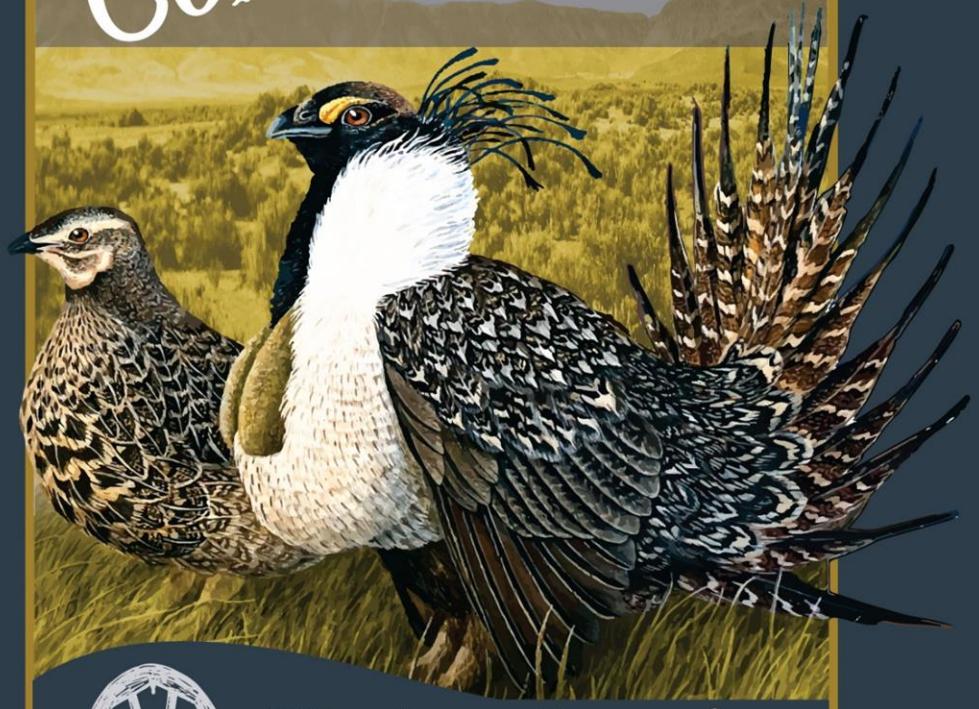
Oregon Presents:

Pioneering Conservation

June 21-24
2021



Western Agencies

Sage and Columbian Sharp-tailed Grouse Workshop

32nd Annual Workshop

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Mikal Cline, ODFW
Lee Foster, ODFW
Glenn Frederick, BLM
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Cathy Campbell and San Stiver

Robert L. Patterson Award Committee

Pat Deibert (Chair), Shawn Espinosa, Ann Moser, Mike Schroeder

Abstract Review Team

Skyler Vold (Chair), Pat Deibert, Katherine Miller, Lief Wiechman

Workshop Logo

Artwork by John Conner, Design by Rinee Merritt

PROGRAM

PACIFIC DAYLIGHT TIME (PDT)	**Monday, June 21, 2021**
8:00 am – 11:30 am	Joint Sage and Columbian Sharp-tailed Grouse Technical Committee and Rangewide Interagency Sage-grouse Conservation Team (RISCT) Meeting. – Invitation Only
11:30 am – 12:30 pm	Lunch Break
12:30 pm – 5:00 pm	Tech Committee and RISCT meeting continues

WAFWA Sage and CSTG Technical Committee Members

Mikal Cline and Skyler Vold – Oregon (Co-Chairs)
Avery Cook and Heather Talley - Utah (Incoming Co-Chairs)
Joel Nicholson – Alberta
Alicia Goddard – British Columbia
Katherine Miller – California
Kathy Griffin – Colorado
Ann Moser and Jeff Knetter – Idaho
Lorelle Berkeley - Montana
Shawn Espinosa – Nevada
Jesse Kolar – North Dakota
Jessus Karst and Beatriz Prieto – Saskatchewan
Travis Runia – South Dakota
Mike Schroeder – Washington
Leslie Schreiber - Wyoming
Pat Deibert and Megan McLachlan - BLM
Rema Sadak - USFS
Dawn Davis and Heather McPherron – USFWS

RISCT (includes the above, plus…)

Thad Heater – NRCS
Lief Wiechman – USGS
Rod Hamilton – Farm Service Agency
San Stiver – WAFWA Sagebrush Coordinator
Tony Wasley -WAFWA Sagebrush Executive Oversight Committee Chair
Ken Mayer – WAFWA Fire and Invasives Coordinator
Tom Remington – WAFWA Sagebrush Science Coordinator

PROGRAM

Tuesday, June 22, 2021

PDT

8:00 AM Welcome and Housekeeping – Mikal Cline

8:15 AM Opening Remarks – Curt Melcher, Director – Oregon Dept. of Fish and Wildlife

8:30 AM Keynote Address – Dr. Mary Zeiss Stange –Professor and Author
Hard Grass – Life on the Crazy Woman Bison Ranch

Tuesday Symposium will begin promptly at 9:00 AM.

Session #1	**Time**	**Title**	**Presenter**
Partnerships, Policy, and Population Trends Moderator: Jon Dinkins	9:00 AM	Using remote sensing in rangeland management: turning an abundance of spatial data into actionable information	Megan Creutzburg
	9:20 AM	Thinking outside the box for at risk species: mitigation 101	Katie Andrle
	9:40 AM	There's more than one way to conserve a grouse: a contextualization of greater sage-grouse management plan development	Madison Smith
	10:00 AM	Have past sampling bias, lek count averaging, and increased sampling led to some overestimates of greater sage-grouse population declines?	Robert Arkle
	10:20 AM	Morning Break	
	10:30 AM	Identifying greater sage-grouse population structures to inform a hierarchical monitoring framework	Michael O'Donnell
	10:50 AM	A novel approach to estimating range-wide population trends for greater sage-grouse at multiple spatial scales	Peter Coates
	11:10 AM	A range-wide multi-scale assessment of greater sage-grouse population performance using a targeted annual warning system	Brian Prochazka
	11:30 AM	Lunch Break	

Session #2	Time	Title	Presenter
Sagebrush ecosystems and sagebrush restoration Moderator: Christian Hagen	12:20 PM	Reconvene	
	12:30 PM	Network and resistance modeling reveal priority corridors for functional connectivity conservation of greater sage-grouse	Todd Cross
	12:50 PM	Response of greater sage-grouse to habitat treatments in Wyoming big sagebrush	Kurt Smith
	1:10 PM	Piceance Basin restoration for wildlife	Danielle Bilyeu Johnston
	1:30 PM	Analysis of six years of native seedling monitoring from post-fire restoration efforts in southwest Idaho	Karie Pappani
	1:50 PM	Playa Restoration Project: A multiple resource restoration effort	Larry Ashton
	2:10 PM	Afternoon Break	

Session #3	Time	Title	Presenter
Genetics Moderator: Christian Hagen	2:25 PM	Genetic recapture identifies long-distance breeding dispersal in greater sage-grouse *(Centrocercus urophasianus)*	Todd Cross
	2:45 PM	Genetic diversity within a hierarchical monitoring framework as an early indicator of population decline in greater sage-grouse	Shawna Zimmerman
	3:05 PM	Identifying population genetic structure and effective migration across the range of greater sage-grouse	Sara Oyler-McCance
	3:25 PM	Molecular insights on greater sage-grouse breeding strategies in the northwestern Great Basin	Tessa Behnke
	3:40 PM	Tuesday Wrap-Up	

Wednesday, June 23, 2021

Session #4	Time	Title	Presenter
Threats and Impacts (Raven, Energy, and Roads) Moderator: Lief Wiechman	8:00 AM	Open Wednesday Session	
	8:05 AM	Assessing impacts of common raven (*Corvus corax*) density on greater sage-grouse (*Centrocercus urophasianus*) to develop science-driven adaptive management strategies	Sarah Webster
	8:25 AM	Expanding abundance of a native predator, common raven, within the habitat of two sensitive native prey species, greater and Gunnison sage-grouse	Jonathan Dinkins
	8:45 AM	The response of greater sage-grouse to the reclamation of an oil and gas development landscape	Chris Kirol
	9:05 AM	Understanding the effects of 50-years of Wyoming vehicular traffic on sage-grouse populations	Richard Inman
	9:25 AM	Feral horse impacts on greater sage-grouse nest site selection and success	Jeffrey Beck
	9:40 AM	Morning Break	
	9:50 AM	Free-roaming horses adversely impact greater sage-grouse population dynamics in sagebrush ecosystems	Shawn O'Neil
	10:10 AM	Resource selection and occurrence overlap between feral horses, pronghorn, and greater sage-grouse	Jacob Hennig
	10:30 AM	Impacts of non-native grazers to vegetation structure results in cascading effects for native species	Phillip Street
	10:50 AM	Functional responses in greater sage-grouse habitat selection in response to large-scale disturbance	Bryan Stevens
	11:10 AM	Sage-grouse response to wildfire: Analyses of range-wide effects and relationships between sage-grouse demography and underlying post-fire sagebrush recovery processes	Ian Dwight
	11:30 AM	Lunch Break	

Session #5	Time	Title	Presenter
Columbian Sharp-tailed Grouse Moderator: Glenn Frederick	12:20 PM	Reconvene	
	12:30 PM	Potential impacts of wildfires on sharp-tailed grouse and greater sage-grouse in Washington state	Michael Schroeder
	12:50 PM	Brood habitat quality predicts lek occurrence and male lek attendance in Columbian sharp-tailed grouse	Jonathan Lautenbach
	1:10 PM	Productivity and abundance of Columbian sharp-tailed grouse in Idaho: Multi-scale effects of weather, habitat, and disturbance	Bryan Stevens
	1:30 PM	Analyzing the relationship of land use and land cover change with Columbian sharp-tailed grouse populations in eastern Idaho	Dane Coats
	1:40 PM	Historical samples elucidate sharp-tailed grouse subspecific distributions and the genetic lineage of individuals of unknown origin in southwestern Montana	Todd Cross
	1:55 PM	Afternoon Break	

Session #6	Time	Title	Presenter
Lightning Round #1 (IAG, Remote Sensing) Moderator: Glenn Frederick	2:10 PM	Early estimates of exotic annual grass percent cover in the sagebrush biome, May 2021	Stephen Boyte
	2:20 PM	The cheatgrass challenge: a proactive strategy for tackling invasive annual grasses	Charles Sandford
	2:30 PM	Trade-offs in managing fire, invasion, and disturbance impacts in the greater sage-grouse landscape	Julie Heinrichs
	2:40 PM	Temporal changes in greater sage-grouse seasonal habitat selection in response to large-scale wildfire	Elizabeth Schuyler
	2:50 PM	Lightning Round Q&A (10 min)	

Session #7	Time	Title	Presenter
Lightning Round #2 (Fuels and Fire) Moderator: Glenn Frederick	3:00 PM	Timestamping Wyoming anthropogenic disturbances to inform wildlife studies in sagebrush ecosystems	Benjamin Robb
	3:10 PM	Modeling sagebrush recovery across the sage-grouse range using three decades of remotely-sensed vegetation estimates	Bryan Tarbox
	3:20 PM	Rebuilding sagebrush habitat: using state-transition simulations to project post-fire restoration and habitat recovery efficacy for greater sage-grouse	Elizabeth Orning
	3:30 PM	Lightning Round Q&A (10 min); Adjourn	

Thursday, June 24, 2021

Session #8	Time	Title	Presenter
Habitat Associations, Gunnison Sage-grouse Moderator: Skyler Vold	8:00 AM	Open Thursday Session	
	8:05 AM	Sage-grouse seasons, home ranges and habitats, what are they and how many are there?	Robert Haynam
	8:25 AM	A regionally varying habitat suitability model to identify areas for greater sage-grouse persistence	Gregory Wann
	8:45 AM	Management-focused habitat selection models for Gunnison sage-grouse	Cameron Aldridge
	9:05 AM	Optimizing spatial application of habitat management actions for the Gunnison sage-grouse satellite populations	Jessica Shyvers
	9:15 AM	Gunnison sage-grouse habitat vulnerability to climate change, development, and fire in the 21st century	Nathan Van Schmidt
	9:25 AM	Gunnison sage-grouse recovery tracking: conservation efforts database v3.0	Lief Wiechman
	9:35 AM	Morning Break	

