

AN ABSTRACT OF THE THESIS OF

Vanessa Schroeder for the degree of Master of Science in Wildlife Science presented on December 3, 2020.

Title: The Role of Grazing and Weather in Nest Predator-Prey Dynamics and Reproductive Success of Sagebrush-obligate Songbirds

Abstract approved:

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Livestock grazing occurs worldwide, spanning over 25% of land globally. Effective conservation of biodiversity relies upon understanding the interactions of agricultural management practices and increasingly variable weather associated with climate change. I evaluated grazing, weather and predator-prey interactions within a grazing experiment in the sagebrush ecosystem of southeastern Oregon. I studied key weather variables, nest predator activity and the nest success rates of two species of sagebrush-obligate songbirds, Brewer's sparrow (*Spizella breweri*) and sagebrush sparrow (*Artemisiospiza nevadensis*) under dormant season grazing, rotational grazing and a no-graze control. I found that while weather was an important factor explaining nest success for both songbird species, nest success for sagebrush sparrows increased in grazed pastures relative to no grazing. Grazing influenced the nest predator community of these songbirds and was likely one mechanism explaining the increase in sagebrush sparrow nest success relative to a no-graze control. Nest predator activity was lower for most predators in rotationally grazed pastures relative to no grazing, and lower rodent and badger activity was associated with higher songbird nest success. Ten species, predominately birds and snakes were documented on camera depredating failed Brewer's sparrow and sagebrush sparrow nests. My results suggest that reductions in screening cover caused by grazing within the range of reductions observed in my study do not present a threat to these birds, and conservation should focus on

management to mitigate the negative effects of extreme weather on the sagebrush ecosystem and associated wildlife. Grazing can have unexpected indirect effects on wildlife population dynamics, and it is important for managers to understand the mechanisms behind grazing effects. Effective conservation will also rely on understanding how land management interacts with other ecosystem issues such as predator-prey dynamics and increasingly variable weather associated with climate change.

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The Role of Grazing and Weather in Nest Predator-Prey Dynamics and Reproductive
Success of Sagebrush-obligate Songbirds

by
Vanessa Schroeder

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Vanessa Schroeder, Author

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CHAPTER 1

GENERAL INTRODUCTION

Vanessa Schroeder

Wildlife populations are precipitously declining worldwide due to human-induced habitat modification, fragmentation and loss (Fischer and Lindenmayer, 2007; Foley et al., 2005; Vitousek et al., 1997). The sagebrush ecosystem is among those at greatest risk, having reduced drastically in size since European settlement, owing to landscape-scale modifications and their interactions with climate change (Davies et al., 2011). The sagebrush-ecosystem supports a diversity of wildlife species, providing essential habitat for the particularly vulnerable and declining group of sagebrush-obligate birds, including Brewer's sparrow (*Spizella breweri*), sagebrush sparrow (*Artemisiospiza nevadensis*) and sage thrasher (*Oreoscoptes montanus*), which require adequate levels of sagebrush and herbaceous cover for nesting. Population declines of these species have paralleled habitat loss and fragmentation resulting from the primary threats to the ecosystem, including invasion by annual grasses, encroachment by juniper and altered fire regimes, reduced reproductive success and increased predation (Connelly et al., 2011; Davies et al., 2011, Hethcoat and Chalfoun, 2015a; Knick et al., 2003, 2005; Nielson et al., 2015; Sauer et al., 2013; Vander Haegen, 2007). In the face of multifaceted, landscape scale threats and wildlife population declines in the sagebrush ecosystem, it is imperative to maintain the productivity and resiliency of the remaining tracts of sagebrush habitat. Effective long-term ecosystem management relies on understanding the mechanisms influencing ecosystems, including weather, predator-prey dynamics and primary land uses, such as livestock grazing, so managers may mitigate effects on species in precipitous decline, such as shrubland songbirds.

Understanding the role weather plays in wildlife population dynamics, and to what extent changing weather conditions influence management decisions, is critical for continued conservation of at-risk wildlife. Weather has been shown to influence reproductive success in songbirds (Ricklefs, 1969), a pattern also observed in sagebrush-obligate songbirds (Petersen et al., 1986). Severe weather can affect food availability, potentially leading to delayed fledging and lowered recruitment (Shutler et al., 2006), reduced nestling growth rates (Wright et al., 1998) and increased nestling mortality rates

(Zanette et al., 2006). Rainfall and temperature have been shown to significantly affect reproductive success and timing, nest success and nestling growth rates from coastal rain forests to the arctic (Chase et al., 2005; Gaston et al., 2005; Pérez et al., 2016). The expectation of increased precipitation intensity and variability in summer temperatures and number of extreme warm days due to climate change (Meehl et al., 2000, 2016) heightens the need for information regarding the effect of weather on sagebrush-obligate songbird reproductive success.

Livestock grazing is the predominant use of the sagebrush ecosystem and has the potential to influence both the plant community and wildlife populations through potential shifts in food resources, cover availability or predator populations (Coates et al., 2016a; DeBano, 2006; Jones, 2000; Krausman et al., 2009; Kruess and Tschardtke, 2002; Vander Haegen et al., 2000). Habitat structure is an essential aspect of quality habitat driving habitat use and fledgling success of sagebrush-obligate songbirds. Shrub canopy cover provides vertical visual obstruction from avian predators, while bunchgrass and shrub volume laterally obscure nesting sagebrush-obligate songbirds from land-based predators. Cattle grazing can affect habitat structure through its influences on sagebrush and bunchgrass cover and density. While overgrazing during the growing season has been identified as a potential threat to sagebrush-obligate avian species (Beck and Mitchell, 2000; Monroe et al., 2017), common moderate grazing regimes incorporating rest and rotation have not been connected to changes in sagebrush-obligate avian species' reproductive success (Dettenmaier, 2018; Ruth, 2019; Smith et al., 2018b, 2018a).

Cattle have not been identified as a depredation threat to sagebrush-obligate songbirds, as trampling or eating of nest contents has rarely occurred (Welstead, 1996). However, the effect of livestock grazing on sagebrush-obligate avian species is most often assumed to occur as an indirect effect from a reduction in herbaceous or shrub nest-concealment, a metric thought to correlate with predation risk (Borgmann and Conway, 2015; Gregg and Crawford, 2009; Sveum et al., 1998). Predation ranks as the primary cause of nest failure in passerines and has the potential to influence species

demography (Martin, 1995; Ricklefs, 1969). Predators of songbird nests in sagebrush ecosystems are known to include birds, reptiles and mammals, particularly rodents (Chalfoun and Martin, 2007, 2010; Hethcoat and Chalfoun, 2015a; Ribic et al., 2012; Vander Haegen et al., 2002; Welstead et al., 2005). However, identities of predators of sagebrush sparrow nests are largely assumed, as no research has enumerated their nest predator assemblages. In addition to indirect effects caused by reductions in herbaceous cover, livestock grazing could have varying direct and indirect effects on potential nest predators through a change in food resources, alteration in screening cover for ground-dwelling predators or direct avoidance of cattle. A grazing-induced change in the local nest predator community could increase songbird nest success through a reduction in nest predators such as snakes (Larson, 2014), rodents (Bich et al., 1995; Bock et al., 1984; Jones et al., 2003; Medin and Clary, 1989), raptors (Johnson and Horn, 2008) and badgers (Bylo et al., 2014). The role cattle grazing and differing grazing management regimes play in structuring nest predator communities in the sagebrush ecosystem has yet to be studied.

In this study we implemented a spatially replicated cattle grazing experiment assessing how dormant season grazing and rotational spring/summer grazing influenced nest success and predator activity in pastures and at songbird nests relative to a control pasture experiencing no grazing during the study. We collected nest success and predator activity data using a variety of methods to address the following objectives:

1. Evaluate differences in sagebrush-obligate songbird nest success in pastures experiencing different grazing regimes.
 - 1.1 Quantify weather, specifically precipitation and temperature, during the nesting season.
 - 1.2 Develop a set of vegetative habitat variables at study sites that predict nest success.
 - 1.3 Estimate daily survival rates (DSR) in relation to weather, grazing, and vegetation.

2. Evaluate the hypothesis that predator activity was one mechanism behind a grazing-induced increase in nest success.
 - 2.1 Assess the influence of grazing on predator communities of sagebrush-obligate songbird nests across an experimental landscape where timing of grazing was manipulated.
 - 2.2 Enumerate nest predator assemblages for sagebrush sparrow and Brewer's sparrow.
 - 2.3 Evaluate which predators were most responsible for nest losses and how they varied across grazing treatment pastures.

REFERENCES

- Beck, J.L., Mitchell, D.L., 2000. Influences of livestock grazing on sage grouse habitat. *Wildl. Soc. Bull.* 28, 993–1002. <https://doi.org/10.2307/3783858>
- Bich, B.S., Butler, J.L., Schmidt, C.A., 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides* / *Hilaria jamesii* communities of Glen Canyon National Recreation Area. *Southwest. Assoc. Nat.* 40, 281–287.
- Bock, C.E., Bock, J.H., Kenney, W.R., Hawthorne, V.M., 1984. Responses of birds, rodents, and vegetation to livestock Enclosure in a semidesert grassland site. *J. Range Manag.* 37, 239–242.
- Borgmann, K.L., Conway, C.J., 2015. The nest-concealment hypothesis: New insights from a comparative analysis. *Wilson J. Ornithol.* 127, 646–660. <https://doi.org/10.1676/14-162.1>
- Bylo, L.N., Koper, N., Molloy, K.A., 2014. Grazing intensity influences ground squirrel and American badger habitat use in mixed-grass prairies. *Rangel. Ecol. Manag.* 67, 247–254. <https://doi.org/10.2111/REM-D-13-00152.1>
- Chalfoun, A.D., Martin, T.E., 2010. Facultative nest patch shifts in response to nest predation risk in the Brewer's sparrow: A "win-stay, lose-switch" strategy? *Oecologia* 163, 885–892. <https://doi.org/10.1007/s00442-010-1679-0>
- Chalfoun, A.D., Martin, T.E., 2007. Assessments of habitat preferences and quality depend on spatial scale and metrics of fitness. *J. Appl. Ecol.* 44, 983–992. <https://doi.org/10.1111/j.1365-2664.2007.01352.x>
- Chase, M., Nur, N., Geupel, G., 2005. Effects of weather and population density on reproductive success and population dynamics in a song sparrow (*Melospiza melodia*) population: A long-term study. *Auk* 122, 571–592. [https://doi.org/10.1642/0004-8038\(2005\)122\[0571:EOWAPD\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2005)122[0571:EOWAPD]2.0.CO;2)
- Coates, P.S., Brussee, B.E., Howe, K.B., Gustafson, K.B., Casazza, M.L., Delehanty, D.J., 2016. Landscape characteristics and livestock presence influence common ravens: Relevance to greater sage-grouse conservation. *Ecosphere* 7, 1–20. <https://doi.org/10.1002/ecs2.1203>
- Connelly, J.W., Hagen, C.A., Schroeder, M.A., 2011. Characteristics and dynamics of greater sage-grouse populations, in: *Studies in Avian Biology*. pp. 53–67.
- Davies, K.W., Boyd, C.S., Beck, J.L., Bates, J.D., Svejcar, T.J., Gregg, M.A., 2011. Saving the sagebrush sea: An ecosystem conservation plan for big sagebrush plant communities. *Biol. Conserv.* 144, 2573–2584. <https://doi.org/10.1016/j.biocon.2011.07.016>
- Debano, S.J., 2006. Effects of livestock grazing on aboveground insect communities in semi-arid grasslands of southeastern Arizona. *Biodivers. Conserv.* 15, 2547–2564. <https://doi.org/10.1007/s10531-005-2786-9>
- Dettenmaier, S.J., 2018. Effects of livestock grazing management practices on greater sage-grouse nest and female survival. Utah State University.

- Fischer, J., Lindenmayer, D.B., 2007. Landscape modification and habitat fragmentation: A synthesis. *Glob. Ecol. Biogeogr.* 16, 265–280. <https://doi.org/10.1111/j.1466-8238.2007.00287.x>
- Foley, J.A., DeFries, R., Asner, G.P., Barford, C., Bonan, G., Carpenter, S.R., Chapin, F.S., Coe, M.T., Daily, G.C., Gibbs, H.K., Helkowski, J.H., Holloway, T., Howard, E.A., Kucharik, C.J., Monfreda, C., Patz, J.A., Prentice, I.C., Ramankutty, N., Snyder, P.K., 2005. Global consequences of land use. *Science*. 309, 570–574. <https://doi.org/10.1126/science.1111772>
- Gaston, A. J., Martin, J.L., Allombert, S., 2005. Sea surface temperatures mediated by the El Niño-Southern Oscillation affect birds breeding in temperate coastal rain forests. *Avian Conserv. Ecol.* 1, 4.
- Gregg, M.A., Crawford, J.A., 2009. Survival of greater sage-grouse chicks and broods in the northern Great Basin. *J. Wildl. Manage.* 73, 904–913. <https://doi.org/10.2193/2007-410>
- Hethcoat, M.G., Chalfoun, A.D., 2015. Towards a mechanistic understanding of human-induced rapid environmental change: A case study linking energy development, nest predation and predators. *J. Appl. Ecol.* 52, 1492–1499. <https://doi.org/10.1111/1365-2664.12513>
- Johnson, M.D., Horn, C.M., 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. *West. North Am. Nat.* 68, 444–452. <https://doi.org/10.3398/1527-0904-68.4.444>
- Jones, A.L., 2000. Effects of cattle grazing on North American arid ecosystems: A quantitative review. *West. North Am. Nat.* 60, 155–164. <https://doi.org/10.2307/41717026>
- Jones, Z.F., Bock, C.E., Bock, J.H., 2003. Rodent communities in a grazed and ungrazed Arizona grassland, and a model of habitat relationships among rodents in southwestern grass/shrublands. *Am. Midl. Nat.* 149, 384–394. [https://doi.org/10.1674/0003-0031\(2003\)149](https://doi.org/10.1674/0003-0031(2003)149)
- Knick, S.T., Dobkin, D.S., Rotenberry, J.T., Schroeder, M.A., Vander Haegen, W.M., van Riper, C., 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. *Condor* 105, 611. <https://doi.org/10.1650/7329>
- Knick, S.T., Holmes, A.L., Miller, R.F., 2005. The role of fire in structuring sagebrush habitats and bird communities, in: *Studies in Avian Biology*. pp. 1–13.
- Krausman, P.R., Naugle, D.E., Frisina, M.R., Northrup, R., Bleich, V.C., Block, W.M., Wallace, M.C., Wright, J.D., 2009. Livestock grazing, wildlife habitat, and rangeland values. *Rangelands* 31, 15–19. <https://doi.org/10.2111/1551-501X-31.5.15>
- Kruess, A., Tschardtke, T., 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biol. Conserv.* 106, 293–302. [https://doi.org/10.1016/s0006-3207\(01\)00255-5](https://doi.org/10.1016/s0006-3207(01)00255-5)
- Larson, D.M., 2014. Grassland fire and cattle grazing regulate reptile and amphibian assembly among patches. *Environ. Manage.* 54, 1434–1444. <https://doi.org/10.1007/s00267-014-0355-2>
- Martin, T.E., 1995. Avian life history evolution in relation to nest sites, nest predation, and food. *Ecol. Monogr.* 65, 101–127. <https://doi.org/10.2307/2937160>

- Medin, D.E., Clary, W.P., 1989. Small mammal populations in a grazed and ungrazed riparian habitat in Nevada. Ogden, UT.
- Meehl, G.A., Tebaldi, C., Adams-Smith, D., 2016. US daily temperature records past, present, and future. *Proc. Natl. Acad. Sci. U. S. A.* 113, 13977–13982. <https://doi.org/10.1073/pnas.1606117113>
- Meehl, G.A., Zwiers, F., Evans, J., Knutson, T., Mearns, L., Whetton, P., 2000. Trends in extreme weather and climate events: Issues related to modeling extremes in projections of future climate change. *Bull. Amer. Meteor. Soc.* 81, 427–436.
- Monroe, A.P., Aldridge, C.L., Assal, T.J., Veblen, K.E., Pyke, D.A., Casazza, M.L., 2017. Patterns in greater sage-grouse population dynamics correspond with public grazing records at broad scales. *Ecol. Appl.* 27, 1096–1107. <https://doi.org/10.1002/eap.1512>
- Nielson, R.M., McDonald, L.L., Mitchell, J., Howlin, S., Lebeau, C., 2015. Analysis of greater sage-grouse lek data: Trends in peak male counts 1965–2015. Cheyenne, Wyoming, USA.
- Pérez, J.H., Krause, J.S., Chmura, H.E., Bowman, S., McGuigan, M., Asmus, A.L., Meddle, S.L., Hunt, K.E., Gough, L., Boelman, N.T., Wingfield, J.C., 2016. Nestling growth rates in relation to food abundance and weather in the Arctic. *Auk* 133, 261–272. <https://doi.org/10.1642/AUK-15-111.1>
- Petersen, K.L., Best, L.B., Winter, B., 1986. Growth of nestling sage sparrows and Brewer's sparrows. *Willson Bull.* 98, 535–546.
- Ribic, C.A., Thompson, F.R., Piets, P.J., 2012. Video surveillance of nesting birds, 43rd ed. University of California Press, Berkeley, CA.
- Ricklefs, R.E., 1969. An analysis of nesting mortality in birds. *Smithson. Contrib. to Zool.* 9, 1–48. <https://doi.org/10.5479/si.00810282.9>
- Ruth, K.A., 2019. Population and breeding ecology of sagebrush steppe songbirds. University of Montana.
- Sauer, J.R., Link, W.A., Fallon, J.E., Pardieck, K.L., Ziolkowski, D.J., 2013. The North American Breeding Bird Survey 1966–2011: Summary analysis and species accounts. *North Am. Fauna* 79, 1–32. <https://doi.org/10.3996/nafa.79.0001>
- Shutler, D., Clark, R.G., Fehr, C., Diamond, A.W., 2006. Time and recruitment costs as currencies in manipulation studies on the costs of reproduction. *Ecology* 87, 2938–2946. [https://doi.org/10.1890/0012-9658\(2006\)87\[2938:TARCAC\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2006)87[2938:TARCAC]2.0.CO;2)
- Smith, J.T., Tack, J.D., Berkeley, L.I., Szczypinski, M., Naugle, D.E., 2018a. Effects of rotational grazing management on nesting greater sage-grouse. *J. Wildl. Manage.* 82, 103–112. <https://doi.org/10.1002/jwmg.21344>
- Smith, J.T., Tack, J.D., Berkeley, L.I., Szczypinski, M., Naugle, D.E., 2018b. Effects of livestock grazing on nesting sage-grouse in central Montana. *J. Wildl. Manage.* 82, 1503–1515. <https://doi.org/10.1002/jwmg.21500>

- Sveum, C.M., Daniel, W.D., Crawford, J.A., 1998. Nesting habitat selection central Washington by sage grouse in south-central Washington. *J. Range Manag.* 51, 265–269.
- Vander Haegen, W.M., 2007. Fragmentation by agriculture influences reproductive success of birds in a shrubsteppe landscape. *Ecol. Appl.* 17, 934–947. <https://doi.org/10.1890/06-0990>
- Vander Haegen, W.M., Dobler, F.C., Pierce, D.J., 2000. Shrubsteppe bird response to habitat and landscape variables in Eastern Washington, USA. *Conserv. Biol.* 14, 1145–1160. <https://doi.org/10.1046/j.1523-1739.2000.99293.x>
- Vander Haegen, W.M., Schroeder, M.A., DeGraaf, R.M., 2002. Predation on real and artificial nests in shrubsteppe landscapes fragmented by agriculture. *Condor* 496–506. [https://doi.org/10.1650/0010-5422\(2002\)104](https://doi.org/10.1650/0010-5422(2002)104)
- Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M., 1997. Human domination of Earth's ecosystems. *Science.* 494–499. https://doi.org/10.1007/978-0-387-73412-5_1
- Welstead, K., 1996. Factors affecting nest predation of artificial and real sagebrush Brewer's sparrow (*Spizella breweri breweri*) nests in the South Okanagan and Similkameen Valleys, British Columbia. The University of British Columbia.
- Welstead, K., Krannitz, P., Mahony, N., 2005. Using survival analysis of artificial and real Brewer's sparrow (*Spizella breweri breweri*) nests to model site level and nest site factors associated with nest success in the South Okanagan region of Canada, USDA Forest Service General Technical Report.
- Wright, J., Both, C., Cotton, P.A., Bryant, D., 1998. Quality vs. quantity: energetic and nutritional trade-offs in parental provisioning strategies. *J. Anim. Ecol.* 67, 620–634. <https://doi.org/10.1046/j.1365-2656.1998.00221.x>
- Zanette, L.Y., Clinchy, M., Smith, J.N.M., 2006. Combined food and predator effects on songbird nest survival and annual reproductive success: Results from a bi-factorial experiment. *Oecologia* 147, 632–640. <https://doi.org/10.1007/s00442-005-0330-y>

CHAPTER 2

Grazing and Weather Explain Differences in Sagebrush-Obligate Songbird Nest Success

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INTRODUCTION

Effective conservation of biodiversity relies upon understanding how working landscapes affect wildlife populations (Dirzo et al., 2014; König et al., 2020; Vitousek et al., 1997). Given the increasing demand for multiple land-uses, particularly for agricultural lands, understanding the interactions of agricultural management practices and natural sources of variation in population dynamics can help guide management and conservation (Hovick et al., 2015). For example, grazing, one of the world's most widespread agricultural activities, covers at least 25% of global land surface and occurs across most biomes, particularly grasslands, open woodlands, deserts and sagebrush ecosystems (Asner et al., 2004). Livestock grazing may play an important role in wildlife population dynamics, such as songbirds, by altering plant community composition and structure (Johnson et al., 2011; Jones, 2000), changing the distribution and abundance of predators (Bock et al., 1984; Bylo et al., 2014; Coates et al., 2016a; Johnson and Horn, 2008; Jones et al., 2003; Larson, 2014; Mullen et al., 2013) or via direct interactions with cattle (Nack and Ribic, 2005; Paine et al., 1996).

Seasonal timing of grazing may lead to varying effects on songbirds. For example, grazing during the dormant season when birds are not breeding can eliminate direct interactions between cattle and songbirds. Yet both dormant and growing season grazing may reduce available vegetative cover, potentially influencing available screening cover for nesting or food resources for birds or some of their omnivorous predators (Davies et al., 2018; DeBano, 2006; Kruess and Tschardtke, 2002; Torre et al., 2007). Excessive grazing pressure during the growing season has been identified as a potential threat to sagebrush-obligate avian species (Beck and Mitchell, 2000; Monroe et al., 2017), but moderate grazing regimes incorporating rest and rotation have not been associated with decreasing bird reproduction (Dettenmaier, 2018; Ruth, 2019; Smith et al., 2018a, 2018b).

While grazing effects on sagebrush-obligate songbird populations remains poorly quantified, weather effects are better understood. Weather might play the most significant role in determining reproductive success in sagebrush birds (Dettenmaier, 2018; Dinkins et al., 2016; Hightower et al., 2018; Petersen et al., 1986; Rotenberry and Wiens, 1991; Smith et al., 2018a, 2018b; Webb et al., 2012). High daily maximum temperatures can reduce sagebrush sparrow growth rates, potentially through heat stress, or by impairing adults' foraging ability (Petersen et al., 1986). Severe weather might exert bottom-up effects by reducing food availability, potentially delaying fledging which lowers recruitment (Shutler et al., 2006), reducing nestling growth rates (Wright et al., 1998) or increasing nestling mortality rates (Zanette et al., 2006). Changes in wind speeds, temperature and moisture can alter nest predation by enhancing or dissipating scent plumes or altering bird movements (Dinkins et al., 2016; Ruzicka and

Conover, 2012). The expectation of more extreme high temperatures, greater precipitation intensity, and variability in summer temperatures due to climate change (Meehl et al., 2000) heightens the need for information regarding effects of weather on sagebrush-obligate songbirds as well as potential interactive effects with grazing.

We evaluated grazing and weather interactions within a replicated grazing experiment testing different grazing seasons of use versus no-grazing in the sagebrush ecosystem of southeastern Oregon. We studied two key weather variables, temperature and precipitation, and the nest success rates of two species of sagebrush-obligate songbirds, Brewer's sparrow (*Spizella breweri*) and sagebrush sparrow (*Artemisiospiza nevadensis*). To do so, we connected daily nest success from each nest with daily weather data across three years. We then determined potential influences of grazing on the weather-nest success relationships by comparing nests in three sets (blocks) of experimental pastures. Each block of pastures contained two treatments and a control. One treatment was grazed during the dormant season (late-fall) and one was rotationally grazed one year during the growing season (spring) and the following year after plants senesced (summer). This experimental design allowed us to evaluate the effects of grazing on nest success, as well as the interactions of weather variables with grazing. We hypothesized that weather would be an important factor in determining nest success, potentially via changes in bird physiology, predation risk, or food resources. Furthermore, we hypothesized that grazing could lead to differences in nest success, potentially through decreased herbaceous nesting cover, food resources or altered predator-prey dynamics, but would have a lesser influence on Brewer's sparrows, which nest off the ground in shrubs, than sagebrush sparrows, which nest closer to the ground.

METHODS

Study Area

We conducted our study in nine pastures (5.69–7.41 HA) arranged into three blocks consisting of three treatments each within the Northern Great Basin Experimental Range (NGBER; lat 43°29'N, long 119°43'W) 50–60 km west of Burns, Oregon, from 2017–2019. Elevation of the pastures ranged from 1,300–1,500 m. Climate was typical of the northern Great Basin, and consisted of wet, cool winters followed by hot, dry summers with a long-term (1938–2015) average precipitation of 278 mm (NOAA station, Riley 10 WSW, OR US). Precipitation during the study years was 107%, 66%, and 130% of the long-term average for 2017, 2018 and 2019, respectively.

All pastures experienced a similar historical grazing regime, had similar plant communities, soils, aspect and gradients prior to treatment. Soils in two of the three blocks were primarily Actem cobbly loam, while soils in the third block were mostly comprised of Raz-Bruce complex. Soils in all sites were well drained but underlain with a welded tuff and basalt geology, restricting root penetration at a hardpan around 30–50 cm in the Actem soils and 50–95 cm in the Raz-Brace. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) and green rabbitbrush (*Chrysothamnus viscidiflorus*) were the dominant shrubs. The dominant perennial bunchgrasses varied by block but were relatively consistent among pastures within a block. Dominant grasses included bluebunch wheatgrass (*Pseudoroegneria spicata*), Thurber's needlegrass (*Achnatherum thurberianum*), bottlebrush squirreltail (*Elymus elymoides*), Idaho fescue (*Festuca idahoensis*), prairie junegrass (*Koeleria macrantha*), and needle and thread (*Hesperostipa comata*). Pasture plant communities were representative of those in the northern Great Basin (Davies et al., 2006; Davies and Bates, 2010) dominated by native perennial species, and exhibited minimal invasion by exotic annual grasses.

Study Design and Grazing Treatment Application

We used a randomized complete block design with three blocks to determine the effects of three grazing treatments on sagebrush-obligate songbird nest success (Figure 2.1). Grazing treatments consisted of dormant season grazing, rotational grazing and a control experiencing no grazing during the study. Treatments were assigned randomly to one of the three pastures in each block. Pasture size varied among, but not within blocks. Dormant season grazing treatment occurred during fall or winter from 2017–2019, after the native bunchgrasses entered dormancy. The rotational grazing treatment consisted of alternating between summer grazing after bunchgrasses completed reproduction (~mid-July 2017) and spring growing season grazing during May (2018; Figure 2.1).

Herbaceous forage production varied across space (blocks and pastures) and through time (year and season). In practice, using a consistent stocking rate throughout pastures and years would have resulted in variable grazing intensities due to differences in available forage. Therefore, we varied stocking rates by herbaceous forage amount, quantified by systematically clipping herbaceous material in 15 1 m² quadrats throughout each pasture, in order to achieve moderate grazing utilization (Bates and Davies, 2014). We visually assessed pastures every few days during cattle grazing to prevent over or under-utilization. An employee of the local Bureau of Land Management (BLM) helped assess the post-treatment level of grazing utilization using BLM landscape appearance protocols. The landscape appearance method (e.g., Coulloudon et al., 1999) visually estimates forage utilization by comparing

observations with written descriptions of six different grazing utilization classes from no use to severe use (BLM personal communication): no use (0–5%), slight (6–20%), light (21–40%), moderate (41–60%), heavy (61–80%) or severe (81–100%). The same BLM employee annually assessed the pastures post-grazing treatment application by making assessments at 15 evenly spaced locations within each pasture and averaging the utilization assessments to determine a pasture level grazing utilization level.

