of non-sagebrush shrubs within 94.7 ha	4	1497.626	25.451	0.000
	Proportion of non-sagebrush shrubs within 202.6 ha	4	1503.933	31.757	0.000
	Null	2	1520.856	48.680	0.000
4	Proportion of annual herbaceous plants within 15.0 ha	4	1515.452	0.000	0.490
	Proportion of annual herbaceous plants within 202.6 ha	4	1516.351	0.899	0.313
	Proportion of annual herbaceous plants within 7.1 ha	4	1518.667	3.215	0.098

Table A.10. *Continued…*

Model Set	Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics			
	Proportion of annual herbaceous plants within 94.7 ha	4	1519.469	4.017	0.066
	Null	2	1520.856	5.404	0.033
5[b]	Proportion of perennial herbaceous plants within 7.1 ha	4	1353.879	0.000	1.000
	Proportion of perennial herbaceous plants within 15.0 ha	4	1389.728	35.848	0.000
	Proportion of perennial herbaceous plants within 94.7 ha	4	1498.652	144.772	0.000
	Proportion of perennial herbaceous plants within 202.6 ha	4	1500.850	146.970	0.000
	Null	2	1520.856	166.977	0.000
6	Proportion of bare ground within 7.1 ha	4	1356.056	0.000	1.000
	Proportion of bare ground within 15.0 ha	4	1395.322	39.266	0.000
	Proportion of bare ground within 202.6 ha	4	1494.125	138.069	0.000
	Proportion of bare ground within 94.7 ha	4	1495.196	139.140	0.000
	Null	2	1520.856	164.800	0.000
7	Proportion of litter within 7.1 ha[c]	4	1357.956	0.000	1.000

Table A.10. *Continued…*

		Model Fit Statistics			
Model Set	Model	K	AIC_c	ΔAIC_c	ω_i
	Proportion of litter within 15.0 ha	4	1399.669	41.713	0.000
	Proportion of litter within 94.7 ha	4	1500.390	142.434	0.000
	Proportion of litter within 202.6 ha	4	1500.714	142.758	0.000
	Null	2	1520.856	162.900	0.000
8	Proportion of cover class I juniper within 202.6 ha	4	1357.278	0.000	1.000
	Proportion of cover class I juniper within 94.7 ha	4	1404.043	46.765	0.000
	Proportion of cover class I juniper within 15.0 ha	4	1487.665	130.387	0.000
	Proportion of cover class I juniper within 7.1 ha	4	1500.265	142.987	0.000
	Null	2	1520.856	163.578	0.000
9	Proportion of cover class II juniper within 7.1 ha	4	1494.233	0.000	0.917
	Proportion of cover class II juniper within 15.0 ha	4	1499.031	4.798	0.083
	Proportion of cover class II juniper within 202.6 ha	4	1512.040	17.807	0.000
	Null	2	1520.856	26.623	0.000

Table A.10. *Continued…*

Model Set	Model	K	AIC$_c$	ΔAIC$_c$	ω_i
			Model Fit Statistics		
	Proportion of cover class II juniper within 94.7 ha	4	1522.501	28.268	0.000
10	Proportion of cover class III juniper within 7.1 ha	4	1455.860	0.000	0.982
	Proportion of cover class III juniper within 15.0 ha	4	1463.813	7.952	0.018
	Proportion of cover class III juniper within 94.7 ha	4	1515.823	59.963	0.000
	Null	2	1520.856	64.996	0.000
	Proportion of cover class III juniper within 202.6 ha	4	1523.390	67.529	0.000
11	Proportion of woody wetlands within 202.6 ha[d]	4	1420.082	0.000	1.000
	Proportion of woody wetlands within 94.7 ha	4	1441.611	21.530	0.000
	Proportion of woody wetlands within 15.0 ha	4	1470.609	50.527	0.000
	Proportion of woody wetlands within 7.1 ha	4	1477.455	57.373	0.000
	Null	2	1520.856	100.774	0.000
12	Edge density of woody wetlands within 15.0 ha[d]	4	1468.154	0.000	0.999
	Edge density of woody wetlands within 7.1 ha	4	1481.769	13.615	0.001

Table A.10. *Continued…*

Model Set	Model	K	AIC$_c$	ΔAIC$_c$	ω_i
			Model Fit Statistics		
	Null	4	1520.856	52.702	0.000
	Edge density of woody wetlands within 94.7 ha	4	1523.692	55.537	0.000
	Edge density of woody wetlands within 202.6 ha	2	1524.470	56.315	0.000
13	Proportion of herbaceous wetlands within 202.6 ha	4	1479.789	0.000	1.000
	Proportion of herbaceous wetlands within 94.7 ha	4	1500.226	20.438	0.000
	Proportion of herbaceous wetlands within 7.1 ha	4	1515.999	36.211	0.000
	Proportion of herbaceous wetlands within 15.0 ha	4	1517.132	37.343	0.000
	Null	2	1520.856	41.067	0.000
14	Edge density of herbaceous wetlands within 7.1 ha	4	1447.923	0.000	0.971
	Edge density of herbaceous wetlands within 15.0 ha	4	1494.652	46.728	0.029
	Null	2	1520.856	72.933	0.000
	Edge density of herbaceous wetlands within 94.7 ha	4	1524.046	76.122	0.000
	Edge density of herbaceous wetlands within 202.6 ha	4	1524.050	76.127	0.000

Table A.10. *Continued…*

Model Set	Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics			
15	Distance (m) to nearest woody wetlands	4	1517.709	0.000	0.240
	Elevation (m)	4	1517.761	0.051	0.233
	Distance (m) to nearest cover class I juniper	4	1518.050	0.341	0.202
	Distance (m) to nearest cover class III juniper[d]	4	1518.200	0.491	0.187
	Null	2	1520.856	3.147	0.050
	Distance (m) to nearest cover class II juniper	4	1521.035	3.326	0.045
	Distance (m) to nearest herbaceous wetlands	4	1521.171	3.461	0.042

[a] Created using the difference in proportions between percent shrub and percent sagebrush fractional components.
[b] Created using the difference in proportions between percent herbaceous and percent annual herbaceous fractional components.
[c] Highly correlated with proportion of all sagebrush within 94.7 ha and removed from future analyses.
[d] Highly correlated with distance to nearest cover class I juniper and removed from future analyses.

Table A.11. All multinomial models from step 2 of model selection evaluating habitat selection for greater sage-grouse (*Centrocercus urophasianus*) hens during the early-season period (30 April–13 June) at macro-scales (7.1, 15.0, 94.7, 202.6 ha) in Owyhee County, Idaho 2017–18. Selection for juniper (*Juniperus occidentalis*) was evaluated as cover class I juniper (> 0–10% cover), cover class II juniper (> 10–20% cover), and cover class III juniper (> 20% cover). K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + Rip202	18	1050.444	0.000	0.906
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + CCIDis + Rip202	18	1057.187	6.742	0.031
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Per7 + Rip202	18	1058.454	8.010	0.017
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Per7 + Rip202	18	1058.514	8.070	0.016
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + Wet202	18	1059.277	8.833	0.011
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202	16	1060.520	10.076	0.006
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + Rip202	18	1060.993	10.549	0.005
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + RipDis	18	1061.514	11.070	0.004

Table A.11. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + Rip202	18	1061.524	11.080	0.004
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + CCIDis + Rip202	18	1064.594	14.150	0.001
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + Rip202	18	1066.524	16.080	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202 + Wet202	18	1070.724	20.280	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202 + Wet202	18	1070.924	20.480	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + CCIDis	18	1071.027	20.583	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + Rip202 + Wet202	18	1071.490	21.046	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Per7 + Rip202	18	1071.565	21.120	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Per7 + CCIDis	18	1072.260	21.816	0.000

Table A.11. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Per7 + Rip202	18	1072.307	21.863	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + Rip202	16	1072.708	22.264	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Per7 + Rip202	18	1072.818	22.374	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202 + RipDis	18	1072.988	22.544	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202	16	1073.524	23.080	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202	16	1073.954	23.510	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + Rip202 + RipDis	18	1074.259	23.815	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + Wet202	16	1075.699	25.254	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage7 + CCIDis	18	1075.830	25.386	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202 + RipDis	18	1076.115	25.670	0.000

Table A.11. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + CCIDis + Rip202	18	1076.517	26.073	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + RipDis + Wet202	18	1077.688	27.244	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + Rip202 + Wet202	18	1078.051	27.607	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Per7 + CCIDis	18	1078.824	28.379	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + RipDis	16	1079.369	28.925	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202	14	1079.700	29.256	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis	16	1081.193	30.749	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + Rip202 + RipDis	18	1081.894	31.450	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Nsage7 + Rip202	18	1082.108	31.663	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + Wet202	18	1082.266	31.822	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + Rip202	16	1082.796	32.352	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202 + RipDis	18	1083.587	33.143	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + RipDis	18	1084.582	34.137	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Rip202 + Wet202	18	1084.660	34.215	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage7 + Rip202	18	1085.481	35.037	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202 + Wet202	18	1085.778	35.334	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Rip202 + RipDis	18	1086.651	36.207	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + CCIDis + Rip202	18	1087.960	37.515	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202	16	1090.502	40.057	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Rip202	16	1090.805	40.361	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Nsage7 + CCIDis	18	1092.598	42.154	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev + CCIDis	18	1092.817	42.373	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Nsage7 + Per7	18	1094.413	43.969	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis	16	1094.461	44.016	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Per7 + CCIDis	18	1094.950	44.506	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Per7 + CCIDis	18	1095.159	44.715	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + CCIDis + Wet202	18	1095.252	44.808	0.000

Table A.11. *Continued…*

Model	Model Fit Statistics			
	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Per7 + CCIDis	18	1095.507	45.063	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage7 + Per7	18	1095.560	45.116	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + Wet202	18	1096.081	45.637	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + CCIDis	16	1096.134	45.690	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + CCIDis	16	1097.092	46.648	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + RipDis	18	1097.758	47.314	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + CCIDis + Wet202	18	1098.148	47.703	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + CCIDis + RipDis	18	1098.229	47.784	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + Wet202	18	1098.396	47.952	0.000