Session #9	Time	Title	Presenter
Habitat Selection Moderator: Skyler Vold	9:50 AM	At what scales do sage-grouse populations respond to sagebrush cover in landscapes?	Adrian Monroe
	10:10 AM	Multi-scale resource selection functions controlling for differences in habitat availability perform best when transferred to a novel site	Kristopher Winiarski
	10:30 AM	Quantifying the temporal stability in seasonal habitat for sage-grouse using regression and ensemble tree approaches	Bradley Fedy
	10:50 AM	Linking microhabitat, home range, reproductive stage, and behavior in greater sage-grouse during brood-rearing season	Erin Gelling
	11:10 AM	Prioritizing the placement of conifer removal projects for concurrent multi-species management	Nicholas Van Lanen
	11:30 AM	Lunch Break	

Session #10	Time	Title	Presenter
Special Presentation	12:30 PM	Awards Ceremony	Pat Deibert, Valle Patterson
Translocations Moderator: Pat Deibert	12:45 PM	Field methods for translocating female greater sage-grouse with their broods	Kade Lazenby
	1:00 PM	Brood translocations are more effective and efficient than translocation of pre-nesting females	Steven Mathews
	1:15 PM	Behavioral-state dependent habitat selection in translocated greater sage-grouse in North Dakota, USA	Simona Picardi
	1:30 PM	Nesting, brood rearing, and summer habitat selection by translocated greater sage-grouse in North Dakota, USA	David Dahlgren
	1:45 PM	Afternoon Break	

Session #11	Time	Title	Presenter
Lightning Round #3 (Planning, Winter Use, and Population Trends Moderator: Pat Deibert	2:00 PM	Prioritizing restoration areas to conserve multiple sagebrush-associated wildlife species	Courtney Duchardt
	2:10 PM	Greater sage-grouse landscape connectivity prioritization when data is limited: a case study in systematic conservation planning	Marie Racioppa
	2:20 PM	Management recommendations for greater sage-grouse winter concentration areas	Aaron Pratt
	2:30 PM	Comparison of songbird population trends to sage-grouse lek trends: assessing sage-grouse core areas and umbrella species concept	Jonathan Dinkins
	2:40 PM	Lightning Round Q&A (10 min)	

Session #12	Time	Title	Presenter
Lightning Round #4 (Sagebrush Ecosystems) Moderator: Pat Deibert	2:50 PM	Timestamping Wyoming anthropogenic disturbances to inform wildlife studies in sagebrush ecosystems	Erin Buchholtz
	3:00 PM	Modeling sagebrush recovery across the sage-grouse range using three decades of remotely-sensed vegetation estimates	Brianne Brussee
	3:10 PM	Rebuilding sagebrush habitat: using state-transition simulations to project post-fire restoration and habitat recovery efficacy for greater sage-grouse	Daniel Manier
	3:20 PM	Lightning Round Q&A (10 min)	
	3:30 PM	Adjourn 32nd Workshop	

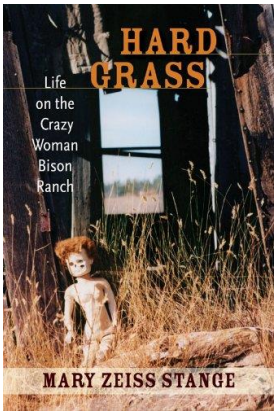
Keynote Speaker

The author of *Woman the Hunter* (Beacon Press, 1997), the first cultural history of the relationship of women and hunting, Mary Zeiss Stange has gained international recognition. She has been profiled in *The Chronicle of Higher Education, USA Today,* and in widely syndicated Associated Press stories; has been interviewed by *The New York Times, SierraMagazine*, *Outside Magazine, Montana Quarterly* and the BBC; and has done numerous interviews on National Public Radio. Stange and her work were the subject of "She Got Game," a lengthy feature interview by Barbara Ehrenreich, in the June/July 1999 issue of *"Ms." Magazine.*

Stange's other books include *Gun Women: Firearms and Feminism in Contemporary America,* (New York: New York University Press, 2000); *Heart Shots: Women Write about Hunting*, a critical anthology of historical and contemporary women's outdoor writing (2003, Stackpole Books); and *Hard Grass: Life on the Crazy Woman Bison Ranch,* which traces the changing realities of high plains ranch life in light of contemporary environmental theory (University of New Mexico Press, 2010). She also was general editor of the "Sisters of the Hunt" reprint series of classic women's writing about hunting, which Stackpole published from fall of 2003 through 2005. Her numerous articles have been published in both popular and scholarly venues.

Stange consults, in the US and Europe, on the complex relationship between hunter/conservationism and "green" environmentalism. She is since 2013 an Expert Member of the International Council on Game and Wildlife Conservation (CIC), and a member of its Artemis working group on women's hunting and environmental sustainability. Meanwhile on this side of the Atlantic, in 2014 she was a Senior Scholar at the Center for Humans and Nature, co-directing with Jan Dizard their "Questions for a Resilient Future" project on the question, "Does Hunting Make Us Human?" The result of that collaboration is a book--*Hunting: A Cultural History*-- forthcoming this fall from MIT Press. Stange serves as a member of the Board of Directors of Orion, the Hunters Institute.

Mary Zeiss Stange, Ph.D.



The Robert L. Patterson Award

The Robert L. Patterson Award was established in 2008 by the Western Agencies Sage and Columbian Sharp-tailed Grouse Technical Committee to recognize outstanding resource professionals who have contributed significant efforts to the conservation and management of these species. The award honors Patterson's pioneering work, captured in his 1952 seminal publication, *The Sage Grouse in Wyoming*, and is given to one or two recipients at the biennial Sage and Columbian Sharp-tailed Grouse Workshop. Nominations are made by peers, and award recipients are selected on their significant contributions, and outstanding commitment, to the long-term conservation of these species. They may be engaged research, management, or policy, and need to demonstrate a long-term commitment to these species.

YEAR	MEETING LOCATION	RECIPIENT
2008	Mammoth, California	Clait E. Braun
2010	Twin Falls, Idaho	Randall B. Smith
2010	Twin Falls Idaho	John W. Connelly, Jr.
2012	Steamboat Springs, Colorado	Michael Schroeder
2012	Steamboat Springs, Colorado	San Juan Stiver
2014	Elko, Nevada	Kerry P. Reese
2014	Elko, Nevada	Clinton McCarthy
2016	Lander, Wyoming	Steven T. Knick
2016	Lander, Wyoming	Patricia A. Deibert
2018	Billings, Montana	James S. Sedinger
2018	Billings, Montana	Thomas J. Christiansen

CONTRIBUTED PRESENTATIONS ABSTRACTS

USING REMOTE SENSING IN RANGELAND MANAGEMENT: TURNING AN ABUNDANCE OF SPATIAL DATA INTO ACTIONABLE INFORMATION

Megan K. Creutzburg[1]

[1]Institute for Natural Resources, Oregon State University, 2112 SW 5th Ave, Portland, OR 97201

Abstract. The number of maps and spatial decision support tools for rangelands in the western US has exploded in recent years as interest in rangeland management has climbed and technological advances have opened new doors. These new products offer great opportunities to incorporate data crossing broad spatial scales and long timeframes into decision-making, but also present an overwhelming amount of new and ever-changing information for users to digest. This presentation will start with some guiding principles for how to approach the use of remotely sensed maps in rangeland management, with examples of how maps can improve efficiency and effectiveness of decision-making. It will also highlight how the Oregon SageCon Partnership has leveraged new spatial data into simplified products targeted toward specific management applications, including a set of Ecostate Time Series maps to depict change in the distribution and severity of threats to rangeland ecosystems over the last few decades, and an Invasives Geographic Strategy to guide opportunities for proactive, landscape-scale management of invasive annual grasses in the state.

THINKING OUTSIDE THE BOX FOR AT RISK SPECIES: MITIGATION 101

Carolyn Sime[1], Katie Andrle[2], Nigel Seidel[3], Taylor Elm[4], Amy Waring[5]

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[3] Oregon Dept of Fish & Wildlife, 4034 Fairview Industrial Dr SE, Salem, OR 97302
[4] Colorado Parks and Wildlife, 711 Independent Ave., Grand Junction, CO 81505
[5] Bureau of Land Management, Montana / Dakotas State Office, 5001 Southgate Drive, Billings, MT 59105

Abstract. The Greater Sage-grouse (GRSG) is an at-risk species, having been considered for Endangered Species Act (ESA) protections eight times. Population status and trends, regulatory mechanisms, and habitat loss are key drivers in U.S. Fish and Wildlife Service determinations about whether ESA protections are warranted. Mitigation is a market-driven, proactive way to address and ameliorate threats to at-risk species *before* a species is listed. Mitigation *after* a species is listed offers fewer options with limited effectiveness and has not been widely successful in species recovery. Mitigation for impacts to GRSG habitat was incorporated into federal land use plans and state conservation strategies, respectively, to proactively address threats. Mitigation for impacts from known, identified threats attributed to anthropogenic disturbance was foundational to the 2015 finding that listing was not warranted range wide. Mitigation motivates developers to avoid, minimize, reclaim, and compensate for impacts by siting and implementing projects in ways that are least impactful. Developers are incentivized to design and site projects to keep mitigation obligations and costs low. In some cases, mitigation obligations would have been so high that the project was never implemented. State and federal mitigation policy approaches and impact quantification methods vary, but endeavor to offset impacts using common, universal principles. Mitigation must be timely, adequate, and effective to offset habitat impacts and losses. This talk will provide an overview of mitigation principles and give examples of how mitigation can be a beneficial tool to squarely address habitat loss and fragmentation for GRSG so that anthropogenic development is balanced with conservation.

THERE'S MORE THAN ONE WAY TO CONSERVE A GROUSE: A CONTEXTUALIZATION OF GREATER SAGE-GROUSE MANAGEMENT PLAN DEVELOPMENT

Madison E. Smith[1], Andrew Gregory[1]

[1]Department of Biological Sciences, University of North Texas, 1155 Union Circle, Denton, TX 76203

Abstract. Wildlife management agencies are tasked with the difficult prospect of managing wildlife species in light of ongoing anthropic pressures and stakeholder involvement. This project examines how management agencies orchestrate actions that balance wildlife needs and human stakeholder desires in effective management policies. Using Greater Sage-grouse (*Centrocercus urophasianus*) as a case study, we evaluate the relative contributions of socio-political and ecological factors driving state management plan development and structure in six western states. Socio-political factors will include social, ecological, and economic value of sage-grouse conservation as derived from interviews and surveys. Ecological factors will include precipitation extremes, temperature extremes, sagebrush percent cover, lambda, and R^2 as derived from existing climatological data and state lek counts. Through the use of mixed methods analysis and Random Forest machine learning algorithms, each factor will be given a weighted importance score. These weights will be used to understand the degree to which these factors influenced the development of management plan-stipulated goals.

HAVE PAST SAMPLING BIAS, LEK COUNT AVERAGING, AND INCREASED SAMPLING LED TO SOME OVERESTIMATES OF GREATER SAGE-GROUSE POPULATION DECLINES?

Robert S. Arkle[1], David S. Pilliod[1], Michelle I. Jeffries[1], Justin L. Welty[1], Ethan Ellsworth[2], Ann Moser[3]

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[2]U.S. Bureau of Land Management, Idaho BLM T&E Program, 1387 South Vinnell Way, Boise, ID 83709
[3]Idaho Department of Fish and Game, Wildlife Bureau, 600 S. Walnut St, Boise, ID 83712

Abstract. It is widely accepted that Greater Sage-grouse populations have been in decline for decades across the Intermountain West. However, preliminary findings from the examination of 70 years of data from Idaho indicate that several factors related to sampling and summarizing of lek count data could result in overestimates of decline magnitude. Evidence suggests that not all leks within a given cluster, or sub-population, are equally important and that selection by grouse, or differences in recruitment, may result in a desirability hierarchy. Along these lines, early investigators may have understandably selected the larger leks for monitoring. As concern over population trends grew around 1990, substantially more leks were sampled annually, resulting in a disproportionate number of smaller leks contributing to population estimates calculated over the last 30 years. As additional leks within sub-populations are surveyed within a given year, average male counts decline sharply, whereas the total number of males counted plateaus. This phenomenon was observed even during the 1950s and 1960s, suggesting that: 1) even when populations were most robust during the period of data collection, that both birds and researchers were selecting for certain lek types, and 2) that the widely-employed practice of averaging lek counts within sub-populations may result in declining trends if more leks are sampled over time.