Field Methods: Nest Searching and Monitoring

We found nests of Brewer's sparrow and sagebrush sparrow by systematically searching each pasture during April–July. Pastures were searched weekly, unless time-constraints or weather prevented a weekly search and were then searched bi-weekly. We found nests through the combination of behavioral cues and systematic searches, where researchers walked transects 5 m apart, lightly tapping shrubs with a 2 m long flush stick, and intensively searching shrubs when songbirds flushed.

We monitored nests every 2–4 days until failure or fledging (Chalfoun and Martin, 2010; Hethcoat and Chalfoun, 2015b; Martin and Geupel, 1993). We defined success as nests which produced at least one fledgling, determined by the presence of fledglings near the nest, adults giving alarm calls or carrying food items nearby, or the condition of the nest bowl and evidence that chicks were old enough to fledge (Chalfoun and Martin, 2010; Manolis et al., 2000; Martin and Geupel, 1993). We deemed nests unsuccessful if there was obvious sign of a destroyed nest, we documented a depredation event or disappearance of eggs or chicks before fledging age (Chalfoun and Martin, 2010; Manolis et al., 2000). To aid in accurate determination of nest success, we utilized cameras (Cuddeback Black Flash [Silver Series], Model 1231) and iButton temperature loggers (model DS1921GF5) at a random subset of nests. Paired iButtons helped us identify an empty or abandoned nest when temperatures from a nest iButton fell below the temperature profile of an iButton located outside the nest within that nesting shrub, indicating an empty nest or cessation of parental care (Hartman and Oring, 2006; Sutti and Strong, 2014). Cameras were well camouflaged and placed 20–150 cm away from nests either within the nesting shrub or in an adjacent shrub that optimized the viewshed while minimizing disturbance (Hethcoat and Chalfoun, 2015a).

Weather Data

We obtained weather data from the nearest NOAA station (Riley 10 WSW, OR US; 43.4711°, -119.6917°). The weather station was 1 km from the closest pasture and 2.5 km from the furthest, and generally captured all weather events experienced by all study pastures. We assessed temperature and

precipitation variables for two different time frames: fate date and while the nest was active. Due to uncertainty around the exact date a nest succeeded or failed, fate date weather metrics summarized weather variables for the 72-hour period centered on the estimated fate date. To account for uncertainty around both nest initiation and date of nest fate, all nesting timeframe weather metrics were calculated from 24 hours prior to the expected first egg-lay date to 24 hours after estimated success or failure (Appendix I; Table A2.1).

Analyses

We analyzed nest success in program R (x64 version 3.6.1; RStudio version 1.2.5019) using package lme4 and the logistic exposure method (Shaffer, 2004). Logistic exposure utilizes an encounter history to model nest success as a logistic function of the explanatory variables over the timeframe the nest was active. This method accounts for possible bias imposed by nests with different exposure periods found after nest-initiation.

We modelled nest success separately for Brewer's sparrow and sagebrush sparrow, using an information-theoretic approach (Anderson, 2007). Models were compared using Akaike's Information Criterion corrected for small sample sizes (AIC_c) and Akaike model weights (w_i ; Akaike, 1987, 1973; Burnham and Anderson, 2002) using the AICcmodavg package in R (Mazerolle, 2020). We generated covariate model sets based on specific *a priori* hypotheses and habitat variables. Our covariate model sets were weather, grazing, camera/iButton and vegetation (pasture-level and nest-level). We evaluated the potential effect of grazing with two different categorical grazing treatment variables: treatment type (dormant, rotational spring/summer and control) and grazing versus no grazing. Instead of incorporating an additional study design model set for year and block, we included these variables in the weather model set, treating year as a continuous variable and block as a categorical variable (Appendix I; Table A2.1).

We evaluated the ability of individual covariates to explain variation in daily survival rates (DSR) within each model set (weather, grazing, camera, vegetation) (Appendix I; Table A2.1). Variables were evaluated as interaction terms when biologically relevant and not correlated. Day of nesting season, defined as the timing of nesting within the nesting season where day 1 is the earliest date a nest was found in the study (April 25th), incorporated many biological factors important to nest success that we were otherwise unable to quantify. These included plant community, insect phenology, bird condition throughout the breeding season and predator activity (e.g., Andersson et al., 2018; Diller and Wallace, 1996; Everts et al., 2004; Kenagy, 1973; Lieth, 2013; Rodríguez-Robles, 2003; Wolda, 1988). In order to

avoid multicollinearity we did not include any two predictor variables with Pearson's correlation coefficient $r \geq |0.65|$ in additive models. When two variables were highly correlated, we retained the best fitted variable as ranked by ΔAIC_c . We then followed Arnold (2010)'s approach for eliminating uninformative parameters, and removed non-informative covariates with parameter estimate 85% CIs that overlapped zero. We considered models within two ΔAIC_c of the top overall model competitive (Burnham and Anderson, 2002).

Next in the modelling process, we tested and ranked, using ΔAIC_c , additive combinations of all remaining informative predictor variables and pairwise interactions within each model set. In the final step, we compared the top AIC_c models from all model sets (weather, grazing, camera/iButton, vegetation) and their additive combinations. We only present the tables including the top 10 models, and effects plots only from the top supported model. Finally, we ensured all beta-coefficients for model parameters were stable between all models (i.e., without changes in sign [+/-] or parameter estimate changes of an order of magnitude or larger), and only discuss results and inferences for competitive models.

RESULTS

We monitored a total of 230 sagebrush-obligate songbird nests, including 132 sagebrush sparrows and 97 Brewer's sparrows for a total of 1,672 and 1,181 cumulative exposure days, respectively. Number of nests varied across treatment types for each species with 31, 31, and 35 Brewer's sparrow nests and 41, 52 and 40 sagebrush sparrow nests in control, dormant and rotational graze plots, respectively. One nest was excluded from the analysis due to researcher caused failure where a researcher led cattle directly to a nest upon which it was trampled. We attributed predation, abandonment and parasitism as the causal factor for 77%, 22% and 1% of failed nests, respectively. Estimated Mayfield nest success for Brewer's sparrow over an average incubation to fledging timeframe of 20 days ranged from 0.28 to 0.71 and for sagebrush sparrow over a 23-day average nesting timeframe ranged from 0.23 to 0.84. Mayfield nest success varied across years and species (Table 2.1). Nests suspected to have failed due to added stress to the bird from placement of nest cameras were included in analyses to assess influence of cameras on nest success. Apparent nest success (number of successful nests divided by total number of nesting attempts) for nests with and without cameras was 65% and 45% for sagebrush sparrows, and 65% and 54% for Brewer's sparrows, respectively. We deployed 104 nest cameras and 14 iButtons. Herbaceous utilization from grazing averaged 50.1% (range: 28.0–61.1%) throughout the study.

Brewer's Sparrow

We found support for models from the weather, vegetation and camera covariate sets, but not the grazing covariate set (Appendix I; Table A2.2). Of the weather variables tested, precipitation, temperature swings (average temperature [°C] difference [maximum- minimum] during the time period the nest was active including 24 hours prior to estimated egg lay date and 24 hours after estimated fate date), and maximum temperature around the fate date (the 72-hour period centered on the suspected fate date) best explained differences in nest success (Appendix I; Table A2.2). We found the most, albeit limited, support for dead sagebrush cover and camera in the vegetation and camera/iButton covariate sets, respectively, as the null models were also competitive (Appendix I; Table A2.2).

For our overall top model, we found support for a combination of weather and vegetation covariates explaining differences in nest success (Table 2.2, modeling step 3). Other models were competitive, including the weather-only model. Models two and three included camera as an imprecise covariate (95% CI: -0.254 to 1.374 and -0.203 to 1.416). These did not change our overall conclusions; thus, we only report on the most parsimonious model, which was the top model (Table 2.2).

Nests survived better when weather was drier. In particular, nests were more likely to fail when rain occurred on $\geq 40\%$ of the days during a Brewer's sparrow's nest cycle (Figure 2.2 D). Large daily temperature swings early in the nesting season resulted in more nest failures, whereas daily temperature swings later in the season had little effect on nest success (Figure 2.3 A). Nests experiencing very low or very high maximum temperatures near fate date appear to be slightly more successful than nests experiencing intermediate temperatures (Table 2.3, Figure 2.2 C). Higher percent cover of dead sagebrush plants within a pasture predicted more nest failures, and nests with a camera were more likely to fledge (Table 2.3).

Sagebrush Sparrow

We found that sagebrush sparrow nest success was best predicted by weather, grazing treatment, vegetation and camera covariates (Table 2.2). Precipitation, daily temperature swings, and minimum and maximum temperature around the nest fate date influenced nest success in our best model for the weather covariate set (Appendix I; Table A2.3). The second model was competitive with the top model and included all of the parameters in the top model plus the minimum temperature at the 72-hour period around the estimated fate date as a quadratic relationship, but the additional parameter was not precise (95% CI: -0.018 to 0.008). Therefore, we advanced only the most parsimonious and top ranked model from the weather covariate set (Appendix I; Table A2.3). The top

selected model for the grazing covariate set was the grazed versus no-graze treatment pastures \times year interaction. Pastures experiencing any type of grazing treatment had higher nest success in post-treatment years compared to pre-treatment, while nests in no-graze control treatment pastures exhibited lower nest success in post-treatment years compared to pre-treatment (Appendix I; Table A2.3, Figure 2.4). We also compared the effect of the dormant season grazing treatment to all other treatments (no-grazing and rotational grazing combined). This dormant treatment versus other sites \times year interaction was competitive with the best model, holding 0.26 of the w_i (Appendix I; Table A2.3). Similar to the grazed versus no-graze treatment application, the dormant season grazing relative to all other treatments resulted in a higher nest success in dormant season grazed pastures (95% CI: 0.06 to 1.49). The model with dead sagebrush cover was the top ranked in the vegetation covariate set but was competitive with the null, suggesting limited support, while camera presence outcompeted the iButton and null models in the camera/iButton covariate set (Appendix I; Table A2.3).

During step three of our modeling process, the combination of the top models from the weather, vegetation, camera/iButton and grazing covariate sets best described nest success (Table 2.2). The second ranked model was competitive but did not include additional covariates (Table 2.2). Higher rates of average precipitation during the nesting period were associated with more failed nests late in the nesting season (Table 2.3, Figure 2.3 B). When average daily precipitation exceeded 1 mm, late season nests were most likely to fail, whereas mid-season nests survived better, remaining successful at up to 2 mm of precipitation prior to the 60th day of the nesting season (Figure 2.3 B). Nests in the first third of the nesting season fledged at all but the highest levels of precipitation, remaining successful even when experiencing over 3 mm of daily precipitation (Figure 2.3 B, Table 2.3). Sagebrush sparrow nests remained incredibly resilient to almost all levels of daily temperature swings and only declined during extreme high or low temperature conditions (Figure 2.2 B). Nest success was lower for nests experiencing extremely high maximum temperatures (>30 °C) late in the nesting season on the day of expected nest fate (Table 2, Figure 2.3 C). Lower minimum temperatures during the 72-hour timeframe around expected nest fate resulted in more failed nests (Table 2.3, Figure 2.2 A). Despite limited variation in dead sagebrush cover across sites (0.18–1.13% cover), nests were less likely to survive in pastures with more dead sagebrush (Table 2.3). There were initial study treatment site differences; pastures assigned to the grazing treatments had lower nest success compared to the controls, prior to treatment (i.e., during the first year of the study; Tables 2.1 and 2.3). However, the application of grazing appears to have increased sagebrush sparrow nest success, while nest success in pastures experiencing no grazing continued to decline through time (Table 2.3; Figure 2.4).

DISCUSSION

Effective conservation relies on understanding the respective roles and interactions of management and natural drivers of population dynamics. Our research found that despite overlapping territories and nesting in close proximity, the two songbirds responded differently to grazing management and weather, suggesting that management benefits may vary under various weather conditions and across species. Grazing, a primary land-use across much of the western US, has not previously been connected to songbird nest success in the sagebrush ecosystem. We documented a positive effect of grazing on sagebrush sparrow nest success, supporting our grazing hypothesis (Figure 2.3), suggesting that grazing indirectly modifies songbird habitat. Similar to other studies, we found that weather was an important factor explaining nest success (Hightower et al., 2018; Macdonald et al., 2013; Pérez et al., 2016; Rotenberry and Wiens, 1991). Both species experienced more nest failures when nests experienced more extreme weather conditions. Sagebrush sparrows were resilient to all but the most extreme weather, but their nest success was influenced by grazing, while Brewer's sparrows exhibited the opposite effect, where nest success was primarily driven by weather and unaffected by the grazing regimes tested. We found little support for vegetation metrics explaining nest success. However, nest success did trend downward with increasing dead sagebrush cover, although all study pastures had canopies dominated by live sagebrush with very low levels of dead sagebrush cover.

Despite an overall decline across years, nest success improved in pastures experiencing grazing but declined in no-graze control pastures for sagebrush sparrows (Figure 2.4). Dormant season grazing treatment might have driven this effect (Appendix I; Table A2.3). However, two years was a very short grazing regime, and the effects of grazing treatments may shift as the study continues. We did not test the actual mechanism by which grazing influenced nest success, but it could be related to changes in predator abundances, food resources or territory sizes. Livestock grazing directly affects the plant community through a reduction in herbaceous cover, a pattern supported by our results, where grazing at moderate levels did reduce perennial bunchgrass cover in grazed pastures relative to controls by 19.85% on average (Schroeder unpublished data). Previous work has suggested a grazing-induced reduction in herbaceous cover might lead to a reduction in nest concealment (Beck and Mitchell, 2000; Boyd et al., 2014; Cagney et al., 2010). However, the direction of our observed grazing effect suggests reduced nesting cover due to grazing did not play a large role in the nest success of our species, a finding supported by other research in the sagebrush ecosystem (Chalfoun and Martin, 2007; Smith et al., 2018a, 2018b). Livestock grazing can influence the abundance and species composition of invertebrates which nestlings and fledglings rely upon for growth and survival (Debano, 2006; Petersen and Best,

1986). Increased invertebrate abundance caused by changes in vegetation structure and cow patty deposition might explain the observed increase in nest success, a hypothesis warranting future investigation (Borges and Brown, 2001; Lee and Wall, 2006; Siemann, 1998; Skidmore, 1991; Wenninger and Inouye, 2008). Reduced herbaceous cover might have allowed for increased ground movement of sagebrush sparrows for foraging and predator avoidance, while not being so extreme as to expose them to increased predation (Eiserer, 1980; Macías-Duarte and Panjabi, 2013; Roth, 1979). Alternatively, higher nest success in grazed pastures could be due to grazing affecting predatory species diversity and abundance, a relationship that can vary by grazing intensity and species (Bich et al., 1995; Bock et al., 1984; Bylo et al., 2014; Jones and Longland, 1999; Jones et al., 2003; Larson, 2014). Predator communities likely vary throughout the sagebrush ecosystem, and the role cattle might play in the predator-prey dynamics of sagebrush-obligate songbirds is largely understudied. Alternatively, if cattle grazing acts as a deterrent to nesting songbirds, leading to lower nest density in grazed areas, nest success might increase from more available resources resulting from larger territories for the few birds who chose to nest in grazed areas. This highlights a need for research assessing the role of grazing on other reproductive metrics, such as nest density and territory size. Research examining the effects of grazing on other reproductive success metrics and potential mechanisms behind grazing effects, such as changes in invertebrate food resources or the nest predator community, are needed to better understand the role grazing plays in these complex ecosystems.

Precipitation and temperature can significantly affect reproductive success metrics in passerines (Chase et al., 2005; Macdonald et al., 2013; Pérez et al., 2016). Both sparrow species in our study were influenced by inter-annual and inter-seasonal weather variation, and experienced declines beyond certain temperature and precipitation thresholds (Figures 2.2 and 2.3). While wetter years are generally associated with higher reproductive success (Gaston et al., 2005; Morrison and Bolger, 2002; Rotenberry and Wiens, 1991), within season precipitation can be associated with declines in nest success (Collister and Wilson, 2007; Macdonald et al., 2013; Smith et al., 2018a), a pattern supported by our data. Nest success for both species precipitously declined beyond relatively high precipitation thresholds, particularly later in the breeding season (Figures 2.2 and 2.3). Late season precipitation events often represent extreme weather in the Great Basin, such as hail storms, which have documented extreme nest mortality for sagebrush-obligate species (Hightower et al., 2018). Rotenberry and Wiens (1991) conducted the most comprehensive study on the effects of weather on sagebrush-obligate songbird reproductive metrics, and found no effect of weather on nest success, but did document sagebrush sparrow responses in other reproductive metrics to inter-annual weather variation. However, they

found no such pattern for Brewer's sparrows, suggesting their ability to buffer the effects of short-term variation in weather by adjusting reproductive investment through altering clutch size. Brewer's sparrows face more extreme temperatures, higher spring precipitation, increased intense precipitation events and prolonged drought today compared to the 1976–1980 breeding seasons (Easterling et al., 2017; Meehl et al., 2016; Vose et al., 2017), which was analyzed by Rotenberry and Wiens (1991). Our observed susceptibility of Brewer's sparrows to inter-annual weather variation might indicate a shift in the species response to weather in the face of climate-driven weather changes. However, these datasets were collected in different locations and this hypothesis warrants future investigation.

Large temperature swings early in the season predicted more nest failures in the smaller bodied Brewer's sparrows, while sagebrush sparrow nests remained resilient to daily temperature differences (Figures 2.2, 2.3). Brewer's sparrows tend to nest higher in shrubs, arrive at breeding grounds later than sagebrush sparrow, and appear to be more sensitive to extreme temperature variability, suggesting an increase in thermoregulatory costs, negatively affecting reproduction (Pendlebury and Bryant, 2005). Lower minimum temperatures around day of fate were more likely to result in nest failures for sagebrush sparrows (Figure 2.2). Sagebrush sparrow nests failed on days exhibiting temperature extremes, such as late season high max temperatures or very cold minimum temperatures (Figures 2.2, 2.3). During energetically stressful times, adults may be forced to choose between survival of their nest or of themselves. Sparrows may have chosen self-preservation under energetically stressful times, shifting resources away from nest incubation (Macdonald et al., 2013).

When weather conditions are extreme, they can have a larger influence on nest success than grazing management, particularly under moderate, rotational grazing conducted in a healthy sagebrush plant community exhibiting limited invasion or degradation. Our results suggest that projected changes in climate and weather provide greater concern for these species than contemporary grazing practices. The expectation of increased extreme temperature days, precipitation intensity, and variability in summer temperatures due to climate change (Meehl et al., 2016, 2000) will likely have mixed effects on sagebrush-obligate songbird reproductive success. Over the next century, temperatures are projected to rise between 2 and 5.78 °C in the Pacific Northwest with the summer months experiencing the greatest changes (Diffenbaugh et al. 2005, IPCC 2007). Climate precipitation models generally indicate larger inter- and intra-annual variation with wetter winters, drier summers, and more precipitation falling as rain associated with a decrease in snow cover and depth (Diffenbaugh et al. 2005, IPCC 2007). A shift to larger, less frequent precipitation events (IPPC 2007, Polley et al. 2013) may be problematic for sagebrush sparrows (Figure 2.3). A decline in days with precipitation could benefit Brewer's sparrow

nest success, unless it is associated with increased late season precipitation or hail storms (Hightower et al., 2018). Overall, these species, particularly sagebrush sparrow, are well adapted to the extreme and variable conditions of the high desert, and might be relatively insulated to climate induced weather changes, but effects will depend on the exact timing and magnitude of the changes in temperature and precipitation. An increase in Brewer's sparrows' susceptibility to weather compared to almost four decades ago could signal concern for their populations amidst future climate projections. These findings highlight the need for research to assess the current adaptive flexibility of these species to respond to inter- and intra-annual variation through adjustments in reproductive investment. Climate projections forecast bad news for these sparrows not only in terms of their reproductive success, but in climate driven processes contributing to landscape scale loss of the sagebrush ecosystem, such as an unprecedented rise in frequency and intensity of wildfire, woody encroachment and invasion by exotic species (Abatzoglou and Williams, 2016; Coates et al., 2016b; Miller et al., 2014; Mohamed et al., 2011; Pechony and Shindell, 2010; Polley et al., 2013). Ultimately, our results indicate reductions in screening cover caused by grazing do not present a threat to these birds and conservation should focus on management to mitigate the negative effects of extreme weather on the sagebrush ecosystem and associated wildlife.

REFERENCES

- Abatzoglou, J.T., Williams, A.P., 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proc. Natl. Acad. Sci. U. S. A.* 113, 11770–11775. <https://doi.org/10.1073/pnas.1607171113>
- Akaike, H., 1987. Factor analysis and AIC. *Psychometrika* 52, 317–332. <https://doi.org/10.1007/BF02294359>
- Akaike, H., 1973. Maximum likelihood identification of gaussian autoregressive moving average models. *Biometrika* 60, 255–265. <https://doi.org/10.1093/biomet/60.2.255>
- Anderson, D.R., 2007. *Model based inference in the life sciences: A Primer on evidence*. Springer, New York, NY.
- Andersson, N., Piha, M., Meller, K., Välimäki, K., Lehikoinen, A., 2018. Variation in body condition of songbirds during breeding season in relation to sex, migration strategy and weather. *Ornis Fenn.* 95, 70–81.
- Arnold, T.W., 2010. Uninformative parameters and model selection using Akaike's Information Criterion. *J. Wildl. Manage.* 74, 1175–1178. <https://doi.org/10.2193/2009-367>
- Asner, G.P., Elmore, A.J., Olander, L.P., Martin, R.E., Harris, T., 2004. Grazing systems, ecosystem responses, and global change. *Annu. Rev. Environ. Resour.* 29, 261–299. <https://doi.org/10.1146/annurev.energy.29.062403.102142>
- Bates, J.D., Davies, K.W., 2014. Cattle grazing and vegetation succession on burned sagebrush steppe. *Rangel. Ecol. Manag.* 67, 412–422. <https://doi.org/10.2111/REM-D-14-00011.1>
- Beck, J.L., Mitchell, D.L., 2000. Influences of livestock grazing on sage grouse habitat. *Wildl. Soc. Bull.* 28, 993–1002. <https://doi.org/10.2307/3783858>
- Bich, B.S., Butler, J.L., Schmidt, C.A., 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides* / *Hilaria jamesii* communities of Glen Canyon National Recreation Area. *Southwest. Assoc. Nat.* 40, 281–287.
- Bock, C.E., Bock, J.H., Kenney, W.R., Hawthorne, V.M., 1984. Responses of birds, rodents, and vegetation to livestock Enclosure in a semidesert grassland site. *J. Range Manag.* 37, 239–242.
- Borges, P.A. V, Brown, V.K., 2001. Phytophagous insects and web-building spiders in relation to pasture vegetation complexity. *Ecography (Cop.)*. 24, 68–82.
- Boyd, C.S., Johnson, D.D., Kerby, J.D., Svejcar, T.J., Davies, K.W., 2014. Of grouse and golden eggs: Can ecosystems be managed within a species-based regulatory framework? *Rangel. Ecol. Manag.* 67, 358–368. <https://doi.org/10.2111/REM-D-13-00096.1>
- Burnham, K.P., Anderson, D.R., 2002. *Model selection and multimodel inference: A practical information–theoretic approach*, Second. ed. Springer-Verlag, New York, NY.
- Bylo, L.N., Koper, N., Molloy, K.A., 2014. Grazing intensity influences ground squirrel and American badger habitat use in mixed-grass prairies. *Rangel. Ecol. Manag.* 67, 247–254. <https://doi.org/10.2111/REM-D-13-00152.1>

- Cagney, J., Bainter, E., Budd, R., Christiansen, T., Herren, V., Holloran, M.J., Rashford, B., Smith, M.D., Williams, J., 2010. Grazing influence, objective development, and management in Wyoming's greater sage-grouse habitat with emphasis on nesting and early brood rearing. Univ. Wyoming Coop. Ext. Serv. Publ. 60pp.
- Chalfoun, A.D., Martin, T.E., 2010. Facultative nest patch shifts in response to nest predation risk in the Brewer's sparrow: A "win-stay, lose-switch" strategy? *Oecologia* 163, 885–892.
<https://doi.org/10.1007/s00442-010-1679-0>
- Chalfoun, A.D., Martin, T.E., 2007. Assessments of habitat preferences and quality depend on spatial scale and metrics of fitness. *J. Appl. Ecol.* 44, 983–992. <https://doi.org/10.1111/j.1365-2664.2007.01352.x>
- Chase, M., Nur, N., Geupel, G., 2005. Effects of weather and population density on reproductive success and population dynamics in a song sparrow (*Melospiza melodia*) population: a long-term study. *Auk* 122, 571–592. [https://doi.org/10.1642/0004-8038\(2005\)122\[0571:EOWAPD\]2.0.CO;2](https://doi.org/10.1642/0004-8038(2005)122[0571:EOWAPD]2.0.CO;2)
- Coates, P.S., Brussee, B.E., Howe, K.B., Gustafson, K.B., Casazza, M.L., Delehanty, D.J., 2016a. Landscape characteristics and livestock presence influence common ravens: Relevance to greater sage-grouse conservation. *Ecosphere* 7, 1–20. <https://doi.org/10.1002/ecs2.1203>
- Coates, P.S., Ricca, M.A., Prochazka, B.G., Brooks, M.L., Doherty, K.E., Kroger, T., Blomberg, E.J., Hagen, C.A., Casazza, M.L., 2016b. Wildfire, climate, and invasive grass interactions negatively impact an indicator species by reshaping sagebrush ecosystems. *Proc. Natl. Acad. Sci.* 113, 12745–12750.
<https://doi.org/10.1073/pnas.1606898113>
- Collister, D.M., Wilson, S., 2007. Contributions of weather and predation to reduced breeding success in a threatened northern loggerhead shrike population. *Avian Conserv. Ecol.* 2.
<https://doi.org/10.5751/ace-00193-020211>
- Davies, K.W., Bates, J.D., 2010. Vegetation characteristics of mountain and Wyoming big sagebrush plant communities in the northern Great Basin. *Rangel. Ecol. Manag.* 63, 461–466.
<https://doi.org/10.2111/REM-D-09-00055.1>
- Davies, K.W., Bates, J.D., Miller, R.F., 2006. Vegetation characteristics across part of the Wyoming big sagebrush alliance. *Rangel. Ecol. Manag.* 59, 567–575. <https://doi.org/10.2111/06-004R2.1>
- Davies, K.W., Boyd, C.S., Bates, J.D., 2018. Eighty years of grazing by cattle modifies sagebrush and bunchgrass structure. *Rangel. Ecol. Manag.* 71, 275–280.
<https://doi.org/10.1016/j.rama.2018.01.002>
- Debano, S.J., 2006. Effects of livestock grazing on aboveground insect communities in semi-arid grasslands of southeastern Arizona. *Biodivers. Conserv.* 15, 2547–2564.
<https://doi.org/10.1007/s10531-005-2786-9>
- Dettenmaier, S.J., 2018. Effects of livestock grazing management practices on greater sage-grouse nest and female survival. Utah State University.
- Diffenbaugh, N.S., Pal, J.S., Trapp, R.J., Giorgi, F., 2005. Fine-scale processes regulate the response of extreme events to global climate change. *Proc. Natl. Acad. Sci. U. S. A.* 102, 15774–15778.
<https://doi.org/10.1073/pnas.0506042102>