Table A.11. *Continued…*

Model	K	AICc	ΔAICc	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + CCIDis + RipDis	18	1098.476	48.031	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis	16	1099.401	48.957	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Per7	16	1100.035	49.591	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Per7 + Wet202	18	1100.067	49.623	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7	14	1100.990	50.546	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Per7	16	1101.019	50.575	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + CCIDis + Rip202	18	1101.122	50.678	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Wet202	16	1101.381	50.937	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7	16	1101.788	51.343	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + RipDis	18	1101.827	51.383	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + Wet202	18	1102.138	51.694	0.000

Table A.11. *Continued…*

Model	K	AICc	ΔAICc	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Per7 + Wet202	18	1102.223	51.779	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Rip202 + Wet202	18	1102.481	52.037	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Per7 + RipDis	18	1103.546	53.101	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev + Per7	18	1103.726	53.282	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Rip202 + RipDis	18	1103.741	53.297	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + RipDis	16	1104.550	54.106	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Per7 + RipDis	18	1104.914	54.470	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + RipDis + Wet202	18	1104.947	54.503	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + RipDis + Wet202	18	1105.229	54.785	0.000

Table A.11. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + RipDis	18	1105.831	55.386	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202 + Wet202	18	1105.990	55.546	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Rip202 + Wet202	18	1107.199	56.754	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + Wet202	16	1107.217	56.773	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Wet202	16	1107.440	56.996	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev + Rip202	18	1107.778	57.334	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + RipDis	16	1108.350	57.906	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + RipDis + Wet202	18	1109.044	58.600	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202 + RipDis	18	1109.601	59.157	0.000

Table A.11. *Continued…*

Model	K	AICc	ΔAICc	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + RipDis	16	1109.928	59.483	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Per7 + Wet202	18	1110.015	59.571	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + CCIDis + Wet202	18	1110.022	59.578	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis	14	1110.087	59.643	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Rip202 + RipDis	18	1110.684	60.240	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + CCIDis + Rip202	18	1111.043	60.599	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Rip202	16	1111.115	60.671	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Nsage7 + Rip202	18	1111.358	60.914	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + CCIDis + Rip202	18	1112.626	62.182	0.000

Table A.11. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Rip202	16	1112.668	62.224	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + CCIDis + RipDis	18	1112.733	62.289	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202	16	1113.080	62.636	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Nsage7 + Per7	18	1113.385	62.941	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Wet202	16	1113.435	62.991	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + CCIDis	16	1113.520	63.075	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + CCIDis + Wet202	18	1113.701	63.257	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + CCIDis	16	1113.712	63.268	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Per7	16	1114.076	63.632	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + CCIDis + RipDis	18	1114.581	64.137	0.000

Table A.11. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Per7 + Wet202	18	1115.032	64.588	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202	14	1115.105	64.660	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Wet202	16	1115.200	64.756	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Per7 + Wet202	18	1115.521	65.077	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis	14	1115.694	65.250	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7	14	1115.880	65.436	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis + Rip202 + Wet202	18	1116.077	65.633	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Per7	16	1116.463	66.019	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Per7	16	1116.513	66.069	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + Wet202	16	1116.608	66.164	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + RipDis	16	1116.615	66.171	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + RipDis + Wet202	18	1117.038	66.594	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis + Rip202 + RipDis	18	1117.124	66.679	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7	14	1117.128	66.684	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Per7 + RipDis	18	1117.237	66.793	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Per7 + RipDis	18	1117.316	66.872	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + RipDis + Wet202	18	1117.494	67.049	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis + Rip202	16	1118.324	67.880	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Nsage7 + Wet202	18	1118.593	68.149	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + RipDis	16	1118.752	68.308	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Per7 + RipDis + Wet202	18	1118.902	68.458	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + RipDis	16	1119.010	68.566	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Wet202	14	1119.310	68.866	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Per7 + RipDis	18	1119.521	69.077	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev + Nsage7	18	1120.238	69.794	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + Wet202	16	1120.872	70.428	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + Wet202	16	1121.512	71.067	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Nsage7	16	1121.534	71.090	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + RipDis + Wet202	18	1122.590	72.146	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis	14	1122.665	72.221	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7	12	1122.680	72.235	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Nsage7 + RipDis	18	1123.178	72.734	0.000

Table A.11. *Continued…*

Model	Model Fit Statistics K	AIC$_c$	ΔAIC$_c$	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Rip202 + Wet202	16	1124.801	74.357	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7 + RipDis	16	1125.090	74.646	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Rip202 + Wet202	18	1125.186	74.741	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Rip202 + RipDis + Wet202	18	1125.522	75.078	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Per7	14	1125.748	75.303	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage7 + Wet202	18	1126.755	76.311	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Rip202 + Wet202	18	1127.058	76.613	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Nsage7 + CCIDis	18	1127.765	77.321	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis + Rip202 + Wet202	18	1127.804	77.360	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Rip202 + RipDis	16	1127.812	77.368	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202	16	1128.468	78.024	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202 + Wet202	18	1128.622	78.178	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage7	16	1129.000	78.556	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis + Rip202 + RipDis	18	1129.233	78.789	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis + Rip202	16	1129.823	79.379	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Rip202 + RipDis	18	1130.159	79.715	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Rip202	16	1130.240	79.796	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Rip202	14	1130.729	80.285	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage7 + RipDis	18	1130.764	80.320	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202 + RipDis	18	1131.466	81.022	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Rip202 + RipDis	18	1131.547	81.103	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + Wet202	16	1131.633	81.189	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Rip202	16	1131.654	81.210	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7	14	1133.850	83.406	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + RipDis + Wet202	18	1135.043	84.599	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage7 + RipDis	16	1135.954	85.510	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + Wet202	16	1136.707	86.263	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + CCIDis + Wet202	18	1137.537	87.093	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + RipDis	16	1137.604	87.160	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + CCIDis	16	1137.804	87.360	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + RipDis + Wet202	18	1137.902	87.458	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202	14	1138.730	88.286	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Rip202 + Wet202	16	1138.880	88.435	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Rip202 + RipDis + Wet202	18	1140.215	89.771	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + CCIDis + RipDis	18	1140.267	89.823	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev + Wet202	18	1141.333	90.889	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Wet202	16	1141.518	91.074	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Rip202 + RipDis	16	1141.884	91.440	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Rip202	14	1143.095	92.650	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev	16	1143.873	93.429	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + RipDis + Wet202	18	1143.926	93.482	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7	14	1144.442	93.998	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + RipDis	16	1145.054	94.610	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + CCIDis	16	1145.569	95.125	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + Wet202	16	1145.895	95.451	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Bgnd7 + Elev + RipDis	18	1146.134	95.689	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + RipDis + Wet202	18	1147.919	97.475	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + CCIDis + Wet202	18	1147.931	97.487	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + Wet202	14	1148.131	97.687	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + Wet202	16	1149.288	98.844	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + CCIDis + RipDis	18	1149.337	98.893	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Wet202	14	1149.520	99.076	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + RipDis	16	1149.593	99.149	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Nsage7 + Wet202	18	1149.771	99.327	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202	14	1149.874	99.430	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis	14	1149.995	99.551	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + CCIDis + Wet202	18	1150.346	99.902	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + Wet202	16	1150.694	100.250	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + CCIDis	16	1150.707	100.263	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis	14	1150.836	100.392	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Wet202	16	1150.962	100.518	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis + Wet202	16	1151.348	100.903	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7	12	1151.509	101.065	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Nsage7	16	1152.094	101.650	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + Wet202	16	1152.331	101.887	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev	14	1152.491	102.047	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis	14	1152.811	102.367	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202	12	1152.853	102.408	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7	14	1153.070	102.625	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis + RipDis	16	1153.609	103.164	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + RipDis + Wet202	18	1153.609	103.165	0.000

Table A.11. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + RipDis + Wet202	18	1153.891	103.447	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + CCIDis + RipDis	18	1154.374	103.929	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + RipDis	16	1154.575	104.131	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Nsage7 + RipDis	16	1154.603	104.159	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Nsage7 + RipDis	18	1155.296	104.852	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + CCIDis + RipDis + Wet202	18	1155.347	104.903	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis	14	1164.505	114.060	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Wet202	14	1164.777	114.333	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7	12	1165.765	115.321	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + Wet202	16	1166.733	116.289	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Wet202	16	1166.973	116.529	0.000

Table A.11. *Continued…*

Model	K	Model Fit Statistics AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis + Wet202	16	1167.238	116.794	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev	14	1167.247	116.803	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis	14	1167.719	117.275	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + RipDis	16	1168.142	117.698	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + RipDis	14	1168.523	118.079	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + RipDis + Wet202	16	1168.579	118.135	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis + RipDis	16	1169.429	118.985	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + CCIDis + RipDis + Wet202	18	1169.817	119.373	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + RipDis + Wet202	18	1170.190	119.746	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + RipDis + Wet202	18	1170.796	120.352	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann7 + Elev + RipDis	16	1170.893	120.448	0.000

Table A.11. *Continued…*

Model	K	AICc	ΔAICc	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis	12	1171.528	121.084	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Wet202	14	1172.792	122.347	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + Wet202	16	1174.653	124.209	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis	14	1174.747	124.303	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + Wet202	16	1176.521	126.077	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7	14	1176.589	126.144	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + RipDis + Wet202	18	1178.603	128.159	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage7 + RipDis	16	1180.326	129.882	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + Wet202	14	1187.225	136.781	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7	12	1188.762	138.318	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + RipDis + Wet202	16	1189.921	139.477	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage7 + RipDis	14	1190.434	139.990	0.000

Table A.11. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Elev	12	1191.282	140.838	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Wet202	14	1191.616	141.172	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Wet202	12	1193.131	142.687	0.000
Sage7 + CCI202 + CCII7 + CCIII7[b]	10	1193.194	142.750	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis	14	1194.996	144.552	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + Wet202	16	1195.627	145.183	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis	12	1196.189	145.745	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + Wet202	14	1196.870	146.426	0.000

[a] Sage7 = proportion of sagebrush within 7.1 ha; CCI202 = proportion of cover class I juniper within 202.6 ha; CCII7 = proportion of cover class II juniper within 7.1 ha; CCIII7 = proportion of cover class III juniper within 7.1 ha; Ann7 = proportion of annual herbaceous plants within 7.1 ha; Bgnd7 = proportion of bare ground within 7.1 ha; Nsage7 = proportion of non-sagebrush shrubs within 7.1 ha; Per7 = proportion of perennial herbaceous plants within 7.1 ha; Rip202 = proportion of woody wetlands within 202.6 ha; Wet202 = proportion of herbaceous wetlands within 202.6 ha; RipDis = distance (m) to nearest woody wetlands; CCIDis = distance (m) to nearest cover class I juniper; Elev = elevation (m).
[b] Null model.