IDENTIFYING GREATER SAGE-GROUSE POPULATION STRUCTURES TO INFORM A HIERARCHICAL MONITORING FRAMEWORK

Michael S. O'Donnell[1], David R. Edmunds[2*], Cameron L. Aldridge[1], Julie A. Heinrichs[2], Adrian P. Monroe[1], Peter S. Coates[3], Brian G. Prochazka[3], Steve E. Hanser[1], Lief A. Wiechman[1]

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[*]Current affiliation: U.S. Geological Survey, Fort Collins Science Center, 2150 Centre Avenue, Building C, Fort Collins, CO, USA, 80526-8118

Abstract. Population monitoring is important to wildlife and land management agencies, but analyses of population data rarely account for processes occurring across spatial and temporal scales. We present a multi-scaled framework to inform long-term monitoring and population trend assessments of sage-grouse across the western United States. First, we defined population structure uniquely using an amalgamation of factors that encompassed dispersal capabilities, seasonal habitat conditions, dispersal distances informed from genetic flow, and functional processes (scale effects) affecting movements. Second, we assessed multi-scaled habitat selection needs with constraint-based rules of connectivity (population structure) using a landscape partitioning approach known as the Spatial "K"luster Analysis by Tree Edge Removal clustering algorithm (SKATER). This unique combination of methods provided a biologically-informed methodology of grouping breeding populations at multiple nested scales. We evaluated the hierarchical framework (13 cluster levels) based on its assumption of closed populations using >1.7 million telemetry locations (2006 – 2021) and 2,821 unique birds (fine-scaled clusters captured 92% of birds' time). The resulting population structure is intended to support numerous needs, including a hierarchical and spatially balanced framework for population monitoring and a Targeted Annual Warning System that can provide wildlife managers an adaptive management tool.

A NOVEL APPROACH TO ESTIMATING RANGE-WIDE POPULATION TRENDS FOR GREATER SAGE-GROUSE AT MULTIPLE SPATIAL SCALES

Peter S. Coates[1], Brian G. Prochazka[1], Michael S. O'Donnell[2], Cameron L. Aldridge[2], David R. Edmunds[2], Adrian P. Monroe[2], Mark A. Ricca[1*], Gregory T. Wann[2], Steve E. Hanser[2], Lief A. Wiechman[2], Michael P. Chenaille[1]

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Abstract. Incorporating spatial and temporal scales into greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) population monitoring strategies is challenging and rarely implemented. Sage-grouse populations are characterized by temporal oscillations, making trend estimation sensitive to start and stop years. Accounting for environmental and demographic stochasticity is critical to reliably estimating population trends and identifying deterministic factors on the landscape more amenable to management action. We used a range-wide standardized database of lek counts within a hierarchical Bayesian state-space model and a biologically-informed, multi-scale network of breeding populations, known as 'clusters,' to estimate trends across different spatiotemporal scales. While accounting for oscillations in population abundance, our models estimated 37.0, 65.2, and 80.7% range-wide declines across short (17 years), medium (33 years), and long (53 years) temporal scales, respectively. Recent rates of decline were greater in western portions of the range, particularly the Great Basin, where wildfire and invasive grasses are prominent. Conversely, some areas in the eastern range exhibited evidence of population growth in recent decades. This modeling framework serves as the foundation for a 'Targeted Annual Warning System' decision support tool to direct management efforts toward populations with the greatest need and may be modified to evaluate the effectiveness of conservation efforts.

A RANGE-WIDE MULTI-SCALE ASSESSMENT OF GREATER SAGE-GROUSE POPULATION PERFORMANCE USING A TARGETED ANNUAL WARNING SYSTEM

Brian G. Prochazka[1], Peter S. Coates[1], Michael S. O'Donnell[2], Cameron L. Aldridge[2], David R. Edmunds[2], Adrian P. Monroe[2], Mark A. Ricca[1*], Gregory T. Wann[2], Steve E. Hanser[2], Lief A. Wiechman[2], Michael P. Chenaille[1]

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Abstract. In the absence of local perturbations, greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) populations exhibit short-term fluctuations in abundance, governed by environmental and demographic stochasticity, and long-term oscillations in response to large-scale climatic patterns. Multi-scale spatiotemporal fluctuations in abundance can hinder population performance assessments when additional information regarding the metapopulation structure is absent. By utilizing a hierarchical population monitoring framework previously developed for sage-grouse across their range, we made intra-annual comparisons of population performance across multiple spatially nested scales. Log odds ratios developed from local and broad-scale population growth rates served as a within-year performance metric, which captures local-scale declines that outpace the broad-scale. Multi-year assessments of log odds ratios accounted for environmental and demographic stochasticity, as well as observation error, and identified populations exhibiting strong evidence of aberrant decline. Post hoc analyses identified optimal thresholds for log odds ratio indices by assessing when populations reached broad-scale stability from simulated management intervention. Using this framework, we identified population declines that are likely attributable to disturbances on the landscape rather than environmental stochasticity or intrinsic factors across broader regions, which can help immediately inform when and where increased monitoring or direct management intervention may be needed to reverse negative trends.

NETWORK AND RESISTANCE MODELING REVEAL PRIORITY CORRIDORS FOR FUNCTIONAL CONNECTIVITY CONSERVATION OF GREATER SAGE-GROUSE

Todd B. Cross[1], Jason D. Tack[2], Kevin E. Doherty[3], Sara J. Oyler-McCance[4], Brad C. Fedy[1]

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Abstract. Connectivity among populations is paramount to conservation. Of primary concern is identifying corridors that conserve functional connectivity. We integrated two published models of functional connectivity—a landscape resistance model and a network model—to identify, prioritize, and characterize corridors connecting greater sage-grouse lek complexes range wide. Using the network model minimum spanning tree† (MST) we identified leks connected by the greatest genetic exchange, prioritized those connections based on betweenness*, then modeled corridors among connected leks by thresholding current maps based on a circuit theory analysis of the landscape resistance model. Out of 457 MST connections among 458 nodes, we identified 92 connections within the top 25% of betweenness, and thresholded the corresponding pairwise current maps to the top 0.5% of current, resulting in 6725 km^2 corridors for functional connectivity. Many of these priority corridors were central to the species range, were largely encompassed within priority areas for conservation (62% of total corridor area), and were composed of high quality breeding habitat (50% ≥65% HSI) and high sagebrush cover (60%). Nevertheless, on average, 61% of corridor area was classified as moderately resistant and resilient, 44% as moderately human disturbed, and 23% as at moderate risk of conversion to tillage agriculture.

†The minimum subset of total network connections required to connect all nodes, without cycles, with the maximum possible edge weight (genetic covariance).
*The total number of pairwise network connections fostered by a given connection

RESPONSE OF GREATER SAGE-GROUSE TO HABITAT TREATMENTS IN WYOMING BIG SAGEBRUSH

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Abstract. Sagebrush (*Artemisia* spp.) often has been treated through chemical application, mechanical treatments, and prescribed burning to increase herbaceous forage species released from competition with sagebrush. We initiated a 9-year (2011–2019) study in central Wyoming to better understand how greater sage-grouse (*Centrocercus urophasianus*) respond to vegetation treatments in Wyoming big sagebrush communities. We used a Before-After Control-Impact study design to evaluate the influence of 2 common sagebrush treatments on greater sage-grouse demography and resource selection. Our results generally suggested neutral demographic responses and slight avoidance by greater sage-grouse in response to Wyoming big sagebrush treated by mowing and tebuthiuron. Perennial grass cover and height, and forb cover and species richness varied temporally, yet did not vary systematically between treatment and control plots. We also found no evidence that perennial grass cover, perennial grass height, forb cover, or forb species richness was greater in mowed or tebuthiuron treated areas that received grazing rest compared to areas that received no grazing rest. Finally, forb and invertebrate dry matter did not differ between treated plots and control plots in any years following treatments. Results from our study support a developing paradigm that sage-grouse in Wyoming big sagebrush do not respond positively to sagebrush treatments.

PICEANCE BASIN RESTORATION FOR WILDLIFE

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Abstract. The Piceance Basin in northwest Colorado provides critical habitat for mule deer and greater sage-grouse, and is also impacted by natural gas development. With elevations of 5,000-8,000 feet, sagebrush communities vary from Wyoming big sage with a cheatgrass understory to Mountain big sage with a diverse native understory. In 2008, Colorado Parks and Wildlife (CPW) set up 6 sagebrush restoration experiments at 12 sites spanning the elevation range. Monitoring continued through 2019. Key findings emphasize the importance of controlling cheatgrass dispersal and seed density within disturbances at all elevations. Cheatgrass dispersal and seed density are lessened when barriers to seed movement are provided, and this allows lighter use of herbicides and competitive grasses, both of which hinder sagebrush establishment. Sagebrush seed collected near restoration sites is essential, as sagebrush is site-adapted at a fine scale. Replacing dead sagebrush skeletons back on restoration sites slightly but consistently improves sagebrush establishment. With the suite of tools now available, including dispersal control, herbicides, forb/shrub-heavy seed mixes, local sagebrush seed, and shrub skeletons, disturbances within degraded sagebrush communities should be viewed as an opportunity to improve habitat. Findings are synthesized in CPW technical publication #57, Piceance Basin Restoration for Wildlife.

ANALYSIS OF SIX YEARS OF NATIVE SEEDLING MONITORING FROM POST-FIRE RESTORATION EFFORTS IN SOUTHWEST IDAHO

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Abstract. It is widely acknowledged that locally adapted and source-identified native plant materials are necessary for restoration of functional sagebrush steppe ecosystems and associated Greater Sage-Grouse habitat. Monitoring of post-fire restoration treatments is critical to gathering insight on how best to improve restoration success. Our program fills both of these needs by collecting locally adapted native seed for use in restoration plantings and by monitoring seedling growth, establishment, and survival. This research tracks short-term growth and survival of a random subset of out-planted seedlings across 30 sites in southwest Idaho occurring from 2016-present. 2,680 seedlings were monitored including 250 low sagebrush, 1,276 big sagebrush, 1,104 bitterbrush, and 50 saltbush during the spring and fall of these years. Preliminary results indicate that nursery seedling quality, season of planting, and soil type have a combined effect on survival of bitterbrush and sagebrush seedlings. Higher quality seedling stock has a higher probability of survival to the establishment phase at year two. Bitterbrush survives better when planted in the spring and sagebrush when planted in the fall. Bitterbrush survival and height are greater on clayey/loamy sites. Big sagebrush survival and height are greater on sandy/granitic sites. Future analysis will delve into microsite climatic factors.

PLAYA RESTORATION PROJECT: A MULTIPLE RESOURCE RESTORATION EFFORT

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Abstract. Playas are low lying depressions with clay soils where water seasonally collects across the high desert. Playas provide limited suitable growing conditions required by some forbs and insects. These features provide important habitat to sage-grouse rearing their broods. When the west was settled, playas were altered by digging deep into the center, allowing water to collect for livestock. The water footprint then decreased in size, thus reducing the amount of forbs and insects at the playas. Because of this, the quality of brood-rearing habitat was reduced or lost completely. Over the past 10 years, the Prineville District BLM has collaborated with multiple resource specialists, grazing permittees, and partners to restore two altered playas on BLM managed lands. Within this case study planning, implementation, and lessons learned will be analyzed.

GENETIC RECAPTURE IDENTIFIES LONG-DISTANCE BREEDING DISPERSAL IN GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*)

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Abstract. Dispersal can strongly influence the demographic and evolutionary trajectory of populations. For many species, little is known about dispersal, despite its importance to conservation. The greater sage-grouse (*Centrocercus urophasianus*) is a species of conservation concern that ranges across 11 western U.S. states and 2 Canadian provinces. To investigate dispersal patterns among spring breeding congregations, we examined a 21-locus microsatellite DNA dataset of 3,244 greater sage-grouse sampled from 763 leks throughout Idaho, Montana, North Dakota, and South Dakota, USA, across 7 yr. We recaptured ~2% of individuals, documenting 41 instances of breeding dispersal (median dispersal distance = 15 km), with seven dispersal events of >50 km, including one of 194 km. We identified 39 recaptures on the same lek up to 5 yr apart, which supports the long-held paradigm of philopatry in lekking species. We found no difference between the sexes in breeding dispersal distances or in the tendency to disperse vs. remain philopatric. We also documented movements within and among state-delineated priority areas of conservation importance, further supporting the need to identify movement corridors among these reserves. Our results can be used to inform the assumptions of count-based population models and the dispersal thresholds used to model population connectivity.