- Diller, L. V., Wallace, R.L., 1996. Comparative ecology of two snake species (*Crotalus viridis* and *Pituophis melanoleucus*) in southwestern Idaho. *Herpetologica* 52, 343–360.
- Dinkins, J.B., Conover, M.R., Kirol, C.P., Beck, J.L., Frey, S.N., 2016. Effects of common raven and coyote removal and temporal variation in climate on greater sage-grouse nesting success. *Biol. Conserv.* 202, 50–58. <https://doi.org/10.1016/j.biocon.2016.08.011>
- Dirzo, R., Young, H.S., Galetti, M., Ceballos, G., Isaac, N.J.B., Collen, B., 2014. Defaunation in the Anthropocene. *Science* (80). 345, 401–406. <https://doi.org/10.1126/science.1251817>
- Easterling, D.R., Kunkel, K.E., Arnold, J.R., Knutson, T.R., LeGrande, A.N., Leung, L.R., Vose, R.S., Waliser, D.E., Wehner, M., 2017. Precipitation change in the United States. *Clim. Sci. Spec. Rep. Fourth Natl. Clim. Assessment, Vol. I I*, 207–230.
- Everts, L.G., Strijkstra, A.M., Hut, R.A., Hoffmann, I.E., Millesi, E., 2004. Seasonal variation in daily activity patterns of free-ranging European ground squirrels (*Spermophilus citellus*). *Chronobiol. Int.* 21, 57–71. <https://doi.org/10.1081/CBI-120027982>
- Eiserer, L.A., 1980. Effects of grass length and mowing on foraging behavior of the American robin (*Turdus migratorius*). *Auk* 97, 576–580.
- Gaston, A.J., Martin, J.L., Allombert, S., 2005. Sea surface temperatures mediated by the El Niño-Southern Oscillation affect birds breeding in temperate coastal rain forests. *Avian Conserv. Ecol.* 1, 4.
- Hartman, C.A., Oring, L.W., 2006. An inexpensive method for remotely monitoring nest activity. *J. F. Ornithol.* 77, 418–424.
- Hethcoat, M.G., Chalfoun, A.D., 2015a. Energy development and avian nest survival in Wyoming, USA: A test of a common disturbance index. *Biol. Conserv.* 184, 327–334. <https://doi.org/10.1016/j.biocon.2015.02.009>
- Hethcoat, M.G., Chalfoun, A.D., 2015b. Towards a mechanistic understanding of human-induced rapid environmental change: A case study linking energy development, nest predation and predators. *J. Appl. Ecol.* 52, 1492–1499. <https://doi.org/10.1111/1365-2664.12513>
- Hightower, J.N., Carlisle, J.D., Chalfoun, A.D., 2018. Nest mortality of sagebrush songbirds due to a severe hailstorm. *Wilson J. Ornithol.* 130, 561–567. <https://doi.org/10.1676/17-025.1>
- Hovick, T.J., Elmore, R.D., Fuhlendorf, S.D., Dahlgren, D.K., 2015. Weather constrains the influence of fire and grazing on nesting greater prairie-chickens. *Rangel. Ecol. Manag.* 68, 186–193.
- Johnson, M.D., Horn, C.M., 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. *West. North Am. Nat.* 68, 444–452. <https://doi.org/10.3398/1527-0904-68.4.444>
- Johnson, T.N., Kennedy, P.L., DelCurto, T., Taylor, R. V., 2011. Bird community responses to cattle stocking rates in a Pacific Northwest bunchgrass prairie. *Agric. Ecosyst. Environ.* 144, 338–346. <https://doi.org/10.1016/j.agee.2011.10.003>
- Jones, A.L., 2000. Effects of cattle grazing on North American arid ecosystems: A quantitative review. *West. North Am. Nat.* 60, 155–164. <https://doi.org/10.2307/41717026>

- Jones, A.L., Longland, W.S., 1999. Effects of cattle grazing on salt desert rodent communities. *Am. Midl. Nat.* 141, 1–11.
- Jones, Z.F., Bock, C.E., Bock, J.H., 2003. Rodent communities in a grazed and ungrazed Arizona grassland, and a model of habitat relationships among rodents in southwestern grass/shrublands. *Am. Midl. Nat.* 149, 384–394. [https://doi.org/10.1674/0003-0031\(2003\)149](https://doi.org/10.1674/0003-0031(2003)149)
- Kenagy, G.J., 1973. Daily and seasonal patterns of activity and energetics in a *Heteromyid* rodent community. *Ecology* 54, 1201–1219.
- König, H.J., Kiffner, C., Kramer-Schadt, S., Fürst, C., Keuling, O., Ford, A.T., 2020. Human–wildlife coexistence in a changing world. *Conserv. Biol.* 34, 786–794. <https://doi.org/10.1111/cobi.13513>
- Kruess, A., Tschardt, T., 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biol. Conserv.* 106, 293–302. [https://doi.org/10.1016/s0006-3207\(01\)00255-5](https://doi.org/10.1016/s0006-3207(01)00255-5)
- Larson, D.M., 2014. Grassland fire and cattle grazing regulate reptile and amphibian assembly among patches. *Environ. Manage.* 54, 1434–1444. <https://doi.org/10.1007/s00267-014-0355-2>
- Lee, C.M., Wall, R., 2006. Cow-dung colonization and decomposition following insect exclusion. *Bull. Entomol. Res.* 96, 315–322. <https://doi.org/10.1079/ber2006428>
- Lieth, 2013. Phenology and seasonality modeling. Spring Science and Business Media.
- Macdonald, E.C., Camfield, A.F., Jankowski, J.E., Macdonald, E.C., Camfield, A.F., Jankowski, J.E., Martin, K., 2013. Extended incubation recesses by alpine-breeding horned larks : A strategy for dealing with inclement weather. *J. F. Ornithol.* 84, 58–68. <https://doi.org/10.1111/jofo>
- Macías-Duarte, A., Panjabi, A.O., 2013. Association of habitat characteristics with winter survival of a declining grassland bird in Chihuahuan Desert grasslands of Mexico. *Auk* 130, 141–149. <https://doi.org/10.1525/auk.2012.12047>
- Manolis, J.C., Andersen, D.E., Cuthbert, F.J., 2000. Uncertain nest fates in songbird studies and variation in Mayfield estimation. *Auk* 117, 615–626. <https://doi.org/10.2307/4089587>
- Martin, T.E., Geupel, G.R., 1993. Nest-monitoring plots: Methods for locating nests and monitoring success. *J. F. Ornithol.* 64, 507–519.
- Mazerolle, M.M.J., 2020. Model selection and multimodel inference based on (Q)AIC(c).
- Meehl, G.A., Tebaldi, C., Adams-Smith, D., 2016. US daily temperature records past, present, and future. *Proc. Natl. Acad. Sci. U. S. A.* 113, 13977–13982. <https://doi.org/10.1073/pnas.1606117113>
- Meehl, G.A., Zwiers, F., Evans, J., Knutson, T., Mearns, L., Whetton, P., 2000. Trends in extreme weather and climate events: Issues related to modeling extremes in projections of future climate change. *Bull. Amer. Meteor. Soc.* 81, 427–436.
- Miller, R.F., Ratchford, J., Roundy, B.A., Tausch, R.J., Hulet, A., Chambers, J., 2014. Response of conifer-encroached shrublands in the Great Basin to prescribed fire and mechanical treatments. *Rangel. Ecol. Manag.* 67, 468–481. <https://doi.org/10.2111/REM-D-13-00003.1>
- Mohamed, A.H., Holechek, Jerry L., Bailey, D.W., Campbell, C.L., DeMers, M.N., 2011. Mesquite

- encroachment impact on southern New Mexico rangelands: Remote sensing and geographic information systems approach. *J. Appl. Remote Sens.* 5, 1–11. <https://doi.org/10.1117/1.3571040>
- Monroe, A.P., Aldridge, C.L., Assal, T.J., Veblen, K.E., Pyke, D.A., Casazza, M.L., 2017. Patterns in greater sage-grouse population dynamics correspond with public grazing records at broad scales. *Ecol. Appl.* 27, 1096–1107. <https://doi.org/10.1002/eap.1512>
- Morrison, S.A., Bolger, D.T., 2002. Variation in a sparrow's reproductive success with rainfall: Food and predator-mediated processes. *Oecologia* 133, 315–324. <https://doi.org/10.1007/s00442-002-1040-3>
- Mullen, E.M., MacWhite, T., Maher, P.K., Kelly, D.J., Marples, N.M., Good, M., 2013. Foraging Eurasian badgers *Meles meles* and the presence of cattle in pastures. Do badgers avoid cattle? *Appl. Anim. Behav. Sci.* 144, 130–137. <https://doi.org/10.1016/j.jinf.2020.04.010>
- Nack, J.L., Ribic, C.A., 2005. Apparent predation by cattle at grassland bird nests. *Wilson Bull.* 117, 56–62.
- Paine, L., Undersander, D.J., Sample, D.W., Bartelt, G.A., Schatteman, T.A., 1996. Cattle trampling of simulated ground nests in rotationally grazed pastures. *J. Range Manag.* 49, 294–300. <https://doi.org/10.2307/4002586>
- Pechony, O., Shindell, D.T., 2010. Driving forces of global wildfires over the past millennium and the forthcoming century. *Proc. Natl. Acad. Sci.* 107, 19167–19170. <https://doi.org/10.1073/pnas.1003669107>
- Pendlebury, C.J., Bryant, D.M., 2005. Effects of temperature variability on egg mass and clutch size in great tits. *Condor* 107, 710–714. [https://doi.org/10.1650/0010-5422\(2005\)107\[0710:EOTVOE\]2.0.CO;2](https://doi.org/10.1650/0010-5422(2005)107[0710:EOTVOE]2.0.CO;2)
- Pérez, J.H., Krause, J.S., Chmura, H.E., Bowman, S., McGuigan, M., Asmus, A.L., Meddle, S.L., Hunt, K.E., Gough, L., Boelman, N.T., Wingfield, J.C., 2016. Nestling growth rates in relation to food abundance and weather in the Arctic. *Auk* 133, 261–272. <https://doi.org/10.1642/AUK-15-111.1>
- Petersen, K.L., Best, L.B., 1986. Diets of nestling sage sparrows and Brewer's sparrows in an Idaho sagebrush community. *J. F. Ornithol.* 57, 283–294.
- Petersen, K.L., Best, L.B., Winter, B., 1986. Growth of nestling sage sparrows and Brewer's sparrows. *Wilson Bull.* 98, 535–546.
- Polley, H.W., Briske, D.D., Morgan, J.A., Wolter, K., Brown, J.R., 2013. Climate change and north american rangelands: Trends, projections, and implications. *Rangel. Ecol. Manag.* 66, 493–511.
- Rodríguez-Robles, J.A., 2003. Home ranges of gopher snakes (*Pituophis catenifer*, Colubridae) in Central California. *Copeia* 391–396.
- Rotenberry, J.T., Wiens, J.A., 1991. Weather and reproductive variation in shrubsteppe sparrows: A hierarchical analysis. *Ecology* 72, 1325–1335. <https://doi.org/10.2307/1941105>
- Roth, R.R., 1979. Foraging behavior of mockingbirds: The effect of too much grass. *The Auk* 96, 421–422.
- Ruth, K.A., 2019. Population and breeding ecology of sagebrush steppe songbirds. University of

Montana.

- Ruzicka, R.E., Conover, M.R., 2012. Does weather or site characteristics influence the ability of scavengers to locate food? *Ethology* 118, 187–196. <https://doi.org/10.1111/j.1439-0310.2011.01997.x>
- Shaffer, T.L., 2004. A unified approach to analyzing nest success. *Auk* 121, 526–540. <https://doi.org/10.2307/4090416>
- Shutler, D., Clark, R.G., Fehr, C., Diamond, A.W., 2006. Time and recruitment costs as currencies in manipulation studies on the costs of reproduction. *Ecology* 87, 2938–2946. [https://doi.org/10.1890/0012-9658\(2006\)87\[2938:TARCAC\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2006)87[2938:TARCAC]2.0.CO;2)
- Siemann, E., 1998. Experimental tests of effects of plant productivity and diversity on grassland arthropod diversity. *Ecology* 79, 2057–2070. [https://doi.org/10.1890/0012-9658\(1998\)079\[2057:ETOEOP\]2.0.CO;2](https://doi.org/10.1890/0012-9658(1998)079[2057:ETOEOP]2.0.CO;2)
- Skidmore, P., 1991. *Insects of the British cow-dung community*. Field Studies Council, Shrewsbury, United Kingdom.
- Smith, J.T., Tack, J.D., Berkeley, L.I., Szczypinski, M., Naugle, D.E., 2018a. Effects of rotational grazing management on nesting greater sage-grouse. *J. Wildl. Manage.* 82, 103–112. <https://doi.org/10.1002/jwmg.21344>
- Smith, J.T., Tack, J.D., Berkeley, L.I., Szczypinski, M., Naugle, D.E., 2018b. Effects of livestock grazing on nesting sage-grouse in central Montana. *J. Wildl. Manage.* 82, 1503–1515. <https://doi.org/10.1002/jwmg.21500>
- Sutti, F., Strong, A.M., 2014. Temperature loggers decrease costs of determining bird nest survival. *Wildl. Soc. Bull.* 38, 831–836. <https://doi.org/10.1002/wsb.473>
- Torre, I., Díaz, M., Martínez-Padilla, J., Bonal, R., Viñuela, J., Fargallo, J.A., 2007. Cattle grazing, raptor abundance and small mammal communities in Mediterranean grasslands. *Basic Appl. Ecol.* 8, 565–575. <https://doi.org/10.1016/j.baae.2006.09.016>
- Vitousek, P.M., Mooney, H.A., Lubchenco, J., Melillo, J.M., 1997. Human domination of Earth's ecosystems. *Science* (80). 494–499. https://doi.org/10.1007/978-0-387-73412-5_1
- Vose, R.S., Easterling, D.R., Kunkel, K.E., LeGrande, A.N., Wehner, M.F., 2017. Temperature changes in the United States. *Clim. Sci. Spec. Rep. Fourth Natl. Clim. Assess. I*, 185–206.
- Webb, S.L., Olson, C. V., Dzialak, M.R., Harju, S.M., Winstead, J.B., Lockman, D., 2012. Landscape features and weather influence nest survival of a ground-nesting bird of conservation concern, the greater sage-grouse, in human-altered environments. *Ecol. Process.* 1, 1–15. <https://doi.org/10.1186/2192-1709-1-4>
- Wenninger, E.J., Inouye, R.S., 2008. Insect community response to plant diversity and productivity in a sagebrush-steppe ecosystem. *J. Arid Environ.* 72, 24–33. <https://doi.org/10.1016/j.jaridenv.2007.04.005>
- Wolda, H., 1988. Insect seasonality: Why? *Annu. Rev. Ecol. Syst.* 19, 1–18.

- Wright, J., Both, C., Cotton, P.A., Bryant, D., 1998. Quality vs. quantity: Energetic and nutritional trade-offs in parental provisioning strategies. *J. Anim. Ecol.* 67, 620–634. <https://doi.org/10.1046/j.1365-2656.1998.00221.x>
- Zanette, L.Y., Clinchy, M., Smith, J.N.M., 2006. Combined food and predator effects on songbird nest survival and annual reproductive success: Results from a bi-factorial experiment. *Oecologia* 147, 632–640. <https://doi.org/10.1007/s00442-005-0330-y>

Table 2.1. Mayfield estimated nest success for Brewer's sparrow ($n = 97$, average 11-day incubation period, 9-day nestling period) and sagebrush sparrow ($n = 132$, average 13-day incubation period, 10-day nestling period) across treatments and years in experimental pastures experiencing dormant, rotational or no-grazing at the Northern Great Basin Experimental Range in southeast Oregon 2017–2019. Standard error in parentheses, and n indicates number of nests for each year, treatment and species combination.

	Pre-Treatment	Post-Treatment	
	2017	2018	2019
Brewer's Sparrow			
Control	0.88 (0.12) $n = 6$	0.59 (0.11) $n = 17$	0.75 (0.25) $n = 8$
Dormant	0.27 (0.12) $n = 12$	0.43 (0.29) $n = 10$	0.79 (0.21) $n = 9$
Rotational	0.88 (0.12) $n = 12$	0.39 (0.14) $n = 14$	0.30 (0.18) $n = 9$
Sagebrush Sparrow			
Control	0.92 (0.08) $n = 9$	0.72 (0.12) $n = 23$	0.29 (0.05) $n = 9$
Dormant	0.38 (0.10) $n = 14$	0.43 (0.12) $n = 22$	0.40 (0.08) $n = 16$
Rotational	0.69 (0.18) $n = 13$	0.62 (0.19) $n = 13$	0.25 (0.07) $n = 11$

Table 2.2. Logistic exposure models of nest success comparing weather, grazing treatment, vegetation and camera covariate sets (top models from Appendix 1; Tables A2.2–3) among sites and years for Brewer’s sparrow ($n = 97$) and sagebrush sparrow ($n = 132$) in southeast Oregon, USA, 2017–2019. The number of model parameters is denoted by K , ΔAIC_c is the difference from the top model in Akaike’s Information Criterion adjusted for small sample size, and w_i is the model weight. See Appendix I; Table A2.1 for a list of all tested covariates, their descriptions and summaries. Top Brewer’s sparrow model $AIC_c = 249.12$ and sagebrush sparrow $AIC_c = 362.37$.

Model	K	ΔAIC_c	w_i	Deviance
Brewer’s sparrow				
Weather + Vegetation	10	0.00	0.38	-114.46
Weather + Vegetation + Camera	11	0.30	0.30	-113.59
Weather + Camera	10	1.13	0.16	-115.03
Weather	9	1.18	0.16	-116.07
Vegetation	2	29.35	0.00	-137.23
Camera	2	29.87	0.00	-137.49
Null	1	30.28	0.00	-138.69
Sagebrush sparrow				
Weather + Graze + Vegetation + Camera	16	0.00	0.64	-165.02
Weather + Graze + Vegetation	15	1.43	0.31	-166.76
Weather + Graze	14	6.59	0.02	-170.35
Weather + Graze + Camera	15	7.27	0.02	-169.67
Weather + Vegetation	12	10.66	0.00	-174.42
Weather	11	12.15	0.00	-176.18
Weather + Camera	12	12.35	0.00	-175.26
Graze + Vegetation + Camera	6	44.14	0.00	-197.23
Graze + Camera	5	45.91	0.00	-199.12
Graze	3	47.79	0.00	-202.07
Camera	4	50.94	0.00	-202.64
Graze + Vegetation	2	51.79	0.00	-205.08
Vegetation	5	51.95	0.00	-202.14
Null	2	52.00	0.00	-205.18

Table 2.3. Parameter estimates and 95% confidence intervals (LCL and UCL) from top AIC_c-selected logistic exposure models for sagebrush sparrow and Brewer's sparrow (Appendix I; Table A2.2) in southeast Oregon, USA, 2017–2019. Precip % nesting indicates proportion of days with precipitation during nesting, see Appendix I; Table A2.1 for a list of all tested covariates, their descriptions and summaries. Nesting indicates weather while nest was active, and @fate indicates 72-hour period around date of nest fate.

Parameter	Estimate	Std. Error	z value	Pr(> z)	95% CI
Brewer's sparrow					
(Intercept)	-32.54	13.03	-2.50	0.01	(-58.079, -6.996)
Precip % Nesting	9.72	5.45	1.78	0.07	(-0.967, 20.401)
Precip % Nesting ²	-28.69	9.47	-3.03	0.00	(-47.258, -10.128)
Temp Diff Nesting	8.90	1.93	4.61	0.00	(5.119, 12.689)
Temp Diff Nesting ²	-0.31	0.07	-4.32	0.00	(-0.451, -0.17)
Day of Nesting Season	-0.38	0.12	-3.18	0.00	(-0.616, -0.146)
Max Temp @Fate	-1.64	0.74	-2.24	0.03	(-3.086, -0.203)
Max Temp @Fate ²	0.03	0.01	2.31	0.02	(0.005, 0.059)
Dead Sage Cover	-1.50	0.80	-1.87	0.06	(-3.068, 0.073)
Temp Diff Nesting ² × Day	0.00	0.00	2.74	0.01	(0.000, 0.002)
Sagebrush sparrow					
(Intercept)	-4.63	3.69	-1.26	0.21	(-11.858, 2.596)
Temp Difference Daily	1.42	0.30	4.65	0.00	(0.819, 2.011)
Temp Difference Daily ²	-0.04	0.01	-4.51	0.00	(-0.057, -0.022)
Precip Average Nesting	2.90	0.77	3.78	0.00	(1.394, 4.398)
Precip Average Nesting ²	0.35	0.29	1.21	0.23	(-0.214, 0.905)
Day of Nesting Season	0.06	0.04	1.81	0.07	(-0.005, 0.13)
Max Temp @Fate	-0.67	0.29	-2.31	0.02	(-1.246, -0.102)
Max Temp @Fate ²	0.03	0.01	3.22	0.00	(0.01, 0.041)
Min Temp @Fate	0.18	0.06	3.05	0.00	(0.063, 0.29)
Grazed Sites	-4.16	1.21	-3.43	0.00	(-6.537, -1.783)
Year	-0.93	0.46	-2.03	0.04	(-1.834, -0.031)
Dead Sage Cover	-2.13	0.70	-3.06	0.00	(-3.493, -0.763)
Camera Present	0.62	0.33	1.88	0.06	(-0.027, 1.275)
Precip Average Nesting ² × Day	-0.04	0.01	-3.96	0.00	(-0.055, -0.019)
Max Temp @Fate ² × Day	0.00	0.00	-3.37	0.00	(-0.0003, -0.0001)
Grazed Sites × Year	1.79	0.52	3.49	0.00	(0.785, 2.801)

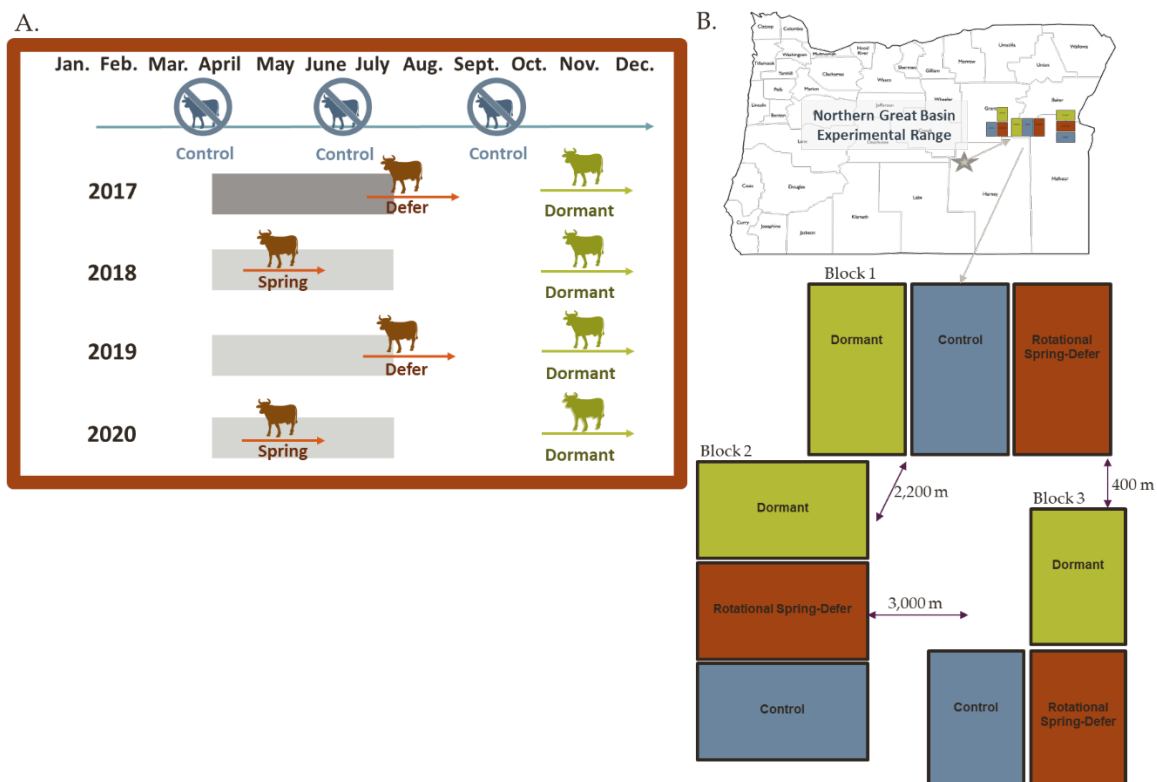


Figure 2.1. A) Timeline of grazing treatment application and songbird nest success collection. Grazing treatments represented by cow icons and include dormant season (green), rotational spring/summer graze (red orange) and control (no-grazing, blue). Grey boxes represent nesting season data collection. The dark grey box represents pre-treatment nesting season data collection. B) Study pasture layout of randomized experimental block design, consisting of 3 blocks, each with 1 pasture of each treatment. Double sided arrows indicate closest distance from fence to fence within blocks. Study located at the Northern Great Basin Experimental Range (NGBER) in southeast Oregon from 2017–2020. Data presented only for 2017–2019 breeding seasons. Treatments were randomly assigned. Pasture size varied among, but not within, blocks (5.69–7.41 HA)

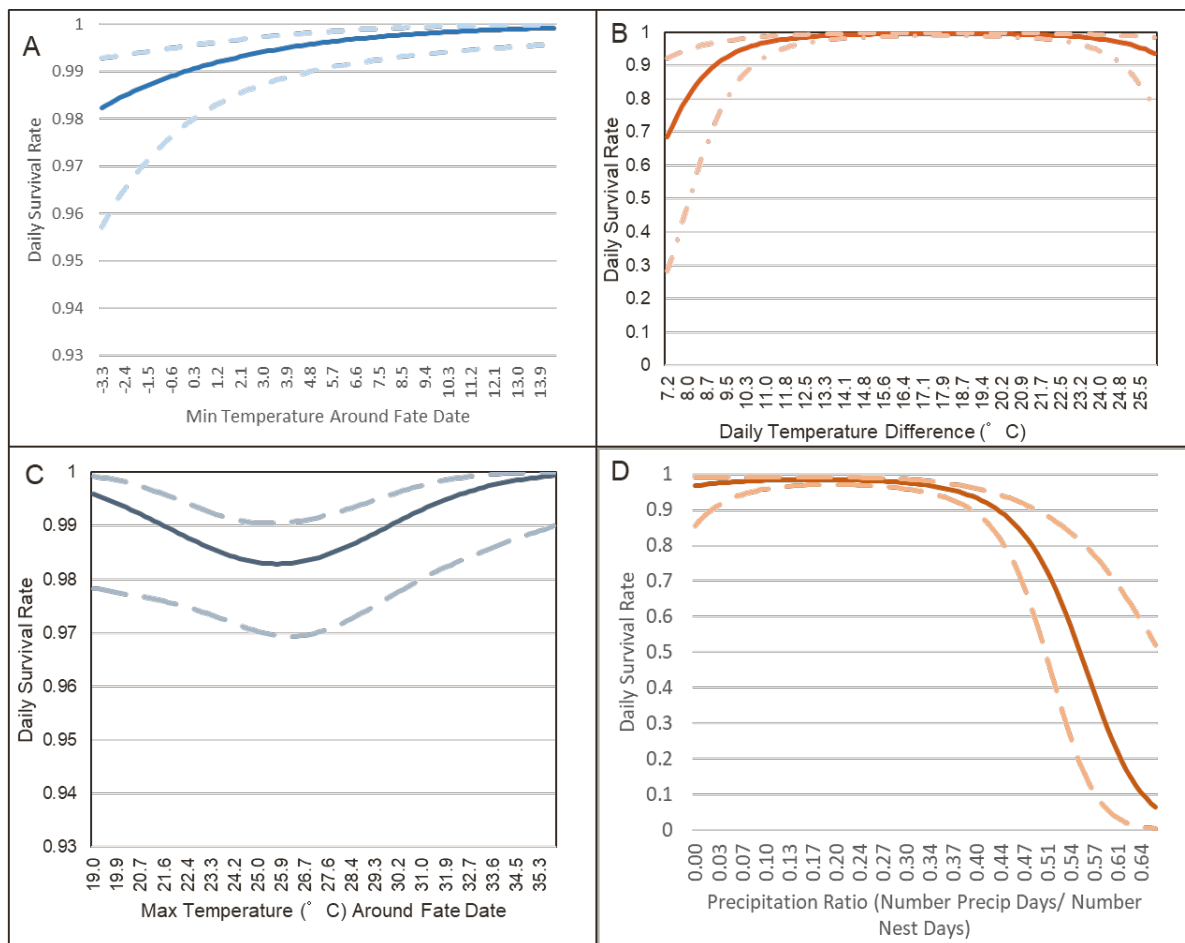


Figure 2.2. Daily survival rate estimates for showing weather variables in the top models, holding all other variables at their median values, for and sagebrush sparrow (A–B) and Brewer’s sparrow (C–D), including temperature (A–C) and precipitation (D) in southeast Oregon, USA 2017–2019. Dashed lines represent 95% confidence intervals.