Table A.12. Multinomial models from step 2 of model selection evaluating habitat selection by greater sage-grouse (*Centrocercus urophasianus*) hens at macro-scales (7.1, 15.0, 94.7, 202.6 ha) during the late-season period (14 June–26 July) in Owyhee County, Idaho 2017–18. Selection for western juniper (*Juniperus occidentalis*) was evaluated as cover class I juniper (0–10% cover), cover class II juniper (10–20% cover), and cover class III juniper (> 20% cover). K = number of parameters multiplied by the number of reproductive groups; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + WEdge7	18	941.377	0.000	0.991
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + REdge15	18	953.210	11.833	0.003
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + RipDis	18	953.333	11.956	0.003
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202 + Wet202	18	953.387	12.011	0.002
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7 + Rip202	18	956.045	14.669	0.001
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Rip202	16	957.029	15.653	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + Rip202	18	957.694	16.318	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7 + Rip202	18	959.078	17.701	0.000

Table A.12. *Continued…*

Model	Model Fit Statistics K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + Rip202	18	959.510	18.134	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + RipDis + WEdge7	18	964.491	23.114	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Rip202 + WEdge7	18	965.014	23.637	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + Wet202 + WEdge7	18	965.394	24.017	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + RipDis + Wet202	18	966.365	24.988	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + WEdge7	16	966.411	25.034	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Rip202 + WEdge7	18	966.698	25.322	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + REdge15 + WEdge7	18	968.206	26.830	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202 + WEdge7	18	969.250	27.873	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202 + WEdge7	18	970.462	29.086	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Rip202 + RipDis	18	971.074	29.697	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + RipDis	16	971.075	29.699	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + RipDis + REdge15	18	971.710	30.334	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Rip202 + RipDis	18	972.547	31.171	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + REdge15 + Wet202	18	973.043	31.666	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Rip202 + REdge15	18	973.577	32.200	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202 + RipDis	18	973.700	32.324	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + REdge15	16	973.731	32.354	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202 + Wet202	16	974.762	33.385	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Rip202	14	974.804	33.427	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Rip202 + Wet202	18	974.891	33.514	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202 + RipDis	18	975.074	33.698	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Rip202	16	975.271	33.894	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Rip202 + REdge15	18	975.344	33.967	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + Rip202	18	975.941	34.565	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Rip202 + Wet202	18	976.070	34.694	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Rip202	16	976.107	34.730	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202 + REdge15	18	976.639	35.262	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + Rip202	18	976.778	35.401	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202 + Wet202	18	977.398	36.022	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Rip202	16	977.697	36.320	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202 + REdge15	18	977.777	36.401	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202 + Wet202	18	978.407	37.030	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + Rip202	18	978.637	37.260	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Rip202	16	978.709	37.332	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + CCIDis + Rip202	18	978.955	37.579	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + CCIDis + Rip202	18	979.143	37.766	0.000

Table A.12. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + Rip202	18	981.582	40.206	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + REdge15 + WEdge7	18	985.866	44.490	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + REdge15 + Wet202	18	992.821	51.444	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202 + WEdge7	18	993.874	52.498	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + WEdge7	18	994.283	52.907	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Wet202 + WEdge7	18	994.419	53.042	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + REdge15	18	996.168	54.791	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + WEdge7	18	996.202	54.825	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + REdge15	18	998.080	56.704	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + REdge15	16	999.759	58.382	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7 + REdge15	18	999.848	58.471	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + WEdge7	16	999.953	58.576	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7 + WEdge7	18	1000.294	58.918	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7 + REdge15	18	1001.591	60.214	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + RipDis + REdge15	18	1001.705	60.329	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + Rip202	18	1002.107	60.730	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7 + WEdge7	18	1002.320	60.943	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + RipDis + WEdge7	18	1002.471	61.094	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Rip202 + WEdge7	18	1005.300	63.923	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + Wet202 + WEdge7	18	1006.069	64.692	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202 + WEdge7	18	1007.177	65.801	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + Wet202	18	1007.867	66.490	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + Wet202	18	1009.861	68.485	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202 + Wet202	18	1010.267	68.891	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + REdge15 + WEdge7	18	1012.219	70.842	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + REdge15 + WEdge7	18	1012.584	71.207	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7 + Wet202	18	1012.949	71.573	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + RipDis + Wet202	18	1013.117	71.741	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + Wet202	16	1013.668	72.291	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + RipDis + WEdge7	18	1014.384	73.008	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + WEdge7	16	1015.049	73.672	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Wet202 + WEdge7	18	1015.342	73.966	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7 + Wet202	18	1015.739	74.362	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + REdge15 + Wet202 + WEdge7	18	1016.199	74.823	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + REdge15 + WEdge7	18	1016.232	74.855	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + REdge15 + Wet202	18	1016.263	74.886	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Rip202 + WEdge7	18	1017.074	75.698	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + REdge15 + WEdge7	16	1017.298	75.922	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + REdge15 + WEdge7	18	1017.471	76.095	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis + RipDis	18	1018.280	76.903	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + CCIDis + WEdge7	18	1018.717	77.340	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + REdge15 + WEdge7	18	1018.975	77.598	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + RipDis	18	1019.083	77.707	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Rip202 + Wet202	18	1019.388	78.012	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + CCIDis + WEdge7	18	1019.623	78.246	0.000

Table A.12. *Continued…*

Model	K	AICc	ΔAICc	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + CCIDis + REdge15	18	1019.778	78.402	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7	16	1019.891	78.514	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + WEdge7	16	1019.915	78.538	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202 + REdge15	18	1020.020	78.643	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + REdge15	16	1020.047	78.670	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Per7 + CCIDis	18	1020.141	78.765	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + REdge15 + WEdge7	18	1020.245	78.868	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7 + CCIDis	18	1020.498	79.121	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + Per7	18	1020.587	79.210	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + CCIDis + REdge15	18	1020.627	79.250	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7 + RipDis	18	1020.866	79.489	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + CCIDis	16	1021.052	79.675	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + WEdge7	18	1021.170	79.793	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + CCIDis + Rip202	18	1021.182	79.805	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7 + CCIDis	18	1021.718	80.341	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + REdge15	18	1021.723	80.347	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7 + RipDis	16	1022.034	80.658	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + RipDis + REdge15	18	1022.286	80.910	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + WEdge7	18	1022.474	81.097	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + REdge15	18	1022.869	81.492	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + REdge15 + Wet202	16	1022.898	81.521	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + REdge15 + Wet202	18	1022.932	81.556	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + Per7	18	1022.932	81.556	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + REdge15 + Wet202	18	1022.991	81.615	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Per7	16	1023.574	82.197	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + RipDis + WEdge7	18	1023.621	82.245	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Wet202 + WEdge7	18	1023.668	82.291	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202 + Wet202	18	1023.670	82.293	0.000

Table A.12. *Continued…*

	Model Fit Statistics			
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + REdge15 + Wet202	18	1023.689	82.312	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Per7	14	1023.911	82.534	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Wet202 + WEdge7	18	1024.094	82.718	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Wet202 + WEdge7	16	1024.275	82.898	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + REdge15	14	1024.597	83.221	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + REdge15 + Wet202	18	1024.806	83.430	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7 + RipDis	18	1024.809	83.432	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + REdge15 + Wet202	18	1024.945	83.568	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202 + RipDis	18	1024.981	83.605	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + REdge15	16	1025.073	83.697	0.000

Table A.12. *Continued…*

Model	Model Fit Statistics			
	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + REdge15	16	1025.202	83.825	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + RipDis + Wet202	18	1025.463	84.086	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Wet202 + WEdge7	18	1025.635	84.258	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + Per7	18	1025.773	84.396	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + WEdge7	16	1026.056	84.679	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + WEdge7	16	1026.250	84.873	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + WEdge7	14	1026.331	84.954	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + REdge15	16	1026.637	85.261	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Per7	16	1026.651	85.275	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + REdge15	18	1027.127	85.750	0.000

Table A.12. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + Wet202 + WEdge7	18	1027.177	85.800	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + REdge15	16	1027.198	85.821	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + RipDis + REdge15	18	1027.432	86.055	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + RipDis + REdge15	18	1027.606	86.230	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + WEdge7	18	1027.615	86.238	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + WEdge7	16	1027.669	86.292	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + REdge15	18	1027.703	86.326	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Rip202 + REdge15	18	1027.858	86.481	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + CCIDis + Wet202	18	1027.958	86.581	0.000