GENETIC DIVERSITY WITHIN A HIERARCHICAL MONITORING FRAMEWORK AS AN EARLY INDICATOR OF POPULATION DECLINE IN GREATER SAGE-GROUSE

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Abstract. Wildlife population monitoring typically occurs at one arbitrary scale and does not include genetic information, despite the known importance of genetic variation to population fitness and potential follies of mismatch between spatial scale and monitoring. Recently developed methods generating hierarchically nested monitoring units (clusters) for greater sage-grouse (*Centrocercus urophasianus*) have identified population trend declines across spatiotemporal scales. The same clusters used as proxy for spatial scale can detect local units (i.e., neighborhood-scale) with low genetic diversity, further facilitating identification of management targets; providing a local signal of decline that is less sensitive to stochasticity than population trend. We defined genetic diversity thresholds for conservation concern, developed a model to robustly estimate genetic diversity, and used previously developed clusters to identify management-relevant areas within in the greater sage-grouse range based on genetic diversity levels. We found strong, cross-scale indications of decline in the small and isolated Washington population unlikely to respond to typical local management actions. Importantly, we found 36 neighborhood-scale clusters as potential targets of conservation action; many of which correspond to documented local trend declines. Our findings could facilitate conservation action prioritization in combination with population trend assessments and act as baseline of genetic diversity for future comparison.

IDENTIFYING POPULATION GENETIC STRUCTURE AND EFFECTIVE MIGRATION ACROSS THE RANGE OF GREATER SAGE-GROUSE

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Abstract. Conservation efforts for Greater sage-grouse require an understanding of population structure, gene flow, and connectivity across the species range. Our objectives were to describe large-scale patterns of population genetic structure and gene flow across the range and characterize genetic population kernels—those areas that serve as spatio-genetic centroids of genetic differentiation—across the range. We used samples from 2134 individuals from 927 leks and genotyped them at 15 microsatellite loci. We used a variety of spatial genetic analyses to evaluate population genetic structure and effective gene flow. Using standard STRUCTURE analysis as well as spatial principal components analysis, we found six main areas of large-scale genetic differences. Additionally, a new analysis involving a spatial iterative bifurcation process identified 12 subpopulation kernels of differentiation. Gene flow was generally higher and differentiation lower in areas of contiguous habitat (eastern Montana, most of Wyoming, much of Oregon, Nevada, and parts of Idaho). Fragmented areas in Utah had the greatest differentiation (6 kernels) and lowest effective migration. Comprehensive management of sage-grouse includes monitoring programs that arguably should include genetic data. The data and analyses presented here provide a baseline for monitoring future changes in connectivity and genetic diversity resulting from landscape changes.

MOLECULAR INSIGHTS ON GREATER SAGE-GROUSE BREEDING STRATEGIES IN THE NORTHWESTERN GREAT BASIN

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Abstract. Though sage-grouse males are fully on display during the breeding season, female mating behavior is more secretive. Genetic analysis can reveal true parentage of resulting clutches. We extracted DNA from 350 eggs in 46 clutches and feathers of putative mothers from our study site in Northwestern Nevada. We targeted 14 microsatellite loci developed for sage-grouse and one sex determination locus. Using the female feather samples, we verified maternity to examine nest parasitism, and then reconstructed possible male genotypes and looked for evidence of multiple matings. We found four clutches that had at least two distinct sires, but no evidence of nest parasitism by other females. For one clutch, the two males each sired half of the offspring. In the other three, only one or two eggs were of different parentage than the rest of the clutch. We found additional single-locus mismatches, but we cannot determine if these are from closely related additional parents or genotyping errors. Multiple parentages in clutches may help maintain genetic diversity for the population or allow females to hedge their bets on male quality, and therefore the quality of offspring. These results provide important insights about sage grouse breeding behavior that observational studies alone cannot.

ASSESSING IMPACTS OF COMMON RAVEN (*CORVUS CORAX*) DENSITY ON GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) TO DEVELOP SCIENCE-DRIVEN ADAPTIVE MANAGEMENT STRATEGIES

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Abstract. The common raven (*Corvus corax*) is a behaviorally flexible predator with drastically increasing populations that negatively impact sensitive prey species, including greater sage-grouse (*Centrocercus urophasianus*). Accurate estimates of raven density remain difficult to obtain, and effective, adaptive management protocols are needed to mitigate negative impacts of surging raven populations. We mapped raven density across the Great Basin, USA, and evaluated effects of density on sage-grouse nest survival in order to estimate a critical raven density that can serve as a predator-prey conflict threshold for sage-grouse. We found density adversely impacted sage-grouse nest survival, and we identified a threshold of ~0.40 ravens km^2. Importantly, average raven density across study extent was 0.54 ravens km^2 (95% CI = 0.42–0.70). We used underlying data to demonstrate a science-based adaptive approach to inform management of ravens in western landscapes with emphasis on sage-grouse habitats. We also developed a map that delineated areas used by breeding versus non-breeding ravens as management options could vary across these areas. Our strategy is amenable to different management objectives and is a valuable resource for managers wanting to ameliorate impacts of ravens on sage-grouse and other sensitive species. Findings are preliminary and provided for best timely science.

EXPANDING ABUNDANCE OF A NATIVE PREDATOR, COMMON RAVEN, WITHIN THE HABITAT OF TWO SENSITIVE NATIVE PREY SPECIES, GREATER AND GUNNISON SAGE-GROUSE

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Abstract. Common raven (*Corvus corax*; hereafter, raven) abundance has increased throughout western North America during the past century. Human subsidies have allowed ravens to maintain higher annual survival and reproduction than with natural resources alone in greater (*Centrocercus urophasianus*) and Gunnison (*C. minimus*) sage-grouse habitat. Using Breeding Bird Survey data, 1995–2014, we evaluated raven abundance and expansion into sagebrush ecosystems focusing on the seven sage-grouse Management Zones (MZs). We assessed the effects of numerous land cover and anthropogenic features on instantaneous growth rate or carrying capacity of ravens. Abundance of ravens in western and southeastern MZs was greater than northeastern MZs within the greater sage-grouse range; however, percent increase was high in all MZs. High abundance in MZ VII indicated Gunnison sage-grouse have been exposed to higher raven abundance for many years. Higher numbers or instantaneous growth of ravens was positively associated with transmission line density, proportion urban land cover within 25 km, and burned area within 3 km and negatively related to proportion forest land cover within 15 km. Our findings suggest ravens have capitalized on human subsidies to increase abundance and expand into sagebrush ecosystems, which likely has ramifications for sensitive species that inhabit sagebrush ecosystems.

THE RESPONSE OF GREATER SAGE-GROUSE TO THE RECLAMATION OF AN OIL AND GAS DEVELOPMENT LANDSCAPE

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Abstract. Habitat selection studies at an individual level can reveal patterns in selection that are not apparent when using a population-level approaches. We explored individual-level movements, space use (e.g., home ranges) and habitat selection of female greater sage-grouse (*Centrocercus urophasianus*) that raised chicks (brood-rearing sage-grouse) in an established oil and gas production area. We used integrated step selection analysis (iSSA) that permit the quantification of the effects of environmental and anthropogenic covariates on the movement and selection process simultaneously. On average, brood-rearing female sage-grouse established home ranges in areas with a majority of the home range comprised of sagebrush landcover (mean = 77.4%) and a minimal proportion of the area comprised of anthropogenic surface disturbance (mean = 3.5%). Brood-rearing females consistently selected for natural vegetation and avoided disturbed surfaces, both active and reclaimed surfaces, at fine spatial scales. Power line visibility generally led to avoidance behavior; however, much shorter (3m) wells structures generally did not. We found that individual variability was partially explained by age (adult or first year), or previous experience of the landscape. Adults were more likely than first year females to demonstrate avoidance of energy features and adults were also less likely than first year females to establish home ranges in areas with energy infrastructure. Our results reiterate the importance of accounting for, or at least recognizing, individual variability in population-level modeling efforts.

UNDERSTANDING THE EFFECTS OF 50-YEARS OF WYOMING VEHICULAR TRAFFIC ON SAGE-GROUSE POPULATIONS

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Abstract. Road networks and their associated vehicular traffic may negatively impact populations of many terrestrial species due to noise, barriers to movement and direct mortality from collisions. Documented declines and extirpation of Greater sage-grouse (*Centrocercus urophasianus*) at lek sites near major highways have been observed but not well studied. Further, recent decades have seen increased truck traffic associated with energy development such as oil and gas drilling, which can elevate stress hormones, change lekking behavior, and increase mortality. However, the cumulative and long-term impacts of vehicular traffic on sage-grouse populations are largely unknown. We address this knowledge gap by developing estimates of yearly traffic volume on Wyoming Department of Transportation's network of paved roads using a novel machine learning method (XGBoost). We show how spatial patterns of vehicular traffic on these roads have changed through time and use these estimates to assess how traffic has impacted sage-grouse population trends within a hierarchical modeling framework. We also highlight future efforts of estimating annual traffic volume on unpaved roads and demonstrate the utility of incorporating estimates of traffic volume when assessing cumulative impacts on sage-grouse populations.

FERAL HORSE IMPACTS ON GREATER SAGE-GROUSE NEST SITE SELECTION AND SUCCESS

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Abstract. Burgeoning feral horses (*Equus ferus caballus*) have been identified as a potential threat to many greater sage-grouse (*Centrocercus urophasianus*) populations. Though feral horses are thought to negatively impact sage-grouse, until recently, quantitative investigation has generally focused on better understanding habitat alteration. We evaluated the potential impact of free-roaming horses on greater sage-grouse nest site selection and survival. During August 2019 we recorded horse feces along 230, 1-km transects across two study areas. We modeled nest site selection and nest survival from sage-grouse nests near Jeffrey City in central Wyoming and Adobe Town in south-central Wyoming. These two study areas were both impacted by feral horses with the highest fecal density in Adobe Town. Patterns in sage-grouse nest site selection were similar across study areas, with selection for greater big sagebrush (*Artemisia tridentata*) canopy cover. Females tended to nest in areas with greater horse fecal density, suggesting that sage-grouse and feral horses selected sites with similar resources. However, we found moderate support that sage-grouse in both study areas had lower nest success in areas with higher horse fecal densities These results contribute to a growing body of literature suggesting feral horses may be negatively impacting sage-grouse populations where populations overlap.

FREE-ROAMING HORSES ADVERSELY IMPACT GREATER SAGE-GROUSE POPULATION DYNAMICS IN SAGEBRUSH ECOSYSTEMS

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Abstract. Free-roaming horse (*Equus caballus*) populations have increased in sagebrush ecosystems and surpass appropriate management levels (AMLs). Concomitantly, greater sage-grouse (*Centrocercus urophasianus*) populations have declined from loss and degradation of critical habitats. Overgrazing can degrade sagebrush communities, but evidence of horse impacts on sage-grouse population dynamics is lacking. We employed Bayesian state-space models to estimate sage-grouse population rate of change (λ) using 15 years of lek surveys in relation to horse abundance (relative to AML) and other environmental covariates. For every 50% increase in horse abundance over AML, a 2.6% annual decline in sage-grouse abundance was predicted. When horse abundance was at or below AML, sage-grouse λ estimates mirrored trends at areas with no horses. Conversely, results indicated a 75% and 99% probability of λ decline relative to controls when % AML was 200% and 300%, respectively. For context, horse herds were estimated at 405% AML in Nevada, USA during 2019. Model projections indicate ~70% declines in sage-grouse populations within horse-occupied areas by 2034 if horse population trends continue unabated. Monitoring frameworks that consider sage-grouse and other ecosystem indicator species can guide management decisions promoting wildlife-livestock coexistence within multiple-use landscapes. Findings are preliminary and provided for best timely science.