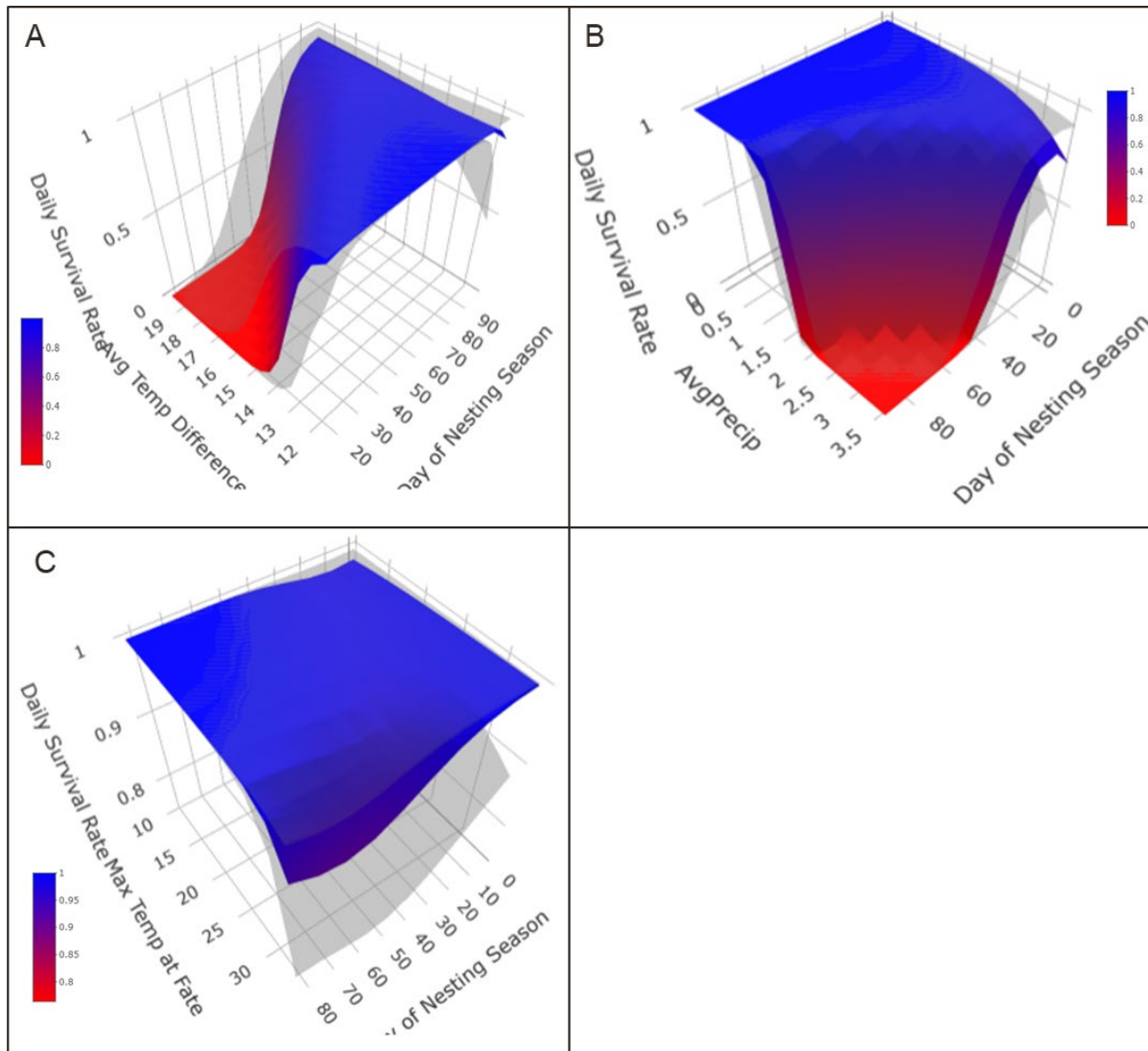


Figure 2.3. (A) Daily survival rate estimates for the average temperature difference by day of nesting season interaction for Brewer's sparrow, (B) average precipitation by day of nesting season interaction, and (C) max temperature around fate date by nesting season interaction for sagebrush sparrow in southeast Oregon, 2017–2019. Results from the top AIC_c ranked model with all other covariates held at their median. Grey transparent planes represent 95% confidence intervals. Interactive graphs found at A: <https://rpubs.com/schroeva/654141> B: <https://rpubs.com/schroeva/654162> C: <https://rpubs.com/schroeva/655076>

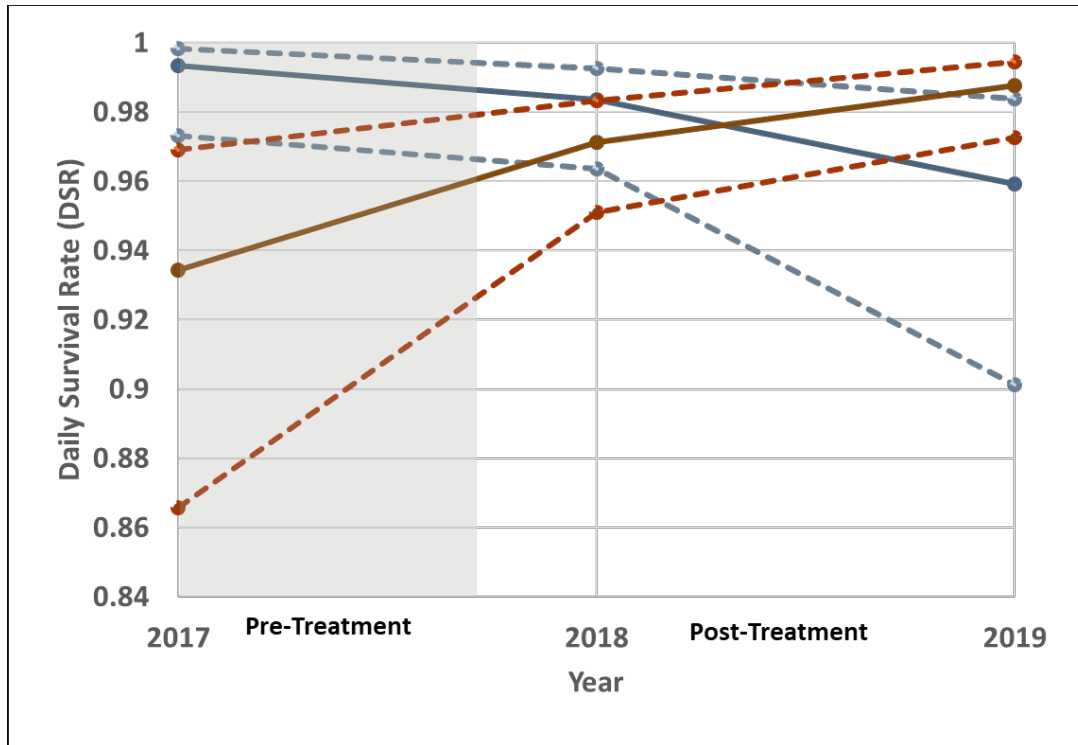


Figure 2.4. Estimated daily survival rate for the grazing site (control sites: blue, $n = 41$, grazing sites: burnt orange, $n = 91$) by year interaction for sagebrush sparrow nests in southeast Oregon, 2017–2019. Results from the top AIC_c ranked model, day held at day 54 of nesting season, no nest camera, and all other covariates held at their median. Shaded box indicates pre-treatment daily survival rate in 2017. Dashed lines represent 95% confidence intervals.

CHAPTER 3

How does cattle grazing affect the nest predator community of sagebrush-obligate songbirds?

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INTRODUCTION

Livestock grazing occurs worldwide, spanning over 25% of global land, and serves as the predominate land-use on private and public rangelands throughout the western US, occurring on roughly 70% of the landmass across western states (Asner et al., 2004; Fleischner, 1994). Cattle grazing decreases herbaceous plant cover (Davies et al., 2010; Kerns et al., 2011; Sternberg et al., 2000), influences insect communities (Debano, 2006; Kruess and Tschardtke, 2002) and alters plant community composition and structure (Davies et al., 2018; Holechek et al., 1999; Jones, 2000; Krausman et al., 2009). These plant and insect community effects could translate to increasing or decreasing use, behavior or abundance of wildlife species that rely on these resources for food and cover (Bock et al., 1984; Bylo et al., 2014; Johnson et al., 2011; Jones, 2000; Milchunas et al., 1998; Torre et al., 2007). Grazing occurs extensively across the arid sagebrush ecosystem that is home to many sensitive and declining sagebrush-obligate birds, including the Brewer's sparrow (*Spizella breweri*) and sagebrush sparrow (*Artemisospiza nevadensis*; Knick et al., 2003). Despite extensive overlap of grazing and these species' breeding ranges, information on how grazing influences metrics important to species population dynamics, such as reproductive success, is scarce. Schroeder (2020, Chapter 2) found a grazing-induced increase in sagebrush sparrow nest success but did not detect an effect of grazing on Brewer's sparrow nest success. The effect on sagebrush sparrows was associated with habitat quality changes in response to our cattle grazing treatments, potentially due to grazing influencing the predator community, indirectly leading to changes in nest success.

Predation has the potential to strongly influence species population dynamics, and it ranks as the primary cause of songbird nest failure (Martin, 1993; Ricklefs, 1969). Despite its critical role in songbird demography, nest predator assemblages remain largely understudied for many species, particularly in arid habitats, although recent technological advances have sparked increasing research interest (Ibáñez-álamó et al., 2015; Moore and Robinson, 2004). Identifying nest predator species, both common and uncommon, is required to assess whether grazing-driven changes in the predator community influence nest success. Predators of songbird nests in sagebrush ecosystems are known to include birds, reptiles and mammals, particularly rodents (Chalfoun and Martin, 2010, 2007; Hethcoat and Chalfoun, 2015a; Ribic et al., 2012; Vander Haegen et al., 2002; Welstead et al., 2005), although nest predator species and community compositions throughout the sagebrush ecosystem may differ. Livestock grazing has the potential to alter local songbird predator communities through management of timing and magnitude of grazing. For example, grazing can decrease the abundance or activity of

potential nest predators including snakes (Larson, 2014), rodents (Bich et al., 1995; Bock et al., 1984; Jones et al., 2003; Medin and Clary, 1989), raptors (Johnson and Horn, 2008) and badgers (Bylo et al., 2014; Mullen et al., 2013). Moderate grazing, specifically in arid rangelands, can reduce rodent species diversity and abundance (Bich et al., 1995; Bock et al., 1984; Jones, 2000; Jones et al., 2003; Medin and Clary, 1989), although the effect varies by species, and under higher grazing intensities some rodents increase (Bich et al., 1995; Bylo et al., 2014; Jones et al., 2003). The removal of herbaceous material by cattle may reduce food sources or screening cover for certain rodents, altering their foraging and predator avoidance behaviors (Kotler, 1984). These factors could potentially reduce rodent activity in grazed pastures. A reduction in rodents that prey on songbird nests could directly benefit songbirds if rodents are a significant source of predation (Hethcoat and Chalfoun, 2015a), or indirectly if their reduction simultaneously reduces predators that prey on both rodents and songbirds, such as bobcats, badgers or snakes.

In this study, we evaluated the influence of grazing on predator communities of sagebrush-obligate songbird nests across an experimental landscape where timing of grazing was manipulated. We studied activity of songbird predators in pastures experiencing dormant season grazing, rotational grazing or no grazing. To assess differences across treatments in the predator communities, we first identified all known and suspected nest predator species and measured indices of their abundance for Brewer's sparrow and sagebrush sparrow using multiple survey methods across the landscape. We then determined from cameras placed at nests, which of those predators were most responsible for nest losses and how those losses varied across treatments. By assessing predator activity at nests and throughout the pastures at the same spatial and temporal scale as the grazing treatments, we evaluated the hypothesis that decreased predator activity was one mechanism behind a grazing-induced increase in nest success.

METHODS

Study Area

We conducted our study in nine pastures (5.69–7.41 HA) arranged into three blocks consisting of three treatments each within the Northern Great Basin Experimental Range (NGBER; lat 43°29'N, long 119°43'W) 50–60 km west of Burns, Oregon, from 2017–2020 (Figure 3.1). Elevation of the pastures ranged from 1,300–1,500 m. Climate consisted of wet, cool winters followed by hot, dry summers, typical of the northern Great Basin, with a long-term (1938–2020) average precipitation of 278 mm

(standard deviation = 82.8 mm) according to the nearest NOAA station (RILEY 10 WSW, OR US). Crop year (September 1–August 30) precipitation during the study years was 74%, 124% and 79% of the long-term average for 2018, 2019 and 2020, respectively.

All pastures experienced a similar historical grazing regime and had similar plant communities, soils, aspect and gradients prior to this study. Soils in two of the three blocks were primarily Actem cobbly loam, while soils in the third block were mostly comprised of Raz-Bruce complex. Soils in all sites were well drained but underlain with a welded tuff and basalt geology, restricting root penetration at a hardpan around 30–50 cm in the Actem soils and 50–95 cm in the Raz-Brace. Wyoming big sagebrush (*Artemisia tridentata wyomingensis*) and green rabbitbrush (*Chrysothamnus viscidiflorus*) were the dominant shrubs. The dominant perennial bunchgrasses varied by block but were relatively consistent among pastures within a block. Dominant grasses included bluebunch wheatgrass (*Pseudoroegneria spicata*), Thurber's needlegrass (*Achnatherum thurberianum*), bottlebrush squirreltail (*Elymus elymoides*), Idaho fescue (*Festuca idahoensis*), prairie junegrass (*Koeleria macrantha*), and needle and thread (*Hesperostipa comata*). Plant communities within pastures exhibited minimal invasion by exotic annual grasses and were representative of those in the northern Great Basin (Davies et al., 2006; Davies and Bates, 2010).

Study Design and Grazing Treatment Application

We used a randomized complete block design with three blocks to determine the effects of three grazing treatments on sagebrush-obligate songbird predator community and nest success (Figure 3.1). Grazing treatments consisted of dormant season grazing, rotational grazing and a control experiencing no grazing during the study. Treatments were assigned randomly to one of the three pastures in each block. Pasture size varied among, but not within blocks. The dormant season grazing treatment occurred during fall or winter from 2017–2020 (Figure 3.1), after the native bunchgrasses entered dormancy. The rotational grazing treatment consisted of alternating season of grazing each year, between summer grazing after bunchgrasses completed reproduction and seed shatter, and were less susceptible to grazing (~mid-July 2017 and 2019) and spring growing season grazing when grasses were more sensitive to grazing during May (2018 and 2020) (Figure 3.1). This study focused on predator community mechanisms hypothesized to vary with grazing treatment. However, predator data collection began in 2018 after grazing treatment implementation began in 2017; thus, the data collection for this study was 2018–2020 (Figure 3.1).

Each year we varied stocking rates based on the amount of available herbaceous forage, quantified by systematically clipping herbaceous material in 15 evenly spaced 1 m² frames in each pasture prior to cattle grazing (e.g., Chapter 2, Schroeder 2020; Bates and Davies, 2014). We visually checked each pasture during cattle grazing every few days to prevent over or under-utilization. We assessed the post-treatment level of grazing utilization by using protocols employed by the local Bureau of Land Management (BLM), which were based on the landscape appearance method (e.g., Coulloudon et al., 1999). This technique visually estimated forage utilization based on the general appearance of the pasture. Utilization was determined by comparing observations with written descriptions of six different grazing utilization classes from no use to severe use: no use (0–5%), slight (6–20%), light (21–40%), moderate (41–60%), heavy (61–80%) or severe (81–100%; BLM personal communication). After grazing treatments were completed and cattle removed, the same BLM employee assessed each pasture for grazing utilization.

Predator Activity

We utilized pasture-level and nest-level game cameras (Cuddeback Black Flash [Silver Series], Model 1231 and Browning Dark Ops HD Max), transect surveys and avian point counts to calculate indices of predator activity throughout our study pastures. Predators were stratified into group (avian, reptile, rodent, or meso-predator) and identified to species when possible. A grid of pasture-level cameras was placed in study pastures for the duration of the breeding season. The number of cameras remained consistent within each year but varied across years (ranging from $n = 4$ to $n = 9$). Due to camera failures, sampling effort was not consistent across all pastures and years; thus, the number of predators observed was standardized by number of camera trap days (summed number of days each camera in a pasture was active and functioning). All cameras were set to be triggered by motion detection. Settings varied slightly between camera models, so camera model was randomly distributed for pasture-level and nest-level cameras. Pasture-level cameras were placed at a height, angle and orientation which was previously tested to capture small (rodents) and larger mammals (Schroeder unpublished data). We set pasture-level cameras to capture one-third sky within the viewshed, avoided east or west orientations to prevent sunrise and sunset from falsely triggering, and cleared herbaceous vegetation away from an average of a 30 cm diameter area in front of the cameras. Pasture-level cameras were secured with wire at the base of sagebrush, utilizing rebar to stabilize if needed, with the sensor roughly 15 cm above ground level. To calculate our index of pasture level predator activity, we

summed predators across all pasture-level cameras in a pasture for the entire nesting season and standardized by the total number of camera trap days.

Our game camera methods were not designed to adequately detect reptiles or avian predators in flight throughout the study pastures (Hobbs and Brehme, 2017); thus, we conducted transect predator surveys as an additional method for predators unlikely to be captured by cameras (Kelly, 2008; Marcus Rowcliffe et al., 2011). Observers quantified potential nest predators heard or observed during transects, including snakes, rodents and avian predators. Transects were conducted with observers spread 5 m apart, using a handheld GPS unit to avoid transect overlap, until the pasture was completely searched. Transect surveys were conducted weekly in most cases; however, access and time constraints resulted in some transect surveys occurring bi-weekly. Walking direction (E-W or N-S) was alternated between complete transect surveys. Activity or abundance quantified from transect surveys and point surveys can be used as a reliable index to assess relative differences in numbers of larger bodied predatory birds (Hardey et al., 2006). We followed standardized methods, allowing us to calculate an avian predator activity index specific to this study, where observers walked with eyes ahead focused on sagebrush within the study plots (not searching the sky), noting any predators heard or seen within pasture boundaries. While avian detections >75 m from transects were likely limited or undetected, we have high confidence in avian predator detections within a 75 m radius ahead of each observer. The avian predators detected in this manner likely represent birds hunting within the area, and not simply passing through.

We also conducted a total of 397 5-minute avian point count surveys within 3 hours of sunrise at a total of 18 locations ($n = 2$ per pasture) repeated 6–9 times annually as an additional metric for quantifying avian predators. Avian predator point count metrics were summarized across blocks, not treatments, as treatment pastures are separated by a fence with no spatial buffer, and avian predators likely used entire blocks. The point count method was unable to quantify differences in predator foraging time among treatments; thus point count data was not included in the grazing treatment/predator analysis for this reason.

Nest Searching and Monitoring

Nests of Brewer's sparrow and sagebrush sparrow were found by systematically searching each pasture weekly or bi-weekly during April–July during the transect predator surveys. We found nests through a combination of behavioral cues and systematic searches, lightly tapping shrubs with a 2-m

long flush stick, and intensively searching shrubs when songbirds flushed. We monitored nests every 2–4 days until fledging or failure to determine nest fate (Chalfoun and Martin, 2010; Hethcoat and Chalfoun, 2015b; Martin and Geupel, 1993). We defined success as nests which produced at least one fledgling, determined by the presence of fledglings near the nest, adults giving alarm calls or carrying food items nearby, observation of a fledging event, or the condition of the nest bowl and evidence that chicks were old enough to fledge (Chalfoun and Martin, 2010; Manolis et al., 2000; Martin and Geupel, 1993). We deemed nests unsuccessful if there was obvious sign of a destroyed nest, disappearance of eggs or chicks before possible fledging age, or we observed the predation event (Chalfoun and Martin, 2010; Manolis et al., 2000). To aide in nest success determination we utilized temperature sensors (iButtons model DS1921GF5) at a subset of nests. Paired iButtons helped us identify an empty or abandoned nest when temperatures in a nest matched the temperature profile of the reference iButton set outside the nest in the nesting shrub, indicating eggs or nestlings were gone or no longer kept warm when parental care ceased (Hartman and Oring, 2006; Sutti and Strong, 2014).

Nest Predator Identification

We utilized game cameras near nests (i.e., nest-level cameras) to identify which predators were responsible for nest losses, and to aide in accurate determination of nest success. Cameras at nests were highly camouflaged and placed 20–150 cm away from nests either within the nesting shrub or in an adjacent shrub to optimize the view of the nest while minimizing disturbance (Hethcoat and Chalfoun, 2015a). We defined nest predators as predators caught on nest-level cameras during the timeframe a nest was known to have been depredated, or actively seen within a nest bowl. Predators caught on nest-level cameras not in the nest bowl or not during the timeframe the nest was depredated were not included in the analyses. Similar to the pasture-level predator activity variables, nest-level predator variables were summed across the entire season for an entire pasture and standardized for effort.

Analyses

Predator Activity

We assessed raw predator count data from pasture-level and nest-level cameras and transect data using a Poisson or negative binomial distribution with the negative binomial distribution used if overdispersion was detected in models using the Poisson distribution. These analyses were conducted in program R (x64 version 4.0.2; RStudio version 1.3.959). Effort was included as an offset term in all count

based models to account for differences in traps nights and transect effort hours among pastures and camera types, which is a common method used for estimating prey abundance and distribution from camera trap data (e.g., Kafley et al., 2019). We estimated counts of each potential nest predator separately as individual species, including American badger (*Taxidea taxus*, hereafter badger); coyote (*Canis latrans*); bobcat (*Lynx rufus*); chipmunks (*Tamias spp.*); ground squirrels (*Spermophilus spp.*); mice (subfamily *Neotominae*); loggerhead shrike (*Lanius ludovicianus*, hereafter shrike); gopher snake (*Pituophis catenifer*); western yellow-bellied racer (*Coluber constrictor mormon*) and common raven (*Corvus corax*, hereafter raven). We also quantified predators by groups (snake, rodent, avian and meso-predator) and analyzed their counts as response variables in addition to the individual species analyses. All predators for count-based analyses were counted at the resolution of grazing treatments (i.e., pasture by year). For example, the counts of badger summed across a pasture were used as the response variable, and we tested grazing treatment and camera type as predictor variables. We included grazing treatment (categorical: no-grazing, dormant grazing, rotational grazing) covariates in the model associated with *a priori* hypotheses. Camera type (nest-level or predator-level camera) was incorporated into each predator activity model as a predictor variable to compare predator activity throughout study pastures with the predator species responsible for nest losses. For predator species not captured on nest-level cameras and/or not in one of the grazing treatments, thus exhibiting complete separation between nest and pasture predator communities or between grazing treatments and control treatments within our dataset, we only report the raw number of predators caught on camera and number of trap days, as estimating regression coefficients was not possible. We interpreted our beta coefficients as percent change, calculated from the count models by back transforming the coefficients and multiplying by 100.

Nest Success

We analyzed nest success in program R (x64 version 4.0.2; RStudio version 1.3.959) using package lme4 (version 1.1-23; Bates et al., 2015) and the logistic exposure method (Shaffer, 2004). Logistic exposure utilizes an encounter history to model nest survival as a logistic function of the explanatory variables over the timeframe the nest was active. This method accounts for possible bias imposed by nests with different exposure periods found after nest-initiation. We analyzed nest success separately for Brewer's sparrow and sagebrush sparrow, using an information-theoretic approach (Anderson, 2007). Models were compared using Akaike's Information Criterion corrected for small sample sizes (AIC_c) and Akaike model weights (w_i ; Akaike, 1987, 1973; Burnham and Anderson, 2002)

using the AICcmodavg package (version 2.3.1-2; Mazerolle, 2020) in R. All nests found during the study (with and without nest cameras) were included in the nest success analyses.

Previous analyses conducted using data from the same study, with different, but overlapping years, demonstrated the importance of weather in explaining nest success (Chapter 2, Schroeder 2020). We included weather variables determined from Chapter 2, Schroeder 2020 in all nest success analyses to account for effects of weather. Precipitation and temperature swings during the nesting period and maximum and minimum temperatures around the estimated fate (see Appendix I; Table A2.1 for variable descriptions) were included in base models. Data collection for predator variables began in 2018, the first year of grazing treatment application, which was one year after the weather and songbird nest success data collection began for the overall study (Figure 3.1). To test specific *a priori* predator hypotheses, we first fit a predictive weather model based on known effects (Chapter 2, Schroeder 2020), against which we tested models representing our predator hypotheses. Predator variables calculated from pasture-level game cameras in the nest success analysis were calculated as time-varying variables and were quantified during the timeframe in which those nests were predicted to be active (24 hours before estimated egg laying and 24 hours after estimated fate). For example, predator activity covariates were calculated using pasture-level game cameras as described above, but the timeframe was narrowed from the entire nesting season to the period in which each individual nest was predicted to be active. These variables were calculated as the sum of predators caught on all active game cameras located in the pasture the nest occurred in, during the timeframe the nest was active, and standardized by effort (summed total of active cameras by days active; Appendix II; Table A3.1). To allow for easier interpretation, we scaled variables by multiplying by 100 to give the number of predators per 100 trap days. Finally, all avian predators seen or heard during point count surveys were recorded and avian predator variables for nest success analyses were calculated by summing the predators observed within the effective detection radii (Dinkins et al., 2014, 2012) and standardizing by the number of visits.

In order to avoid multicollinearity, we did not include any two variables with Pearson's correlation coefficient $r \geq |0.65|$ in additive models. When two variables were highly correlated, we retained the best fitted variable as determined by lowest AIC_c value from single variable models, or that made the most sense biologically. We then followed Arnold (2010)'s approach for eliminating uninformative parameters, and removed non-informative covariates with parameter estimate 85% confidence intervals (CIs) that overlapped zero. Next in the modeling process, we tested additive combinations of all remaining informative predictor variables, including pairwise interactions. We then

ranked using ΔAIC_c , and we considered models within two ΔAIC_c of the top overall model competitive (Burnham and Anderson, 2002).

Predator, Treatment and Year Interactions

In addition to the potential predator and nest predator analyses described above under predator activity, we tested post-hoc hypotheses using only the pasture-level predator camera count data. We analyzed the count data as described above, using a Poisson or negative binomial distribution depending on overdispersion and trap day effort as an offset term. For all pasture-level camera predator covariates that helped explain differences in nest success (i.e., ranked by ΔAIC_c above the base weather model) from the nest success analyses described above, we tested post-hoc multi-predator interaction hypotheses. Predators were tested as both the response variable as counts and an explanatory variable as predator activity (count standardized by trap days) for other nest predator species, in addition to treatment and year models and their combinations. For example, if we found support for badger and ground-squirrel activity in the nest success analyses, then we would assess raw badger counts as the response variable using count models and include year, treatment, treatment \times year and ground squirrel activity (count standardized by trap days) and the various additive combinations. We would then include badger activity (count standardized by trap days) as an explanatory variable for the other nest predators. Effort was accounted for as an offset term for all raw count variables used as a response variable. We ranked models using ΔAIC_c , and report only the top ranked models.

RESULTS

Predator Activity by Grazing Treatment

Game cameras were deployed throughout pastures for a total of 11,907 trap days and at nests for 1,272 trap days (Table 3.1). Due to overdispersion in all of our predator data, we analyzed count data using negative binomial models and found that rotational grazing, and to a lesser extent, dormant season grazing, had lower nest predator activity throughout study pastures and across all predator groups (Tables 3.1–3.2). Predator activity across pasture-level cameras and nest-level cameras for the two sparrow species were similar for all predator species and groups (Table 3.2). Activity of meso-predators, rodents, and avian predators throughout the pastures was 52 to 85% less, depending on the predator species, in rotationally grazed pastures relative to the control pastures (Table 3.2). We did not detect ravens in rotationally grazed pastures, nor bobcats in control pastures (Table 3.1). Badgers and chipmunks were 50% and 90–91% lower, respectively, in both grazing treatments relative to controls,

although confidence intervals slightly overlapped zero for the badger variable in dormant grazed pastures, and mice activity was 70–71% lower in rotationally grazed pastures (Table 3.2). Dormant grazed pastures also experienced fewer avian predators compared to controls (Tables 3.1–3.2).

In our walking transect surveys, totaling 1,220 effort hours, we recorded 813 ground squirrels, 67 chipmunks, 24 snakes, of which 10 were Great Basin rattlesnakes (*Crotalus viridis lutosus*), 5 were gopher-snakes and 9 were not identified to species, 12 burrowing owls (*Athene cunicularia*), 11 shrikes, 6 red-tailed hawks (*Buteo jamaicensis*), 2 ferruginous hawks (*Buteo regalis*) and 32 ravens over three years. Sample sizes were too small for all avian predators to analyze, except for ravens. There was no relationship between treatment and predator groups detected during transect surveys (where 95% CIs overlapped zero), except for ravens, where detections were lower in dormant season pastures relative to controls ($\beta = -1.32$ 95% CI: [-2.72 to -0.10]).

During point-count surveys, we detected 67 ravens and 9 shrikes. Only 10 raven sightings and 6 shrike sightings were detected within pasture boundaries. Thus, point count data was summarized across blocks rather than treatments, where number of ravens within an effective detection radii per visit varied from 0.03 to 0.27.