Table A.12. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + WEdge7	18	1028.155	86.778	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7 + Rip202	18	1028.641	87.264	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + Wet202	16	1028.760	87.384	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + RipDis + Wet202	18	1028.771	87.394	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + RipDis + REdge15	18	1029.248	87.871	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Rip202	16	1029.318	87.941	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202 + REdge15	18	1029.433	88.057	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + CCIDis + Rip202	18	1029.612	88.236	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + RipDis + WEdge7	18	1029.748	88.372	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + RipDis + WEdge7	18	1029.970	88.594	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202 + RipDis	18	1030.051	88.674	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + WEdge7	16	1030.149	88.773	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + CCIDis + Wet202	18	1030.259	88.883	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Rip202 + RipDis	18	1030.455	89.079	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + REdge15 + WEdge7	18	1031.100	89.724	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + Wet202	16	1031.126	89.749	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7 + Rip202	18	1031.439	90.063	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + RipDis + WEdge7	18	1031.521	90.144	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + Wet202	18	1031.527	90.150	0.000

Table A.12. *Continued…*

Model	K	AICc	ΔAICc	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Rip202 + Wet202	18	1031.682	90.306	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + Wet202	18	1033.948	92.571	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + CCIDis	16	1034.964	93.587	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Wet202 + WEdge7	18	1035.136	93.760	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis	14	1035.279	93.902	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + CCIDis + RipDis	18	1036.209	94.832	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + RipDis + REdge15	18	1036.565	95.188	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + CCIDis + RipDis	16	1036.642	95.265	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Rip202	16	1036.858	95.482	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Rip202	16	1037.057	95.681	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Wet202	16	1037.179	95.802	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + CCIDis	16	1037.233	95.857	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + CCIDis	18	1037.257	95.881	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Wet202	14	1037.599	96.222	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + CCIDis	18	1037.641	96.264	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + RipDis + Wet202	18	1037.980	96.604	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7 + Rip202	18	1037.989	96.612	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis	16	1038.180	96.804	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + CCIDis + RipDis	18	1038.331	96.955	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + CCIDis	18	1038.510	97.134	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis + Wet202	16	1038.514	97.138	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + Wet202	18	1038.739	97.363	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Wet202	16	1038.860	97.484	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + Wet202	16	1038.998	97.621	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Rip202 + WEdge7	18	1039.559	98.182	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + CCIDis + RipDis	18	1039.610	98.234	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + RipDis + Wet202	18	1039.868	98.491	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + RipDis + Wet202	18	1039.973	98.597	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + WEdge7	18	1040.484	99.107	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15	16	1040.620	99.244	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + Wet202	18	1040.684	99.308	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + REdge15	16	1040.773	99.396	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Rip202 + REdge15	18	1040.798	99.421	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + REdge15 + Wet202	18	1041.800	100.423	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7	12	1041.905	100.528	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev	14	1042.029	100.652	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + Nsage15 + RipDis	18	1042.502	101.125	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202 + RipDis	16	1042.631	101.255	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + Nsage15	18	1042.829	101.453	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7	14	1043.166	101.790	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + RipDis	14	1043.441	102.065	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev	16	1043.582	102.205	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Rip202 + RipDis	18	1043.690	102.314	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Elev + RipDis	16	1043.734	102.358	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15	14	1043.886	102.509	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + RipDis	16	1044.922	103.545	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Bgnd7 + Nsage15 + RipDis	16	1045.277	103.901	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Elev + RipDis	18	1045.399	104.023	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + CCIDis + Rip202	18	1045.548	104.172	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15	16	1045.578	104.201	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Rip202 + WEdge7	18	1045.869	104.493	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + Wet202 + WEdge7	18	1046.475	105.099	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Bgnd7 + Nsage15 + RipDis	18	1047.216	105.840	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + REdge15 + WEdge7	18	1047.379	106.002	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + REdge15 + Wet202 + WEdge7	18	1048.503	107.127	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Rip202	16	1048.955	107.578	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + RipDis + WEdge7	18	1049.251	107.875	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + REdge15	18	1049.566	108.189	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + WEdge7	16	1049.747	108.370	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7 + WEdge7	18	1050.367	108.990	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Rip202 + Wet202	18	1050.415	109.038	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Rip202	14	1050.415	109.039	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + WEdge7	16	1050.605	109.228	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202 + WEdge7	18	1051.205	109.829	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + REdge15 + WEdge7	18	1051.678	110.302	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Rip202 + REdge15	18	1052.171	110.794	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + RipDis + WEdge7	18	1052.771	111.395	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7 + WEdge7	18	1053.116	111.740	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Rip202 + WEdge7	18	1053.188	111.812	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + Wet202 + WEdge7	18	1053.244	111.867	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Rip202	16	1053.433	112.056	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Rip202 + RipDis	18	1053.443	112.067	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Wet202 + WEdge7	18	1054.383	113.006	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Rip202 + WEdge7	18	1055.168	113.792	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + REdge15 + Wet202	18	1056.289	114.912	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + CCIDis + Rip202	18	1057.012	115.635	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + WEdge7	16	1057.109	115.732	0.000

Table A.12. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Rip202 + Wet202	18	1057.793	116.416	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + REdge15 + WEdge7	18	1058.113	116.737	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + REdge15 + WEdge7	18	1058.293	116.916	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + RipDis + WEdge7	18	1058.342	116.965	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + REdge15 + WEdge7	18	1058.884	117.507	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + RipDis + Wet202	18	1059.231	117.855	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + REdge15 + Wet202	18	1059.905	118.528	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + REdge15 + WEdge7	16	1060.852	119.475	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + RipDis + REdge15	18	1061.254	119.878	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7 + REdge15	18	1061.439	120.063	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + REdge15 + WEdge7	18	1061.579	120.203	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + RipDis + WEdge7	18	1062.277	120.900	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + Wet202	16	1062.317	120.941	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + REdge15	16	1062.457	121.080	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Rip202 + REdge15	18	1062.492	121.116	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + Wet202 + WEdge7	18	1064.718	123.341	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Rip202 + RipDis	18	1064.758	123.381	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7 + REdge15	18	1065.423	124.046	0.000

Table A.12. *Continued…*

Model	Model Fit Statistics			
	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + Wet202 + WEdge7	18	1065.506	124.130	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202 + Wet202	18	1065.630	124.253	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + Wet202 + WEdge7	18	1065.799	124.423	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + Wet202 + WEdge7	16	1065.803	124.426	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Rip202 + Wet202	18	1066.119	124.742	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Rip202	16	1066.183	124.807	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + CCIDis + WEdge7	18	1066.228	124.851	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + REdge15 + Wet202 + WEdge7	18	1066.342	124.966	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + Wet202	18	1066.656	125.280	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + REdge15	16	1066.875	125.498	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + RipDis + Wet202	18	1067.175	125.798	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Wet202 + WEdge7	18	1067.368	125.991	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202 + REdge15	18	1067.588	126.211	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + RipDis + REdge15	18	1067.622	126.245	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + RipDis + Wet202	18	1067.792	126.416	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + WEdge7	16	1068.045	126.668	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Wet202 + WEdge7	18	1068.116	126.739	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + WEdge7	16	1068.168	126.791	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Wet202 + WEdge7	16	1068.351	126.974	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + CCIDis + Rip202	18	1068.376	126.999	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + REdge15 + Wet202	18	1068.573	127.197	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + REdge15 + Wet202	18	1068.708	127.332	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + Wet202 + WEdge7	18	1068.916	127.540	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202 + RipDis	18	1069.153	127.776	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + REdge15 + WEdge7	18	1069.356	127.979	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202 + RipDis	16	1069.446	128.069	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + Rip202	18	1069.454	128.078	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics AICc	ΔAICc	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7 + WEdge7	18	1069.584	128.208	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + REdge15 + Wet202	18	1069.660	128.283	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + WEdge7	14	1069.680	128.303	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + RipDis + REdge15	18	1069.809	128.432	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Rip202 + REdge15	18	1070.142	128.766	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + RipDis + WEdge7	18	1070.218	128.842	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Rip202	16	1070.291	128.914	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Rip202	14	1070.580	129.203	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + REdge15 + WEdge7	16	1070.614	129.237	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Rip202 + WEdge7	18	1070.748	129.372	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + REdge15 + Wet202	16	1071.008	129.631	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7 + Wet202	18	1071.147	129.771	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + REdge15 + Wet202	18	1071.209	129.832	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + CCIDis + REdge15	18	1071.507	130.130	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + Wet202	16	1071.604	130.227	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + WEdge7	16	1071.736	130.360	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Rip202 + Wet202	18	1071.773	130.396	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + WEdge7	16	1072.220	130.843	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Rip202 + RipDis	18	1072.381	131.004	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + Wet202	16	1072.398	131.022	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics		
		AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + REdge15 + WEdge7	18	1072.773	131.396	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + REdge15 + WEdge7	18	1073.338	131.962	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + RipDis + WEdge7	18	1073.559	132.183	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + RipDis + WEdge7	18	1073.792	132.415	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Rip202	16	1073.987	132.610	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7 + Wet202	18	1074.444	133.068	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + REdge15	16	1075.154	133.777	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + WEdge7	16	1075.427	134.050	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + REdge15	16	1076.325	134.949	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + RipDis + WEdge7	18	1076.433	135.056	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7 + REdge15	18	1076.549	135.173	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + RipDis + REdge15	18	1076.561	135.184	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Rip202 + REdge15	18	1077.039	135.662	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + CCIDis + WEdge7	18	1077.554	136.177	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + RipDis + Wet202	18	1078.993	137.617	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202 + RipDis	16	1079.302	137.925	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + RipDis + Wet202	18	1079.613	138.236	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + REdge15 + Wet202	18	1079.613	138.236	0.000

Table A.12. *Continued…*

Model	K	AICc	ΔAICc	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + REdge15 + Wet202	18	1080.372	138.996	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Rip202 + RipDis	18	1080.728	139.352	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Rip202	14	1080.777	139.400	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + Wet202	16	1080.880	139.504	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + REdge15 + Wet202	16	1081.221	139.844	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + RipDis + REdge15	18	1081.334	139.957	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + WEdge7	16	1081.345	139.968	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Rip202	16	1082.368	140.992	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + WEdge7	16	1082.451	141.075	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + Wet202	16	1082.681	141.305	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + WEdge7	14	1083.490	142.114	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + CCIDis + REdge15	18	1083.704	142.328	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis + RipDis	18	1083.991	142.614	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + Wet202	14	1084.178	142.802	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + RipDis + Wet202	18	1084.245	142.868	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + REdge15 + Wet202	18	1084.771	143.394	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + REdge15	16	1084.849	143.472	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + REdge15	16	1085.325	143.949	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + RipDis + REdge15	18	1085.393	144.016	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + RipDis + REdge15	18	1085.801	144.425	0.000