RESOURCE SELECTION AND OCCURRENCE OVERLAP BETWEEN FERAL HORSES, PRONGHORN, AND GREATER SAGE-GROUSE

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Abstract. Feral horse (*Equus ferus caballus*) populations on western rangelands continue to increase, potentially impacting co-occurring wildlife, particularly greater sage-grouse (*Centrocercus urophasianus*) and pronghorn (*Antilocapra americana*). Sage-grouse and pronghorn range overlap with horses is greatest in Wyoming; therefore, evaluation of horse influence on these species within the state has population-wide implications. While ranges overlap, we lack understanding of comparative resource selection and space use between these species, but this information is critical to implement successful management strategies. To address this knowledge gap, we attached global positioning system (GPS) transmitters to female horses (*n* = 30), sage-grouse (*n* = 46), and pronghorn (*n* = 30) within the Bureau of Land Management–Adobe Town Herd Management Area in southern Wyoming between 2017 and 2021 to evaluate seasonal resource selection and predicted proportion of occurrence overlap between these species. We found comparative resource selection was most similar between pronghorn and horses, consequently these species displayed a high degree of predicted occurrence overlap in both summer (0.84) and winter (0.90). Occurrence overlap was lowest between horses and sage-grouse during the breeding (0.68) and winter (0.62) seasons, but selection by both species for closer proximity to water and herbaceous cover resulted in a high degree of occurrence overlap (0.91) in summer. Our results suggest that pronghorn face potential competition with horses year-round in this area, while the threat of decreased habitat quality, as influenced by feral horses, is most prevalent for sage-grouse during late brood-rearing. Our work can guide consideration of potential management actions, whereas future research should examine links between feral horse effects and fitness metrics of pronghorn and sage-grouse.

IMPACTS OF NON-NATIVE GRAZERS TO VEGETATION STRUCTURE RESULTS IN CASCADING EFFECTS FOR NATIVE SPECIES

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Abstract. Competition among livestock, feral horses, and Greater Sage-grouse has been the subject of numerous legal actions and management policies, yet, data documenting the details of this competition are lacking. Using fecal abundance as an index of livestock and feral horse use, we evaluated whether these non-native grazers were impacting the habitat and if Greater Sage-grouse could compensate by choosing where to nest and brood their chicks. We found Greater Sage-grouse were choosing sites with higher percentages of perennial grasses and forbs to build their nests, and even higher percentages to brood their chicks. As livestock increased, we observed decreases in perennial grasses, forbs that are known to be consumed by Greater Sage-grouse chicks, all other forbs, cheatgrass, and documented increases in the amount of bare ground. These effects were consistent at all sites. We observed similar results at available sites with high predicted horse use, but at sites chosen by females to nest and brood their chicks, we observed substantial increases in the amount of cheatgrass as horses increased. These results suggest that non-native ungulates are resulting in impacts on the herbaceous plants associated with Greater Sage-grouse reproduction, and likely population dynamics.

FUNCTIONAL RESPONSES IN GREATER SAGE-GROUSE HABITAT SELECTION IN RESPONSE TO LARGE-SCALE DISTURBANCE

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Abstract. Habitat selection studies are ubiquitous in wildlife ecology, yet statistical inference about preferred habitat is conditional on the habitat available to the study population. Consequently, patterns in selection can change over time as natural or anthropogenic disturbances alter habitat composition. Assessing functional responses allows investigators to quantify how selection changes in response available habitat, and we used this framework to assess changes in greater sage-grouse habitat selection in response to a wildfire in southeastern Idaho. We monitored >300 female sage-grouse with satellite transmitters in high-elevation mountain big sagebrush communities. This study spanned a 6-year period that included observations both before and after a high-intensity burn that covered >40,000 hectares. We tested for functional responses in nest-site and brood-rearing habitat selection and assessed the consistency of responses across spatial scales. We also built generalized resource selection functions that incorporate functional responses and optimally predict habitat selection in response to changes in availability. We found that functional responses in were common and relationships were often consistent across spatial scales. Our results demonstrate the importance of understanding functional responses and also provide a generalized model for predicting sage-grouse habitat selection in the presence of large-scale changes in the composition of sagebrush steppe communities.

SAGE-GROUSE RESPONSE TO WILDFIRE: ANALYSES OF RANGE-WIDE EFFECTS AND RELATIONSHIPS BETWEEN SAGE-GROUSE DEMOGRAPHY AND UNDERLYING POST-FIRE SAGEBRUSH RECOVERY PROCESSES

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Abstract. Wildfire has long-term adverse impacts on greater sage-grouse (*Centrocercus urophasianus;* hereafter sage-grouse) population persistence within the Great Basin. However, chronic effects of wildfire may vary across the entire distributional range of sage-grouse based on regional variation in climate and ecological properties related to sagebrush (*Artemisia spp*.) ecosystem resilience and resistance to invasive annual grasses. We extend previous methods of modeling sage-grouse population rate of change ($\hat{\lambda}$) in the Great Basin to a range-wide study extent and developed an advanced sagebrush recovery model using back-in-time classification of satellite imagery in burned areas over the past 34 years. Specifically, we employed a Bayesian state-space model framework, which relates variation in $\hat{\lambda}$ to changes in cumulative burned area around leks, while accounting for environmental covariates and density dependent mechanisms (Gompertz). Across the range of sage-grouse, we found support for an interaction between cumulative burned area and a one-year lag effect for summer precipitation on lambda. However, the positive influence of precipitation was negated by long-term negative impacts of wildfire, yet the strength of this effect varied among regions. Understanding patterns of variation among broad-scale regions can elucidate wildfire impacts across a large ecological gradient. Findings are preliminary and provided for timely best science.

POTENTIAL IMPACTS OF WILDFIRES ON SHARP-TAILED GROUSE AND GREATER SAGE-GROUSE IN WASHINGTON STATE

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Abstract. Wildfires have increased in both frequency and extent throughout western North America. In the state of Washington, the record for the largest wildfire was set in 2014 (256,000-acre Carlton Complex), then broken in 2015 (305,000-acre Okanogan Complex), and broken again in 2020 (410,000-acre Cold Springs Canyon/Pearl Hill). All three of these wildfires, along with other smaller wildfires, have impacted both Sharp-tailed Grouse and Greater Sage-grouse habitat. Twenty six of 58 sharp-tailed grouse leks and 13 of 29 greater sage-grouse leks active between 2008 and 2021 were within a wildfire perimeter at least once between 2012 and 2020. Lek counts at 'impacted' sharp-tailed grouse leks dropped 82% in the year following the wildfire while leks outside the wildfire perimeters dropped 6%. In contrast, the 1-year declines for sage-grouse were 16% inside and 12% outside the fire perimeters. Examination of long-term impacts to sharp-tailed grouse suggest that post-fire recovery takes about 6 years. Because most of the potential sage-grouse impacts occurred between 2020 and 2021, no long-term trends could be examined. Some of the observations include: (1) fire impacts may extend beyond the fire perimeter; (2) sage-grouse and sharp-tailed grouse appear to respond differently to burned habitat on a lek site; and (3) unburned refugia may be critical for recovery of habitats and populations.

BROOD HABITAT QUALITY PREDICTS LEK OCCURRENCE AND MALE LEK ATTENDANCE IN COLUMBIAN SHARP-TAILED GROUSE

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Abstract. The lek hotspot hypothesis predicts that leks will be located in areas more frequented by females. To identify if leks are placed in areas more likely to be frequented by female Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*), we evaluated habitat selection and quality (modeled by nest, brood, and adult female winter survival) for nesting, brood-rearing, and wintering female sharp-tailed grouse in south-central Wyoming (2017-2019). We compared habitat selection and quality across life-history stages for 213 VHF-marked females to 24 known lekking locations to evaluate whether habitat selection or quality influenced lek occurrence and male lek attendance. Female habitat selection and survival were influenced by vegetation and topographic conditions—we used influential covariates from each model to generate predictive surfaces of habitat selection and quality for each life-history stage. Lek locations and male lek attendance were best predicted by brood-rearing habitat quality within 400- and 800-m of leks, respectively, with an increasing proportion of high-quality brood-rearing habitat indicating a higher probability of lek occurrence ($\beta = 2.5$) and increased male lek attendance ($\beta = 11.5$). Our findings suggest quality of brood-rearing habitat helps predict lek occurrence and male lek attendance and supports Columbian sharp-tailed grouse population and habitat monitoring near leks.

PRODUCTIVITY AND ABUNDANCE OF COLUMBIAN SHARP-TAILED GROUSE IN IDAHO: MULTI-SCALE EFFECTS OF WEATHER, HABITAT, AND DISTURBANCE

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Abstract. The distribution of Columbian sharp-tailed grouse (CSTG) has contracted dramatically, yet Idaho remains a stronghold for CSTG populations (>60% of the remaining birds are found in this state). We used long-term monitoring data to assess patterns of CSTG productivity and relative abundance in Idaho and evaluated the effects of weather, habitat, and disturbance variables (e.g., fire frequency data) on demographic traits. We used 20 years of age-ratio data collected from hunter harvested birds (10,281 wings collected from 2000-2019) to assess patterns of CSTG productivity and 26 years of lek count data (6,114 surveys at 573 leks from 1995-2020) to assess patterns of relative abundance. We used generalized linear mixed-effects regression models to explore the relationships between productivity and abundance data and covariates measured over multiple spatial and temporal extents. We used model selection to identify the optimal spatial-temporal scales of effect for each covariate and to evaluate relative support for each covariate concurrently in multi-scale regression models. Our results provide the first large-scale assessment of drivers of productivity and abundance for CSTG populations across Idaho and consequently will provide important insights for management and conservation of CSTG.

ANALYZING THE RELATIONSHIP OF LAND USE AND LAND COVER CHANGE WITH COLUMBIAN SHARP-TAILED GROUSE POPULATIONS IN EASTERN IDAHO

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Abstract. Wildfire affects habitat quality in Southeastern Idaho which is home to 65% of the Columbian Sharp-tailed Grouse population of North America. In Idaho's Bannock, Oneida, and Power Counties the population of Columbian Sharp-tailed Grouse declined over the period of 1985 to 2018. 797 fires burned habitat in those counties over the same time period. We examined trends in nearby land cover and land use within 4 kilometers of Columbian Sharp-tailed Grouse leks to determine the relationship between land use and land cover with counts at lek sites. We found a significant relationship between Columbian Sharp-tailed Grouse counts and the rate of change in nearby sagebrush and shrub land cover types, as well as the change in burned area within 4 kilometers of a lek between 1985 and 2018. A mitigating factor in strengthening habitat near lek sites is the presence of Conservation Reserve Program lands that provide nesting and brood-rearing habitat. We have identified a connection between Conservation Reserve Program land coverage and lek counts that are unchanging to increasing over the recent decade. Bolstering the Conservation Reserve Program could provide an invaluable resource for protecting Columbian Sharp-tailed Grouse populations in Southeast Idaho.

HISTORICAL SAMPLES ELUCIDATE SHARP-TAILED GROUSE SUBSPECIFIC DISTRIBUTIONS AND THE GENETIC LINEAGE OF INDIVIDUALS OF UNKNOWN ORIGIN IN SOUTHWESTERN MONTANA

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Abstract. We examined the subspecific assignment of historical and contemporary sharp-tailed grouse, *Tympanuchus phasianellus*, in Montana. We had two objectives: first, to find genetic evidence for the existence of and delineation between subspecies believed to be distinct to either side of the Continental Divide; second, to identify the genetic origin of a seasonal occurrence of sharp-tailed grouse in the Centennial Valley of southwestern Montana. We compared mitochondrial DNA across three different mtDNA regions from 13 historical and 22 contemporary samples (including two from greater prairie-chicken, *T. cupido*) to 28 publicly available sequences representing eight different species. For *T. phasianellus*, we found 17 control region haplotypes, three cytochrome b haplotypes, and one cytochrome c oxidase I haplotype, some of which were geographically distinct to either side of the Divide (control region: six east, eight west, three spanning; cytochrome b: two west, one spanning), suggestive of genetic isolation resulting from the Divide. However, neither individuals on either side of the Divide nor species were monophyletic within phylogenetic trees. While the Centennial Valley sample exhibited a cytochrome b haplotype found only west of the Divide, haplotypes at other regions were not geographically distinct, and phylogenetic groupings spanned populations in eastern Idaho and northeastern Montana.