Predator Identification at Nests

In total, 52 Brewer's sparrow and 72 sagebrush sparrow nests were photo monitored, but 16 and 35 cameras failed to operate properly for Brewer's and sagebrush sparrows, respectively. We video confirmed 19 and 21 fledging events, 8 and 9 predators, and missed 8 and 7 predation events for Brewer's sparrow and sagebrush sparrow, respectively. We captured 10 nest predator species, including avian predators: shrike, raven, American Kestrel (*Falco sparverius*), and red-tailed hawk; reptilian predators: gopher snake and western yellow-bellied racer; rodent predators: ground squirrel, and chipmunk; and meso-predators: bobcat, and badger (Table 3.3). Avian predators represented 60% of identified depredations in Brewer's sparrow nests. Gopher snakes were the primary nest predator captured on camera for sagebrush sparrow, representing 50% of identified nest depredations (Table 3.3). Several species of potential nest predators, including coyote, mice, and kangaroo rats (*Dipodomys spp*) were photographed <1 m from nests on nest-level cameras but did not depredate those nests. Known nest predators, including badgers and ground squirrels, were also caught on nest-level cameras without depredating nests; these instances were excluded from analyses.

Not all potential predators detected in the overall study were documented on camera depredating nests (Tables 3.1–3.3). We did not detect bobcats, coyotes, ground squirrels nor mice as depredators of Brewer’s sparrow nests, nor badgers, coyotes, mice, ravens, nor shrikes as depredators of sagebrush sparrow nests (Tables 3.1–3.3). Meso-predator and rodent activity, particularly chipmunk activity, was higher in pastures than in Brewer’s sparrow nests, while more avian predators were detected depredating Brewer’s sparrow nests than expected based on pasture-level activity (Tables 3.1–3.2). Sagebrush sparrow nests experienced fewer meso-predator, chipmunk and ground squirrel depredations than expected based on activity in pastures (Table 3.2). Snakes depredated nests of both sparrow species, although snake species varied, and there was only one incidence of a snake (yellow-bellied racer) captured on pasture-level predator cameras (Tables 3.1–3.3). Nest-level cameras did not capture any snakes depredating nests in control pastures (Table 3.1–3.2).

Nest Searching and Monitoring

We monitored a total of 262 sagebrush-obligate songbird nests, including 130 Brewer’s sparrow and 132 sagebrush sparrow. One sagebrush sparrow nest was excluded from the dataset due to researcher caused failure when a researcher led cows to a nest that was subsequently trampled. Mayfield nest success varied between 0.47 and 0.56 for Brewer’s sparrow and 0.29 and 0.69 for sagebrush sparrow and across years (Table 3.4). Apparent nest success (number of successful nests divided by total number of nesting attempts) for nests with and without cameras was 69% and 34% for sagebrush sparrows, and 65% and 58% for Brewer’s sparrows respectively. We deployed 131 nest cameras and 35 iButtons. We attributed predation, abandonment and parasitism as the causal factor for 74%, 18% and 1% of failed nests, respectively.

Nest Success and Predator Activity

All covariates for each songbird species’ respective predictive base-weather models were informative and thus used as the predictive base model to compare to models related to our predator hypotheses (Table 3.5–3.6). We found some evidence that predator activity during the nesting timeframe influenced nest success for both Brewer’s sparrow and sagebrush sparrow (Table 3.6). Coyote activity, snakes found during transects and badger activity best explained differences in nest success for Brewer’s sparrow (Tables 3.6–3.7). We found that ground squirrel activity best described differences in sagebrush sparrow nest success (Tables 3.6 and 3.8). Our results indicated that rodents detected during transects and badger activity during the nesting timeframe played a role in declining

sagebrush sparrow nest success (Tables 3.6 and 3.8). Brewer's sparrow nests survived better when snake and badger activity was less, and coyote activity was higher (Table 3.7). Sagebrush sparrow nest success was higher when ground squirrel and badger activity was less during the nesting period and when rodent activity (as a predictor variable quantifying chipmunk and ground squirrels together) detected during transects throughout a pasture for the entire nesting season was lower (Table 3.8). Several competitive models included raven detections during transects, but the covariate remained imprecise (95% CIs that widely overlapped zero) in all model variations (Tables 3.6 and 3.8).

Predator, Treatment and Year Interactions

We tested models including year and treatment \times year for predator species that had adequate sample sizes, including badgers, coyotes, chipmunks, ground squirrels and shrikes (Appendix II; Table A3.2). The null model was the top model for the shrike model set. Chipmunks increased over time, and overall, ground squirrel activity remained constant through time (Table 3.9, Appendix II; Table A3.2). Rotationally grazed pastures experienced lower ground squirrel activity overall compared to control pastures, but these pastures saw increases through time, while dormant pastures remained constant (Table 3.9, Appendix II; Table A3.2).

Predator activity was influenced not only by grazing treatment, but also by other nest predators (Appendix II; Table A3.2). Badger activity was best explained by grazing treatment, coyote and ground-squirrel activity (Table 3.9, Appendix II; Table A3.2). Badger activity was lower in grazed pastures. Independent of other variables, greater ground squirrel activity predicted higher badger activity. Badger activity appears to correlate with coyote activity, where higher badger activity predicted greater coyote activity in a pasture (Table 3.9).

DISCUSSION

Successful conservation of wildlife on working lands relies upon understanding both the direct effects of grazing management and the underlying mechanisms affecting fitness of sensitive species. However, few studies document songbird predator communities first-hand, and even fewer assess the role grazing management can play in nest predator-prey dynamics (Heske et al., 2001). We assessed and found support for the hypothesis that grazing influenced the nest predator community and was likely one mechanism explaining a previously observed increase in sagebrush sparrow nest success associated with grazing (Chapter 2, Schroeder 2020). Despite a small sample size, unlike previous research, we found that birds and snakes rather than rodents were the dominant predators documented on camera

depredating failed nests for both Brewer's sparrow and sagebrush sparrow nests (Table 3.3; Hethcoat and Chalfoun, 2015; Rotenberry and Wiens, 1989; Vander Haegen et al., 2002; Welstead, 1996). While avian species and snakes were documented proportionally depredating more songbird nests than rodents, rodents contributed to lower nest success of sagebrush sparrow nests (Tables 3.1 and 3.8). Pasture-level activity of potential nest predators was lower in rotationally grazed pastures relative to control pastures for all predator groups, and higher ground-squirrel, rodent, badger and snake activity was associated with lower songbird nest success (Tables 3.6–3.8).

Nest predator activity was generally lower in grazed pastures than controls with the lowest activity seen in rotationally grazed pastures (Table 3.2). We documented lower badger activity in grazed pastures, a pattern similar to research conducted in mixed-grass prairies (Bylo et al., 2014). Rodent activity, consisting of mostly mice and chipmunks, was lower in rotationally grazed pastures. Rodents similarly declined in response to grazing in arid rangelands (Bock et al., 1984; Jones and Longland, 1999; Jones et al., 2003). Deer mice can increase in abundance as disturbance increases, including grazing, and have been identified as a key nest predator for Brewer's sparrows (Bich et al., 1995; Hethcoat and Chalfoun, 2015a). We could not identify observed mice to species, thus were unable to disentangle more nuanced species levels effects. Unlike previous research, we did not document mice depredating nests (Hethcoat and Chalfoun, 2015a). Although, we did capture mice on pasture-level cameras on-top of and immediately in front of cameras, suggesting that the lack of mice documented on nest cameras was not an issue of camera avoidance, but instead a reflection of predation risk for the songbird species at our sites. While we cannot conclusively state that grazing lowered activity of these species due to our lack of pre-treatment data, the predator community was different under the different grazing treatments and grazing likely explains part of the mechanism behind the decline. Treatment pastures within blocks had no buffer between them and were separated by a permeable fence allowing for movement of all species except for cattle, and perennial vegetation did not differ among treatment pastures prior to grazing treatment application (Appendix II; Table A3.3). While grazing was the most likely cause of lower predator activity across treatment pastures, we cannot preclude the possibility that observed differences in predator activity existed prior to grazing treatments.

Sagebrush-obligate songbirds face a variety of potential nest predators, but the type or species of predator has historically been identified based on condition of the nest bowl for failed nests, which is a method known to inaccurately reflect predator identification (Coates et al., 2008; Larivière, 1999; Pietz, Pamela J., Granfors, 2000; Robinson et al., 2005; Thompson III et al., 1999). Understanding the species responsible for nest failures is critical when assessing predator-prey dynamics and their role

within a management context (Heske et al., 2001). Our study is the first to document a nest predator assemblage for sagebrush sparrows and added to the known predator community for Brewer's sparrows by recording ravens and bobcats at Brewer's sparrow nest predators. Nest predator assemblages included 10 different predator species but differed by sparrow species and were diverse in both predator species and type (Table 3.3). Surprisingly, we identified a far smaller proportion of rodents on nest-level cameras than previous research (Hethcoat and Chalfoun, 2015a). A large proportion of nest cameras missed the nest predation event, potentially due to species type, distance from nest or an unsatisfactory camera set (Table 3.3). Although possible, it is unlikely functioning cameras missed large nest predators, and more likely disproportionately missed smaller predators, such as rodents, birds or snakes. Even if we assume all missed predators were rodents, the nest predator assemblage in our study would still remain more diverse and have proportionally fewer rodents (47% versus 89%) than previous research on Brewer's sparrows (Hethcoat and Chalfoun, 2015a). This could be a result of differing disturbance levels across study areas. Hethcoat and Chalfoun documented an increase in rodent activity along a gradient of energy development, which was associated with lower nest success. Our study has no energy development in the area, thus could account for the observed differences in predator communities.

Unlike Hethcoat and Chalfoun (2015), we did document ravens at nests, a species identified as an important nest predator for the sagebrush-obligate greater sage-grouse (*Centrocercus urophasianus*) (Bui et al., 2010; Coates et al., 2020, 2008; Coates and Delehanty, 2010; Dinkins et al., 2016). Other nest predator species documented, including rodents, badgers, shrikes, snakes and kestrels, have previously been recorded for Brewer's sparrows (Chalfoun and Martin, 2010; Hethcoat and Chalfoun, 2015a). Snakes have long been suspected of playing a critical role in predator-prey dynamics for sagebrush songbirds but are notoriously hard to identify as nest predators, and are often missed in artificial nest experiments (Mahony et al., 2006; Reynolds, 1979; Rotenberry and Wiens, 1989; Welstead, 1996). Gopher snakes represented 50% of the total predators identified on sagebrush sparrow nest cameras, and the western yellow-bellied racer was captured consuming a clutch of Brewer's sparrow eggs (Table 3.3). Our findings suggest snakes likely play a much larger role in predator-prey dynamics of these songbirds than previously reported, especially for sagebrush sparrow, which nest closer to the ground than Brewer's sparrows (Reynolds, 1981, Appendix II; Table A3.1).

After accounting for weather effects, which accounted for a large proportion of variation in nest success, we found a negative effect of predator activity on nest success of both sparrows, supporting our hypothesis that nests in sites with greater predator activity while the nest was active also had a

greater probability of nest failure. However, pasture-level activity of predators that had a negative effect on nest success did not always align with predators documented on nest-level cameras. This suggests that identifying predators depredating nests alone is not sufficient to draw conclusions regarding the role of predation in reproductive success metrics (Tables 3.3 and 3.6). For example, badgers represented a relatively small portion of predators documented in nests, but higher badger activity was associated with lower nest success for both species, although the relationship was weak for sagebrush sparrow. Conversely, snakes were documented most frequently on sagebrush sparrow nest cameras but were not associated with lower nest success. This pattern could occur from a quantification bias by predator type, as our pasture-level camera methods for recording predators were more appropriate for mammals than reptiles as the passive infrared sensor in game cameras is designed to detect based on a combination of heat and motion (Hobbs and Brehme, 2017; Rowcliffe et al., 2011). Small animals, especially ectotherms like reptiles, have a smaller heat signature and are less reliably detected (Rowcliffe et al., 2011). While we incorporated transect surveys to document predators difficult to detect with pasture-level game cameras (Hobbs and Brehme, 2017; Kelly, 2008; Rowcliffe et al., 2011), our snake activity indices might not be representative of the snake predation threat, especially for sagebrush sparrows early in the season when reduced snake activity and behavioral differences likely influenced snake detections. This potentially could account for the discrepancy between finding snakes in nests but not as a predictor of nest success. Brewer's sparrows exhibited the opposite pattern, as we only documented one snake depredating a nest but did find evidence that increased snake activity resulted in lower nest success (Tables 3.6 and 3.7). Snakes captured on nest cameras were at very close range, and there is a chance that depredation events missed by functioning cameras ($n = 7$, Table 3.3) and at nests without cameras, were depredated by snakes. Despite potential snake detection issues in our study, and unlike previous research, our results suggest that snakes might play a much larger role in the predator-prey dynamics of sagebrush-obligate songbirds than previously thought, a hypothesis warranting additional testing.

Contrary to previous work, rodents did not play as large of a role in predator-prey dynamics of Brewer's sparrows, as they were not associated with differences in nest success nor documented on cameras depredating many nests (Hethcoat and Chalfoun, 2015a; Ribic et al., 2012; Rotenberry and Wiens, 1989). Conversely, higher rodent activity predicted lower nest success for sagebrush sparrows, confirming previous research (Hethcoat and Chalfoun, 2015a). Rodents might indirectly affect songbird nest success if increased rodent abundance or activity attracts more snakes, badgers or avian predators to the area (Bylo et al., 2014; Johnson and Horn, 2008; McCauley et al., 2006; Wolf et al., 2018), resulting in decreased nest success. Despite snakes comprising a larger proportion of predators captured

on nest-level cameras than rodents, increased snake activity was not associated with decreased sagebrush sparrow nest success. However, predators captured depredating nests on camera do not always translate to differences in population level reproductive success (Taylor et al., 2017). While these sparrow species share overlapping territories and nest in close proximity, their nest predator assemblages and nest success responses to different predator activities varied. These observed differences in predator-prey dynamics might explain observed differences in response to cattle grazing (Chapter 2, Schroeder 2020).

Brewer's sparrow nest success increased to our surprise with higher pasture-level coyote activity (Table 3.7). We hypothesized that coyotes and other meso-predators, such as bobcats and badgers, might decrease activity of other nest predators. Coyotes do not seem to play a large role in depredating sagebrush-obligate songbird nests as no other work has documented coyote depredations in sagebrush-obligate songbird nests and avian species comprise a minimal portion of their diet (MacCracken and Hansen, 1982; Marti et al., 1993; White et al., 1995). In addition, we documented a coyote on a nest camera walking within 1 m of a nest without depredating it. Increased coyote activity could result in higher nest success if other nest predators avoid areas with coyotes (Crooks and Soule, 1999; Greenwood et al., 1995; MacCracken and Hansen, 1982; Sovada et al., 1995). Post-hoc analyses did not support this hypothesis, as badger and coyote activity were positively associated (Table 3.9). By initiating predator data collection post-treatment, we potentially missed any effects that occurred immediately before or following grazing, rendering it difficult to fully explain changes in rodent activity patterns based on grazing treatment. Ground squirrel activity was lower in the grazed relative to control pastures but increased through time in the rotationally grazed pastures. We were unable to assess the mechanism behind this observed pattern, but decreasing ground squirrels could result from grazing induced changes in badgers, snakes or coyotes, suggesting more in-depth community level analyses are needed to fully understand the role grazing plays in predator-prey dynamics in this ecosystem.

While weather explained much of the variation in songbird nest success, grazing management influenced the nest predator community of sagebrush-obligate songbirds, reducing predator activity relative to control pastures. Increased activity of certain nest predators during the nesting period predicted lower nest success. This reduction in predator activity, and the role predation played in nest success, suggests that grazing induced changes in the predator community could be a significant mechanism behind the observed increase in sagebrush sparrow nest success resulting from several years of grazing (Chapter 2, Schroeder 2020). The effect of grazing likely varies across ecosystems, grazing regimes, site potential and health of the wildlife and plant community. It is critical to note that

we utilized moderate rotational and dormant season grazing quantified with the more conservative landscape appearance approach, in a relatively healthy sagebrush plant-community. Important next steps include more fully assessing how grazing impacts predator communities, particularly avian and reptilian, and assessing these effects across larger spatial scales, longer time frames and varying timing and intensities of grazing. Our experimental design logistically necessitated a small-scale approach, but livestock grazing, and associated predator-prey dynamics, play out over tens of thousands of acres. Furthermore, the observed trends relating nest predator interactions highlights the need for future research more fully assessing the role grazing plays in structuring predator-prey dynamics in the sagebrush ecosystem. Our results suggest the importance of simultaneously assessing the implications of land management changes on predators and prey holistically.

Management Implications

Our findings suggest that grazing affects the activity of nest predator species differently, and in turn, how they influence nest success of sagebrush-obligate birds. While we found that grazing generally decreased predators of our target songbirds, which in turn influenced nest success, those effects can interact with or be over-ridden by the extreme variability in weather patterns experienced by these songbirds. The role grazing plays in the predator-prey dynamics of sagebrush-obligate songbirds warrants more rigorous study into the mechanisms behind the observed patterns as well as across spatial and temporal scales, grazing intensities and predator classes. Ultimately, grazing can have unexpected indirect effects on wildlife population dynamics, and it is important for managers to understand the mechanisms driving observed changes and how land management interacts with natural processes such as weather and interactions with other ecosystem issues such as predator-prey dynamics and plant communities.

REFERENCES

- Akaike, H., 1987. Factor analysis and AIC. *Psychometrika* 52, 317–332.
<https://doi.org/10.1007/BF02294359>
- Akaike, H., 1973. Maximum likelihood identification of gaussian autoregressive moving average models. *Biometrika* 60, 255–265. <https://doi.org/10.1093/biomet/60.2.255>
- Anderson, D.R., 2007. *Model based inference in the life sciences: A primer on evidence*. Springer, New York, NY.
- Arnold, T.W., 2010. Uninformative parameters and model selection using Akaike’s information criterion. *J. Wildl. Manage.* 74, 1175–1178. <https://doi.org/10.2193/2009-367>
- Asner, G.P., Elmore, A.J., Olander, L.P., Martin, R.E., Harris, T., 2004. Grazing systems, ecosystem responses, and global change. *Annu. Rev. Environ. Resour.* 29, 261–299.
<https://doi.org/10.1146/annurev.energy.29.062403.102142>
- Bates, D., Mächler, M., Bolker, B., Walker, S., 2015. Fitting linear mixed-effects models using lme4. *J. Stat. Softw.* 67, 1–48. <https://doi.org/10.18637/jss.v067.i01>
- Bates, J.D., Davies, K.W., 2014. Cattle grazing and vegetation succession on burned sagebrush steppe. *Rangel. Ecol. Manag.* 67, 412–422. <https://doi.org/10.2111/REM-D-14-00011.1>
- Bich, B.S., Butler, J.L., Schmidt, C.A., 1995. Effects of differential livestock use on key plant species and rodent populations within selected *Oryzopsis hymenoides/Hilaria jamesii* communities of Glen Canyon National Recreation Area. *Southwest. Assoc. Nat.* 40, 281–287.
- Bock, C.E., Bock, J.H., Kenney, W.R., Hawthorne, V.M., 1984. Responses of birds, rodents, and vegetation to livestock enclosure in a semidesert grassland site. *J. Range Manag.* 37, 239–242.
- Bui, T.V.D., Marzluff, J.M., Bedrosian, B., 2010. Common raven activity in relation to land use in western Wyoming: Implications for greater sage-grouse reproductive success. *Condor* 112, 65–78.
<https://doi.org/10.1525/cond.2010.090132>
- Burnham, K.P., Anderson, D.R., 2002. *Model selection and multimodel inference: A practical information–theoretic approach*, Second. ed. Springer-Verlag, New York, NY.
- Bylo, L.N., Koper, N., Molloy, K.A., 2014. Grazing intensity influences ground squirrel and American badger habitat use in mixed-grass prairies. *Rangel. Ecol. Manag.* 67, 247–254.
<https://doi.org/10.2111/REM-D-13-00152.1>
- Chalfoun, A.D., Martin, T.E., 2010. Facultative nest patch shifts in response to nest predation risk in the Brewer’s sparrow: A “win-stay, lose-switch” strategy? *Oecologia* 163, 885–892.
<https://doi.org/10.1007/s00442-010-1679-0>
- Chalfoun, A.D., Martin, T.E., 2007. Assessments of habitat preferences and quality depend on spatial scale and metrics of fitness. *J. Appl. Ecol.* 44, 983–992. <https://doi.org/10.1111/j.1365-2664.2007.01352.x>

- Coates, P.S., Connelly, J.W., Delehanty, D.J., 2008. Predators of greater sage-grouse nests identified by video monitoring. *J. F. Ornithol.* 79, 421–428. <https://doi.org/10.1111/j.1557-9263.2008.00189.x>
- Coates, P.S., Delehanty, D.J., 2010. Nest predation of greater sage-grouse in relation to microhabitat factors and predators. *J. Wildl. Manage.* 74, 240–248. <https://doi.org/10.2193/2009-047>
- Coates, P.S., O'Neil, S.T., Brussee, B.E., Ricca, M.A., Jackson, P.J., Dinkins, J.B., Howe, K.B., Moser, A.M., Foster, L.J., Delehanty, D.J., 2020. Broad-scale impacts of an invasive native predator on a sensitive native prey species within the shifting avian community of the North American Great Basin. *Biol. Conserv.* 243, 108409. <https://doi.org/10.1016/j.biocon.2020.108409>
- Coulloudon, B., Eshelman, K., Gianola, J., Habich, N., Hughes, L., Johnson, C., Pellant, M., Podborny, P., Rasmussen, A., Robles, B., Shaver, P., Spehar, J., Willoughby, J., 1999. Utilization studies and residual measurements. Washington, D.C.
- Crooks, K.R., Soule, M.E., 1999. Mesopredator release and avifauna extinctions in a fragmented landscape. *Nature.* 400, 563–566.
- Davies, K.W., Bates, J.D., 2010. Vegetation characteristics of mountain and Wyoming big sagebrush plant communities in the Northern Great Basin. *Rangel. Ecol. Manag.* 63, 461–466. <https://doi.org/10.2111/REM-D-09-00055.1>
- Davies, K.W., Bates, J.D., Miller, R.F., 2006. Vegetation characteristics across part of the Wyoming big sagebrush alliance. *Rangel. Ecol. Manag.* 59, 567–575. <https://doi.org/10.2111/06-004R2.1>
- Davies, K.W., Bates, J.D., Svejcar, T.J., Boyd, C.S., 2010. Effects of long-term livestock grazing on fuel characteristics in rangelands: An example from the sagebrush steppe. *Rangel. Ecol. Manag.* <https://doi.org/10.2111/REM-D-10-00006.1>
- Davies, K.W., Boyd, C.S., Bates, J.D., 2018. Eighty years of grazing by cattle modifies sagebrush and bunchgrass structure. *Rangel. Ecol. Manag.* 71, 275–280. <https://doi.org/10.1016/j.rama.2018.01.002>
- Debano, S.J., 2006. Effects of livestock grazing on aboveground insect communities in semi-arid grasslands of southeastern Arizona. *Biodivers. Conserv.* 15, 2547–2564. <https://doi.org/10.1007/s10531-005-2786-9>
- Dinkins, J.B., Conover, M.R., Kirol, C.P., Beck, J.L., 2012. Greater sage-grouse (*Centrocercus urophasianus*) select nest sites and brood sites away from avian predators. *Auk* 129, 600–610. <https://doi.org/10.1525/auk.2012.12009>
- Dinkins, J.B., Conover, M.R., Kirol, C.P., Beck, J.L., Frey, S.N., 2016. Effects of common raven and coyote removal and temporal variation in climate on greater sage-grouse nesting success. *Biol. Conserv.* 202, 50–58. <https://doi.org/10.1016/j.biocon.2016.08.011>
- Dinkins, J.B., Conover, M.R., Kirol, C.P., Beck, J.L., Frey, S.N., 2014. Greater sage-grouse (*Centrocercus urophasianus*) select habitat based on avian predators, landscape composition, and anthropogenic features. *Condor* 116, 629–642. <https://doi.org/10.1650/condor-13-163.1>

- Fleischner, T.L., 1994. Ecological costs of livestock grazing in western North America. *Conserv. Biol.* 8, 629–644. <https://doi.org/10.1046/j.1523-1739.1994.08030629.x>
- Greenwood, R.J., Sargeant, A.B., Johnson, D.H., Cowardin, L.M., Shaffer, T.L., 1995. Factors associated with duck nest success in the Prairie Pothole region of Canada. *Wildl. Monogr.* 1–57.
- Hardey, J., Crick, H.Q.P., Wernham, C. V., Riley, H.T., Etheridge, B., Thompson, D.B.A., 2006. *Raptors: a field guide to survey and monitoring.* The Stationary Office, Edinburgh.
- Hartman, C.A., Oring, L.W., 2006. An inexpensive method for remotely monitoring nest activity. *J. F. Ornithol.* 77, 418–424.
- Heske, E.J., Robinson, S.K., Brawn, J.D., 2001. Nest predation and neotropical migrant songbirds: piecing together the fragments. *Wildl. Soc. Bull.* 29, 52–61. <https://doi.org/10.1017/CBO9781107415324.004>
- Hethcoat, M.G., Chalfoun, A.D., 2015a. Towards a mechanistic understanding of human-induced rapid environmental change: A case study linking energy development, nest predation and predators. *J. Appl. Ecol.* 52, 1492–1499. <https://doi.org/10.1111/1365-2664.12513>
- Hethcoat, M.G., Chalfoun, A.D., 2015b. Energy development and avian nest survival in Wyoming, USA: A test of a common disturbance index. *Biol. Conserv.* 184, 327–334. <https://doi.org/10.1016/j.biocon.2015.02.009>
- Hobbs, M.T., Brehme, C.S., 2017. An improved camera trap for amphibians, reptiles, small mammals, and large invertebrates. *PLoS One* 12, 1–15. <https://doi.org/10.1371/journal.pone.0185026>
- Holechek, J.L., Gomez, H., Galt, D., 1999. Grazing studies: What we've learned. *Rangelands* 21, 12–16.
- Ibáñez-álamó, J.D., Magrath, R.D., Oteyza, J.C., Chalfoun, A.D., Haff, T.M., Schmidt, K.A., Thomson, R.L., Martin, T.E., 2015. Nest predation research: Recent findings and future perspectives. *J. Ornithol.* 156, S247–S262. <https://doi.org/10.1007/s10336-015-1207-4>
- Johnson, M.D., Horn, C.M., 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. *West. North Am. Nat.* 68, 444–452. <https://doi.org/10.3398/1527-0904-68.4.444>
- Johnson, T.N., Kennedy, P.L., DelCurto, T., Taylor, R. V., 2011. Bird community responses to cattle stocking rates in a Pacific Northwest bunchgrass prairie. *Agric. Ecosyst. Environ.* 144, 338–346. <https://doi.org/10.1016/j.agee.2011.10.003>
- Jones, A.L., 2000. Effects of cattle grazing on North American arid ecosystems: A quantitative review. *West. North Am. Nat.* 60, 155–164. <https://doi.org/10.2307/41717026>
- Jones, A.L., Longland, W.S., 1999. Effects of cattle grazing on salt desert rodent communities. *Am. Midl. Nat.* 141, 1–11.
- Jones, Z.F., Bock, C.E., Bock, J.H., 2003. Rodent communities in a grazed and ungrazed Arizona grassland, and a model of habitat relationships among rodents in southwestern grass/shrublands. *Am. Midl. Nat.* 149, 384–394. [https://doi.org/10.1674/0003-0031\(2003\)149](https://doi.org/10.1674/0003-0031(2003)149)

- Kafley, H., Lamichhane, B.R., Maharjan, R., Thapaliya, B., Bhattarai, N., Khadka, M., Gompfer, M.E., 2019. Estimating prey abundance and distribution from camera trap data using binomial mixture models. *Eur. J. Wildl. Res.* 65. <https://doi.org/10.1007/s10344-019-1308-0>
- Kelly, M.J., 2008. Design, evaluate, refine: Camera trap studies for elusive species. *Anim. Conserv.* 11, 182–184. <https://doi.org/10.1111/j.1469-1795.2008.00179.x>
- Kerns, B.K., Buonopane, M., Thies, W.G., Niwa, C., 2011. Reintroducing fire into a ponderosa pine forest with and without cattle grazing: Understory vegetation response. *Ecosphere* 2, 1–23. <https://doi.org/10.1890/ES10-00183.1>
- Knick, S.T., Dobkin, D.S., Rotenberry, J.T., Schroeder, M.A., Vander Haegen, W.M., van Riper, C., 2003. Teetering on the edge or too late? Conservation and research issues for avifauna of sagebrush habitats. *Condor* 105, 611. <https://doi.org/10.1650/7329>
- Kotler, B.P., 1984. Risk of predation and the structure of desert rodent communities. *Ecology* 65, 689–701.
- Krausman, P.R., Naugle, D.E., Frisina, M.R., Northrup, R., Bleich, V.C., Block, W.M., Wallace, M.C., Wright, J.D., 2009. Livestock grazing, wildlife habitat, and rangeland values. *Rangelands* 31, 15–19. <https://doi.org/10.2111/1551-501X-31.5.15>
- Kruess, A., Tschardtke, T., 2002. Contrasting responses of plant and insect diversity to variation in grazing intensity. *Biol. Conserv.* 106, 293–302. [https://doi.org/10.1016/s0006-3207\(01\)00255-5](https://doi.org/10.1016/s0006-3207(01)00255-5)
- Larivière, S., 1999. Reasons why predators cannot be inferred from nest remains. *Condor* 101, 718–721.
- Larson, D.M., 2014. Grassland fire and cattle grazing regulate reptile and amphibian assembly among patches. *Environ. Manage.* 54, 1434–1444. <https://doi.org/10.1007/s00267-014-0355-2>
- MacCracken, J.G., Hansen, R.M., 1982. Seasonal foods of coyotes in southeastern Idaho: a multivariate analysis. *Gt. Basin Nat.* 42, 45–49.
- Mahony, N., Krannitz, P.G., Martin, K., 2006. Seasonal fecundity of sagebrush Brewer's sparrow (*Spizella breweri breweri*) at the northern edge of its breeding range. *Am. Ornithol. Soc.* 123, 512–523.
- Manolis, J.C., Andersen, D.E., Cuthbert, F.J., 2000. Uncertain nest fates in songbird studies and variation in Mayfield estimation. *Auk* 117, 615–626. <https://doi.org/10.2307/4089587>
- Marcus Rowcliffe, J., Carbone, C., Jansen, P.A., Kays, R., Kranstauber, B., 2011. Quantifying the sensitivity of camera traps: An adapted distance sampling approach. *Methods Ecol. Evol.* 2, 464–476. <https://doi.org/10.1111/j.2041-210X.2011.00094.x>
- Marti, C.D., Steenhof, K., Kochert, M.N., Marks, J.S., 1993. Community trophic structure: The roles of diet, body size, and activity time in vertebrate predators. *Oikos* 67, 6. <https://doi.org/10.2307/3545090>
- Martin, T.E., 1993. Nest predation and nest sites: New perspectives on old patterns. *Bioscience* 43, 523–532.