Table A.12. *Continued…*

Model	Model Fit Statistics			
	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Rip202 + Wet202	18	1086.445	145.069	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202 + RipDis	16	1087.149	145.773	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7 + RipDis	18	1087.837	146.460	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + Wet202	16	1087.920	146.544	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Rip202	14	1088.566	147.190	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Rip202 + REdge15	18	1088.579	147.203	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + REdge15	14	1088.956	147.579	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis + REdge15	16	1089.149	147.772	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7 + Wet202	18	1089.243	147.867	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + Wet202	16	1089.417	148.040	0.000

Table A.12. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + REdge15	16	1089.551	148.174	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + CCIDis + Wet202	18	1089.769	148.392	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + REdge15	16	1089.842	148.465	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Rip202 + RipDis	18	1090.084	148.707	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202 + RipDis	14	1091.544	150.167	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + RipDis + REdge15	18	1091.672	150.295	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + RipDis	16	1091.722	150.346	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + REdge15 + WEdge7	18	1091.814	150.438	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Rip202	16	1092.007	150.631	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + REdge15	16	1092.081	150.704	0.000

Table A.12. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + REdge15	14	1092.130	150.753	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Rip202	12	1093.610	152.233	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202 + RipDis	16	1094.274	152.897	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7 + RipDis	18	1094.567	153.190	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7 + CCIDis	18	1094.689	153.313	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7 + CCIDis	18	1094.795	153.418	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + CCIDis + RipDis	18	1095.123	153.746	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + RipDis + Wet202	18	1095.387	154.011	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7 + CCIDis	16	1095.478	154.102	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + RipDis + Wet202	18	1095.496	154.120	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + REdge15 + Wet202 + WEdge7	18	1095.676	154.299	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis + Wet202	16	1095.809	154.432	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Wet202 + WEdge7	18	1096.773	155.397	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Rip202	14	1096.854	155.477	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + REdge15 + WEdge7	18	1097.502	156.125	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + RipDis	16	1097.707	156.331	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + CCIDis + WEdge7	18	1098.537	157.160	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7 + RipDis	18	1098.816	157.439	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + REdge15 + WEdge7	16	1100.496	159.119	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + REdge15 + Wet202 + WEdge7	18	1101.816	160.440	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + REdge15 + Wet202	18	1102.135	160.758	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Per7	16	1102.188	160.811	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + CCIDis + Wet202	18	1102.751	161.374	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + REdge15 + WEdge7	18	1103.061	161.684	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + REdge15 + WEdge7	18	1103.237	161.861	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + WEdge7	16	1103.358	161.982	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Wet202 + WEdge7	18	1103.622	162.246	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis + REdge15 + WEdge7	18	1103.940	162.563	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + Per7	18	1104.056	162.680	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + WEdge7	18	1104.352	162.975	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + CCIDis + REdge15	18	1104.721	163.345	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + Wet202	16	1104.784	163.407	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Per7	14	1104.816	163.439	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + RipDis + WEdge7	18	1106.043	164.667	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Wet202 + WEdge7	16	1106.334	164.958	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + REdge15 + WEdge7	16	1106.596	165.219	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Per7	16	1106.648	165.271	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + REdge15 + WEdge7	18	1106.881	165.504	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + REdge15 + Wet202	18	1108.115	166.738	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis + Wet202 + WEdge7	18	1108.791	167.414	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + Wet202	14	1109.559	168.182	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Wet202 + WEdge7	18	1109.624	168.248	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Wet202 + WEdge7	18	1110.161	168.785	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + REdge15 + WEdge7	18	1110.296	168.920	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + WEdge7	16	1110.315	168.939	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + Wet202	16	1110.559	169.182	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + REdge15 + Wet202	16	1110.856	169.480	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + CCIDis + RipDis	18	1110.889	169.513	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + REdge15	16	1111.105	169.728	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7 + CCIDis	18	1112.046	170.670	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + RipDis + WEdge7	18	1112.375	170.999	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis + REdge15 + Wet202	18	1112.423	171.047	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + CCIDis + WEdge7	18	1112.560	171.183	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + RipDis + REdge15	18	1112.763	171.387	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + WEdge7	14	1112.968	171.591	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + REdge15	18	1113.248	171.871	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Wet202 + WEdge7	16	1113.581	172.205	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Wet202 + WEdge7	18	1113.923	172.546	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + RipDis	16	1114.333	172.956	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis + WEdge7	16	1114.453	173.077	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + REdge15 + Wet202	18	1114.558	173.182	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + WEdge7	16	1115.762	174.385	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + REdge15	16	1116.030	174.653	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis + RipDis	16	1116.100	174.724	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + CCIDis + WEdge7	18	1116.286	174.909	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Per7	16	1116.409	175.032	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + Wet202 + WEdge7	18	1116.413	175.036	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + REdge15 + Wet202	18	1116.758	175.381	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + RipDis	14	1116.984	175.608	0.000

(Header group "Model Fit Statistics" spans K, AIC_c, ΔAIC_c, ω_i.)

Table A.12. *Continued…*

		Model Fit Statistics		
Model	K	AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + RipDis + WEdge7	18	1117.063	175.687	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + RipDis + REdge15	18	1117.557	176.181	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + WEdge7	16	1118.011	176.635	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + CCIDis + REdge15	18	1119.112	177.736	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + REdge15 + Wet202	16	1119.381	178.005	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7 + CCIDis	16	1119.472	178.095	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + REdge15	14	1119.807	178.430	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Per7	14	1119.997	178.620	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + REdge15 + Wet202	18	1120.164	178.787	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + WEdge7	14	1120.261	178.885	0.000

Table A.12. *Continued…*

Model	K	AIC$_c$	ΔAIC$_c$	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis + REdge15	16	1120.573	179.197	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + RipDis + WEdge7	18	1120.643	179.267	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + CCIDis + Wet202	18	1120.801	179.425	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + REdge15 + Wet202	18	1120.808	179.432	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + WEdge7	16	1120.894	179.517	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + REdge15 + Wet202 + WEdge7	16	1121.875	180.498	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + REdge15 + Wet202 + WEdge7	18	1122.004	180.628	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + WEdge7	16	1122.716	181.340	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + RipDis + Wet202	18	1123.093	181.716	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics AICc	ΔAICc	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + REdge15	16	1123.151	181.775	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + RipDis + REdge15	18	1123.679	182.303	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + RipDis + WEdge7	18	1123.704	182.328	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + REdge15 + Wet202 + WEdge7	18	1124.808	183.431	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Wet202	16	1124.837	183.460	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + REdge15 + Wet202 + WEdge7	18	1124.933	183.556	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + CCIDis + REdge15	18	1125.725	184.349	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + REdge15 + WEdge7	14	1126.812	185.436	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + Wet202	18	1127.245	185.868	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + REdge15	16	1127.938	186.561	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics AICc	ΔAICc	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + REdge15 + WEdge7	16	1128.041	186.664	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7 + CCIDis	16	1128.675	187.299	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + REdge15	14	1128.721	187.344	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + REdge15	16	1128.994	187.617	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + REdge15 + WEdge7	16	1129.299	187.922	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + REdge15 + WEdge7	16	1129.472	188.095	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + RipDis + REdge15	18	1129.558	188.182	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + REdge15	16	1130.172	188.796	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + REdge15 + WEdge7	18	1130.221	188.845	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + RipDis + Wet202	18	1130.497	189.121	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics		
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + REdge15 + WEdge7	18	1130.589	189.212	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + RipDis + REdge15	18	1130.870	189.494	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + CCIDis + RipDis	18	1131.423	190.046	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis + REdge15 + WEdge7	18	1131.635	190.258	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis + Wet202	16	1131.829	190.452	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + Wet202	16	1133.158	191.781	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Per7	14	1133.202	191.826	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + CCIDis	16	1135.000	193.623	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Wet202	14	1135.154	193.778	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + RipDis + Wet202	18	1135.269	193.892	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics AICc	ΔAICc	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + RipDis	16	1135.789	194.413	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Wet202 + WEdge7	14	1136.101	194.725	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Wet202 + WEdge7	16	1136.243	194.867	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + CCIDis + Wet202	18	1136.550	195.174	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + Wet202 + WEdge7	16	1137.136	195.759	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + Wet202 + WEdge7	18	1137.287	195.910	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + CCIDis	18	1137.295	195.919	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + Wet202	16	1138.629	197.252	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Wet202 + WEdge7	18	1139.195	197.819	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Wet202 + WEdge7	16	1139.350	197.973	0.000