EARLY ESTIMATES OF EXOTIC ANNUAL GRASS PERCENT COVER IN THE SAGEBRUSH BIOME, MAY 2021

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Abstract. The USGS EROS Center plans to release a dataset titled "Early Estimates of Exotic Annual Grass (EAG) in the Sagebrush Biome, May 2021," as part of the USGS Rangeland Exotic Plant Monitoring System series. The dataset estimates percent cover of EAGs across much of the western U.S. The release continues a series that, since 2015, has estimated within-year EAG percent cover (https://www.sciencebase.gov/catalog/item/5f0ddd6e82ce21d4c4053e17). Historically, EAG datasets were developed with Moderate Resolution Imaging Spectroradiometer (MODIS) data at 250-m spatial resolution, but with recent access to new remotely sensed data (Harmonized Landsat 8 / Sentinel-2) and high-performance computing, new products have a finer 30-m spatial resolution. The study area expanded almost three times and now covers all or part of 17 states. Specific species maps of cheatgrass and medusahead have been developed in addition to a general EAG map. The maps were developed using field-based BLM Assessment Inventory and Monitoring data integrated into machine-learning software with environmental, remotely sensed, land cover, soils, and vegetation data. Preliminary model accuracy metrics indicate satisfactory results (training/test R^2 = 0.94/0.67 and Median Absolute Error = 2.15%/3.16%). This timely dataset represents current estimates of ecological conditions having substantial impacts on grazing and fire management in the current year.

THE CHEATGRASS CHALLENGE: A PROACTIVE STRATEGY FOR TACKLING INVASIVE ANNUAL GRASSES

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Abstract. Cheatgrass increases wildfire size and frequency and is a primary threat to greater sage-grouse and sagebrush ecosystems, particularly in the Great Basin. Efforts to control invasive annual grasses are often reactive and uniformed by landscape context. Science shows that invasive species control is more effective and cost-efficient when done early, before infestations become widespread, and when management is informed by what's going on in the surrounding landscape. Idaho partners have come together to develop and implement a new proactive state-wide strategy to halt conversion of sagebrush habitats to annual grasslands. With the aid of technology provided by the Rangeland Analysis Platform (RAP), partners mapped three coarse region types across the state: 1) Core - representing regionally intact rangelands characterized by relatively low cover of annuals, 2) Annual Grass Region - large areas dominated by moderate-to-high cover of annuals, and 3) Transition Zones - areas between core and annual grass region. A spatial strategy for prioritizing management was then devised: defend the core, grow the core, and mitigate impacts. The Cheatgrass Challenge provides a proactive, rather than reactive, alternative to preventing further loss of intact sagebrush ecosystems to the cheatgrass-fire cycle and serves as a model for other western states.

TRADE-OFFS IN MANAGING FIRE, INVASION, AND DISTURBANCE IMPACTS IN THE GREATER SAGE-GROUSE LANDSCAPE

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Abstract. Several landscape-level changes influence Greater Sage-grouse (*Centrocercus urophasianus*) habitats and populations. Increasing fire, proliferating invasive annual grasses, land-use change and disturbances impact landscapes and populations in many ways. There is increasing need to understand the combined effects of these changes and design management interventions that consider multiple threats and actions taken to address them. In this talk, we synthesize key findings from a range of research projects that model the implications of fire, plant invasion, and management actions on the sagebrush ecosystem. Results from individual studies identify multiple different management opportunities, but sometimes conflicting recommendations that require researchers and managers to balance ecological trade-offs. Syntheses among multiple projects highlights opportunities for greater integration among projects and people. We highlight specific needs for collaborative research and action, modeling approaches that integrate different kinds of information, and communication of results beyond scientific repositories.

TEMPORAL CHANGES IN GREATER SAGE-GROUSE SEASONAL HABITAT SELECTION IN RESPONSE TO LARGE-SCALE WILDFIRE

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Abstract. We modeled seasonal habitat use by female Greater sage-grouse (*Centrocercus urophasianus*) in the Trout Creek Mountains of Oregon and Nevada, USA, to identify landscape characteristics that influenced sage-grouse habitat selection and to create predictive surfaces of seasonal use 1 and 7 years after a large wildfire (>180,000 ha). We developed resource selection function models using GPS location data from 2013 – 2019 for each of 3 biologically distinct seasons (breeding, *n* = 149: 8 Mar – 12 Jun, summer, *n* = 140: 13 Jun – 20 Oct, winter, *n* = 94: 21 Oct – 7 Mar). For all seasons, by year 4-5 post-fire, sage-grouse selected for unburned patches more than all other burn severity patches. Generally, use of unburned areas relative to burned areas increased through time. Seven years post-fire (2019), the area predicted to have high probability of use in each seasonal range decreased (breeding: 16.4%, summer: 12.2%, winter: 4.2%) while the area predicted to have low or low-medium probability of use increased (breeding: 14.5%, summer: 22.5%, winter: 22.8%) when compared to 1-year post wildfire (2013). Our results showed that sage-grouse continued to avoid burned areas 7 years post-fire, and may limit populations if available habitat recovery lags behind.

TIMESTAMPING WYOMING ANTHROPOGENIC DISTURBANCES TO INFORM WILDLIFE STUDIES IN SAGEBRUSH ECOSYSTEMS

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Abstract. Greater sage-grouse (*Centrocercus urophasianus*) populations in Wyoming are managed by the Core Area strategy, whereby surface disturbances are limited to a 5% threshold. The Density and Disturbance Calculation Tool (DDCT) estimates density of surface disturbance within Core Areas using mapped disturbances compiled through the Wyoming Habitat Protection program. However, 89% of DDCT data lack temporal context. Understanding the mechanistic effects of disturbance on wildlife population trends depends on temporally accurate data. Using DDCT mapped disturbances and back-in-time sagebrush fractional components (1985–2018), we timestamped disturbances by identifying the year of greatest change in loss of sagebrush cover. Comparing the estimated year of sagebrush loss to a subset of disturbances with a reported year of disturbance, we found we could accurately estimate disturbance dates for oil and gas well pads 0.037 years after (SD 5.976, n = 2868) and wind turbines 0.686 years before (SD 6.162, n = 398) the reported disturbance year, on average. We are applying this approach to disturbances throughout Wyoming, limited to post-1985 disturbances and areas with temporal sagebrush estimates. Estimating timestamps for disturbance layers will let us assess how disturbances affect population trends for sage-grouse and mule deer (*Odocoileus hemionus*) at broad spatio-temporal scales.

MODELING SAGEBRUSH RECOVERY ACROSS THE SAGE-GROUSE RANGE USING THREE DECADES OF REMOTELY-SENSED VEGETATION ESTIMATES

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Abstract. Imperiled species such as the Greater Sage-grouse (*Centrocercus urophasianus*) depend on sagebrush, yet habitat continues to be lost. Effective sagebrush restoration is needed to reverse this trend, but understanding the conditions that determine when, where, and at what rate, sagebrush recovery will occur is a pressing research need for prioritizing and implementing restoration efforts across this vast landscape. We have developed a framework for modeling and predicting sagebrush recovery using datasets that catalog land management treatments and sagebrush cover across the sagebrush biome over time (e.g., Land Treatment Data Library and Rangelands Condition Monitoring Assessment and Projection). We are assessing the influence of environmental factors (e.g., soil moisture availability), disturbance types (e.g., wildfire, brush removal), and restoration treatments (e.g., herbicide application, aerial seeding) on recovery rates of sagebrush cover. Our results will facilitate stewardship of the sagebrush biome and the species that depend on it by providing a variety of spatially explicit predictions and projections of sagebrush recovery to inform regional planning and on-the-ground restoration efforts. These analyses will also support other on-going efforts including economic cost-effectiveness analyses, restoration responses to wildfires, and restoration prioritization tools that optimize management efforts targeted at wildlife species of conservation concern.

REBUILDING SAGEBRUSH HABITAT: USING STATE-TRANSITION SIMULATIONS TO PROJECT POST-FIRE RESTORATION AND HABITAT RECOVERY EFFICACY FOR GREATER SAGE-GROUSE

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Abstract. Restoring naturally and anthropogenically disturbed areas is a critical conservation challenge for land managers across the sagebrush biome. Managers need assessments of post-fire revegetation influence on species-specific habitat restoration and the scope and scale of efforts producing habitat improvement for key wildlife. Additionally, a means of selecting efficient design strategies applicable over temporal scales that allow sagebrush obligate species to persist is essential. We used recent fire events and empirical data on post-fire sagebrush recovery to develop a spatially explicit state-and-transition simulation modeling (STSM) framework that explores habitat recovery as a function of restoration action. We explored scenarios over the Great Basin and examined post-fire restoration outcomes that included (a) type of action (natural regrowth, seeding, planting), (b) duration of effort (single, multi-year), and (c) amount of effort (proportion of burned area mitigated). We then used simulated outcomes to evaluate whether sage-grouse habitat requirements were met by management actions and the feasibility of restoration achieving species-specific recovery goals, in addition to sagebrush revegetation objectives. Our simulated results provide insight into the scope of post-fire restoration effort required to restore sagebrush habitat for sage-grouse across large landscapes. Our flexible framework can aid regional restoration decisions targeting other obligate species or communities.

SAGE-GROUSE SEASONS, HOME RANGES AND HABITATS, WHAT ARE THEY AND HOW MANY ARE THERE?

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Abstract. Wildlife-habitat responses are typically inferred from population-level survival or resource selection models without regard for detailed individual- or population-level movement patterns. Improved spatial generality of inferences may be gained by linking habitat response associations with specific behaviors or activity signatures derived from movement data and expert knowledge. Any movement or phenological stage (e.g., laying, incubating, roosting, transit, exploratory, winter-ranging) may be used to define a functional habitat type. Our primary goal was to quantify sage-grouse space- and time-use signals relevant to management and parse variability in these signals into components due to spatial (landscape elements) and temporal (seasonality) characteristics, while accounting for individual-level variation. We attached a 22-g solar powered Global Positioning System (GPS) Platform Transmitting Terminal to 86 female sage-grouse in north-central Montana. We monitored females and analyzed movement behaviors using a combination of field observations, nonlinear-regression movement models, multivariate clustering techniques, and a time-local convex hull approach. Time-local convex hulls can be thought of as many brief-duration home ranges from which time- and space- use metrics can be calculated. We will present results from our north-central Montana sage-grouse movement ecology research including migration patterns, diversity of movement modes, seasonal space- and time-use patterns, and seasonal landscape-element associations.

A REGIONALLY VARYING HABITAT SUITABILITY MODEL TO IDENTIFY AREAS FOR GREATER SAGE-GROUSE PERSISTENCE

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Abstract. Modeling species habitat suitability over large spatial distributions is challenging because local populations may respond differently to similar habitats in different geographic contexts. We used a recently compiled lek database to model greater sage-grouse (*Centrocercus urophasianus*) lek persistence across their U.S. distribution to help the Bureau of Land Management (BLM) assess habitat suitability. We estimated relationships between lek persistence (active and inactive leks) and landscape characteristics summarized at varying spatial scales (1–30-km radii buffers of leks) using logistic regression. We treated 24 mid-scale regions (representing a second order habitat process) delineated by the BLM as random intercepts and slopes which allowed for regional variability in model predictions and estimated habitat relationships. Preliminary results indicated our model had reasonable predictive capacity (area under curve = 0.708). We developed habitat bins based on probabilities associated with targeted model sensitivities (percentage correctly classified active leks) for mapping purposes, and identified levels of landcover change (pinyon-juniper encroachment) and densities of point and line disturbance above which leks are predicted to go inactive. Our model provides a range-wide layer that can be used to identify sage-grouse habitats and disturbance thresholds that are specific to each mid-scale assessment area considered by the BLM.