- Martin, T.E., Geupel, G.R., 1993. Nest-monitoring plots: Methods for locating nests and monitoring success. *J. F. Ornithol.* 64, 507–519.
- Mazerolle, M.M.J., 2020. Model selection and multimodel inference based on (Q)AIC(c).
- McCauley, D.J., Keesing, F., Young, T.P., Allan, B.F., Pringle, R.M., 2006. Indirect effects of large herbivores on snakes in an African savanna. *Ecology* 87, 2657–2663. [https://doi.org/10.1890/0012-9658\(2006\)87\[2657:IEOLHO\]2.0.CO;2](https://doi.org/10.1890/0012-9658(2006)87[2657:IEOLHO]2.0.CO;2)
- Medin, D.E., Clary, W.P., 1989. Small mammal populations in a grazed and ungrazed riparian habitat in Nevada. Ogden, UT.
- Milchunas, D.G., Lauenroth, W.K., Burke, I.C., 1998. Livestock grazing: Animal and plant biodiversity of shortgrass steppe and the relationship to ecosystem function. *Oikos* 83, 65. <https://doi.org/10.2307/3546547>
- Moore, R.P., Robinson, W.D., 2004. Artificial bird nests, external validity, and bias in ecological field studies. *Ecology* 85, 1562–1567.
- Pietz, Pamela J., Granfors, D.A., 2000. Identifying predators and fates of grassland passerine nests using miniature video cameras. *J. Wildl. Manage.* 64, 71–87.
- Reynolds, T.D., 1981. Nesting of the sage thrasher, sage sparrow, and Brewer’s sparrow in southeastern Idaho. *Condor* 83, 61–64. <https://doi.org/10.2307/1367605>
- Reynolds, T.D., 1979. The impact of loggerhead shrikes on nesting birds in a sagebrush environment. *Auk* 96, 798–800.
- Ribic, C.A., Thompson, F.R., Piets, P.J., 2012. Video surveillance of nesting birds, 43rd ed. University of California Press, Berkeley, CA.
- Ricklefs, R.E., 1969. An analysis of nesting mortality in birds. *Smithson. Contrib. to Zool.* 9, 1–48. <https://doi.org/10.5479/si.00810282.9>
- Robinson, W.D., Rompré, G., Robinson, T.R., 2005. Videography of Panama bird nests shows snakes are principal predators. *Ornitol. Neotrop.* 16, 187–195.
- Rotenberry, J.T., Wiens, J.A., 1989. Reproductive biology of shrubsteppe passerine birds: geographical and temporal variation in clutch size, brood size, and fledging success. *Auk* 91, 1–14.
- Shaffer, T.L., 2004. A unified approach to analyzing nest success. *Auk* 121, 526–540. <https://doi.org/10.2307/4090416>
- Sovada, M.A., Sargeant, A.B., Grier, J.W., 1995. Differential effects of coyotes and red foxes on duck nest success. *J. Wildl. Manage.* 59, 1–9.
- Sternberg, M., Gutman, M., Perevolotsky, A., Ungar, E.D., Kigel, J., 2000. Vegetation response to grazing management in a Mediterranean herbaceous community: A functional group approach. *J. Appl. Ecol.* 37, 224–237. <https://doi.org/10.1046/j.1365-2664.2000.00491.x>

- Sutti, F., Strong, A.M., 2014. Temperature loggers decrease costs of determining bird nest survival. *Wildl. Soc. Bull.* 38, 831–836. <https://doi.org/10.1002/wsb.473>
- Taylor, J.D., Holt, R.D., Orning, E.K., Young, J.K., 2017. Greater sage-grouse nest survival in Northwestern Wyoming. *J. Wildl. Manage.* 81, 1219–1227. <https://doi.org/10.1002/jwmg.21296>
- Thompson III, F.R., Dijak, W., Burhans, D.E., 1999. Video identification of predators at songbird nests in old fields. *Auk* 116, 259–264. <https://doi.org/10.2307/4089477>
- Torre, I., Díaz, M., Martínez-Padilla, J., Bonal, R., Viñuela, J., Fargallo, J.A., 2007. Cattle grazing, raptor abundance and small mammal communities in Mediterranean grasslands. *Basic Appl. Ecol.* 8, 565–575. <https://doi.org/10.1016/j.baae.2006.09.016>
- Vander Haegen, W.M., Schroeder, M.A., DeGraaf, R.M., 2002. Predation on real and artificial nests in shrubsteppe landscapes fragmented by agriculture. *Condor* 496–506. [https://doi.org/10.1650/0010-5422\(2002\)104](https://doi.org/10.1650/0010-5422(2002)104)
- Welstead, K., 1996. Factors affecting nest predation of artificial and real sagebrush Brewer's sparrow (*Spizella breweri breweri*) nests in the South Okanagan and Similkameen Valleys, British Columbia. The University of British Columbia.
- Welstead, K., Krannitz, P., Mahony, N., 2005. Using survival analysis of artificial and real Brewer's sparrow (*Spizella breweri breweri*) nests to model site level and nest site factors associated with nest success in the South Okanagan region of Canada, USDA Forest Service General Technical Report.
- White, P. j., Ralls, K., Vanderbilt White, C.A., 1995. Overlap in habitat and food use between coyotes and San Joaquin kit foxes. *Southwest. Nat.* 40, 342–349.
- Wolf, K.M., Whalen, M.A., Bourbour, R.P., Baldwin, R.A., 2018. Rodent, snake and raptor use of restored native perennial grasslands is lower than use of unrestored exotic annual grasslands. *J. Appl. Ecol.* 55, 1133–1144. <https://doi.org/10.1111/1365-2664.12990>

Table 3.1. Number of predators documented on three types of cameras (pasture cameras, sagebrush sparrow nest cameras and Brewer's sparrow nest cameras) and respective trap days at the Northern Great Basin Experimental Range in southeast Oregon, USA 2018–2020.

Predator species	Pasture cameras			Sagebrush sparrow	Brewer's sparrow
	Control	Dormant	Rotational	Nest camera	Nest camera
Badger	29	14	2	0	2
Bobcat	0	2	5	1	0
Coyote	26	27	13	0	0
Ground Squirrel	676	499	430	1	0
Mouse	486	317	121	0	0
Common Raven	7	2	0	0	2
Loggerhead Shrike	3	1	1	0	1
Snake ^a	0	1	0	5	1
Trap Days	4,071	4,076	3,760	775	497

^a Snake species was gopher snake for sagebrush sparrow, yellow-bellied racer for Brewer's sparrow and for the pasture camera.

Table 3.2. Parameter estimates and standard error (SE) with 95% confidence intervals (LCL and UCL) for predator negative binomial models testing the effects of grazing treatment (rotational, dormant, and no grazing) and camera type (nest-level versus pasture-level cameras). Analyses comparing pasture-level cameras to nest-level cameras were conducted for Brewer's and sagebrush sparrows separately. Data collected in experimental pastures at the Northern Great Basin Experimental Range in southeast Oregon, USA 2018–2020. Each row represents a different model with the predator species or predator group as the response variable. CS indicates complete separation, see Table 3.1 for raw data.

*indicates a 95% CI that does not cross zero.

^a Camera type compared pasture-level predator cameras to nest-level cameras with the reference category designated as the nest-level camera. The grazing treatment variable was categorical, consisting of dormant grazing, rotational spring/summer graze, where the reference category for grazing treatment was the no-graze control.

^b For species with no nest predators captured on nest cameras, we report results from the model with grazing treatment only (see Table 3.1 for nest-level camera versus predator-level camera counts)

^c For predator species with no predators in one of the grazing treatments, only results from the predator-level camera versus nest-level camera model are displayed (see Table 3.1 for counts across grazing treatments).

^d While model did converge within 50 iterations, only one snake was observed on pasture-level cameras, see Table 3.1.

Table 3.2

Predator count at pasture-level cameras versus cameras at Brewer's sparrow nests							
Predator Response Variable	Parameter Estimate (SE)				95% CI		
	Intercept ^a	Dormant	Rotational	Camera Type	Dormant	Rotational	Camera Type
Badger	-5.53 (1.01)	-0.70 (0.42)	-2.12 (0.65)	0.57 (1.02)	(-1.55, 0.11)	(-3.64, -0.94)*	(-1.09, 3.49)
Bobcat ^{bc}	CS	CS	CS	CS	CS	CS	CS
Chipmunk	-5.48 (1.05)	-1.19 (0.32)	-2.38 (0.37)	2.62 (1.06)	(-1.82, -0.57)*	(-3.13, -1.66)*	(0.95, 5.54)*
Coyote ^b	-5.10 (0.23)	0.02 (0.32)	-0.62 (0.38)	CS	(-0.61, 0.65)	(-1.39, 0.11)	CS
Ground squirrel ^b	-1.91 (0.25)	-0.34 (0.36)	-0.43 (0.36)	CS	(-1.03, 0.36)	(-1.13, 0.26)	CS
Mouse ^b	-2.33 (0.24)	-0.31 (0.34)	-1.25 (0.35)	CS	(-0.97, 0.34)	(-1.93, -0.58)*	CS
Raven ^c	-5.51 (0.71)	CS	CS	-1.67 (0.78)	CS	CS	(-3.03, 0.21)
Loggerhead shrike	-5.63 (1.22)	-1.36 (1.23)	-1.35 (1.24)	-1.45 (1.28)	(-4.47, 0.84)	(-4.45, 0.84)	(-3.67, 1.68)
Snake (yellow-bellied racer) ^c	-5.33 (1.22)	CS	CS	-4.09 (1.69)	(-8.72, -2.08)*	CS	(-8.19, -0.18)* ^d
Meso-predator	-5.87 (1.01)	-0.27 (0.27)	-0.87 (0.31)	1.58 (1.01)	(-0.80, 0.25)	(-1.49, -0.26)*	(0.034, 4.46)*
Rodent	-5.86 (1.04)	-0.45 (0.27)	-0.82 (0.27)	5.02 (1.04)	(-0.98, 0.09)	(-1.36, -0.28)*	(3.43, 7.91)*
Avian	-3.73 (0.43)	-1.17 (0.57)	-1.89 (0.76)	-2.31 (0.49)	(-2.43, -0.14)*	(-3.74, -0.62)*	(-3.23, -1.27)*
Non-rodent	-3.75 (0.38)	-0.33 (0.24)	-0.75 (0.26)	-0.31 (0.38)	(-0.80, 0.14)	(-1.28, -0.24)*	(-1.03, 0.53)
All predators	-3.53 (0.39)	-0.43 (0.24)	-0.80 (0.24)	2.72 (0.38)	(-0.90, 0.03)	(-1.27, -0.33)*	(1.97, 3.56)*
Predator count at pasture-level cameras versus cameras at sagebrush sparrow nests							
Badger ^b	-5.05 (0.26)	-0.70 (0.42)	-2.54 (0.77)	CS	(-1.53, 0.10)	(-4.42, -1.21)*	CS
Bobcat ^c	-6.29 (1.02)	CS	CS	-1.14 (1.15)	CS	CS	(-3.55, 2.04)
Chipmunk	-5.92 (1.01)	-1.10 (0.32)	-2.34 (0.38)	3.01 (1.02)	(-1.72, -0.48)*	(-3.08, -1.62)*	(1.39, 5.91)*
Coyote ^b	-5.13 (0.23)	0.01 (0.32)	-0.61 (0.38)	CS	(-0.62, 0.64)	(-1.67, 0.12)	CS
Ground squirrel	-6.42 (1.04)	-0.36 (0.36)	-0.34 (0.36)	4.74 (1.03)	(-1.07, 0.35)	(-1.07, 0.38)	(3.12, 7.64)*
Mouse ^b	-2.41 (0.24)	-0.34 (0.34)	-1.21 (0.00)	CS	(-0.99, 0.31)	(-1.89, -0.53)*	CS
Raven ^{bc}	CS	CS	CS	CS	CS	CS	CS
Loggerhead shrike ^b	-7.31 (0.74)	-1.06 (1.32)	-0.99 (1.34)	CS	(-4.25, 1.36)	(-4.20, 1.44)	CS
Snake (gopher snake) ^{bc}	CS	CS	CS	CS	CS	CS	CS
Meso-predator	-6.35 (1.01)	-0.24 (0.27)	-0.93 (0.31)	2.05 (1.01)	(-0.77, 0.29)	(-1.56, -0.32)*	(0.52, 4.93)*
Rodent	-5.22 (0.61)	-0.34 (0.27)	-0.73 (0.27)	4.31 (0.61)	(-0.86, 0.19)	(-1.26, -0.20)*	(3.25, 5.76)*
Avian	-6.01 (1.02)	-1.20 (0.66)	-1.52 (0.78)	-0.07 (1.03)	(-2.70, -0.02)*	(-3.40, -0.19)*	(-1.68, 2.83)
Non-rodent	-4.46 (0.41)	-0.17 (0.24)	-0.65 (0.26)	0.31 (0.40)	(-0.63, 0.30)	(-1.18, -0.13)*	(-0.42, 1.21)
All predators	-4.01 (0.36)	-0.23 (0.23)	-0.66 (0.24)	3.09 (0.36)	(-0.69, 0.23)	(-1.12, -0.19)*	(2.40, 3.87)*

Table 3.3. Number of predators by species confirmed depredating Brewer's sparrow and sagebrush sparrow nests in experimental pastures experiencing dormant, rotational or no-grazing at the Northern Great Basin Experimental Range in southeast Oregon, USA 2018–2020. In total 52 Brewer's sparrow and 72 sagebrush sparrow nests were photo monitored, 16 and 35 cameras failed to operate properly, and 17 and 16 nests had functioning cameras and were depredated, respectively.

Nest predator	Brewer's sparrow	Sagebrush sparrow
Common raven (<i>Corvus corax</i>)	2	0
Loggerhead shrike (<i>Lanius ludovicianus</i>)	1	0
American kestrel (<i>Falco sparverius</i>)	2	0
Red-tailed hawk (<i>Buteo jamaicensis</i>)	0	1
American badger (<i>Taxidea taxus</i>)	2	0
Bobcat (<i>Lynx rufus</i>)	0	1
Chipmunk (<i>Tamias</i> spp.)	1	1
Ground squirrel (<i>Spermophilus</i> spp.)	0	1
Western yellow-bellied racer (<i>Coluber constrictor mormon</i>)	1	0
Gopher snake (<i>Pituophis catenifer</i>)	0	5
Unknown avian species	1	0
Unknown rodent	0	1
Unknown species	7	6
<i>Total</i>	<i>17</i>	<i>16</i>

Table 3.4. Mayfield estimated nest success and standard error in parentheses, for Brewer's sparrow (average 11-day incubation period, 9-day nestling period, $n = 130$) and sagebrush sparrow (average 13-day incubation period, 10-day nestling period, $n = 132$) across years in experimental pastures experiencing dormant, rotational or no-grazing at the Northern Great Basin Experimental Range in southeast Oregon, USA 2018-2020.

	2018	2019	2020
Brewer's sparrow	0.45 (0.11)	0.59 (0.14)	0.68 (0.07)
Sagebrush sparrow	0.59 (0.09)	0.31 (0.04)	0.52 (0.09)

Table 3.5. Logistic exposure models of nest success comparing weather variables based on predictive weather model derived from the same study area with overlapping, but differing years (2017–2019; for original weather analyses, see Chapter 2, Schroeder 2020). This study (2018–2020) included Brewer’s sparrow ($n = 130$) and sagebrush sparrow ($n = 132$) nests in southeast Oregon, USA, 2018–2020. The number of model parameters is denoted as K , ΔAIC_c is the difference from the top model in Akaike’s Information Criterion adjusted for small sample size, and w_i is the model weight. The top model was advanced as the predictive model to test a priori predator hypotheses.

Model	K	ΔAIC_c	w_i	Deviance
Brewer’s sparrow				
Precip _{Nesting'} , Precip _{Nesting'} ² , TempDiff _{Nesting'} , TempDiff _{Nesting'} ² × Day, Max Temp _{@Fate'} , Max Temp _{@Fate'} ² ^a	9	0	0.85	-154.23
Precip _{Nesting'} , Precip _{Nesting'} ² , TempDiff _{Nesting'} , TempDiff _{Nesting'} ² × Day	7	3.49	0.15	-158.00
Precip _{Nesting'} , Precip _{Nesting'} ²	3	24.35	0	-172.46
TempDiff _{Nesting'} , TempDiff _{Nesting'} ² × Day, Max Temp _{@Fate'} , Max Temp _{@Fate'} ²	7	24.65	0	-168.58
TempDiff _{Nesting'} , TempDiff _{Nesting'} ² × Day	5	27.89	0	-172.22
Null	1	32.79	0	-178.69
Max Temp _{@Fate'} , Max Temp _{@Fate'} ²	3	33.82	0	-177.19
Sagebrush sparrow				
Temp Diff _{Daily'} , Temp Diff _{Daily'} ² , PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day, Max Temp _{@Fate'} , Max Temp _{@Fate'} ² ^b	11	0.00	0.58	-187.62
PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day, Max Temp _{@Fate'} , Max Temp _{@Fate'} ² × Day, Min Temp _{@Fate'}	9	1.67	0.25	-190.48
Temp Diff _{Daily'} , Temp Diff _{Daily'} ² , PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day, Max Temp _{@Fate'} , Max Temp _{@Fate'} ² × Day	10	3.31	0.11	-190.29
PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day, Max Temp _{@Fate'} , Max Temp _{@Fate'} ² × Day	8	4.79	0.05	-193.05
Temp Diff _{Daily'} , Temp Diff _{Daily'} ² , Max Temp _{@Fate'} , Max Temp _{@Fate'} ² × Day, Min Temp _{@Fate'}	8	11.22	0.00	-196.27
Max Temp _{@Fate'} , Max Temp _{@Fate'} ² × Day	5	11.77	0.00	-199.57
PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day, Min Temp _{@Fate'}	6	14.84	0.00	-200.10
Temp Diff _{Daily'} , Temp Diff _{Daily'} ² , PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day	7	17.06	0.00	-200.20
PrecipAvg _{nesting'} , PrecipAvg _{nesting'} ² × Day	5	20.13	0.00	-203.75
Min Temp _{@Fate'}	2	24.01	0.00	-208.70
Null	1	25.89	0.00	-210.65
Temp Diff _{Daily'} , Temp Diff _{Daily'} ²	3	26.25	0.00	-208.82

^aAIC_c = 326.59, ^bAIC_c = 397.40

Table 3.6. Logistic exposure models of nest success comparing predator for Brewer's sparrow ($n = 130$) and sagebrush sparrow ($n = 132$) in southeast Oregon, USA, 2018–2020. See Appendix II; Table A3.1 for a list and description of all tested predator variables. The predictive weather model (Table 3.5) serves as a base model for testing the predator variables, and all models are compared to a null model consisting of an intercept only. The number of model parameters is denoted by K , ΔAIC_c is the difference from the top model in Akaike's Information Criterion adjusted for small sample size, and w_i is the model weight.

Model	K	ΔAIC_c	w_i	Deviance
Brewer's sparrow				
Weather + Coyote + Badger + Transect Snake ^a	12	0	0.34	-148.04
Weather + Coyote + Badger	11	1.42	0.17	-149.76
Weather + Coyote + Transect Snake	11	1.74	0.14	-149.92
Weather + Badger + Transect Snake	11	1.83	0.14	-149.96
Weather + Coyote	10	1.84	0.14	-150.99
Weather + Badger	10	4.79	0.03	-152.46
Weather + Transect Snake	10	5.41	0.02	-152.77
Weather	9	6.33	0.01	-154.24
Null (intercept only)	1	39.10	0.00	-178.69
Sagebrush sparrow				
Weather + Ground Squirrel ^b	12	0.00	0.12	-185.03
Weather + Transect Rodent Index + Badger	13	0.16	0.11	-184.10
Weather + Transect Rodent Index	12	0.46	0.09	-185.26
Weather + Transect Rodent Index + Ground Squirrel	13	0.52	0.09	-184.28
Weather + Ground Squirrel + Transect Raven Block Index	13	0.70	0.08	-184.37
Weather + Ground Squirrel + Badger	13	0.83	0.08	-184.43
Weather + Transect Rodent Index + Ground Squirrel + Badger	14	1.14	0.07	-183.57
Weather + Transect Rodent Index + Badger + Transect Raven Block Index	14	1.52	0.05	-183.76
Weather + Transect Rodent Index + Transect Raven Block Index	13	1.57	0.05	-184.80
Weather + Transect Rodent Index + Ground Squirrel + Transect Raven Block Index	14	1.70	0.05	-183.85
Weather + Ground Squirrel + Badger + Transect Raven Block Index	14	1.77	0.05	-183.89
Weather + Badger	12	1.87	0.05	-185.97
Weather + Badger + Transect Raven Block Index	13	2.09	0.04	-185.06
Weather + Transect Rodent Index + Ground Squirrel + Transect Raven Block Index + Badger	15	2.57	0.03	-183.27
Weather + Transect Raven Block Index	12	2.74	0.03	-186.40
Weather	11	3.15	0.02	-187.62
Null (intercept only)	1	29.04	0.00	-210.65

^a $AIC_c = 320.28$, ^b $AIC_c = 394.26$

Table 3.7. Parameter estimates with 95% confidence intervals (CI) for all Brewer's sparrow ($n = 130$) logistic exposure models that outcompete the null (Table 3.6) in southeast Oregon for 2018–2020. Parameter estimates for weather variables in the predictive portion of the model (Table 3.5) remained similar across all models and previous parameter estimates and are not included here for brevity. A dash indicates that parameter was not included in the model.

Model	Brewer's sparrow					
	Parameter Estimate (SE)			95% CI		
	Coyote	Badger	Transect Snake	Coyote	Badger	Transect Snake
Weather + Coyote + Badger + Transect Snake	0.73 (0.41)	-0.27 (0.13)	-0.19 (0.10)	(0.00, 1.61)*	(-0.53, 0.00)*	(-0.38, 0.01)
Weather + Coyote + Badger	0.79 (0.39)	-0.21 (0.122)	-	(0.11, 1.66)*	(-0.44, 0.06)	-
Weather + Coyote + Transect Snake	0.85 (0.40)	-	-0.14 (0.09)	(0.13, 1.73)*	-	(-0.33, 0.05)
Weather + Badger + Transect Snake	-	-0.34 (0.13)	-0.22 (0.10)	-	(-0.59, -0.06)*	(-0.42, -0.03)*
Weather + Coyote	0.86 (0.39)	-	-	(0.17, 1.74)*	-	-
Weather + Badger	-	-0.25 (0.12)	-	-	(-0.489, 0.010)	-
Weather + Transect Snake	-	-	-0.17 (0.09)	-	-	(-0.35, 0.02)
Weather	-	-	-	-	-	-
Null (intercept only)	-	-	-	-	-	-

*Indicates a 95% CI that does not cross zero.

Table 3.8. Parameter estimates with 95% confidence intervals (CI) for all sagebrush sparrow ($n = 132$) logistic exposure models that outcompeted the null (Table 3.6) in southeast Oregon for 2018–2020. Parameter estimates for weather variables in the predictive portion of the model remain similar across all models and previous parameter estimates and are not included here for brevity.

Table 3.8

Model	Sagebrush sparrow							
	Parameter Estimate (SE)				95% CI			
	Ground Squirrel	Transect Rodent	Badger	Transect Raven	Ground Squirrel	Transect Rodent	Badger	Transect Raven
Weather + Ground Squirrel ^b	-0.02 (0.01)	-	-	-	(-0.03, -0.00)*	-	-	-
Weather + Transect Rodent Index + Badger	-	-0.01 (0.00)	-0.20 (0.12)	-	-	(-0.01, 0.00)*	(-0.42, 0.06)	-
Weather + Transect Rodent Index	-	-0.01 (0.00)	-	-	-	(-0.01, -0.00)*	-	-
Weather + Transect Rodent Index + Ground Squirrel	-0.01 (0.01)	-0.003 (0.00)	-	-	(-0.03, 0.01)	(-0.01, 0.00)*	-	-
Weather + Ground Squirrel + Transect Raven Block Index	-0.02 (0.01)	-	-	0.02 (0.02)	(-0.03, 0.00)*	-	-	(-0.02, 0.07)
Weather + Ground Squirrel + Badger	-0.02 (0.01)	-	-0.15 (0.12)	-	(-0.03, 0.00)*	-	(-0.38, 0.12)	-
Weather + Transect Rodent Index + Ground Squirrel + Badger	-0.01 (0.01)	-0.004 (0.00)	-0.16 (0.12)	-	(-0.03, 0.01)	(-0.01, 0.00)*	(-0.39, 0.11)	-
Weather + Transect Rodent Index + Badger + Transect Raven Block Index	-	-0.004 (0.00)	-0.18 (0.12)	0.02 (0.02)	-	(-0.01, 0.00)*	(-0.41, 0.07)	(-0.03, 0.06)
Weather + Transect Rodent Index + Transect Raven Block Index	-	-0.01 (0.00)	-	0.02 (0.02)	-	(-0.01, 0.00)*	-	(-0.02, 0.07)
Weather + Transect Rodent Index + Ground Squirrel + Transect Raven Block Index	-0.01 (0.01)	-0.003 (0.00)	-	0.02 (0.02)	(-0.03, 0.01)	(-0.01, 0.00)*	-	(-0.02, 0.07)
Weather + Ground Squirrel + Badger + Transect Raven Block Index	-0.02 (0.01)	-	-0.13 (0.13)	0.02 (0.02)	(-0.03, 0.00)*	-	(-0.37, 0.14)	(-0.02, 0.07)
Weather + Badger	-	-	-0.23(0.11)	-	-	-	(-0.44, 0.02)	-
Weather + Badger + Transect Raven Block Index	-	-	-0.20 (0.11)	0.03 (0.02)	-	-	(-0.42, 0.04)	(-0.01, 0.07)
Weather + Transect Rodent Index + Ground Squirrel + Transect Raven Block Index + Badger	-0.01 (0.01)	-0.003 (0.00)	-0.14 (0.12)	0.02 (0.02)	(-0.03, 0.01)	(-0.01, 0.00)*	(-0.38, 0.13)	(-0.03, 0.06)
Weather + Transect Raven Block Index	-	-	-	0.03 (0.02)	-	-	-	(-0.01, 0.07)
Weather	-	-	-	-	-	-	-	-
Null (intercept only)	-	-	-	-	-	-	-	-

*indicates a 95% CI that does not cross zero. A dash indicates that parameter was not included in the model.

Table 3.9. Parameter estimates and 95% confidence intervals (CIs) of associated pasture-level parameters and interaction terms for interrelated negative binomial models for counts of ground squirrel, badger, coyote, mouse or chipmunk in southeast Oregon for 2018–2020. A dash indicates parameter was not in the top model. Results presented for the top model as ranked by Akaike’s Information Criterion adjusted for small sample size (ΔAIC_c).