Table A.12. *Continued…*

Model	K	Model Fit Statistics: AIC_c	ΔAIC_c	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15 + RipDis	18	1139.388	198.012	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis + Wet202 + WEdge7	18	1140.095	198.719	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + REdge15 + Wet202	14	1140.123	198.746	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + REdge15 + Wet202	16	1140.596	199.219	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + REdge15 + Wet202	16	1141.194	199.817	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis + RipDis	16	1141.306	199.930	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + REdge15 + Wet202	18	1141.538	200.162	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev	14	1141.831	200.455	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + WEdge7	14	1142.491	201.114	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + WEdge7	12	1143.146	201.769	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + RipDis	14	1143.422	202.046	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + REdge15 + Wet202	16	1143.741	202.365	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + WEdge7	16	1143.795	202.419	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + CCIDis + RipDis	18	1143.867	202.490	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis + REdge15 + Wet202	18	1143.903	202.527	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7	12	1144.410	203.034	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + WEdge7	14	1144.426	203.049	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + REdge15 + Wet202	18	1144.644	203.268	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Per7 + CCIDis	14	1144.870	203.493	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis + WEdge7	16	1144.929	203.553	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + RipDis + Wet202	18	1145.377	204.001	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Elev + Nsage15	16	1145.476	204.100	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis + Wet202	16	1145.546	204.169	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + RipDis + WEdge7	18	1145.786	204.410	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + WEdge7	14	1145.822	204.446	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + RipDis	16	1146.070	204.694	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + WEdge7	16	1146.638	205.262	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + RipDis + Wet202	18	1147.400	206.023	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + Wet202	16	1147.438	206.061	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + CCIDis + Wet202	18	1148.066	206.690	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Wet202	14	1148.087	206.711	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + CCIDis	14	1148.598	207.221	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + REdge15	14	1148.670	207.293	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + Wet202	16	1149.596	208.219	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + REdge15	12	1149.804	208.427	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + REdge15	16	1150.444	209.067	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15 + CCIDis	16	1150.939	209.562	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + REdge15	14	1151.565	210.188	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis + REdge15	16	1151.594	210.217	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15	12	1152.340	210.963	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + REdge15	14	1153.044	211.668	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + RipDis + REdge15	18	1153.049	211.673	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + REdge15	16	1154.541	213.164	0.000

Table A.12. *Continued…*

Model	Model Fit Statistics K	AIC$_c$	ΔAIC$_c$	ω_i
Sage7 + CCI202 + CCII7 + CCIII7 + Ann15 + Nsage15	14	1154.592	213.216	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + RipDis	14	1159.626	218.249	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis + RipDis	16	1161.419	220.043	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + RipDis	16	1161.552	220.176	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + CCIDis + RipDis	18	1162.563	221.187	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis + Wet202	14	1166.844	225.467	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev	12	1167.589	226.213	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis + Wet202	16	1167.606	226.229	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + CCIDis	14	1168.553	227.176	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15 + CCIDis	16	1168.742	227.365	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Elev + Nsage15	14	1169.190	227.813	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis + Wet202	16	1170.185	228.808	0.000

Table A.12. *Continued…*

Model	K	AIC_c	ΔAIC_c	ω_i
	Model Fit Statistics			
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + RipDis + Wet202	18	1170.738	229.362	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Wet202	12	1174.169	232.792	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + Wet202	14	1174.847	233.470	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + Wet202	14	1177.506	236.130	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + Wet202	16	1177.967	236.590	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + RipDis	12	1179.472	238.096	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis + RipDis	14	1181.351	239.974	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + RipDis	14	1181.960	240.584	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis + RipDis	16	1183.568	242.191	0.000
Sage7 + CCI202 + CCII7 + CCIII7	10	1195.566	254.189	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15	12	1197.314	255.938	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + CCIDis	12	1197.472	256.095	0.000
Sage7 + CCI202 + CCII7 + CCIII7 + Nsage15 + CCIDis	14	1198.933	257.557	0.000

[a] Sage7 = proportion of sagebrush within 7.1 ha; CCI202 = proportion of cover class I juniper within 202.6 ha; CCII7 = proportion of cover class II juniper within 7.1 ha; CCIII7 = proportion of cover class III juniper within 7.1 ha; Ann15 = proportion of annual herbaceous plants within 15.0 ha; Per7 = proportion of perennial herbaceous plants within 7.1 ha; Bgnd7 = proportion of bare ground within 7.1 ha; Nsage15 = proportion of non-sagebrush shrubs within 15.0 ha; Rip202 = proportion of woody wetlands within 202.6 ha; Wet202 = proportion of herbaceous wetlands within 202.6 ha; REdge15 = edge density (perimeter (m)/area (m^2)) of woody wetlands within 15.0 ha; WEdge7 = edge density (perimeter (m)/area (m^2)) of herbaceous wetlands within 7.1 ha; RipDis = distance (m) to nearest woody wetlands; CCIDis = distance (m) to nearest cover class I juniper; Elev = elevation (m).
[b] Null model.

Influences on fecal corticosterone during the lekking period

Results from analysis evaluating influences on fecal corticosterone for greater sage-grouse (*Centrocercus urophasianus*) hens during the lekking period (4 March–8 May) in Owyhee County, Idaho 2017–18. Table A.13 is modeling results from steps 1 and 2 of model selection and Table A.14 is modeling results combining the best nuisance and ecological variables. Table A.15 is modeling results predicting hen mass by using wing chord, tarsus, and capture date as predictor variables. I used the residuals from the top model as an estimate of body condition. For each hen, I averaged all wing chord and tarsus measurements to use as a predictor variable for mass. I first used AIC_c in a model selection framework to compare models with wing chord or tarsus length as a predictor of mass, and selected the structural measurement with the lowest AIC_c value. I then included capture date to the best structural measurement and considered the model improved if ΔAIC_c was ≥ 2 (Blomberg et al. 2014).

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Table A.13. All linear mixed-effects models from steps 1 and 2 of model selection to predict fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; n = 33 hens) during the 2017–18 lekking period (4 March–8 May) in Owyhee County, Idaho. All variables that had AIC_c lower than the null model in set 1 and variables from top models within sets 2–9 were brought forward into future steps of model selection. K = number of parameters; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

		Model Fit Statistics			
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
1[b]	(Sample mass)^2	6	42.579	0.000	0.790
	Sample mass	5	46.178	3.599	0.131
	Null	4	50.017	7.439	0.019
	Elevation (m)	5	51.402	8.824	0.010
	Lek count	5	51.556	8.977	0.009
	Collection date	5	52.149	9.571	0.007
	Age	5	52.562	9.983	0.005
	Maximum temperature	5	52.602	10.024	0.005
	Precipitation	5	52.670	10.091	0.005
	Minimum temperature	5	52.676	10.097	0.005
	(Collection date)^2	6	53.208	10.630	0.004
	Elevation (m)^2	6	53.256	10.677	0.004

Table A.13. *Continued…*

		Model Fit Statistics			
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
	(Lek count)^2	6	54.443	11.864	0.002
	Precipitation^2	6	55.072	12.493	0.002
	(Maximum temperature)^2	6	55.384	12.805	0.001
	(Minimum temperature)^2	6	55.482	12.903	0.001
2	Null	3	459.607	0.000	0.250
	Proportion of annual herbaceous cover within 314.15 km^2	4	50.017	0.000	0.336
	Proportion of annual herbaceous cover within 198.50 km^2	5	51.686	1.668	0.146
	Proportion of annual herbaceous cover within 33.21 km^2	5	52.018	2.001	0.124
	Proportion of annual herbaceous cover within 0.63 km^2	5	52.217	2.200	0.112
	(Proportion of annual herbaceous cover within 198.50 km^2)^2	5	52.595	2.578	0.093
	(Proportion of annual herbaceous cover within 314.15 km^2)^2	6	53.586	3.569	0.056

Table A.13. *Continued…*

		Model Fit Statistics			
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
	(Proportion of annual herbaceous cover within 33.21 $km^2)^2$	6	53.603	3.586	0.056
	(Proportion of annual herbaceous cover within 0.63 $km^2)^2$	6	53.801	3.784	0.051
3	Proportion of perennial herbaceous cover within 0.63 km^2	5	49.320	0.000	0.222
	Null	4	50.017	0.697	0.157
	Proportion of perennial herbaceous cover within 33.21 km^2	5	50.117	0.797	0.149
	Proportion of perennial herbaceous cover within 314.15 km^2	5	50.378	1.059	0.131
	Proportion of perennial herbaceous cover within 198.50 km^2	5	50.495	1.175	0.124
	(Proportion of perennial herbaceous cover within 0.63 $km^2)^2$	6	51.603	2.283	0.071
	(Proportion of perennial herbaceous cover within 314.15 $km^2)^2$	6	51.697	2.377	0.068
	(Proportion of perennial herbaceous cover within 33.21 $km^2)^2$	6	52.536	3.216	0.045

Table A.13. *Continued…*

		Model Fit Statistics			
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
	(Proportion of perennial herbaceous cover within 198.50 $km^2)^2$	6	53.077	3.757	0.034
4	Proportion of big sagebrush (*Artemisia tridentata*) cover within 33.21 km^2	5	49.870	0.000	0.200
	Proportion of big sagebrush cover within 314.15 km^2	5	49.971	0.101	0.190
	Null	4	50.017	0.147	0.185
	Proportion of big sagebrush cover within 198.50 km^2	5	50.076	0.205	0.180
	(Proportion of big sagebrush cover within 314.15 $km^2)^2$	6	51.731	1.861	0.079
	(Proportion of big sagebrush cover within 198.50 $km^2)^2$	6	52.423	2.553	0.056
	(Proportion of big sagebrush cover within 33.21 $km^2)^2$	6	52.643	2.773	0.050
	Proportion of big sagebrush cover within 0.63 km^2	5	52.695	2.824	0.049
	(Proportion of big sagebrush cover within 0.63 $km^2)^2$	6	55.400	5.530	0.013

Table A.13. *Continued…*

			Model Fit Statistics		
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
5	Null	4	50.017	0.000	0.275
	Proportion of non-sagebrush cover within 33.21 km^2	5	51.102	1.085	0.160
	Proportion of non-sagebrush cover within 198.50 km^2	5	51.170	1.153	0.155
	Proportion of non-sagebrush cover within 314.15 km^2	5	51.275	1.258	0.147
	(Proportion of non-sagebrush cover within 33.21 $km^2)^2$	6	52.152	2.135	0.095
	Proportion of non-sagebrush cover within 0.63 km^2	5	52.727	2.710	0.071
	(Proportion of non-sagebrush cover within 198.50 $km^2)^2$	6	54.061	4.043	0.036
	(Proportion of non-sagebrush cover within 314.15 $km^2)^2$	6	54.127	4.109	0.035
	(Proportion of non-sagebrush cover within 0.63 $km^2)^2$	6	54.702	4.685	0.026
6	Null	4	50.017	0.000	0.422