MANAGEMENT-FOCUSED HABITAT SELECTION MODELS FOR GUNNISON SAGE-GROUSE

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Abstract. Gunnison sage-grouse (*Centrocercus minimus*) are a threatened species, and conservation, species recovery, and habitat management efforts are needed in six isolated satellite populations which are declining (San Miguel, Crawford, Piñon Mesa, Dove Creek, Cerro Summit-Cimarron-Sims, and Poncha Pass). We developed a set of habitat selection models across satellite populations using a management-centric modeling approach to evaluate the consistency of key habitat conditions and improvement actions while allowing context-specific environmental variables and spatial scales to nuance selection responses. We used multi-scale and seasonal resource selection analyses to quantify relationships between environmental conditions and sites used by animals. All models included key habitat variables often altered through management actions. We found important similarities and differences among satellites, indicating that although some rules of thumb are generally well-grounded, the consideration of location-specific environmental differences could increase the efficiency of habitat improvement actions. Sage-grouse also had diverse responses to resource conditions at different scales, indicating that regional (e.g., landscape) and local (90 m vs. 570 m) scale conditions can differently influence expected habitat improvements and management actions. These models and approaches may benefit spatially structured populations with different environmental contexts and species with complex habitat needs and associations.

OPTIMIZING SPATIAL APPLICATION OF HABITAT MANAGEMENT ACTIONS FOR THE GUNNISON SAGE-GROUSE SATELLITE POPULATIONS

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Abstract. The Gunnison Sage-Grouse (*Centrocercus minimus*) is a species of conservation concern that is currently listed as threatened under the federal Endangered Species Act (1973). The species has experienced substantial and continuing declines in range-wide abundance and distribution, primarily due to loss of habitat. Gunnison Sage-grouse are predominantly restricted to seven populations in southwest Colorado, six of which are small, isolated satellites where numbers are currently declining or significantly below conservation objectives. We assessed the potential for habitat management actions to improve habitats for these satellite populations using newly developed, population-specific Resource Selection Function maps. Our approach was to 1) estimate the habitats likely to be most responsive to management actions that improve suitability for Gunnison Sage-grouse, 2) apply representative habitat improvement scenarios based on the Bureau of Land Management's current habitat actions for sage-grouse to gauge the benefits of different types of actions, and 3) assess a suite of targeted actions that most improve sage-grouse habitat in each satellite population. We demonstrate how this information can be used to optimize local habitat management efforts within these satellite populations.

GUNNISON SAGE-GROUSE HABITAT VULNERABILITY TO CLIMATE CHANGE, DEVELOPMENT, AND FIRE IN THE 21ST CENTURY

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Abstract. Gunnison Sage-Grouse are a federally-listed endangered species, with only eight extant populations localized largely to southwestern Colorado. Already in serious decline, ongoing climate change and land-use change processes may worsen habitat conditions for the species. We adapted a scenario-based risk assessment framework from the Fish & Wildlife Service's conservation planning into a spatially explicit projection of the landscape's future risk to future change by 2070. Our approach integrated projections of fire risk, development, and shifts in sagebrush habitats, pinyon-juniper encroachment, and mesic habitat due to climate change. This resulted in 30-m maps of risk to sage-grouse habitats under three scenarios: pessimistic (hot and dry future climate, high development), continuation (moderately hot, moderate development) and optimistic (warm & wet, low development). By intersecting the risk maps with sage-grouse habitat use models and a database of management interventions, we identified the degree to which each subpopulation and set of management actions are imperiled by each threat over the next half-century.

GUNNISON SAGE-GROUSE RECOVERY TRACKING: CONSERVATION EFFORTS DATABASE v3.0

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Abstract. Natural and anthropogenic disturbances that are detrimental to fish, wildlife, plants, and ecosystems are the focus of conservation. While the intensity and extent of these impacts may be well documented, the conservation actions applied by resource management agencies and organizations and their effectiveness to address environmental impacts are often poorly and inconsistently documented. Even when conservation actions are documented, it can be difficult to determine the short- and long-term effects on targeted species or habitats because of poor record organization and lack of post-action monitoring. The Conservation Efforts Database (CED) is a secure, on-line web app that collects and summarizes spatially explicit information related to conservation and restoration actions into a comprehensive database. The CED Team worked with a diverse group of stakeholders to develop a module designed to collect information related to recovery actions implemented for the threatened Gunnison sage-grouse. This new module will build upon the existing CED web-based services, to allow stakeholders to summarize recovery efforts across populations and management jurisdictions and evaluate the conservation benefit achieved from conservation and restoration efforts. Spatial data displayed in the CED provides useful context for planning and siting of future conservation efforts, fostering collaborative conservation across the species' range.

AT WHAT SCALES DO SAGE-GROUSE POPULATIONS RESPOND TO SAGEBRUSH COVER IN LANDSCAPES?

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Abstract. The scales at which Greater Sage-grouse (*Centrocercus urophasianus*) respond to features within landscapes have important implications for managing this species under multiple use mandates. While several scales have been posited based on nesting distribution and within-season movements, scales of effects can vary with landscape context and response type. We therefore applied a scale selection approach to identify the scale of effect of sagebrush for sage-grouse population trends using counts from 365 leks in southwest Wyoming (2003–2019) and annual estimates of sagebrush cover from a remote sensing product. This approach allowed us to jointly estimate the most relevant scales for sagebrush cover (with error estimates), temporal lags, and the effect of sagebrush cover while accounting for variation in detectability during lek counts. Preliminary results suggest a positive response to mean sagebrush cover up to 4.3 km from leks and lagged by three years. With increasing availability of data from standardized lek count datasets, back-in-time sagebrush estimates, and other landscape features across much of the sage-grouse range, our approach can be readily applied elsewhere to identify scales relevant to each population, and to other responses such as demography and movement.

MULTI-SCALE RESOURCE SELECTION FUNCTIONS CONTROLLING FOR DIFFERENCES IN HABITAT AVAILABILITY PERFORM BEST WHEN TRANSFERRED TO A NOVEL SITE

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Abstract. Identifying important habitats via methods such as resource selection functions (RSFs), is often necessary over relatively short timeframes. If data are absent, then it is necessary to develop RSFs by either i) collecting new data or ii) using data from an alternative site(s). Unfortunately, RSF predictions can be inaccurate if data are collected over a short timeframe or if RSFs are transferred from a site(s) not representative of the novel site. Using Greater Sage-Grouse as a case study, we compared the performance of multi-scale RSFs developed using available data from an alternative site(s) to an RSF developed using data from the focal site to assess RSF transfer performance using telemetry data from 8 different sites. We fit RSFs developed using nest location data using a generalized functional response (GFR) RSF and the mean of a local and non-local RSF. The GFR RSF consistently transferred well to novel holdout sites, with much less consistency found with the other approaches. Importantly, GFR RSFs, frequently performed better than the focal site RSF. Our results highlight the accuracy and flexibility of the GFR RSF and the potential shortcomings with RSF predictions developed using i) data from an alternative site(s) (without controlling for habitat availability) or ii) data collected at the focal site over a relatively short timeframe.

QUANTIFYING THE TEMPORAL STABILITY IN SEASONAL HABITAT FOR SAGE-GROUSE USING REGRESSION AND ENSEMBLE TREE APPROACHES

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Abstract. Identifying and quantifying the extent to which landscape-level habitat variables drive the spatial distribution of individuals across a region can provide fundamental insights into a species ecology and be essential to wildlife management and conservation plans. Although the preferences for habitat resources and the resources themselves are not static over time, most research at large spatial scales does not consider seasonal effects nor quantify annual temporal variability in the spatial distribution of habitat resources. In this study, we used and compared a machine learning (boosted regression trees; BRT) and mixed-model (GLMM) approach to quantify seasonal habitat selection across three life-stages (nest, late brood and winter habitat) of sage-grouse and estimated annual stability across a 13 year dataset in south-central Wyoming. GLMM models had high AUC values, but were consistently outperformed by the BRT models for all seasons. We assessed annual variation by predicting the BRT models across years and we found significant spatial trends in the distribution of nesting habitat, with general decreases in the relative probability of use across the core of the study area and corresponding increases in selection on the periphery, suggesting birds were shifting out of preferable ranges over the course of our study. The annual dynamics of habitat selection are seldom addressed in large-scale research but can have potentially dramatic influences on our identification of preferred habitats.

LINKING MICROHABITAT, HOME RANGE, REPRODUCTIVE STAGE, AND BEHAVIOR IN GREATER SAGE-GROUSE DURING BROOD-REARING SEASON

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Abstract. We linked reproductive stage, behavioral state, microhabitat selection, and home range for brood-rearing and broodless greater sage-grouse (*Centrocercus urophasianus*) to more comprehensively understand habitat selection by all females during brood-rearing. We used GPS location and accelerometer data collected every 5 min from female sage-grouse in Carbon County, Montana, and Park County, Wyoming during 2018-2019. We sampled microhabitat for 36 females at 276 bird-use and random locations, estimated home ranges for 38 females, and measured activity levels of 43 females spanning 1,317 bird-days. Broods 0–2 weeks selected microhabitat characteristics at night roosts, broods 3–5 weeks selected microhabitat features at foraging locations and night roosts; however, we did not detect significant microhabitat selection by broodless females. Broods 0–2 weeks had the smallest daily home range (0.027 km^2) compared with broods 3–5 weeks (0.038 km^2) and broodless females (0.035 km^2) and the smallest seasonal home range (0.211 km^2) compared with broods 3–5 weeks (0.363 km^2) and broodless females (0.435 km^2). Each reproductive stage differed in daily activity patterns. Our results indicate research and management decisions should consider the importance of reproductive stage and behavioral state to account for habitat and space required by all individuals in a population.

PRIORITIZING THE PLACEMENT OF CONIFER REMOVAL PROJECTS FOR CONCURRENT MULTI-SPECIES MANAGEMENT

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Abstract. The removal of conifers from the sagebrush and pinyon-juniper ecotone is an increasingly popular alternative for enhancing greater sage-grouse habitat, with over 1,400km^2 recently cleared in the western United States. These treatments likely result in mixed effects for wildlife species and responses may vary across space. Declining populations of both sagebrush and pinyon-juniper associated species highlight the need for tools which guide conifer management across the sagebrush ecosystem. To address this need, we developed hierarchical habitat-relationship models of true abundance using avian point count data collected under the Integrated Monitoring in Bird Conservation Regions program. Leveraging these habitat-relationships will allow us to predict abundance for sagebrush and pinyon-juniper associated species across the landscape; given both current conditions and expected conditions following conifer removal. Our optimization framework allows predictions to be weighted based upon management objectives and species' conservation priorities, to assess utility of planned conifer removal at specific locations. The predicted abundance surfaces will map high-quality habitat for these species of interest and can be used to identify core habitat areas. The optimization framework can appropriately prioritize areas for future conifer removal, to maximize conservation outcomes for sage-grouse and minimize negative effects on other pinyon-juniper associated species.

FIELD METHODS FOR TRANSLOCATING FEMALE GREATER SAGE-GROUSE WITH THEIR BROODS

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Abstract. Greater sage-grouse (*Centrocercus urophasianus*) have experienced significant range contraction and reduced abundance within their range in response to habitat loss and degradation. Translocation is a conservation action used to reintroduce extirpated populations or augment existing populations, but current translocation strategies have had limited success in restoring viable populations of sage-grouse. There is a need for translocation strategies that increase site fidelity and reproduction of translocated individuals, the lack of which is often cited as a reason for the limited success of sage-grouse translocations. To improve on previously used methods, we translocated female sage-grouse with their broods to promote fidelity to the release site by both females and their young. We developed a novel protocol to release sage-grouse with chicks using a delayed-release system including a custom release box and acclimation pen designed to promote brood cohesion and prevent chick abandonment. We translocated 39 females with 208 chicks during two separate translocation projects in North Dakota and California and successfully released 88.9% of translocated females with their broods using this protocol. We demonstrate that this release method can be used to successfully release sage-grouse and their broods with minimal chick abandonment. We encourage the use of this protocol in future translocation efforts of sage-grouse as well as additional research on the post-release movement and survival of translocated broods.