Response Variable	Parameter Estimate (SE)								
	Intercept	Dormant	Rotational graze	Year	Dormant * year	Rotational graze * year	Ground squirrel	Badger	Coyote
Ground squirrel	-2.69 (0.72)	-0.25 (1.00)	-3.93 (1.15)	0.34 (0.34)	-0.08 (0.41)	1.32 (0.45)	NA	30.42 (13.50)	-
Badger	-5.57 (0.31)	-0.65 (0.39)	-2.50 (0.76)	-	-	-	1.75 (0.61)	NA	28.57 (13.44)
Coyote	5.35 (0.16)	-	-	-	-	-	-	25.94 (10.24)	NA
Mouse	-2.10 (0.25)	-0.35 (0.35)	-1.30 (0.36)	-	-	-	-	-	-
Chipmunk	-4.40 (0.46)	-1.18 (0.30)	-2.48 (0.37)	0.62 (0.62)	-	-	-	-	-
Response Variable	95% Confidence Interval								
	Intercept	Dormant	Rotational graze	Year	Dormant * year	Rotational graze * year	Ground squirrel	Badger	Coyote
Ground squirrel	(-4.01, -1.11)*	(-2.19, 1.67)	(-6.18, -1.73)*	(-0.26, 0.90)	(-0.86, 0.70)	(0.47, 2.19)*	NA	(0.46, 65.54)*	-
Badger	(-6.20, -4.97)*	(-1.44, 0.11)	(-4.41, -1.17)*	-	-	-	(0.51, 2.98)*	NA	(4.59, 53.87)*
Coyote	(-5.66, -5.05)*	-	-	-	-	-	-	(5.89, 45.92)*	NA
Mouse	(-2.55, -1.58)*	(-1.04, 0.34)	(-2.01, -0.59)*	-	-	-	-	-	-
Chipmunk	(-5.25, -3.51)*	(-1.78, -0.58)*	(-3.22, -1.77)*	(0.29, 0.96)*	-	-	-	-	-

*indicates a 95% CI that does not cross zero.

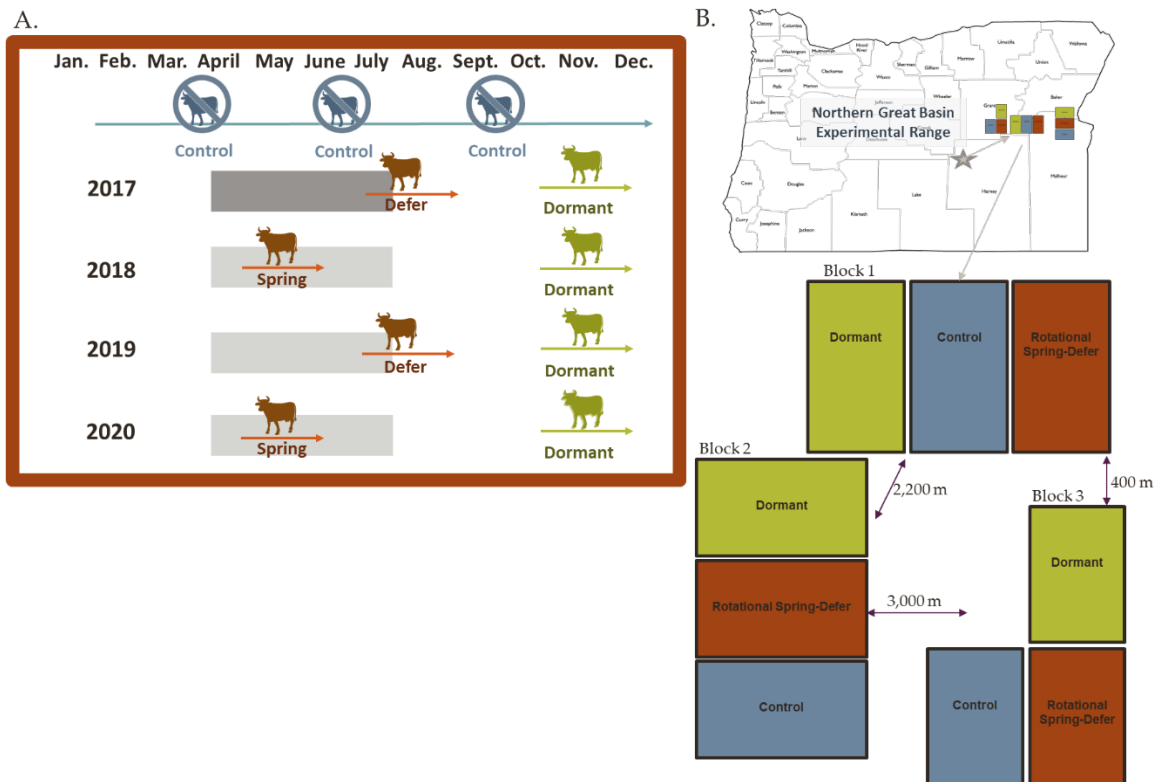


Figure 3.1. A) Timeline of grazing treatment application and songbird nest success and predator data collection. Grazing treatments represented by cow icons and include dormant season (green), rotational spring/summer graze (red orange) and control (no-grazing, blue). Grey boxes represent nesting season data collection. The dark grey box represents pre-treatment nesting season data collection for weather data only, and light grey includes predator data. B) Study pasture layout of randomized experimental block design, consisting of 3 blocks, each with 1 pasture of each treatment. Double sided arrows indicate closest distance from fence to fence within blocks. Study located at the Northern Great Basin Experimental Range (NGBER) in southeast Oregon from 2017–2020. Treatments were randomly assigned. Pasture size varied among, but not within, blocks (5.69–7.41 HA)

CHAPTER 4

SYNTHESIS AND CONCLUSIONS

Vanessa Schroeder

SUMMARY OF KEY FINDINGS

Sagebrush sparrow nest success increased in grazed treatments relative to controls without grazing, suggesting that grazing indirectly modified songbird habitat. We did not find any evidence that grazing influenced Brewer's sparrow nest success. Natural sources of variation in nest success appear to play a larger role than that of grazing management. Weather is an important factor explaining differences in nest success for songbird species, a pattern supported by our data (Hightower et al., 2018; Macdonald et al., 2013; Pérez et al., 2016; Rotenberry and Wiens, 1991). Excessive precipitation and extreme temperatures predicted declines in nest success for both sparrow species. Sagebrush sparrow nest success was positively influenced by grazing but remained surprisingly resilient to extreme changes in daily temperature swings. Conversely, our results indicated that Brewer's sparrows were more sensitive to changes in temperature and more precipitation, while remaining seemingly unaffected by the grazing regimes tested. These patterns could be driven by interactions with available food resources, potential nest predators or other habitat quality metrics (Debano, 2006; Johnson and Horn, 2008; Pérez et al., 2016; Torre et al., 2007).

We tested the hypothesis that grazing influenced the nest-predator community, leading to a change in nest success for sagebrush sparrow. Grazing has been shown to be detrimental to badgers (Bylo et al., 2014; Mullen et al., 2013), and other potential nest predators (Bock et al., 1984; Johnson and Horn, 2008; Jones and Longland, 1999; Larson, 2014; Torre et al., 2007). Our results indicated that grazing influenced the nest predator community, reducing potential nest predators across all predator groups, particularly badgers and chipmunks. We found that snakes and avian species, rather than rodents, were the main predators captured depredating Brewer's sparrow and sagebrush sparrow nests (Hethcoat and Chalfoun, 2015a; Rotenberry and Wiens, 1989; Vander Haegen et al., 2002; Welstead, 1996). Predator activity was lower in both grazed treatments, but particularly so in rotationally grazed pastures relative to control pastures for all predator groups. Predator activity helped explain some variation in nest success, where increased ground-squirrel, rodent, badger and snake activity was associated with lower songbird nest success. These results suggest that grazing driven changes in nest-predator communities were likely one mechanism driving an increase in nest success observed in sagebrush sparrows.

IMPLICATIONS FOR SAGEBRUSH-OBLIGATE SONGBIRDS

Grazing has been identified as a potential threat for sagebrush-obligate avian species (Beck and Mitchell, 2000; Connelly et al., 2004; France et al., 2008; Monroe et al., 2017). The reduction of

herbaceous cover due to livestock grazing has been posited as a threat to nesting birds via a reduction in nest concealment, leading to intense scrutiny of grazing on public lands and a focus on visual obscurity, grass heights and potential screening cover (Beck and Mitchell, 2000; Connelly et al., 1991; Smith et al., 2020; Sveum et al., 1998). While birds do tend to place nests in more concealed areas of the landscape, grazing has not been connected with reduced screening cover around nests (Borgmann and Conway, 2015; Smith et al., 2020, 2018a, 2018b, 2017). However, until recently, grazing effects on sagebrush-obligate birds other than the sage-grouse, were untested. To test the influence of grazing management on the reproductive success of sagebrush-obligate birds, it is important to also account for natural causes of variation in nest success, such as vegetation, weather conditions and food resources (Debano, 2006; Johnson et al., 2011; Rotenberry and Wiens, 1991). Weather conditions in sagebrush ecosystems can be extreme and variable. While avian species that depend on the sagebrush ecosystem evolved with dynamic, variable and often extreme weather, climate change has altered the pace and course of natural climate. Sagebrush-obligate songbirds face very different weather today than they did 50, 100 or 1,000 years ago (IPCC, 2007; Meehl et al., 2016, 2000; Polley et al., 2013). While grazing plays a role in structuring wildlife population dynamics, it is important to understand the interactions of management with natural causes of variation in nest success (Hovick et al., 2015; Johnson and Horn, 2008; Smith et al., 2018a). We found that particularly harsh or extreme weather conditions seem to play a greater role in nest success than grazing management, particularly under moderate, rotational grazing conducted in a healthy sagebrush plant community exhibiting limited invasion or degradation. Extreme, intensive or repeated grazing during the growing season have long been identified as threats to the greater sagebrush ecosystem and the wildlife that call it home (Beck and Mitchell, 2000; Eckert Jr and Spencer, 1987; Fleischner, 1994; Holechek et al., 1999; Jones, 2000). However, the effects of moderate, contemporary grazing practices using dormant or rotational grazing, have not been extensively examined in sagebrush rangelands until now. While the effect of grazing will likely vary across ecosystems, grazing regimes, site potential and health of the wildlife and plant community, our results suggest that projected changes in climate and weather provide greater concern for these species than contemporary grazing practices.

Changing climate, including the expectation of higher frequency of extreme temperature days, precipitation intensity, and variability in summer temperatures due to changing climate (Meehl et al., 2016, 2000) will likely have mixed effects on sagebrush-obligate songbird reproductive success. A shift to more extreme, larger, and less frequent precipitation events (IPCC 2007, Polley et al. 2013) may lead to lower nest success for sagebrush sparrows, while increased late season precipitation or hail storms

could be detrimental for both species, especially Brewer's sparrows (Hightower et al., 2018). These sparrows are well adapted to the extreme and variable conditions of the high desert, but changing trends in the responses of these species, particularly Brewer's sparrows, to extreme weather, indicates they might be less insulated to climate induced weather changes than previously thought (Hightower et al., 2018; Rotenberry and Wiens, 1991). We need additional research to assess the adaptive flexibility of these species to respond to inter- and intra-annual variation.

The effects of grazing vary across predator species, differentially influencing the nest success of sagebrush-obligate bird species. We found the role grazing plays in the predator-prey dynamics of sagebrush-obligate songbirds to be complex, which warrants increased research into the mechanisms behind the cattle-induced reductions of nest-predators. We utilized conservative moderate rotational and dormant season grazing in a relatively healthy sagebrush plant-community with a specific nest predator assemblage. The effect of grazing will likely vary across ecosystems, grazing regimes, site potential and predator communities, and extrapolating these results outside of the range of grazing regimes and intensities we measured should be done with great care. Furthermore, weather in the northern Great Basin is notoriously variable, and the weather captured during the three years of this study likely only captured a small portion of that variability. Thus, the effects of weather and its interactions with other factors may shift under conditions differing from those under which we conducted this study. Ultimately, our results indicate that moderate rotational or dormant season grazing in relatively healthy sagebrush communities plays less of a role in negatively affecting these songbird populations than climate driven processes contributing to decreased nest success of these birds and landscape scale loss of the sagebrush ecosystem, such as an unprecedented rise in frequency and intensity of wildfire, woody encroachment and invasion by exotic species (Abatzoglou and Williams, 2016; Coates et al., 2016b; Miller et al., 2014; Mohamed et al., 2011; Pechony and Shindell, 2010; Polley et al., 2013).

REFERENCES

- Abatzoglou, J.T., Williams, A.P., 2016. Impact of anthropogenic climate change on wildfire across western US forests. *Proc. Natl. Acad. Sci. U. S. A.* 113, 11770–11775. <https://doi.org/10.1073/pnas.1607171113>
- Beck, J.L., Mitchell, D.L., 2000. Influences of livestock grazing on sage grouse habitat. *Wildl. Soc. Bull.* 28, 993–1002. <https://doi.org/10.2307/3783858>
- Bock, C.E., Bock, J.H., Kenney, W.R., Hawthorne, V.M., 1984. Responses of birds, rodents, and vegetation to livestock exclosure in a semidesert grassland site. *J. Range Manag.* 37, 239–242.
- Borgmann, K.L., Conway, C.J., 2015. The nest-concealment hypothesis: New insights from a comparative analysis. *Wilson J. Ornithol.* 127, 646–660. <https://doi.org/10.1676/14-162.1>
- Bylo, L.N., Koper, N., Molloy, K.A., 2014. Grazing intensity influences ground squirrel and American badger habitat use in mixed-grass prairies. *Rangel. Ecol. Manag.* 67, 247–254. <https://doi.org/10.2111/REM-D-13-00152.1>
- Coates, P.S., Ricca, M.A., Prochazka, B.G., Brooks, M.L., Doherty, K.E., Kroger, T., Blomberg, E.J., Hagen, C.A., Casazza, M.L., 2016. Wildfire, climate, and invasive grass interactions negatively impact an indicator species by reshaping sagebrush ecosystems. *Proc. Natl. Acad. Sci.* 113, 12745–12750. <https://doi.org/10.1073/pnas.1606898113>
- Connelly, J.W., Knick, S.T., Schroeder, M.A., Stiver, S.J., 2004. Conservation assessment of greater sage-grouse and sagebrush habitats.
- Connelly, J.W., Wakkinen, W.L., Apa, A.D., Reese, K.P., 1991. Sage grouse use of nest sites in southeastern Idaho. *J. Wildl. Manage.* 55, 521–524.
- Debano, S.J., 2006. Effects of livestock grazing on aboveground insect communities in semi-arid grasslands of southeastern Arizona. *Biodivers. Conserv.* 15, 2547–2564. <https://doi.org/10.1007/s10531-005-2786-9>
- Eckert Jr, R.E., Spencer, J.S., 1987. Growth and reproduction of grasses heavily grazed under rotation management. *J. Range Manag.* 40, 156–159. <https://doi.org/10.1039/c5ra06804e>
- Fleischner, T.L., 1994. Ecological costs of livestock grazing in western North America. *Conserv. Biol.* 8, 629–644. <https://doi.org/10.1046/j.1523-1739.1994.08030629.x>
- France, K.A., Ganskopp, D.C., Boyd, C.S., France, K.A., Ganskopp, D.C., Boyd, C.S., 2008. Interspace / undercanopy foraging patterns of beef cattle in sagebrush habitats. *Rangel. Ecol. Manag.* 61, 389–393. <https://doi.org/10.2111/06-072.1>
- Hethcoat, M.G., Chalfoun, A.D., 2015. Towards a mechanistic understanding of human-induced rapid environmental change: A case study linking energy development, nest predation and predators. *J. Appl. Ecol.* 52, 1492–1499. <https://doi.org/10.1111/1365-2664.12513>

- Hightower, J.N., Carlisle, J.D., Chalfoun, A.D., 2018. Nest mortality of sagebrush songbirds due to a severe hailstorm. *Wilson J. Ornithol.* 130, 561–567. <https://doi.org/10.1676/17-025.1>
- Holechek, J.L., Gomez, H., Galt, D., 1999. Grazing studies: What we've learned. *Rangelands* 21, 12–16.
- Hovick, T.J., Elmore, R.D., Fuhlendorf, S.D., Dahlgren, D.K., 2015. Weather constrains the influence of fire and grazing on nesting greater prairie-chickens. *Rangel. Ecol. Manag.* 68, 186–193.
- IPCC, 2007. Summary for policymakers. In: *Climate Change 2007: The Physical Science Basis. Contrib. Work. Gr. I to Fourth Assess. Rep. Intergov. Panel Clim. Chang.* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor H.L. Mill. (eds.)]. Cambridge Univ. Press. Cambridge, U 104.
- Johnson, M.D., Horn, C.M., 2008. Effects of rotational grazing on rodents and raptors in a coastal grassland. *West. North Am. Nat.* 68, 444–452. <https://doi.org/10.3398/1527-0904-68.4.444>
- Johnson, T.N., Kennedy, P.L., DelCurto, T., Taylor, R. V., 2011. Bird community responses to cattle stocking rates in a Pacific Northwest bunchgrass prairie. *Agric. Ecosyst. Environ.* 144, 338–346. <https://doi.org/10.1016/j.agee.2011.10.003>
- Jones, A.L., 2000. Effects of cattle grazing on North American arid ecosystems: A quantitative review. *West. North Am. Nat.* 60, 155–164. <https://doi.org/10.2307/41717026>
- Jones, A.L., Longland, W.S., 1999. Effects of cattle grazing on salt desert rodent communities. *Am. Midl. Nat.* 141, 1–11.
- Larson, D.M., 2014. Grassland fire and cattle grazing regulate reptile and amphibian assembly among patches. *Environ. Manage.* 54, 1434–1444. <https://doi.org/10.1007/s00267-014-0355-2>
- Macdonald, E.C., Camfield, A.F., Jankowski, J.E., Macdonald, E.C., Camfield, A.F., Jankowski, J.E., Martin-, K., 2013. Extended incubation recesses by alpine-breeding horned larks: A strategy for dealing with inclement weather. *J. F. Ornithol.* 84, 58–68. <https://doi.org/10.1111/jofo>.
- Meehl, G.A., Tebaldi, C., Adams-Smith, D., 2016. US daily temperature records past, present, and future. *Proc. Natl. Acad. Sci. U. S. A.* 113, 13977–13982. <https://doi.org/10.1073/pnas.1606117113>
- Meehl, G.A., Zwiers, F., Evans, J., Knutson, T., Mearns, L., Whetton, P., 2000. Trends in extreme weather and climate events: Issues related to modeling extremes in projections of future climate change. *Bull. Amer. Meteor. Soc.* 81, 427–436.
- Miller, R.F., Ratchford, J., Roundy, B.A., Tausch, R.J., Hulet, A., Chambers, J., 2014. Response of conifer-encroached shrublands in the Great Basin to prescribed fire and mechanical treatments. *Rangel. Ecol. Manag.* 67, 468–481. <https://doi.org/10.2111/REM-D-13-00003.1>
- Mohamed, A.H., Holechek, Jerry L., Bailey, D.W., Campbell, C.L., DeMers, M.N., 2011. Mesquite encroachment impact on southern New Mexico rangelands: remote sensing and geographic

information systems approach. *J. Appl. Remote Sens.* 5, 1–11.
<https://doi.org/10.1117/1.3571040>

- Monroe, A.P., Aldridge, C.L., Assal, T.J., Veblen, K.E., Pyke, D.A., Casazza, M.L., 2017. Patterns in greater sage-grouse population dynamics correspond with public grazing records at broad scales. *Ecol. Appl.* 27, 1096–1107. <https://doi.org/10.1002/eap.1512>
- Mullen, E.M., MacWhite, T., Maher, P.K., Kelly, D.J., Marples, N.M., Good, M., 2013. Foraging Eurasian badgers *Meles meles* and the presence of cattle in pastures. Do badgers avoid cattle? *Appl. Anim. Behav. Sci.* 144, 130–137. <https://doi.org/10.1016/j.jinf.2020.04.010>
- Pechony, O., Shindell, D.T., 2010. Driving forces of global wildfires over the past millennium and the forthcoming century. *Proc. Natl. Acad. Sci.* 107, 19167–19170.
<https://doi.org/10.1073/pnas.1003669107>
- Pérez, J.H., Krause, J.S., Chmura, H.E., Bowman, S., McGuigan, M., Asmus, A.L., Meddle, S.L., Hunt, K.E., Gough, L., Boelman, N.T., Wingfield, J.C., 2016. Nestling growth rates in relation to food abundance and weather in the Arctic. *Auk* 133, 261–272. <https://doi.org/10.1642/AUK-15-111.1>
- Polley, H.W., Briske, D.D., Morgan, J.A., Wolter, K., Brown, J.R., 2013. Climate change and North American rangelands: Trends, projections, and implications. *Rangel. Ecol. Manag.* 66, 493–511.
- Rotenberry, J.T., Wiens, J.A., 1991. Weather and reproductive variation in shrubsteppe sparrows: a hierarchical analysis. *Ecology* 72, 1325–1335. <https://doi.org/10.2307/1941105>
- Rotenberry, J.T., Wiens, J.A., 1989. Reproductive biology of shrubsteppe passerine birds: Geographical and temporal variation in clutch size, brood size, and fledging success. *Auk* 91, 1–14.
- Smith, J.T., Allred, B.W., Boyd, C.S., Carlson, J.C., Davies, K.W., Hagen, C.A., Naugle, D.E., Olsen, A.C., Tack, J.D., 2020. Are sage-grouse fine-scale specialists or shrub-steppe generalists? *J. Wildl. Manage.* 1–16. <https://doi.org/10.1002/jwmg.21837>
- Smith, J.T., Tack, J.D., Berkeley, L.I., Szczypinski, M., Naugle, D.E., 2018a. Effects of livestock grazing on nesting sage-grouse in central Montana. *J. Wildl. Manage.* 82, 1503–1515.
<https://doi.org/10.1002/jwmg.21500>
- Smith, J.T., Tack, J.D., Berkeley, L.I., Szczypinski, M., Naugle, D.E., 2018b. Effects of rotational grazing management on nesting greater sage-grouse. *J. Wildl. Manage.* 82, 103–112.
<https://doi.org/10.1002/jwmg.21344>
- Smith, J.T., Tack, J.D., Doherty, K.E., Allred, B.W., Maestas, J.D., Berkeley, L.I., Dettenmaier, S.J., Messmer, T.A., Naugle, D.E., 2017. Phenology largely explains taller grass at successful nests in greater sage-grouse. *Ecol. Evol.* 356–364. <https://doi.org/10.1002/ece3.3679>
- Sveum, C.M., Daniel, W.D., Crawford, J.A., 1998. Nesting habitat selection central Washington by sage grouse in south-central Washington. *J. Range Manag.* 51, 265–269.

Torre, I., Díaz, M., Martínez-Padilla, J., Bonal, R., Viñuela, J., Fargallo, J.A., 2007. Cattle grazing, raptor abundance and small mammal communities in Mediterranean grasslands. *Basic Appl. Ecol.* 8, 565–575. <https://doi.org/10.1016/j.baae.2006.09.016>

Vander Haegen, W.M., Schroeder, M.A., DeGraaf, R.M., 2002. Predation on real and artificial nests in shrubsteppe landscapes fragmented by agriculture. *Condor* 496–506. [https://doi.org/10.1650/0010-5422\(2002\)104](https://doi.org/10.1650/0010-5422(2002)104)

Welstead, K., 1996. Factors affecting nest predation of artificial and real sagebrush Brewer's sparrow (*Spizella breweri breweri*) nests in the South Okanagan and Similkameen Valleys, British Columbia. The University of British Columbia.

APPENDICES

APPENDIX I – CHAPTER 2 SUPPLEMENTARY INFORMATION

Table A2.1. Summary table of all variables included in step one of the nest survival modeling process, with their descriptions, mean and standard error (SE) for sagebrush sparrow ($n = 132$) and Brewer's sparrow ($n = 97$) by fate (fledge or fail) in southeast Oregon, USA 2017–2019.

Variable name	Description	Sagebrush sparrow mean (SE)		Brewer's sparrow mean (SE)	
		Fledged	Failed	Fledged	Failed
Weather covariate set					
Max Temp Around Fate	The maximum temperature (°C) around the estimated fate date. This is the maximum temperature of the 72-hour period centered on the estimated fate day.	26.96 (0.13)	26.14 (0.25)	27.19 (0.16)	26.00 (0.23)
Min Temp Around Fate	The minimum temperature (°C) around the estimated fate date. This is the minimum temperature of the 72-hour period centered on the estimated fate day.	4.18 (0.11)	4.00 (0.16)	4.32 (0.12)	3.55 (0.22)
Average Temp Around Fate	The average temperature (°C) around the estimated fate date. This is the average temperature the 72-hour period centered on the estimated fate day.	15.61 (0.12)	15.35 (0.21)	15.90 (0.15)	14.71 (0.22)
Temp Difference Around Fate	The average temperature difference (°C) around the estimated fate date. This is the average temperature difference (daily maximum - min) of the 72-hour period centered on the estimated fate day.	22.78 (0.13)	22.14 (0.24)	22.87 (0.14)	22.78 (0.24)
Precip at Fate	The cumulative precipitation (mm) around the estimated fate date. This is the sum of the daily precipitation for the 72-hour period centered on the estimated fate day.	2.43 (0.14)	3.06 (0.28)	1.39 (0.07)	1.84 (0.17)
Average Max Temp During Nesting	The average maximum temperature (°C) during the time period the nest was active including 24 hours prior to estimated egg lay date and 24 hours after estimated fate date	21.78 (0.09)	22.2 (0.17)	23.66 (0.11)	22.7 (0.16)
Average Min Temp During Nesting	The average minimum temperature (°C) during the time period the nest was active including 24 hours prior to estimated egg lay date and 24 hours after estimated fate date	4.72 (0.07)	5.02 (0.12)	5.83 (0.07)	5.57 (0.08)
Average Daily Temp During Nesting	The average daily temperature (°C) during the time period the nest was active including 24 hours prior to estimated egg lay date and 24 hours after estimated fate date	13.54 (0.08)	14.08 (0.15)	15.23 (0.09)	14.46 (0.13)
Average Daily Precip During Nesting	The average amount of precipitation a nest experienced while it was active including 24 hours prior to estimated egg lay date and 24 hours after estimated fate date	0.81 (0.01)	0.95 (0.03)	0.64 (0.01)	0.92 (0.05)
Average Daily Temp Swing: Average Temp Difference During Nesting	The average temperature (°C) difference (maximum- minimum) during the time period the nest was active including 24 hours prior to estimated egg lay date and 24 hours after estimated fate date	17.07 (0.04)	17.18 (0.07)	17.83 (0.05)	17.14 (0.10)
Time Varying Daily Precip	Daily time varying precipitation, lined up with each day of nest exposure in which precipitation (mm) is summed for the 72-hour period centered on that day	2.38 (0.13)	2.91 (0.22)	1.71 (0.11)	2.97 (0.27)

Time Varying Daily Max Temp	Time varying maximum temperature (°C) lined up with each day of nest exposure. Value is the maximum temperature of the 72-hour period centered on that day	25.21 (0.14)	24.92 (0.23)	27.01 (0.14)	25.47 (0.25)
Time Varying Daily Min Temp	Time varying minimum temperature (°C) lined up with each day of nest exposure. Value is the minimum temperature of the 72-hour period centered on that day	2.76 (0.11)	3.03 (0.16)	3.68 (0.13)	3.41 (0.20)
Time Varying Daily Temp Difference	Time varying daily temperature difference (°C) (maximum - minimum) lined up with each day of nest exposure. Value is the average temperature difference of the 72-hour period centered on that day	17.11 (0.1)	16.94 (0.15)	18.01 (0.10)	16.91 (0.18)
Time Varying Daily Average Temp	Time varying average temperature (°C) lined up with each day of nest exposure. Value is the average temperature of the 72-hour period centered on that day	13.93 (0.12)	14.14 (0.20)	15.53 (0.14)	14.5 (0.21)
Hourly Precip Ratio	Number of hours with precipitation divided by the number of active nest hours: a value of 1 indicates 100% of hours during nest exposure period experienced precipitation of any amount	0.04 (0.00)	0.04 (0.00)	0.03 (0.00)	0.03 (0.00)
Precip %: Daily Precip Ratio	Number of days with precipitation divided by the number of active nest days: a value of 1 indicates 100% of days during nest exposure period experienced precipitation of any amount	0.27 (0.00)	0.25 (0.01)	0.24 (0.00)	0.26 (0.01)
Block	Categorical variable indicating the block within which the randomized treatment was assigned	NA	NA	NA	NA
Year (categorical)	Year as a categorical variable	NA	NA	NA	NA
Day of Nesting Season	Day of the nesting season where day 1 is the day the earliest nest was found during the study (April 25 th) regardless of year	38.92 (0.56)	42.75 (0.82)	50.17 (0.50)	45.87 (0.76)
Grazing covariate set					
Year (continuous)	Year as a continuous variable	NA	NA	NA	NA
Grazing vs No-graze (categorical)	Categorical variable of pastures that experience grazing treatments (combining dormant season and rotational treatments) in 2018 and 2019, but not during 2017 (pre-treatment) (grazed) and control pastures (control)	NA	NA	NA	NA
Treatment Sites	Pasture categories (control, dormant, rotational) which had treatments applied in 2018 and 2019, but not during 2017 (pre-treatment)	NA	NA	NA	NA
Dormant graze vs Other	Categorical variable of pastures that experience dormant grazing treatments versus all others (combining rotational and control, no graze treatments)	NA	NA	NA	NA
Treatment Sites * Year (categorical)	Multiplicative interaction between year and treatment sites. This tests for a treatment effect as 2017 was pre-treatment data	NA	NA	NA	NA
Treatment Sites * Year (continuous)	Multiplicative interaction between year and treatment sites. This tests for a treatment effect as 2017 was pre-treatment data	NA	NA	NA	NA
Vegetation covariate set					