Table A.13. *Continued…*

Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Proportion of western juniper (*Juniperus occidentalis*) cover within 0.63 km^2	5	52.317	2.300	0.134
	Proportion of western juniper cover within 33.21 km^2	5	52.418	2.400	0.127
	Proportion of western juniper cover within 314.15 km^2	5	52.600	2.582	0.116
	Proportion of western juniper cover within 198.50 km^2	5	52.611	2.593	0.115
	(Proportion of western juniper cover within 33.21 $km^2)^2$	6	55.201	5.184	0.032
	(Proportion of western juniper cover within 314.15 $km^2)^2$	6	55.481	5.464	0.027
	(Proportion of western juniper cover within 198.50 $km^2)^2$	6	55.500	5.483	0.027
7[b]	Null	4	50.017	0.000	0.426
	Proportion of cover class I (> 0–10% western juniper cover) within 0.63 km^2	5	52.317	2.300	0.135
	Proportion of cover class I within 33.21 km^2	5	52.569	2.551	0.119

Table A.13. *Continued…*

Model Set	Model[a]	Model Fit Statistics K	AIC_c	ΔAIC_c	ω_i
	Proportion of cover class I within 314.15 km^2	5	52.600	2.583	0.117
	Proportion of cover class I within 198.50 km^2	5	52.612	2.595	0.116
	(Proportion of cover class I within 33.21 km^2)^2	6	55.215	5.197	0.032
	(Proportion of cover class I within 198.50 km^2)^2	6	55.484	5.467	0.028
	(Proportion of cover class I within 314.15 km^2)^2	6	55.494	5.477	0.028
8[b,c]	Null	4	50.017	0.000	0.488
	Proportion of cover class II (> 10–20% western juniper cover) within 33.21 km^2	5	52.451	2.434	0.145
	Proportion of cover class II within 314.15 km^2	5	52.595	2.578	0.135
	Proportion of cover class II within 198.50 km^2	5	52.616	2.599	0.133
	(Proportion of cover class II within 33.21 km^2)^2	6	55.203	5.186	0.037
	(Proportion of cover class II within 314.15 km^2)^2	6	55.489	5.471	0.032
	(Proportion of cover class II within 198.50 km^2)^2	6	55.494	5.477	0.032
9[b,c]	Null	4	50.017	0.000	0.485

Table A.13. *Continued…*

Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Proportion of cover class III (> 20% western juniper cover) within 33.21 km^2	5	52.354	2.336	0.151
	Proportion of cover class III within 314.15 km^2	5	52.601	2.584	0.133
	Proportion of cover class III within 198.50 km^2	5	52.611	2.593	0.133
	(Proportion of cover class III within 33.21 km^2)^2	6	55.208	5.191	0.036
	(Proportion of cover class III within 314.15 km^2)^2	6	55.481	5.463	0.032
	(Proportion of cover class III within 198.50 km^2)^2	6	55.502	5.485	0.031

[a] Elevation was estimated using the elevatr package in R (Hollister and Shah 2017). Precipitation and temperature data were from three weather stations: Name (Station ID) = Orchard Range Site (674), Reynolds Creek (2029), and Mud Flat (654) (NRCS 2019). Lek surveys were conducted up to 4 times per lek each year by Idaho Fish and Game and Bureau of Land Management biologists. Big sagebrush, non-sagebrush, and herbaceous plant variables were created using 2016 National Land Cover Data fractional components. Western juniper variables were created using a spatial layer that classified all conifers. Lek nested within year was used as a random effect term.

[b] Sample mass = mass (g) of sample for corticosterone extraction; Precipitation = percent precipitation accumulated over past 30 days compared to the 30-year normal (1981–2010); Maximum temperature = average maximum temperature (°F) over the past 30 days; Minimum temperature = average minimum temperature (°F) over the past 30 days; Lek count = maximum number of hens and males on leks from survey conducted within the fewest days of collecting a fecal sample; Age = yearling or adult; Proportion = proportion of area (m^2).

[c] There was no cover class II or III cover within 0.63 km^2 of leks.

[d] Competitive with linear form and not brought forward into future steps in model selection.

Table A.14. All linear mixed-effects models with combinations of the best nuisance and ecological variables evaluating fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; n = 33 hens) during the 2017–18 lekking period (4 March–8 May) in Owyhee County, southwestern Idaho. K = number of parameters; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model[a]	K	AIC_c	ΔAIC_c	ω_i
Samplewt^2	6	42.579	0.000	0.657
Samplewt^2 + Per0.63	7	45.079	2.500	0.188
Samplewt^2 + Bsage33	7	45.475	2.896	0.154

[a] Samplewt^2 = quadratic form of mass (g) of sample used for corticosterone extraction; Per0.63 = proportion of perennial herbaceous plants within 0.63 km^2; Bsage33 = proportion of big sagebrush (*Artemisia tridentata* spp.) within 33.21 km^2 of leks; Random effects = lek within year.

Table A.15. Generalized linear models predicting mass (g) for greater sage-grouse (*Centrocercus urophasianus*; n = 33 hens) during the lekking period (4 March–8 May) in Owyhee County, Idaho 2017-18. Model set 1 compared mean length of wing chord and tarsus (cm) as predictors for mass (g). Model set 2 evaluated if including capture date improved model fit of the top model in set 1. K = number of parameters; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

		Model Fit Statistics			
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
1	Mean Length of Wing Chord	3	423.661	0.000	0.989
	Mean Length of Tarsus	3	432.851	9.190	0.010
	Null	2	437.390	13.729	0.001
2	Mean Length of Wing Chord + Capture Date	4	415.824	0.000	0.981
	Mean Length of Wing Chord	3	423.661	7.837	0.019

[a] I used the residuals from the top model in set 2 as body condition scores, which allowed me to account for the relationship between structural body size and mass. For each hen, I averaged all wing chord and tarsus measurements to use as a predictor variable for mass. I first used AIC_c in a model selection framework to compare models with wing chord or tarsus length as a predictor of mass, and selected the structural measurement with the lowest AIC_c value (Table C.3). I then included capture date to the best structural measurement and considered the model improved if ΔAIC_c was ≥ 2 (Table C.3; Blomberg et al. 2014).

Influences on fecal corticosterone during the brood-rearing period

Results from analysis evaluating influences on fecal corticosterone for greater sage-grouse (*Centrocercus urophasianus*) hens during the brood-rearing period (24 May–26 July) in Owyhee County, Idaho 2017–18. Table A.16 is modeling results from steps 1 and 2 of model selection and Table A.17 is modeling results combining the best nuisance and ecological variables.

Table A.16. All linear mixed-effects models with a single variable from steps 1 and 2 of model selection predicting fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; n = 22 hens) during the 2017–18 brood-rearing period (24 May–26 July) in Owyhee County, Idaho. All variables within each set that had AIC_c lower than the null model were brought forward into future steps of model selection unless otherwise stated. K = number of parameters; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

		Model Fit Statistics			
Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
1[b]	(Area (km^2) of Minimum Convex Polygon (MCP)^{2,}[c]	6	53.522	0.000	0.201
	Area (km^2) of MCP	5	54.536	1.014	0.121
	(Reproductive effort)^2	6	54.667	1.145	0.113
	Maximum temperature	5	55.305	1.784	0.082
	Null	4	55.340	1.819	0.081
	Reproductive effort	5	55.402	1.880	0.078
	Collection date	5	56.031	2.510	0.057
	Sample mass	5	56.117	2.595	0.055
	Minimum temperature	5	57.147	3.625	0.033
	Age	5	57.256	3.734	0.031
	Elevation (m)	5	57.772	4.250	0.024

Table A.16. *Continued…*

Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Precipitation	5	57.883	4.361	0.023
	Distance (m) of daily movement	5	57.885	4.363	0.023
	$(\text{Maximum temperature})^2$	6	58.172	4.650	0.020
	$(\text{Collection date})^2$	6	58.625	5.103	0.016
	$(\text{Sample mass})^2$	6	59.025	5.503	0.013
	$(\text{Minimum temperature})^2$	6	59.063	5.541	0.013
	Precipitation^2	6	60.478	6.956	0.006
	Elevation^2	6	60.702	7.180	0.006
	$(\text{Mean distance (m) of daily movement})^2$	6	60.790	7.268	0.005
2[b]	Proportion of cover class I (> 0–10% western juniper (*Juniperus occidentalis*) cover) within MCP	5	52.676	0.000	0.232
	Null	4	55.340	2.664	0.061
	$(\text{Proportion of cover class I within MCP})^2$	6	55.588	2.912	0.054
	$(\text{Proportion of non-sagebrush cover within MCP})^2$	6	55.850	3.174	0.048

Table A.16. *Continued…*

Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	(Proportion of western juniper cover within MCP)^2	6	56.177	3.501	0.040
	Proportion of herbaceous wetlands within MCP	5	56.297	3.621	0.038
	Proportion of big sagebrush cover (*Artemisia tridentata*) within MCP	5	56.301	3.625	0.038
	Proportion of cover class II (> 10–20% western juniper cover)	5	56.412	3.736	0.036
	Proportion of cover class III (> 20% western juniper cover)	5	56.412	3.736	0.036
	Proportion of perennial herbaceous cover within MCP	5	56.736	4.060	0.031
	Edge density (perimeter (m)/area (m)^2) of woody wetlands within MCP	5	56.896	4.220	0.028
	Proportion of use locations within cover class I	5	56.958	4.282	0.027
	Mean distance (m) to herbaceous wetlands	6	57.176	4.500	0.024
	Proportion of annual herbaceous cover within MCP	5	57.511	4.835	0.021
	Proportion of non-sagebrush cover within MCP	5	57.567	4.891	0.020