BROOD TRANSLOCATIONS ARE MORE EFFECTIVE AND EFFICIENT THAN TRANSLOCATION OF PRE-NESTING FEMALES

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Abstract. Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) translocations are often employed without adequate monitoring of impacts on source populations. Moreover, translocated sage-grouse frequently fail to reproduce post-release resulting in a net loss to population restoration. We translocated females with chicks, a novel method referred to as 'brood translocation', and pre-nesting females, a more conventional method, across two distinct sage-grouse translocation projects in California and North Dakota (2017–2020). Using integrated population models, we estimated recruitment by translocated pre-nesting and brood-rearing females, and we estimated the impact of translocation on population growth rates ($\hat{\lambda}$) at both source and restoration sites. Recruitment at restoration sites was substantially higher following brood translocations compared to the conventional method of using pre-nesting females, and population growth rates from brood translocations were 11–30% higher than those of pre-nesting translocations. While brood translocations resulted in slightly lower $\hat{\lambda}$ at source sites compared to pre-nesting methods, brood translocations demonstrated a greater net positive cost-benefit ratio in overall abundance after considering impacts to both restoration and source sites. These results indicate that brood translocation is a more efficient method for restoring sage-grouse populations than the established pre-nesting method. Findings are preliminary and provided for best timely science.

BEHAVIORAL-STATE DEPENDENT HABITAT SELECTION IN TRANSLOCATED GREATER SAGE-GROUSE IN NORTH DAKOTA

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Abstract. Post-release monitoring is important to inform future translocation protocols. For example, habitat selection of translocated individuals can inform the choice of future release sites. However, translocated animals undergo post-release behavioral modification and may select for different habitat characteristics when exploring their new environment versus after settlement. We investigated the effect of behavioral state on habitat selection of female greater sage-grouse translocated from Wyoming to North Dakota. We used a Hidden-Markov Model to segment individual trajectories into exploratory and restricted behavioral states. Then we used Integrated Step Selection Analysis to quantify habitat selection within each behavioral state, accounting for reproductive status and seasonality. In exploratory state, sage-grouse selected for high sagebrush cover in all seasons; during winter, they also selected for gentle slopes and avoided roads. In restricted state, females with broods selected for high herbaceous cover and roads. When they did not have a brood, sage-grouse in restricted state selected for gentle slopes year-round and otherwise used resources in proportion to their availability. These results demonstrate that sage-grouse adjust their habitat selection to their current internal state, and indicate the need to account for behavior when estimating habitat selection to inform the choice of future release sites.

NESTING, BROOD REARING, AND SUMMER HABITAT SELECTION BY TRANSLOCATED GREATER SAGE-GROUSE IN NORTH DAKOTA, USA

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Abstract. Human enterprise has led to large-scale changes in landscapes and altered wildlife population distribution and abundance, necessitating efficient and effective conservation strategies for impacted species. Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) are a widespread sagebrush (*Artemisia* spp.) obligate species that has experienced population declines since the mid-1900s resulting from habitat loss and expansion of anthropogenic features into sagebrush ecosystems. Habitat loss is especially evident in North Dakota, USA, on the northeastern fringe of sage-grouse distribution, where a remnant population remains despite recent development of energy-related infrastructure. Resource managers in this region have determined a need to augment sage-grouse populations using translocation techniques that can be important management tools for countering species decline from range contraction. Although translocations are a common tool for wildlife management, very little research has evaluated habitat following translocation, to track individual behaviors such as habitat selection and fidelity to the release site, which can help inform habitat requirements to guide selection of future release sites. We provide an example where locations from previously released radio-marked sage-grouse are used in a resource selection function framework to evaluate habitat selection following translocation and identify areas of seasonal habitat to inform habitat management and potential restoration needs. We also evaluated possible changes in seasonal habitat since the late 1980s using spatial data provided by the Rangeland Analysis Platform coupled with resource selection modeling results. Our results serve as critical baseline information for habitat used by translocated individuals across life stages in this study area, and will inform future evaluations of population performance and potential for long-term recovery.

PRIORITIZING RESTORATION AREAS TO CONSERVE MULTIPLE SAGEBRUSH-ASSOCIATED WILDLIFE SPECIES

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Abstract. Habitat degradation in the sagebrush steppe has been linked to declines in many species, making sagebrush restoration a management priority. However, limited funding, spatiotemporal variation in restoration success, and the need to manage for diverse wildlife species makes decision-making regarding restoration actions challenging. We developed the Prioritizing Restoration of Sagebrush Ecosystems Tool (PReSET) to address this challenge. This decision support tool uses the prioritizr package in program R and an integer linear programming algorithm to select parcels representing both high biodiversity value and high probability of restoration success. We tested PReSET on a sagebrush steppe system within southwestern Wyoming using distributional data for greater sage-grouse (*Centrocercus urophasianus*) and 5 other wildlife species and a spatial layer of predicted sagebrush recovery times to identify restoration targets at landscape and local scales. While the broad-scale portion of our tool outputs can inform policy, local-scale results can be applied directly to on-the-ground restoration. We noted tradeoffs, including that restoring for habitat connectivity may require restoration in areas with lower probability of success. Future applications of PReSET will draw from emerging datasets, including spatially-varying economic costs of restoration, animal movement data, and additional species, to further improve our ability to target effective sagebrush restoration.

GREATER SAGE-GROUSE LANDSCAPE CONNECTIVITY PRIORITIZATION WHEN DATA IS LIMITED: A CASE STUDY IN SYSTEMATIC CONSERVATION PLANNING

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Abstract. Systematic conservation planning (SCP) aims to address research-implementation gaps in ecology by providing a framework for better engagement with stakeholders. In SCP, decision support tools are used to quantify conservation goals as optimization problems, generating solutions to identify areas suitable for specific management actions. The Rock Springs Field Office is a 3.6-million-acre management area located in southwestern Wyoming tasked with addressing the conservation of Greater Sage-Grouse (*Centrocercus urophasianus*) by producing future visions of the landscape considering environmental, social, political, and economic land uses. We used bootstrap and sensitivity analysis approaches to investigate the how integrating costs, other species' distributions, feature weights, expert opinion, and constraints can impact solution quality. We used *prioritizr* to run our prioritizations and assessed solutions with metrics including irreplaceability, a relative score assigned to each planning unit, ROI, and contiguity. Using development potential surfaces to predict threat and inform our costs, led to an increase in irreplaceability values and a decrease in contiguity of the solutions. Feature weights successfully increased the representation of target features in the solutions and through consultation and strategic application, they can be applied to mitigate potential trade-offs built into the conservation problem or weaknesses in the existing protected areas.

MANAGEMENT RECOMMENDATIONS FOR GREATER SAGE-GROUSE WINTER CONCENTRATION AREAS

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Abstract. Our goal was to generate management recommendation guidelines for greater sage-grouse (*Centrocercus urophasianus*) winter concentration areas in Wyoming. Phase 1 of our research utilized data from female sage-grouse equipped with GPS transmitters (~877,000 year-long locations from 536 females) throughout Wyoming. We assessed variables within circular regions (0.1–10.0 km) to identify scales in which sage-grouse selected winter home ranges and habitat within winter home ranges. Median date of arrival and departure from winter range was 7 November and 13 March, respectively. We observed regional variation but sage-grouse generally selected habitat with gentle topography, close to breeding habitat, and dominated by sagebrush (*Artemisia* spp.) land cover absent of juniper (*Juniperus* spp.). Sage-grouse avoided surface disturbance within circular regions ≤3.2 km, but there were nuances relative to types of disturbance and region. Across all disturbance types and circular regions, mean surface disturbance at sage-grouse locations did not exceed ~6%. Trends were more variable for avoidance of disturbance within winter ranges, so selection was likely more important at the larger scale when grouse selected home ranges. Phase 2 will assess the effectiveness of the guidelines developed applied to a novel area located in southern Wyoming where we collected GPS location data from 2018-2021.

COMPARISON OF SONGBIRD POPULATION TRENDS TO SAGE-GROUSE LEK TRENDS: ASSESSING SAGE-GROUSE CORE AREAS AND UMBRELLA SPECIES CONCEPT

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Abstract. Many conservation strategies promote the potential of multiple species benefitting from protection of large areas necessary for the continued viability of one species. One prominent strategy in western North America is Wyoming's Sage-grouse Core Area Policy, which was designed to conserve greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) breeding habitat, but may also serve as an umbrella to conserve other sagebrush (*Artemisia* spp.) obligate wildlife, including songbirds. Sagebrush-obligate songbirds and sage-grouse have undergone population declines attributed to similar habitat issues. We compared trends of sagebrush-obligate songbirds from the Breeding Bird Survey and sage-grouse lek counts in two sage-grouse populations in Wyoming (Powder River Basin and Wyoming Basins), 1996–2013. Our evaluation focused on similarities among population performance of the potential umbrella species and species under that umbrella. Trends of sagebrush-obligate songbirds were not parallel or consistently similar in trajectory to sage-grouse in either Core or non-Core Areas, respectively. Our results indicated Core Areas were successful at maintaining higher sage-grouse trends compared to areas not protected under the Core Area Policy. However, sagebrush-obligate songbird trends did not follow the same pattern. This suggests that protection of only the best sage-grouse habitat may not be a sufficient conservation strategy for other sagebrush-obligate birds.

PATTERNS OF STRUCTURAL CONNECTIVITY IN THE SAGEBRUSH BIOME (1985-2018)

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Abstract. Disturbances across the sagebrush biome, such as fire, invasive grasses, and human development, have modified landscape patterns and connectivity through time. Wildlife have experienced habitat loss and fragmentation, with likely impacts on patterns of movement, gene flow, and related ecosystem processes. Yet, spatial and temporal changes in connectivity across the sagebrush biome are not well understood. We used an omnidirectional circuit theory approach to classify patterns of structural connectivity in the sagebrush biome between 1985 and 2018. Results identify regions of the sagebrush biome that have lost connectivity in sagebrush cover, as well as areas of persistent connectivity and locations that are transitioning to pinch points and in danger of disconnection. These findings can help characterize opportunities for proactive conservation of remaining structural connectivity of sagebrush across the biome, as well as identify degraded areas where targeted management could increase connectivity, offering benefits to multiple species.

HABITAT SELECTION AND SURVIVAL CONSEQUENCES FOR GREATER SAGE-GROUSE DURING MULTIPLE REPRODUCTIVE LIFE PHASES

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Abstract. Actionable science for species of conservation concern is enhanced by models that identify environmental factors linking resource selection and demographic responses during critical life-stages. We evaluated factors influencing these responses for greater sage-grouse (*Centrocercus urophasianus*) during key reproductive phases (786 nests and 356 broods) across 19 sites within the Great Basin, 2009 – 2018. For each life stage, we fit macro- and micro-habitat covariates to selection and survival models while accounting for climatic conditions correlated with ecological productivity. For nesting, sage-grouse selected greater sagebrush cover and height, elevation, and herbaceous cover. We found that shrub cover increased nest survival while annual grass reduced nest survival. For brood rearing, sage-grouse selected areas with greater ecological productivity, greater proportion of shrub cover, and closer to streams and springs. During this brooding stage, burned areas elicited different survival responses to annual grass than unburned areas. At microscales, vegetative cover immediately surrounding the nest was most important to selection and survival, but functional composition varied between mesic and xeric sites. For broods, areas with greater grass and forb composition were selected. We further illustrate how application of this approach facilitates comprehensive multi-scale habitat assessment for reproductive sage-grouse. Preliminary findings are provided for best timely science.

SIMULATION OF SOIL MOISTURE BUDGETS: SPATIALLY REFINED PROJECTIONS OF SAGEBRUSH ECOSYSTEM POTENTIAL

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Abstract. Soil conditions, such as moisture availability, have important effects on plant distributions, growth rates, and habitat conditions. Existing soil moisture data are often inadequate to explain variability in vegetation patterns and habitat conditions. While soils are perceived as being slow to change – compared to vegetation, for example – soil moisture conditions that affect plant growth can change rapidly. Building on existing data and models, we developed a framework that uses spatially explicit estimates of climate, soil properties, microtopography, and snowmelt in a monthly soil-water accounting system (Newhall soil simulation model). Our simulation currently uses 1981-2010 climate normals for temperature and precipitation, but the framework permits easy substitution for future analyses. Analyses (generalized additive models) for correlations between soil-climate estimates and sagebrush cover, bare ground, and annual herbaceous cover confirmed strong relations. The detailed spatial information coupled with attribution describing important relationships with habitats, desirable vegetation (sagebrush) or risk of undesirable conditions (annual herbaceous dominance or excessive bare ground) will facilitate management by connecting habitat conditions to detailed soil-climate maps. The continuous estimates of soil moisture also offer novel information as environmental predictors for habitat and wildlife population models and sagebrush restoration and recovery.