Nest Shrub Species	Species of nesting shrub (big sagebrush, rabbitbrush, low sagebrush etc)	NA	NA	NA	NA
Nest Shrub Big Sagebrush vs Other	Nesting shrub divided into two categories: big sagebrush (<i>Artemesia tridentata</i> vs all other nesting shrubs types)	NA	NA	NA	NA
Shrub Above Nest (cm)	Amount of shrub measured in cm directly above the nest (maximum height of shrub directly above nest minus nest rim height)	51.67 (0.61)	49.36 (0.78)	45.54 (0.72)	51.98 (1.21)
Shrub Percent Live	Ocular estimate of the percentage alive of the nesting shrub	65.45 (0.75)	71.59 (0.92)	75.44 (0.67)	76.86 (1.07)
Nest Orientation (° from N)	Orientation of the nest relative to the stem of the nesting shrub, measured in degrees from north	92.44 (1.85)	85.49 (2.08)	110.17 (2.04)	101.69 (3.46)
Nest Shrub Height	Height of shrub from ground to tallest point, not including inflorescence	69.8 (0.53)	70.92 (0.64)	73.76 (0.55)	72.15 (0.85)
Nest Shrub Area	Area of shrub canopy (cm ²)	5649.54 (127.94)	4917.4 (151.44)	4950.41 (121.01)	5297.87 (146.43)
Nest Height	Height of the nest rim measured from ground level (cm)	26.33 (0.43)	25.07 (0.48)	35.64 (0.38)	31.37 (0.39)
Total Annual Forb Cover	Percent cover of all annual forb (native or invasive) species measured at the pasture level	5.98 (0.11)	7.31 (0.13)	8.42 (0.13)	7.01 (0.25)
Native Annual Forb Cover	Percent cover of all native annual forb species measured at the pasture level	0.98 (0.02)	1.33 (0.04)	0.93 (0.03)	0.93 (0.03)
Invasive Annual Forb Cover	Percent cover of all invasive annual forb species measured at the pasture level	5.00 (0.11)	5.97 (0.14)	7.49 (0.14)	6.07 (0.26)
Total Grass Cover	Percent cover of all grass species measured at the pasture level	11.54 (0.12)	10.5 (0.12)	10.86 (0.12)	10.31 (0.18)
Perennial Bunchgrass Cover	Percent cover of all perennial bunchgrass species measured at the pasture level	11.10 (0.11)	10.29 (0.11)	10.58 (0.11)	10.05 (0.17)
Perennial Forb Cover	Percent cover of all native perennial forb species measured at the pasture level	6.69 (0.12)	8.13 (0.17)	5.42 (0.15)	7.64 (0.27)
Rabbitbrush Cover	Percent cover of all rabbitbrush species measured at the pasture level	1.25 (0.03)	1.24 (0.05)	1.56 (0.03)	1.25 (0.06)
Sagebrush cover	Percent cover of all sagebrush (<i>Artemesia</i>) species measured at the pasture level	18.13 (0.09)	17.59 (0.09)	19.17 (0.07)	18.02 (0.13)
Big sagebrush cover	Percent cover of Big sagebrush (<i>Artemesia tridentata</i>) measured at the pasture level	17.36 (0.10)	16.32 (0.12)	18.79 (0.10)	17.75 (0.14)
Low Sage Cover	Percent cover of low sagebrush (<i>Artemesia arbuscula</i>) measured at the pasture level	0.78 (0.05)	1.27 (0.07)	0.39 (0.04)	0.27 (0.04)
Dead Sage Cover	Percent cover of dead <i>Artemesia</i> species measured at the pasture level	0.60 (0.01)	0.68 (0.01)	0.46 (0.01)	0.65 (0.02)
Perennial Forb Density	Average density of perennial forbs per 1 m ² measured at the pasture level	24.52 (0.42)	25.76 (0.56)	19.85 (0.31)	32.12 (1.12)
Shallow Rooted Grass Density	Average density of shallow rooted perennial bunchgrass: Sandberg bluegrass (<i>Poa secunda</i>) per 1 m ² measured at the pasture level	35.83 (0.39)	33.25 (0.46)	24.97 (0.36)	32.13 (0.68)
Deep Rooted Perennial Bunchgrass Density	Average density of deep-rooted perennial bunchgrass species per 1 m ² measured at the pasture level	5.51 (0.05)	5.11 (0.06)	5.46 (0.04)	5.74 (0.07)
Big Sagebrush Density	Density of Big sagebrush (<i>Artemesia tridentata</i>) per 1 m ² measured at the pasture level	0.71 (0.00)	0.71 (0.01)	0.70 (0.00)	0.74 (0.01)

Rabbitbrush Density	Density of rabbitbrush species per 1 m ² measured at the pasture level	0.06 (0.00)	0.11 (0.01)	0.09 (0.00)	0.07 (0.00)
Low Sage Density	Density of low sagebrush (<i>Artemesia arbuscula</i>) per 1 m ² measured at the pasture level	0.04 (0.00)	0.06 (0.00)	0.02 (0.00)	0.02 (0.00)
Total Sage Density	Density of sagebrush (<i>Artemesia spp</i>) per 1 m ² measured at the pasture level (combining big and low sagebrush)	0.75 (0.00)	0.78 (0.01)	0.72 (0.00)	0.75 (0.01)
Dead Sage Density	Density of dead sagebrush (<i>Artemesia spp</i>) per 1 m ² measured at the pasture level (combining big and low sagebrush)	0.05 (0.00)	0.05 (0.00)	0.04 (0.00)	0.06 (0.00)
Dead Non-Sage Density	Density of shrubs that are not (<i>Artemesia spp</i>) per 1 m ² measured at the pasture level (e.g. rabbitbrush, horsebrush etc)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)	0.01 (0.00)
Total Dead Shrub Density	Density of all dead shrubs per 1 m ² measured at the pasture level	0.06 (0.00)	0.06 (0.00)	0.05 (0.00)	0.06 (0.00)
Camera/ iButton covariate set					
Camera	Presence of a camera placed within 20-150cm of the nest to monitor nest success	NA	NA	NA	NA
iButton	Presence of an iButton placed within the nest	NA	NA	NA	NA

Table A2.2. Logistic exposure models of nest success comparing weather, grazing treatment, vegetation and camera/iButton variables as covariate sets among sites and years for Brewer's sparrow ($n = 97$) in southeast Oregon, USA, 2017-2019. The number of model parameters is denoted by K , ΔAIC_c is the difference from the top model in Akaike's Information Criterion adjusted for small sample size, and w_i is the model weight. See Appendix I; Table A2.1 for variable descriptions. For the weather covariate set, only top models within 10 ΔAIC_c are displayed for brevity. Nesting indicates weather while nest was active, and @fate indicates 72-hour period around date of nest fate.

Covariate set and model	K	ΔAIC_c	w_i	Deviance
Weather				
Precip % Nesting, Precip % Nesting ² , Temp Diff Nesting, Temp Diff Nesting ² × Day, Max Temp @ Fate, Max Temp @ Fate ^{2a}	9	0.00	0.61	-126.32
Precip % Nesting, Precip % Nesting ² × Day, Temp Diff Nesting, Temp Diff Nesting ² × Day, Max Temp @ Fate, Max Temp @ Fate ²	10	2.03	0.22	-128.16
Precip % Nesting, Precip % Nesting ² , Temp Diff Nesting, Temp Diff Nesting ² × Day	7	4.90	0.05	-129.23
Precip % Nesting × Day, Temp Diff Nesting, Temp Diff Nesting ² × Day, Max Temp@ Fate, Temp@ Fate ²	9	5.88	0.03	-130.72
Precip % Nesting, Precip % Nesting ² × Day, Temp Diff Nesting, Temp Diff Nesting ² × Day	8	6.45	0.02	-129.9
Precip % Nesting, Temp Diff Nesting, Temp Diff Nesting ² × Day, Max Temp @ Fate, Max Temp @ Fate ²	8	6.51	0.02	-133.04
Precip Avg Nesting, Precip Avg Nesting ² × Day, Max Temp@ Fate, Max Temp@ Fate ²	7	7.50	0.01	-134.04
Precip % Nesting × Day, Temp Diff Nesting, Temp Diff Nesting ² × Day	7	8.79	0.01	-132.07
Precip Avg Nesting, Precip Avg Nesting ² × Day	5	9.31	0.01	-133.17
Precip % Nesting, Temp Diff Nesting, Temp Diff Nesting ² × Day	6	10.39	0.00	-135.63
1 (Null)	1	29.10	0.00	-138.69
Grazing				
1 (Null) ^b	1	0.00	0.56	-138.69
Grazed Sites	2	1.28	0.30	-138.33
Treatment × Year	6	3.03	0.06	-135.18
Treatment Sites	3	3.14	0.05	-138.25
Grazed Sites × Year	4	4.49	0.03	-137.93
Vegetation				
Dead Sage Cover ^c	2	0.00	0.11	-137.23
Invasive Annual Grass Cover, Nest Height	3	0.47	0.09	-136.46
Perennial Forb Density	2	0.52	0.09	-137.49
Nest Height	2	0.57	0.09	-137.51
Dead Sage Cover, Nest Height	3	0.72	0.08	-136.58
Invasive Annual Grass Cover	2	0.87	0.07	-137.66
Invasive Annual Grass Cover, Dead Sage Cover	3	0.92	0.07	-136.68
1 (Null)	1	0.92	0.07	-138.69
Camera/iButton				
Camera ^d	2	0.00	0.46	-137.49
1 (Null)	1	0.41	0.37	-138.69
iButton	2	2.05	0.16	-138.51

^a $AIC_c = 250.29$, ^b $AIC_c = 279.39$, ^c $AIC_c = 278.47$, ^d $AIC_c = 278.98$.

Table A2.3 Logistic exposure models of nest success comparing weather, grazing treatment, vegetation and camera/iButton variables as covariate sets among sites and years for sagebrush sparrow ($n = 132$). The number of model parameters is denoted by K, ΔAIC_c is the difference from the top model in Akaike's Information Criterion adjusted for small sample size, and w_i is the model weight. See Appendix I; Table A2.1 for all tested covariates descriptions. Top 10 models of weather covariate set displayed for brevity.

Covariate set and model	K	ΔAIC_c	w_i	Deviance
Weather				
Temp Diff Daily, Temp Diff Daily ² , Precip Avg Nesting, Precip Avg Nesting ² × Day, Max Temp @Fate, Max Temp @Fate ² × Day, Min Temp@Fate ^a	11	0.00	0.32	-176.18
Temp Diff Daily, Temp Diff Daily ² , Precip Avg Nesting, Precip Avg Nesting ² × Day, Max Temp @Fate, Max Temp @Fate ² × Day, Min Temp@Fate, Min Temp@Fate ²	12	1.97	0.12	-176.15
Temp Diff Daily, Temp Diff Daily ² , Precip Avg Nesting, Precip Avg Nesting ² × Day, Max Temp@Fate, Min Temp@Fate	9	2.78	0.08	-179.59
Temp Diff Daily, Temp Diff Daily ² , Precip Avg Nesting, Precip Avg Nesting ² × Day, Max Temp@Fate	8	2.93	0.07	-180.68
Temp Diff Daily, Temp Diff Daily ² , Precip Nesting, Precip Nesting ² × Day, Max Temp@Fate, Max Temp@Fate ²	10	3.17	0.07	-178.78
Temp Diff Daily, Temp Diff Daily ² , Precip Nesting, Precip Nesting ² × Day, Max Temp@Fate, Min TempDaily	9	3.54	0.05	-179.97
Temp Diff Daily, Temp Diff Daily ² , Precip Nesting, Precip Nesting ² × Day, Max Temp@Fate, Max Temp@Fate ² × Day, Min Temp @Fate, Min Temp @Fate ² × Day	13	3.93	0.05	-176.12
Temp Diff Daily, Temp Diff Daily ² , Precip Nesting, Precip Nesting ² × Day, Max Temp@Fate, Min Temp@Fate, Min Temp@Fate ² × Day	11	4.17	0.04	-178.27
Temp Diff Daily, Temp Diff Daily ² , Precip Nesting, Precip Nesting ² × Day, Max Temp@Fate, Min Temp@Fate, Min Temp@Fate ²	10	4.32	0.04	-179.35
Temp Diff Daily, Temp Diff Daily ² , Precip Nesting, Precip Nesting ² × Day, Max Temp@Fate, Max Temp@Fate ² × Day, Min Temp Daily	11	4.45	0.03	-178.41
Null	1	43.69	0.00	-208.11
Grazing Covariate Set				
Grazed Sites × Year ^b	4	0.00	0.31	-202.64
Dormant Grazed Versus Other Sites × Year	4	0.37	0.26	-202.83
Grazed Sites, Year	3	2.08	0.11	-204.69
Treatment Sites	6	2.67	0.08	-201.97
Grazed Sites	2	2.74	0.08	-206.02
Dorm_ Dormant Grazed Versus Other Sites, Year	3	2.87	0.07	-205.08
Treatment Sites, Year	7	4.41	0.03	-201.83
Null	1	4.90	0.03	-208.11
Treatment Sites × Year	9	4.99	0.03	-200.1
Vegetation				
Dead Sage Cover ^c	2	0.00	0.30	-206.78
Dead Sage Cover, Low Sage Density	3	0.50	0.24	-206.01
Low Sage Density	2	0.57	0.24	-207.03
Null	1	0.65	0.22	-208.11
Researcher Bias				
Camera ^d	2	0.00	0.84	-205.08
Null	1	4.05	0.11	-208.11
iButton	2	5.82	0.05	-207.99

^a $AIC_c = 386.17$, ^b $AIC_c = 413.31$, ^c $AIC_c = 417.56$, ^d $AIC_c = 414.16$, ^a $AIC_c = 374.52$, ^b $AIC_c = 413.31$, ^c $AIC_c = 417.56$, ^d $AIC_c = 14.16$

APPENDIX II – CHAPTER 3 SUPPLEMENTARY INFORMATION

Table A3.1. Summary table of all variables included in step one of the nest success (daily survival rate) modeling process, with their descriptions, mean and standard error (SE) for sagebrush sparrow and Brewer's sparrow nests by fate (fledge or fail) in experimental pastures experiencing dormant, rotational or no-grazing at the Northern Great Basin Experimental Range in southeast Oregon, USA 2018–2020.

Variable Name	Description	Sagebrush Sparrow Mean (SE)		Brewer's Sparrow Mean (SE)	
		Fledged	Failed	Fledged	Failed
Predators					
<i>Pasture-level predator variables (game cameras)</i>					
Badger	Number of badgers caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.67 (0.04)	0.46 (0.04)	0.52 (0.03)	1.10 (0.06)
Bobcat	Number of bobcats caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.09 (0.01)	0.04 (0.01)	0.03 (0.00)	0.08 (0.01)
Chipmunk	Number of chipmunks caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	3.71 (0.18)	1.09 (0.09)	3.42 (0.18)	2.94 (0.28)
Coyote	Number of coyotes caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.83 (0.07)	0.49 (0.03)	0.30 (0.02)	0.33 (0.03)
Ground squirrel	Number of ground squirrels caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	10.78 (0.47)	11.72 (0.68)	9.59 (0.49)	10.67 (0.81)
Mouse	Number of mice caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	8.71 (0.29)	6.56 (0.38)	7.24 (0.21)	7.44 (0.39)
Raven	Number of common ravens caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.09 (0.01)	0.01 (0.01)	0.12 (0.01)	0.09 (0.01)
Kangaroo rat	Number of kangaroo rats caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.18 (0.02)	0.16 (0.04)	0.34 (0.03)	0.17 (0.04)
Loggerhead shrike	Number of loggerhead shrikes caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.09 (0.01)	0.19 (0.03)	0.02 (0.00)	0.03 (0.01)
Snake	Number of snakes caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.02 (0.00)	0.00 (0.00)	0.01 (0.00)	0.02 (0.01)
<i>Predator Guild Variables (Game Cameras)</i>					
Meso-predator	Summed number of badgers, coyotes and bobcats caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	1.63 (0.10)	0.99 (0.05)	0.86 (0.03)	1.52 (0.06)
Rodent	Summed number of mice, ground squirrels, chipmunks and unknown rodents caught on	26.83 (0.78)	21.00 (0.84)	24.72 (0.79)	26.03 (1.37)

	game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)				
Avian	Summed number of magpies, raven, raptors and loggerhead shrikes caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	0.22 (0.01)	0.24 (0.03)	0.22 (0.01)	0.16 (0.02)
Non-rodent	Summed number of badgers, bobcats, ravens, coyotes, ground squirrels, chipmunks and unknown rodents caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	1.87 (0.10)	1.23 (0.06)	1.09 (0.03)	1.7 (0.06)
All Predators	Summed number of badgers, bobcats, ravens, coyotes, ground squirrels, chipmunks, mice, kangaroo rats, magpies, foxes, logger head shrikes, raptors, snakes and unknown rodents caught on game cameras per 100 trap days during the nesting period (1 day before egg laying and 1 day after estimated fate)	28.33 (0.79)	22.09 (0.86)	25.36 (0.80)	28.12 (1.40)
<i>Transect Predator Variables</i>					
Transect ground squirrel Index	The number of ground squirrels heard or observed during systematic transects conducted weekly or bi-weekly throughout pastures per 100 effort hours. Index is calculated at the pasture level and summarized for the entire nesting season.	63.00 (1.81)	69.94 (2.39)	54.55 (2.15)	56.66 (2.68)
Transect chipmunk index	The number of chipmunks observed during systematic transects conducted weekly or bi-weekly throughout pastures per 100 effort hours. Index is calculated at the pasture level and summarized for the entire nesting season.	7.57 (0.24)	6.00 (0.41)	9.94 (2.68)	8.11 (0.33)
Transect raven block index	The number of ravens heard or observed during systematic transects conducted weekly or bi-weekly throughout pastures per 100 effort hours. Due to raven large territory size, index is calculated at the block level and summarized for the entire nesting season.	10.15 (0.22)	6.33 (0.27)	13.12 (0.22)	9.74 (0.38)
Transect rodent index	The number of rodents (ground squirrels + chipmunks + unknown rodents) heard or observed during systematic transects conducted weekly or bi-weekly throughout pastures per 100 effort hours. Index is calculated at the pasture level and summarized for the entire nesting season.	71.01 (1.76)	75.96 (2.35)	64.86 (2.08)	65.1 (2.65)
Transect snake index	The number of snakes (rattlesnake, gopher snake and yellow-bellied racers combined) observed during systematic transects conducted weekly or bi-weekly throughout pastures per 100 effort hours. Index is	1.88 (0.06)	2.47 (0.09)	2.23 (0.05)	1.99 (0.09)

	calculated at the pasture level and summarized for the entire nesting season.				
Point Count Variables					
Raven point	The number of ravens observed within the effective detection radii (600m) (Dinkins et al., 2014, 2012), summed across blocks (not treatments) and standardized by the number of visits.	0.18 (0.00)	0.18 (0.00)	0.19 (0.00)	0.16 (0.00)
Summary Variables (Standard Deviation)					
Not tested in predator DSR covariate set					
Nest height	Height of nest in cm measured from ground level to top of nest rim	29.97 (14.38)	27.82 (10.68)	38.71 (10.04)	34.17 (8.37)
Hatch date	Estimated hatch date within day of nesting season where day 1 is the earliest day a nest was found during the study timeframe.	43.97 (17.64)	47.12 (20.45)	53.02 (12.09)	55.74 (14.76)
Clutch size	Number of eggs in clutch	3.39 (0.65)	3.31 (0.80)	3.41 (0.60)	3.44 (0.58)
Brood size	Number of chicks hatched from eggs.	3.10 (0.96)	1.80 (1.68)	3.24 (0.65)	2.11 (1.58)
Number fledged	Number of chicks that survived to fledge.	3.14 (0.88)	0.00 (0.00)	3.21 (0.68)	0.00 (0.00)

Table A3.2. Negative binomial models of pasture-level predator counts comparing grazing treatment, year, and pasture-level predator activity variables in experimental pastures experiencing dormant, rotational or no-grazing at the Northern Great Basin Experimental Range in southeast Oregon, USA 2018-2020. The number of model parameters is denoted by K, ΔAIC_c is the difference from the top model in Akaike's Information Criterion adjusted for small sample size, and w_i is the model weight. Top five models and null shown for brevity.

Model	K	ΔAIC_c	w_i	Deviance
Ground squirrel				
Badger, Grazing treatment × year ^a	8	0.00	0.46	-453.09
Grazing treatment × year	7	1.68	0.20	-455.04
Badger, Coyote, Grazing treatment × year	9	1.73	0.20	-452.82
Coyote, Grazing treatment × year	8	3.50	0.08	-454.84
Bobcat, Badger, Coyote, Grazing treatment × year	8	6.76	0.02	-456.47
Null (intercept and offset)	2	14.02	0.00	-466.56
Badger				
Coyote, Ground squirrel, Grazing treatment ^b	6	0.00	0.30	-92.21
Bobcat, Coyote, Ground Squirrel, Grazing treatment	7	0.37	0.25	-91.29
Ground squirrel, Grazing treatment, Coyote, Year	7	2.18	0.10	-92.20
Bobcat, Coyote, Ground squirrel, Grazing treatment, year	8	2.58	0.08	-91.29
Ground squirrel, grazing treatment	5	2.65	0.08	-94.62
Null (intercept and offset)	2	18.96	0.00	-104.90
Coyote				
Badger ^c	3	0.00	0.28	-127.763
Badger, Year	4	1.92	0.11	-127.667
Badger, Grazing treatment	5	1.95	0.11	-126.613
Bobcat, Badger	4	2.08	0.10	-127.746
Badger, Ground squirrel	4	2.11	0.10	-127.763
Null (intercept and offset)	2	3.91	0.04	-130.759
Mouse				
Grazing treatment ^d	4	0.00	0.34	-388.27
Ground squirrel, Grazing treatment	5	0.06	0.33	-387.23
Ground squirrel, Grazing treatment × year	6	1.69	0.15	-386.96
Grazing treatment × Year	5	2.10	0.12	-388.25
Ground squirrel	3	5.58	0.02	-392.11
Null (intercept and offset)	2	9.77	0.00	-394.21
Chipmunk				
Grazing treatment, Year ^e	5	0.00	0.47	-239.98
Ground squirrel, Grazing treatment × Year	6	0.50	0.37	-239.15
Grazing treatment × Year	7	2.24	0.15	-238.92
Ground squirrel, Grazing treatment	5	8.26	0.01	-244.11
Grazing treatment	4	10.28	0.00	-246.19
Null (intercept and offset)	4	42.44	0.00	-264.36

^a $AIC_c = 923.18$, ^b $AIC_c = 197.00$, ^c $AIC_c = 261.69$, ^d $AIC_c = 784.81$, ^e $AIC_c = 490.37$

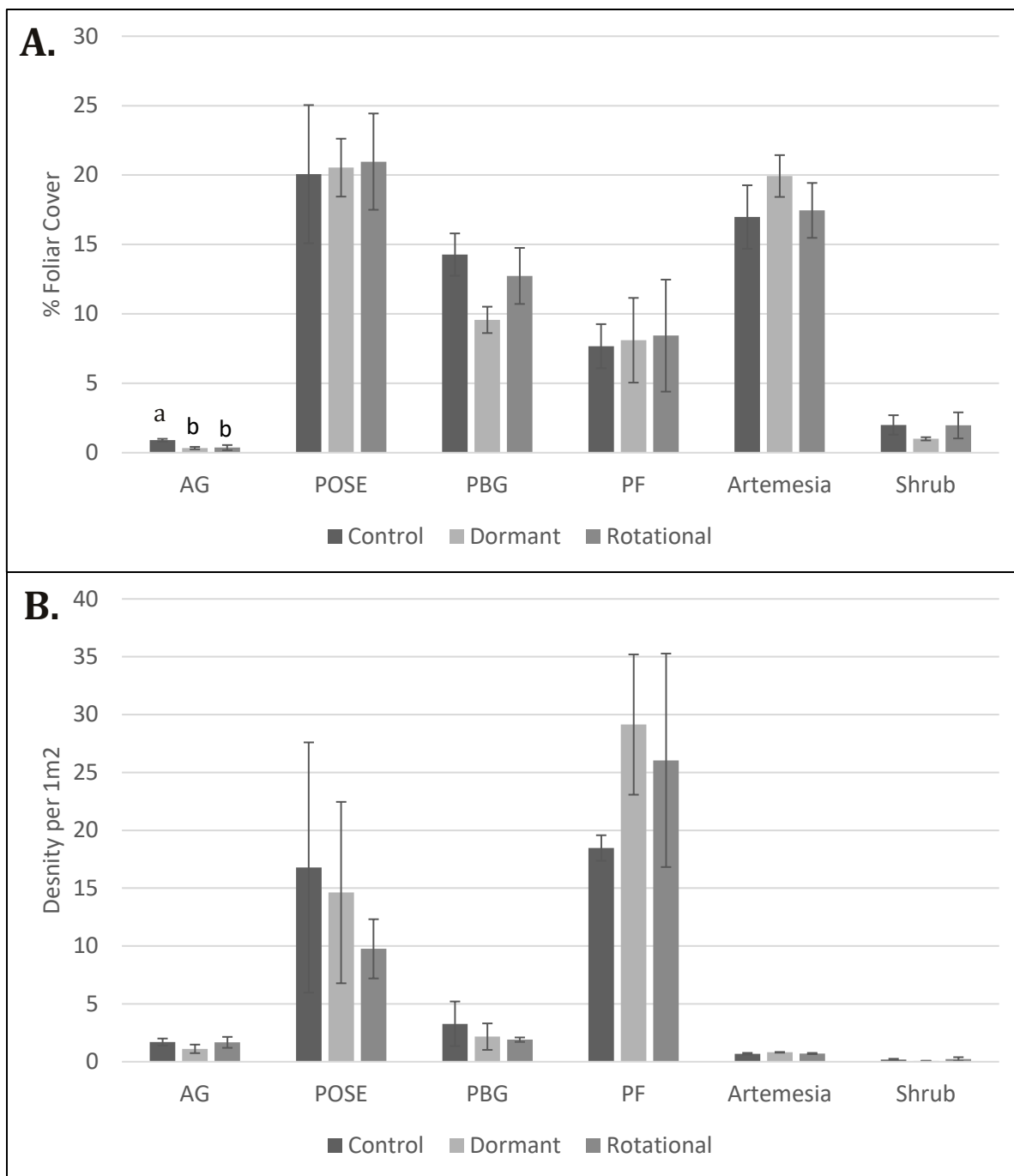


Figure A3.1. Graphs of pre-treatment vegetation collected in 2017 prior to any grazing treatments being applied. We used the PROC MIXED procedure for a randomized complete-block design to test for pre-treatment differences for vegetation variables including cover (%) and density (number plants per 1m²) of perennial forbs and grasses. We used the LSMEANS statement (SAS) for mean separation using comparison of least squares. Different letters indicate pre-treatment differences ($P < 0.05$). Percent foliar cover (A) and density (B) shown for annual grasses (AG), shallow rooted perennial bunchgrass *Poa secunda* (POSE), deep rooted perennial bunchgrasses (PBG), perennial forbs (PF), *Artemesia* species (Artemesia) and non-*Artemesia* shrubs (Shrub) for the pastures planned to have the no-graze control (black) dormant graze (light grey) and rotational graze (grey) treatments in southeast Oregon during 2017. Error bars represent one standard error.