Table A.16. *Continued…*

Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	Proportion of woody wetlands within MCP	5	57.669	4.993	0.019
	Mean distance (m) to herbaceous wetlands	5	57.681	5.005	0.019
	(Proportion of cover class II)^2	6	57.720	5.044	0.019
	(Proportion of cover class III)^2	6	57.720	5.044	0.019
	Mean distance (m) to woody wetlands	5	57.750	5.074	0.018
	Edge density (perimeter (m)/area (m)^2) of herbaceous wetlands within MCP	5	57.855	5.179	0.017
	Mean distance (m) to cover class III	5	58.030	5.354	0.016
	Mean distance (m) to cover class II	5	58.054	5.378	0.016
	Mean distance (m) to cover class I	5	58.066	5.390	0.016
	Proportion of western juniper cover within MCP	5	58.075	5.399	0.016
	(Proportion of perennial herbaceous cover within MCP)^2	6	58.594	5.918	0.012
	(Proportion of big sagebrush cover within MCP)^2	6	58.717	6.040	0.011
	(Proportion of herbaceous wetlands within MCP)^2	6	59.056	6.380	0.010
	(Mean distance (m) to woody wetlands)^2	6	59.236	6.560	0.009

Table A.16. *Continued…*

Model Set	Model[a]	K	AIC_c	ΔAIC_c	ω_i
		Model Fit Statistics			
	(Edge density (perimeter (m)/area (m)^2) of woody wetlands within MCP)^2	6	59.335	6.659	0.008
	(Proportion of woody wetlands within MCP)^2	6	59.553	6.876	0.007
	(Mean distance (m) to cover class I)^2	6	59.751	7.075	0.007
	(Proportion of use locations within cover class I)^2	6	59.833	7.157	0.006
	(Edge density (perimeter (m)/area (m)^2) of herbaceous wetlands within MCP)^2	6	59.910	7.234	0.006
	(Proportion of annual herbaceous cover within MCP)^2	6	60.378	7.702	0.005
	(Mean distance (m) to cover class II)^2	6	60.453	7.777	0.005
	(Mean distance (m) to cover class III)^2	6	60.607	7.931	0.004

[a] Minimum convex polygons were created using all use locations between the first location of a hen for each year and the location a sample was collected. Elevation was estimated using the elevatr package in R (Hollister and Shah 2017). Precipitation and temperature data were from three weather stations: Name (Station ID) = Orchard Range Site (674), Reynolds Creek (2029), and Mud Flat (654) (NRCS 2019). Lek surveys were conducted up to 4 times per lek each year by Idaho Fish and Game and Bureau of Land Management biologists. Big sagebrush, non-sagebrush, and herbaceous plant variables were created using 2016 National Land Cover Data (NLCD) fractional components. Western juniper variables were created using a spatial layer that classified all conifers. Woody wetland (> 20% cover of shrubs and trees) and herbaceous wetland (> 80% perennial herbaceous

cover) variables were created using 2016 NLCD spatial layers. Individual and year were used as random effect terms.

[b] Sample mass = mass (g) of sample for corticosterone extraction; Precipitation = percent precipitation accumulated over past 30 days compared to the 30-year normal (1981–2010); Maximum temperature = average maximum temperature (°F) over the past 30 days; Minimum temperature = average minimum temperature (°F) over the past 30 days; Reproductive effort = cumulative days laying eggs, incubating nest(s), and rearing chicks; Age = yearling or adult; Proportion = proportion of area (m^2).

[c] Quadratic form ΔAIC_c was not ≥ 2 than linear form and not brought forward into future steps of model selection.

Table A.17. Final linear mixed-effects models from step 1 of model selection predicting fecal corticosterone metabolites (ng/g) of greater sage-grouse (*Centrocercus urophasianus*; n = 22 hens) during the 2017–18 brood-rearing period (24 May–26 July) in Owyhee County, Idaho. All models that had $\Delta AIC_c < 2$ than the top model were brought forward to step 3 of model selection unless otherwise stated. K = number of parameters; AIC_c = Akaike's Information Criterion score for small sample sizes; ΔAIC_c = difference in Akaike's Information Criterion score from the top model; ω_i = Akaike weights.

	Model Fit Statistics			
Model[a]	K	AIC_c	ΔAIC_c	ω_i
MCPArea + MaxTemp	6	52.404	0.000	0.312
MCPArea + $RepEffort^2$	7	53.693	1.289	0.164
MCPArea	5	54.536	2.131	0.107
$RepEffort^2$	6	54.667	2.263	0.101
MaxTemp	5	55.305	2.901	0.073
Null	4	55.340	2.936	0.072
MCPArea*MaxTemp	7	55.527	3.123	0.065
MaxTemp* $RepEffort^2$	9	55.855	3.451	0.056
MaxTemp + $RepEffort^2$	7	56.742	4.338	0.036
MCPArea* $RepEffort^2$	9	58.504	6.100	0.015

[a] MCPArea = area (km^2) of minimum convex polygon (MCP) surrounding use locations; MaxTemp = mean maximum temperature (°F) from the past 30 days; $RepEffort^2$ = quadratic form of cumulative days laying eggs, incubating nest(s), and rearing chicks; random effect terms = individual and year.

Appendix B Model validation for fecal corticosterone metabolites

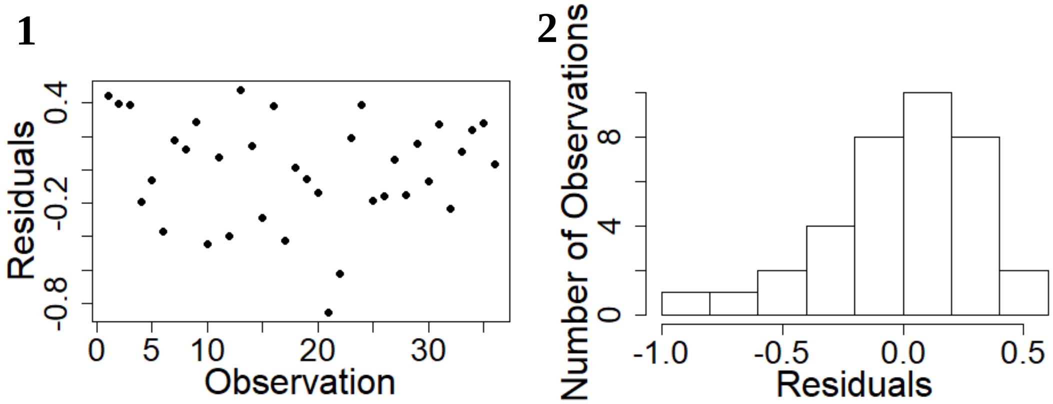

Figure B.1. Residuals from top models evaluating fecal corticosterone metabolites (ng/g) during the lekking season (4 March–8 May) of greater sage-grouse (*Centrocercus urophasianus*; *n* = 33 hens) in Owyhee County, Idaho 2017–18.Scatterplot (1) used to test homogeneity and histogram (2) used to test normality. Predictor variables = mass (g) of sample used to extract corticosterone; Random effect term = lek nested within year.

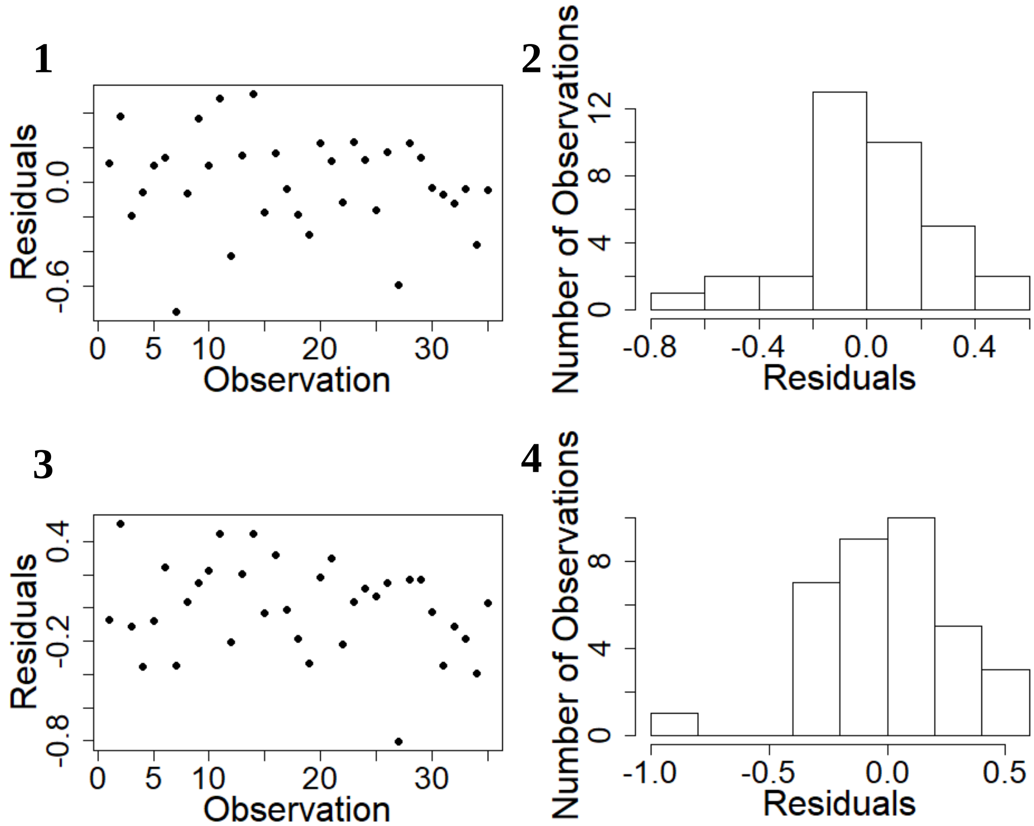

Figure B.2. Residuals from top model evaluating fecal corticosterone metabolites (ng/g) during the brood-rearing period (23 May–26 July) of greater sage-grouse (*Centrocercus urophasianus*; *n* = 22 hens) in Owyhee County, Idaho 2017–18. Scatterplot (1 & 3) used to test homogeneity and histogram (2 & 4) used to test normality. Predictor variables: plots 1 & 2 = area (km^2) of minimum convex polygon (MCP), quadratic form of cumulative days laying eggs, incubating nest(s), and rearing chicks, and proportion of cover class I (> 0–10% western juniper (*Juniperus occidentalis*) cover) within MCP; plots 3 & 4 = area (km^2) of MCP and mean maximum temperautre (°F) over past 30 days; random effect terms = individual hen and year.